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Integrating Safety and Health into Green Construction Rating System

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Abstract:

Green and sustainable approaches to constructing, operating, and maintaining buildings are on the increase worldwide. Green rating systems such as the US Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) play an important role in encouraging and evaluating these practices. A strong case can be made that a truly comprehensive perspective on sustainability must include occupational safety and health and there are opportunities to promote worker safety and health as a fundamental dimension of true sustainability. Incorporating safety and health into green rating systems is an important step for moving toward this goal.

The National Institute for Occupational Safety and Health (NIOSH) Office of Construction Safety and Health, working with industry stakeholders as part of our National Occupational Research Agenda (NORA) process, identified integration of safety and health into green construction as a priority activity area for 2011. NIOSH representatives met with senior USGBC leadership to discuss collaboration and performed outreach to other interested agencies. A NORA Coordinating Committee was formed to facilitate researcher and industry involvement. A two-fold strategy was developed to integrate safety and health into the USGBC LEED rating system.

Current LEED credits include a number of activities that could increase construction worker exposure to hazards. For example, credits for daylighting and vegetative roofs can increase exposures to fall hazards. The presentation describes the rationale for integrating safety and health into green and sustainable construction. It provides examples of existing green credits that could potentially reduce or add to hazards for construction and maintenance workers. It provides specific examples of “enhanced” credits that address safety and health along with examples of new types of credits for best practice safety and health performance. Lastly, the presentation describes an overall strategy for bringing about change in green rating systems.

Investigation into the Level of Compliance to Construction Health and Safety Requirements within the South African Construction Industry

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Abstract

This paper investigates the level of contractors' compliance to construction Health and Safety legislation requirements within the South African construction industry. The paper critically examines whether the contractors comply with construction Health and Safety Legislation requirements in South Africa and also whether location of site, building type, project value and attitudinal disposition of the site manager/agent has any influence on the level of compliance to Health and Safety legislation on construction sites. The rational for the investigation stems from arguments by building associations that there are shortcomings in the adherence by construction companies registered by the building associations to the requirements of the Health and Safety legislation in South Africa. The paper reveals the key areas in the construction Health and Safety legislation requirements in which contractors' have complied and discusses the probable reasons for compliance/non-compliance by contractors to Health and Safety legislation requirements on construction sites. It proposes measures that should be used by building associations to engender total compliance to Health and Safety legislation requirements by their contracting members on construction sites in South Africa.

Keywords: Compliance, Contractors, Health and Safety, Legislation Requirements and Master Builder South Africa (MBSA)

I. Introduction

Ally and Esau (2010) stated that compliance is considered to be the practice of abiding with applicable rules and standards. In practice, it describes a situation where the critical mass of the members of a community adheres to those rules and standards. Compliance according to Ally and Esau (2010) therefore signifies acceptance of the constitutional paradigm to the extent that it is embodied in the legislation.

Construction has a poor safety record in South Africa and as a result of this, the Health and Safety in the South African construction industry has been the focus of attention of many industry stakeholders and role players (Smallwood, et al 2009). However, even though many industry associations, contracting organizations, professional bodies and the government have made significant efforts to improve Health and Safety through the enactment, enforcement and compliance with legislation such as the Occupational Health and Safety Act (OHSA) 1993, within the construction industry, the overall construction Health and Safety record is not improving significantly. Instead according to Smallwood et al (2009), the construction industry continues to contribute a disproportionate number of fatalities and injuries to National accident statistics as shown in Figure 1.

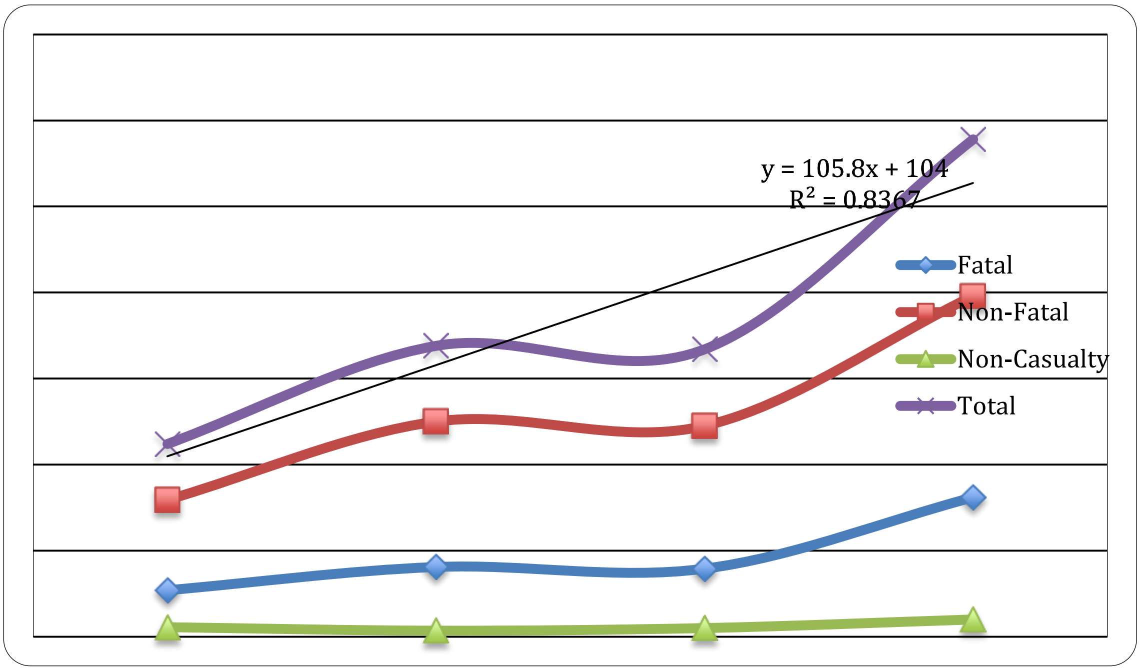

Figure 1. Construction Health and Safety Accidents over a 4-Year Period in South Africa
Source: Smallwood et al (2009)

Compared to other industries, construction has the third highest death rate (Goldenhar, 2002) and there is documented evidence that construction work is one of the most dangerous occupations to engage in (United States Bureau of Labour Statistics (BLS), 2002). According to Smallwood and Haupt (2008), one of the possible ways by which the number of injuries and fatalities on the construction sites in South Africa can be reduced is through better control and compliance to the Health and Safety Legislation. Smallwood et al (2009) however reported a high level of non-compliance by construction contractors to the requirements of OHSA, 1993 and the Construction Regulations (CR) 2003 in South Africa.

In investigating the level of contractors' compliance to construction health and safety requirements in South Africa, the paper will first of all review the health and safety legislation available in the South African construction industry. Secondly, the paper will identify the health and safety requirements embodied within the health and safety legislation and standard methods used in measuring compliance. Thirdly, the paper will present the results of physical inspection carried out on selected construction sites by Master Builder South Africa (MBSA) auditors, using a 19-point evaluation tool in assessing the level of compliance by construction companies to health and safety requirements. Fourthly, the paper will present results of the analysis of data collected, detailing the critical areas in which there are adherence/compliance to health and safety requirements and the effect of site location, building type, project value and attitudinal disposition/commitment of the site manager/agent on the level of compliance to Health and Safety requirements. Finally the paper discusses the probable reasons for compliance/non-compliance by contractors to health and safety legislation on construction sites and proposes measures that could be used by stakeholders which includes the government and building associations to engender total compliance to health and safety requirements by contractors on construction sites in South Africa.

II. Review of Health and Safety (H&S) legislation in the South African construction industry

The primary Acts that are applicable to construction with regard to H&S in SA are Occupational Health and Safety (OHSA) Act No.85 of 1993 and the Complementary Compensation for Occupational Injuries and Diseases Act No.130 of 1993 (COID Act) which replaced the previous machinery and occupational safety Act No.40 of 1989, the Machinery and Occupational Safety Amendment Act No.97 of 1991 and the Construction Regulation (CR) of 2003 under section 43 of the OH&S 1993 Act. However, this study will focus more on OHSA 1993 and CR 2003 because a significant number of the H & S requirements assessed on site during inspection are obtained from these Acts.

The Occupational Health and Safety Act (OHSA) 1993

The OHSA 1993 was produced to provide for the health and safety of people or persons at work, in connection with the use of plants and machinery, the protection of people other than persons at work against the hazards to health and safety of or in connection with the activities of persons at work, to establish an advisory council for Occupational Health and Safety and to provide for matters connected therewith. OHSA contains many rules and regulations that protect all workers in different industries however this paper focuses on the construction industry. OHSA states rules and regulation for both employers and employees to comply with before, during and on leaving the industry. Weil (2001) stated that OHSA must be seen as part of the bigger project of building a society based on the democratic values of human dignity, equality and freedom.

The OHSA 1993 Act is applicable to every work type in South Africa as opposed to the construction regulation, 2003. It specifies the general duties of the employer of which is the contractor in this case to their employees.

The Construction Regulation (CR) 2003

Smallwood & Haupt (2005) stated that the CR 2003 was introduced in the construction industry due to continuing poor construction H&S records. Geminiani & Smallwood (2008) further elaborate that the CR was produced with the intention to have a set of legislations specifically directed at and applicable to the construction industry. The CR 2003 acknowledges every individual including clients, designers and quantity surveyors of their responsibilities with regard to OHS in the construction Industry. Clients are required to – inter alia- provide the principal contractor with the Health and Safety specification and ensure that the principal contractor have made adequate allowance for Health and Safety. Designers are required to –inter alia – provide the client with all relevant information about the design, which will affect the pricing of the works, inform the contractor of any known or anticipated dangers or hazards, provide the contractor with a geo-science technical report, and the methods and sequence of construction, and modify design where dangerous procedures would be necessary, or substitute hazardous materials (ibid cited in Smallwood & Haupt, 2007).

According to Smallwood et al (2009), the manifestations of the impact of CR 2003 are wide spread and it can be inferred that CR had a positive impact on reducing the construction health and safety accidents in the industry. In particular, it has increased

H&S awareness and increased consideration by project managers and general managers and general contractors. However findings by Smallwood & Haupt (2006) indicate that there has not been an increase in consideration for H&S by designers and Quantity Surveyors and only a marginal increase by subcontractors. Agumba & Haupt (2009) opined that Occupational Health and Safety should not be driven by a legal framework however should be seen as a value.

The intention of the CR is good despite various problems that have been pointed out. However, according to Smallwood et al (2009), legislation is just a handy guide in prescribing minimum rules and regulations, but management skill are required to bring a healthy and safe workplace to realization. Occupational health and safety is not only a programme that calls for integration at various phases and stages of a project but it also is a process, which requires continual improvements.

The CR 2003 stipulates the principal contractor's duties as applicable to the contractors that are appointed as principal contractors for the main construction works and whereby they have sub-contractors doing some of the other construction works/trades for them under the same construction site.

- Emphasis on the identification of construction hazards and the assessment of risks to eliminate, avoid or at the very least reduce perceived risks.

III. Data and Methods

The appointed Master Builder South Africa (MBSA) auditor audited fifty-five sites over a period of four months in 2010. The sites were predominantly located in the Cape Town Metropolitan area. However, there were some sites that were situated in the Boland area, which includes Strand, Somerset West, Paarl and Stellenbosch. The types of site audited ranged from high value homes, mass medium housing, shopping centres and hotels to Institutional and civil engineering projects. Members of the MBSA Western Cape, South Africa were managing all these sites.

Compliance to OHSA 1993 and CR 2003 on the construction sites audited was measured by the use of the Master Builders South Africa (MBSA) Audit System, which is compiled using the requirements stated in both Acts. It should be noted that while the MBSA aims to establish what are the shortcomings in the H&S programmes of its members, compliance assessment carried out by Department of Labour (DOL) is statutorily required for enforcement of H&S legislation on construction sites.

The construction companies are said to be compliant with both the OHSA 1993 and CR 2003 when all the requirements starting from the documentations signage on site, H&S plan, Personal Protective Equipments (PPE), etc as stated in law are in place. If a company is found not to have some of the requirements in place, they are registered as being non-complaint.

Statistics and Measurement

In analyzing the site inspection data provided by the MBSA, the paper seeks to understand the nature of compliance to H & S requirements within the South African construction industry by: -

i. finding out the H & S requirements that is the most/least complied with;
ii. finding out if there is any relationship between the level of compliance to H & S requirements achieved on site and the location of the site, the building type, the value of the project and the attitude of the site manager. This is shown schematically in Fig. 2.

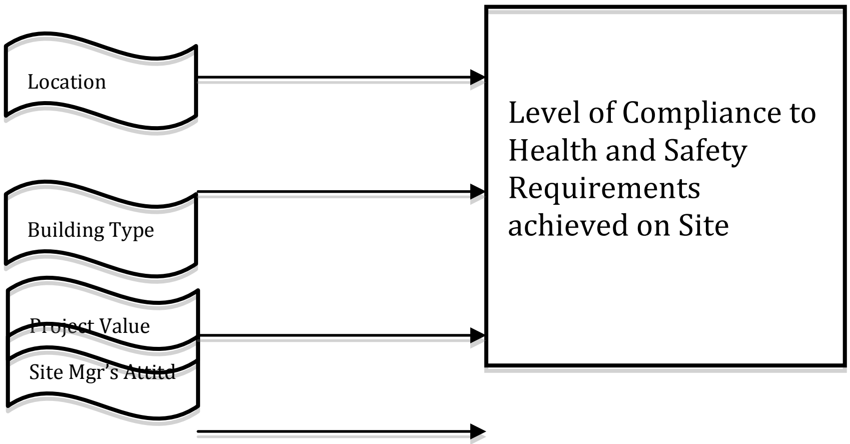

Fig. 2 Schematic Model of Propositions to be tested

The principal method used in analyzing the data provided by the MBSA is the chi-square (χ^2) because it is a test of association between two sets of data that is nominal or ordinal (Naoum, 2007).

The location of the site was measured by identifying the site as either a rural, semi-rural or urban area. The building/facility type was identified using the classification and designation of occupancies available in the National Building Regulations. The project values were also grouped into classes based on the value of work categories found in the MBSA work classification as less than R5m, R5m to <R20m, R20m to < R50m, R50m to < R120m, R120m to < R200m, R200m to < R500m and above R500m. To measure the site manager's attitude, his level of commitment towards and job involvement in the implementation of Health and Safety requirements was observed during the survey. He was then scored as being either committed, low or no commitment.

The MBSA audit system which, looks at 19 different elements of H&S requirements as listed in Table 1 was used in measuring the level of compliance to health and safety requirements on site. This audit tool is used to score the level of compliance on site to the requirements audited using percentages.

IV. Results and Discussion

Table 1 presents the average scores achieved in percentages by all the sites audited in the Western Cape by the MBSA audit team in 2010, for each of the listed Health & Safety requirements.

Table 1 MBSA H&S Requirements and Points Achievable

S/No	Health and Safety Requirements	Points Achievable	% of Total
1	Material Hoist	44	100%
2	Cranes	166	99.9%
3	Emergency/Fire Prevention and Protection	92	97.0%
4	Transport & Material Handling	48	96.2%
5	Tools	50	95.7%
6	Education, Training & Promotion	52	95.0%
7	Administrative and Legal	316	93.6%
8	Public Safety & Emergency Preparedness	54	93.2%
9	Plant & Storage Yards/Site Workshops Specifics	88	93.0%
10	Workplace, Environment, Health & Hygiene	52	92.4%
11	Demolition	44	92.3%
12	Electrical Safeguarding	64	91.4%
13	Housekeeping	98	91.2%
14	Fall Protection	44	91.2%
15	Site Plant & Machinery	98	91.1%
16	Ladders	32	90.9%
17	Scaffolding, Formwork and Support	366	87.6%
18	Personal Protective Equipment and Clothing	102	87.1%
19	Excavation	30	74.5%
	Totals	**1840**	**92.3%**

Source: MBSA Western Cape Audit System (2010)

Table 1 reveals that when scores for all the sites audited are averaged and distributed by compliance to the 19 Health & Safety requirements, 95 % and above level of compliance was obtained in the following areas - material hoist, cranes, emergency/fire prevention and protection, transport and material handling, tools and education, training and promotion, listed in order of magnitude. The least compliance to Health & Safety requirements is seen in the area of excavation.

This data clearly suggests that accidents on site will not be attributable to the use of plant and other equipment but will be most attributable to the negligence of the contractor during excavation work, not providing personal protective equipment and clothing and inadequate scaffolding, formwork and support. The record of the auditor with respect to excavations noted that " the competence of the appointees is questionable, the law requires that the person appointed have knowledge of the soil conditions and in many cases, this very important knowledge is lacking" (Bester, 2010). The auditor observed that the area of lifting equipment is one area of construction that is fairly well managed probably due to the high cost of replacing equipment, the high risk of accidents and the subsequent damage to equipment.

Distribution of Contractors' Site/Facility audited by Level of Compliance

Table 2 presents the distribution of the contractors' site/facility audited by the level of compliance.

Table 2 Distribution of Site/Facility audited by Percentage Compliance to H & S Requirements

Final Compliance Score as Percentage of total points achievable	Frequency	Percentage
Above 95%	14	25.5
90% - 95%	19	34.5
85% - 90%	13	23.6
80% - 85%	4	7.3
Below 80%	5	9.1

Total		**55**	**100**

Table 2 reveals that only 25.5% of the sites audited were able to attain a final H & S compliance score of above 95%. In an ideal situation, 100% compliance to requirements is what the law requires. Giving an allowance of ± 5%, implies that only 25.5% made the mark while an allowance of ± 10% will mean that 60% of the audited sites could be said to have complied with the H & S requirements.

Test of the Relationship between the Level of Compliance to H & S Requirements achieved on Site and other Study Variables

The χ^2 test result for the relationship between the level of compliance to H & S requirements achieved on site and the location of the site, the building type, the value of the project and the attitude of the site manager is presented in Table 3.

Table 3. χ^2 test result for the Relationship between Level of Compliance to H & S Requirements and other Study Variables

Variable	Value	df	Asymp. Significance (2-sided)	Remarks
Location	12.551	8	0.128	Not Significant
Building Type	51.073	32	0.018	Significant
Value of the Project	31.244	24	0.147	Not Significant
Attitude of the Site Manager	31.755	8	0.000	Significant

df = degree of freedom

Table 3 shows that the building type and the attitude of the site manager have a significant relationship with the level of compliance to statutory Health & Safety requirements on the construction sites audited. While, the location of the site and the value of the projects were not significant statistically with compliance levels.

From these results therefore, one can conclude that there is a significant relationship in the level of compliance to Health & Safety requirements between sites audited based on the type of building/project being constructed and the attitude of the site manager/agent. The paper shall discuss further, the implications of these findings to compliance with Health & Safety requirements and accidents on site.

Location. It was presupposed by the author that the farther a site is from the enforcement agencies and municipalities, the likely the site would be found to be non-compliant with requirements. However, the results of the χ^2 tests suggest the contrary. This might be due to the fact that there were only five sites audited in the areas classified as rural and semi-rural and 45 sites were audited in urban areas. The results in this case can be held as inconclusive until sufficient data is obtained.

Building/Site Type. The analyzed data obtained from the MBSA Health and Safety audit indicates that there is a relationship between the building type and level of compliance to Health and Safety Requirements. High compliance to Health and Safety requirements was found in high value homes, manufacturing facilities and plant/storage yards. The data analyzed suggests that the higher the attention to details is required as is the case with high value homes and the more the knowledge of clients such as those found in the manufacturing industry is attuned to the requirements of health and safety, the higher would be the compliance by the contractors engaged to the legislative requirements.

Project Value. There was no significant relationship between the value of work done and the level of compliance to Health and Safety requirements. This might be due partly to the fact that the value of 21 out of the 55 sites/facilities audited could not be ascertained. It is probable that if sufficient information is obtained, it might reveal relationships between project values and level of compliance to Health and Safety legislative requirements.

Site Manager's Attitude. According to Smallwood et al (2009), minimum rules and regulations can be prescribed but, if management skills are not geared towards the realization of health and safety on site, then, there will be no compliance to regulatory requirements. The results of the MBSA audited scores analyzed is consistent with this assertion because the statistical test reveals that the attitude of the site manager in terms of his level of commitment which is based on his involvement in the implementation of Health and Safety requirements, does have a statistically significant effect on the level of compliance of the site he manages to Health and Safety requirements.

Furthermore, the data reveals that of the 28 managers that showed commitment to Health and Safety requirements, only three had sites that recorded less than 90% level of compliance. Whilst the 24 site managers with perceived low commitment recorded above 90% level of compliance in eight sites and less than 90% level of compliance in 16 sites. The implication of this finding is that the attitude of the site manager in terms of level of commitment towards the realization of Health and Safety requirements on site is crucial to levels of compliance achieved on sites.

V. Conclusions

It can be concluded therefore that the probable reasons for compliance/non-compliance by contractors to Health and Safety legislative requirements on construction sites in South Africa can be attributed to the building/site type and the attitude of the site manager. The data obtained from the audit carried out by the MBSA in the Western Cape Province of South Africa suggests a significant relationship between the building/site type and the attitude of the site manager, to the level of compliance to Health and Safety legislative requirements on site.

Thus, the data analyzed suggests that compliance to Health and Safety legislative requirements is a combination of the building site type and the attitude of the site manager. The study indicates that sites of projects developed for manufacturers who are quite knowledgeable about Health and Safety legislative requirements and sites in which there would be use of heavy machinery would have high levels of compliance to Health and Safety requirements and also that sites manned by uncommitted managers/agents would record low levels of compliance.

Not all the hypotheses tested were however supported. Contrary to expectations, the location of the site and the value of the project had no significant effect on the level of compliance to Health and Safety requirements. Admittedly, these results are tentative and discussions made are speculative because data analyzed were insufficient to arrive at conclusive decisions about the effect of some of the variables such as location and value of the projects, which were tested. However, if the results are valid, they suggest an association between the level of compliance to Health and Safety legislative requirements on sites and the building/site type, and site managers' attitude, which provides an intriguing avenue for future research.

Finally the results of the data investigated also indicates that to improve the level of compliance to Health and Safety legislative requirements on construction sites, thereby reducing fatalities and injuries attributable to the construction industry, site managers' attitudes must be evaluated and only site managers with the requisite skills, capacities and flair should be recruited for the job.

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Constructive Ageing: A Survey of Workers in the Construction Industry

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Constructive Ageing: A Survey of Workers in the Construction Industry

Abstract

The age demographic of the workforce is increasing across Europe (Griffiths 1997, Morschhäuser, Sochert 2006, Ilmarinen 2006) and the World (Ross 2010). It is important to investigate the effects of workplace design on healthy ageing. To facilitate this, a questionnaire survey (n=106) was used to identify workplace opportunities and barriers to working later into life at a major UK construction company as part of a larger cross-industry study (n=815?). At this company ~33% (n=29) of respondents were aged ≥50. The survey investigated the impacts of workplace equipment and environments on people's ability to perform job tasks in relation to age. Participants were asked to respond to statements and questions about; musculoskeletal symptoms, work ability, their work environment, equipment, activities and personal attitudes and experiences towards ageing in the workplace. The survey findings were triangulated by interviewing a sample of workers. At this company, musculoskeletal symptoms peaked for period prevalence in the lower back 44% (n=42), followed by the knees 33% (n=32). Point prevalence of reported musculoskeletal symptoms was highest in the knees, 24% (n=23). Several respondents also directly attributed the symptoms to work tasks. The equipment regularly used to perform job tasks included; computers, furniture, PPE as well as many hand tools. Workplace equipment to perform job tasks, the environment and work activities, can impact on musculoskeletal symptoms experienced by respondents.

Keywords: Construction, Survey, Ageing, Design, Health

1. Introduction

Workplaces can have a major influence on a person's health, when coupled with an ageing demographic it is important to not just act on existing health issues but to prevent reoccurrence or indeed the onset of work related ill health on existing and new employees. The workplace environment and equipment (WEE) used to perform job tasks need to meet the requirement of needs of the workforce thought their life course (Winn 2000, Moyers, Coleman 2004). It is hoped that by employing user-centred design methods, WEE can reflect the needs and aspirations of the users by learning from and working with expert users to investigate prevention of injury and illness as people age at work. The research team recognises the particular challenges of workplace design in the construction industry where the workface environment is continually changing (Gibb et al, 2006). This may be why so little serious work has been done in this area in construction.

The New Dynamics of Ageing (NDA) research programme[1] investigates the effects of "older ageing". The authors' "Working Late" ageing productively through design project forms part

[1] The New Dynamics of Ageing (NDA) research programme is funded by the ESRC, BBSRC, AHRC, EPSRC and MRC. This project forms part of a Collaborative research project which investigates the effects of ageing whist working later into life and for this projects how design solutions can facilitate, promote and improve the quality of life for older workers (NDA 2010).

of the NDA research programme and has been designed to address work-related healthy ageing. The output of this research will be web based resource; *Organiser for Working Late* (OWL). It is important to investigate and understand the impacts of WEE design on working populations, including potential injuries and work related ill health. To do this, a large questionnaire survey was conducted across the main UK industries the results from one of the participating companies, a large construction firm, are presented and discussed in this paper.

Three construction sites managed by this company were involved in this study. Employees demonstrated that they use many different pieces of equipment in multiple and changeable work environments. Some of these are potentially hazardous and can affect health at work and, as such, great care is taken by the company in relation to worker safety.

2. Methods

Construction work involves a large cross-section of different workers and skill sets, the jobs these workers perform also vary depending on their job tasks and WEE. Therefore it was important that the sampling process encouraged participation from people working in a broad cross-section of jobs within the company, this included both the office and site based employees as well as people who were involved in traditional construction type work as well as sedentary work. The number of workers at each of the three sites varied depending on the stage of construction. Each site was within an enclosed compound, had portable cabin offices and an active building site. The total workforce for all three sites, at the time of the questionnaire survey, was ~400 people including subcontractors and office staff.

The questionnaire survey was developed and piloted. The Loughborough University Ethical Committee guidance checklist (Loughborough University 2004) was used to evaluate any ethical considerations. Companies were then invited to participate in the research. Meetings were set up where it was discussed how best to encourage participation from employees. For this company, a paper version was made available to staff not on the work email system, this was distributed by the researcher on accompanied site visits. The questionnaire surveys were handed out to employees and then either returned directly to the researcher or in sealed envelopes to an administrator who then forwarded them onto the researchers at Loughborough. An electronic copy was made available through a link in the email (Williams et al. 2010) this was sent to employees with a company email address. The site visits also provided the researcher with the opportunity to meet senior health, safety and environment advisors and gain their support as well as to meet with employees and answer any immediate questions they had about the research, this combination was felt to help increase the response rate.

Participants were asked to respond to six different sections in the self completed questionnaires as presented by Williams et al (2011); about your employer & your employment status, about the environment in which you work today, doing your job, job demands, you & your work and about you. As a way of thanking respondents for their time participating in the study, their names were put into a prize draw.

The results in this paper are based on the responses received; therefore they only provide an overview of the employees working at these three sites of this company and not individual worker populations.

3. Results

A total of 106 surveys from this company were received by the research team (70 were paper based and 36 electronic). The response rate was believed to be ~26% (*n*=106) of the working population of all three sites (*n*=~400). Questionnaire surveys were removed from the final data set where respondents did not indicate their year of birth, gender or did not respond to any part of the NMQ. This left a sample size of 96 respondents. Table 1 provides some basic descriptive statistics from this sample;

Table 1. Descriptive statistics

Descriptive	*n*			Mean
Gender	96	87.5% Male	12.5% female	
Age	96	70% ≤49 years	30% ≥50 years	41.5 years
Length of time working for organisation	92	62% ≤11.9 years	38% ≥12 years	11.9 years (SD 11.1)
Length of time in current job role	93	66% ≤9.2 years	34% ≥9.3 years	9.2 years (SD 10.7)
Hours worked per week	95	98% ≥35-hours	41% ≥ 44-hours	44 hours (SD 6.4)
Body Mass Index (BMI)	91	34% = 18.5 – 24.9 (normal)	72% ≥ 25 (overweight/obese)	27.2 (SD 4.2)

In order to understand the needs of any given population it is important to understand more than just the physical demands placed upon them. To aid this, participants were asked to respond to several statements and questions throughout the questionnaire survey in relation to their thoughts and perceptions of their work ability and ageing as well as how they felt their WEE affected their ability to work. To explore the needs of the workforce that participated in this study, it was important to understand their attitudes towards their jobs and age. Participants were asked to indicate their responses to 13 statements, with each statement based on a five point scale ranging from; strongly agree to strongly disagree (see Williams et al. 2011). To establish if a trend was present, responses were grouped as either being; positive "strongly agree and agree", or negative "disagree and strongly disagree", and were then analysed by age groups; people aged ≤49 (*n*=67) and ≥50 (*n*=29). Five of the 13 statements (Table 2) showed that there was a statistically significant difference ($p \leq 0.05$) in the responses from both groups, based upon two-tailed independent samples *t*-test.

Table 2. The five work related statements which showed statistically significant ($p \leq 0.05$) differences according to age group; ≤49 and ≥50

Statement	p-value; Age groups ≤49 and ≥50 Statistical difference	Greater level of positive agreement
I feel my age has made me less physically active at work than I used to be	Yes (0.002)	≥50
I feel more tired now due to my job then I did when I was younger	Yes (0.008)	≥50
I find learning new skills, and technologies more	Yes (0.000)	≥50

difficult now than when I was younger		
My productivity and capacity to do my job has declined as I have got older	Yes (0.005)	≥50
I feel that I am not as capable as I was when I was younger at learning or retraining	Yes (0.000)	≥50

People aged ≥50 were in stronger agreement (>$p \leq 0.01$) with these five statements. This suggests that people view older age as being a negative barrier to work ability, this notion is supported by findings from another case study which looked at heavy manufacturing at a cement works (Williams et al. 2011). The statement asking participants to reflect on their age and the reduction of the manual labour requirements of their job showed a greater level of agreement for people aged ≥50.

The Work Ability Index (WAI) (Tuomi et al. 2006, Ilmarinen 2007) used for this study has been used in similar case study company results (Williams et al. 2011). The WAI ‘best to current’ scores were high, with a mean of 8.8 (SD 1.3). High score were also achieved for the WAI physical ability score of 1.5 (SD 0.6) and WAI mental ability score of 1.5 (SD 0.7) to do their jobs.

Respondents were also asked to list five of the main pieces of equipment used when performing their work duties this was an open ended question. The researchers later categorized the equipment to aid with identifying work tasks and job types for data analysis. The items were categorized (Table 3) based on the names of the equipment and the understanding of this equipment. The largest category was “work tools and equipment” with 33% (n=151) of all items mentioned (n=456) belonging in this group.

Table 3. Respondents were asked to describe the equipment they use to perform the main duties of their job. This has been divided into 9 main categories (n=659);

Category	**Example of equipment**	***n***	**Frequency (%)**
Communications	Mobile and fixed phones, two-way radio	31	7
Furniture	Chairs, desks	50	11
Hazards	Chemicals	3	1
IT	Desktop and laptop computers, VDUs	58	13
Work tools and equipment	Screwdrivers, shovels, photocopiers, water lance	151	33
PPE	Boots, glasses, hardhats, high-visibility jackets	88	19
Stationary	Calculator, pen, paper	24	5
Vehicles	Car, forklift, mobile plant	38	8
Other/ unknown		13	3

50% (n=76) of the ‘work tools and equipment’ (n=151) mentioned were identified as ‘hand-tools’, which included items such as; hammers, spirit-levels and trowels, some people mentioned using more than one of item of “tools and equipment” to perform their job task. The remaining 'tools and equipment’ were made up of larger items such as; shovels , and lifting equipment, such as sack trucks, as well as office items such as photocopiers. Figure 1 also shows that 25 people who indicated using items from the “work tools and equipment” category also used PPE. There was no significance in this relationship when Pearson Chi-Square and Cramer’s V tests were run. However, there was a statistically significant relationship where $p \leq 0.000$ for the Pearson Chi-Square and Cramer's V between people who indicated using "IT" equipment and "furniture".

Fig 1. Item categorisation by participant

It is also important to understand people's interaction with their WEE. Respondents were asked to indicate the frequency they perform different activities on a scale of "often, sometimes, rarely or never" for sitting, standing or lifting heavy equipment. 12.5% (n=12) of participants performed all three activities frequently. This would suggest these respondents were often active at work. 63% (n=60) of respondents indicated they were "often or sometimes" lifting or handling heavy equipment, this would seem representative of the worker sample at the construction company. 8% (n=6) of respondents said that they "rarely" sat at work and 6% (n=6) indicated that they never sat at work.

The environment that people work in was also important to consider, and respondents indicated that they generally were working "inside a building or enclosed structure". However, almost the same amount of people, 45% (n=43), also described working "outdoors/no shelter" at some point during that day (Table 3).

When investigating WEE design there were also other, less tangible, influences on work ability. Included were statements relating to; temperature, lighting, noise, air quality, exposure to harmful substances and the effect other people had on individuals and their work ability (Huizenga et al. 2006, Smith, Wellens 2007). When asked about lighting at work, the majority (88% n=82) agreed that they were provided with sufficient lighting in their work area to enable them to do their jobs and move around safely. 79% (n=70) agreed that they would be provided with local lighting, if asked for.

Many of the items of "tools and equipment" spoken about in the interviews produce noise, which can be intermittent noise made by hammers through to continuous noise produced by electric drills and saws. 51% (*n*=48) of respondents said that they worked in an environment where the background noise disturbed their concentration and a significant proportion (16% *n*=15), agreed that their work tasks left them with ringing in their ears or a temporary feeling of deafness. The majority of respondents (54% *n*=51) also indicated that their job exposed them to breathing fumes, dust or other potentially harmful substances. Due to the nature of work performed within the construction industry and specifically work performed on site it was not unexpected that respondents indicated working in areas where they felt there were increased noise and lower air quality than in other industrial sectors. On the building site the construction requires the use of concrete, cement and mortar, which contain potentially harmful substances, to fabricate the buildings 28% (*n*=27) of participants said that they "often or sometimes" were required to handle or touch potentially harmful substances or materials. This construction company has a 'gloves on' policy on site and provides different gloves to workers depending on their tasks. The gloves are intended to prevent minor cuts and scratches as well as to protect workers' hands from chemical contact.

The NMQ, used in this study, has been similarly employed to assess the prevalence of self reported musculoskeletal 'troubles' in other research (Gyi, Porter 1998 Williams et al. 2011). Musculoskeletal 'troubles' are referred to in this paper as 'symptoms' and have been defined as; aches, pain, discomfort, numbness or tingling (Kuorinka et al. 1987). Musculoskeletal symptoms are reported in all nine of the body areas identified in the NMQ (Table 4). The severity of the effect of the symptoms was also consistent for most of the body areas. The lower back had the highest frequency for period (the last 12 months) (44% *n*=42) and knees for point (the last seven days) (24% *n*=23) prevalence of MSD symptoms. Period prevalence data was 33% (*n=32*) for the knees, 29% (*n=28*) for ankles and feet and for both the neck and the wrists it was 28% (*n=27*). When asked if they felt their symptoms were actively related to their work, again there was a high response rate for all nine body areas, apart from elbows, attributing the disorder to their job demands. Identifying these symptoms can also facilitate understanding their causes and thus lead to more successful prevention of injury and illness developed through them.

Table 4. Reported musculoskeletal symptoms for period and point prevalence, impact of symptoms on normal activities and attribution to work activities (*n*=96)

Body Area	**Period prevalence (12 months) % (*n*)**	**Point prevalence (7 days) % (*n*)**	**Severity [a] (12 months) % (*n*)**	**Is this trouble actively related to your work? % (*n*)**
Neck	28 (27)	10 (10)	7 (7)	16 (15)
Shoulders	26 (25)	11 (11)	6 (6)	18 (17)
Elbows	18 (17)	7 (7)	0 (0)	0 (0)
Wrists/hands	28 (27)	17 (16)	7 (7)	17 (16)
Middle back	22 (21)	10 (10)	6 (6)	19 (18)
Lower back	44 (42)	21 (20)	17 (16)	31 (30)
Hips/thighs or buttocks	19 (18)	13 (12)	5 (5)	11 (11)
Knees	33 (32)	24 (23)	7 (7)	15 (14)
Ankles/feet	29 (28)	18 (17)	10 (10)	21 (20)

[a] Reported impact on normal activities

4. Discussion

When considering ageing in the workplace it is important to understand what the workplace is made up of. For construction workers, the workplace is a fast changing environment (Gibb et al, 2006) for several reasons this can be due to the weather or indeed that the building project is progressing so the physical work environment has to change rapidly to accommodate this. Also the length of time people have been working at a company might have an effect on their work environment as different companies can work to different guidelines. Generally, at this construction company, people had worked for the company longer than they had been in their current job roles.

66% (*n*=63) indicated that they had experienced some form of musculoskeletal symptom in the last 12 months. Of these, 70% (*n*=19) had also experienced symptoms in the same body areas in the past seven days. The area of the body with the highest period prevalence was the lower back 44% (*n*=42) this is the same result as for people involved in heavy manufacturing work (Williams et al. 2011)). The NMQ was not used to act as clinical diagnosis of the working population, but to provide an overview of the workers self-reported symptoms in relation to their WEE design (Kuorinka et al. 1987, Williams et al. 2011).

On most UK construction sites certain PPE must be worn by all workers and visitors who wish to go out 'on site'. In the UK there is some variety in the different items that are required, with head protection being the most likely and gloves or light eye protection being the least likely. It can be seen in Figure 1 that of the 48% (*n*=45) of people who indicated wearing PPE, 55% (*n*=25) also indicated using an item from the "tools and equipment. During the site visits it was clear, on all occasions, that all persons "on site" were wearing PPE, this included a minimum of; helmets, jackets and safety boots. However, for the questionnaire survey, not all people who would be expected to use PPE mentioned it as part of their five pieces of equipment used to perform job tasks. During interviews it was noted that PPE was worn when performing job tasks but it was not reported as being an item used to perform and complete job tasks in the way other items were, such as trowels or screwdrivers. Considering all of the reported items of "tools and equipment", (*n*=151) only 5% could be directly attributed to office equipment the remainder appeared to be items that would commonly be used for the construction of buildings.

The use of these items might be contributing factors to the musculoskeletal symptoms experienced by workers at this company. Many interview participants indicated travelling on site by foot, climbing up temporary, mobile and fixed stairwells, as well as working in confined spaces, all of these activities can have an effect on the lower back. However, many respondents of the questionnaire also indicated that they "often or sometimes" were involved in the lifting or carrying of heavy equipment.

There is evidence in the literature that a perception of ageing is that as a person gets older their ability, mental and physical, reduces (Buckle et al. 2007). This perception of ageing was reflected in the five work related statements which shows a statistically significant difference between age groups ($p \leq 0.05$), people aged ≥50 were in stronger agreement ($>p \leq 0.01$). Similar findings to this were evident in a case study company involving heavy manufacturing (Williams et al. 2011). During the interviews participants indicated that they felt some job tasks would get harder to do as they got older, these were generally concerns with the physical side of their jobs, especially the moving around on site between locations. Weather was also said to affect their ability to work and was said to contribute to increased awareness of musculoskeletal symptoms.

Unfortunately, one of the limitations of the research in this paper was the sample size of 96 respondents. The results presented and discussed in this paper are only concerned with one construction company therefore there are limitations in the ability to transfer the results to other working populations. However, a previous case study of cement workers has provided some parallel in the results. These workers were involved in heavy manufacture and future research might look in more detail to investigate more similarities between the workers and the results in greater transferability between the results. Also only ~12.5% (*n*=12) of the surveys returned were completed by women, causing a bias towards men, however, this does represent the working population at this construction site.

5. Conclusion

Age can have effect on people's perceptions of work ability and it was evidenced that, with age, respondents thought that work ability reduced. However, there is no evidence to say that this is indeed the case. However, along with other work (Cook et al, 2010), the study does suggest that people working in construction are prone to experiencing musculoskeletal symptoms. These may affect their work ability and some respondents said they felt that their symptoms were directly as a result of their work. Effects of their workplace environment and equipment on their symptoms could be due to the 'nature' of the job, i.e. working outside in all weathers. Cold weather was said to increase awareness of musculoskeletal symptoms and wet working environments were attributed to causing difficult working conditions.

Symptoms were also experienced in the knees, ankles and feet. This could be potentially attributed to the footfall travel on site as described in the interviews. Many of the respondents were involved job tasks that involved them "lifting or handling heavy equipment" this too could have an impact on their musculoskeletal health.

It can be concluded from the results presented in this paper that workplace environment and equipment can influence work ability within the construction industry. Due to the dynamic nature of the work it can be difficult to predict the working conditions of employees as there are many external influences on this, the weather being one and the changing shape of the building or structure being worked on another. As such, it is essential to inform and educate people so that they may be empowered to work in ways that best benefit their health and by doing so reduce the likelihood of injury or ill health through work activities. By employing user-centred design techniques it is hoped that the most appropriate information can be provided by and to construction worker cohorts. The other benefit from this research is that if it is possible to identity good, healthy and practical practice and to disseminate this knowledge across the industry and amongst other, similar, job rolls then perhaps the young today will not experience work-related ill heath tomorrow.

This paper presents and discusses the findings from one case study company. Other companies participating in the research will benefit from the findings drawn from this case study and this company from the findings from the other case studies. Future studies with all companies will involve in-depth research capturing user-centred design ideas and solutions to facilitate healthy working into later life. Due to the sample size it was not possible determine any statistical difference between persons ≤50 years or ≥50 years in relation to musculoskeletal symptoms, this will be investigated when larger data samples are combined. The results from this company and the other case study companies will be shared amongst relevant parties and results will be disseminated to larger audiences where there are there are overlaps in job types, work tasks as well as internally within own industries.

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Reducing Construction Accidents Using Animations in Health and Safety Trainings

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Reducing construction accidents using animations in health and safety trainings

Abstract

The construction industry is one of the most risky sectors for industrial accidents and occupational illnesses all over the world. Lack of proper training and knowledge about health and safety issues are some of the main causes of construction accidents. This paper gives an overview and presents the preliminary stages of an ongoing project which aims to prepare animations that show construction accidents. These animations can be used as learning materials in health and safety trainings in construction industries to minimize accidents. Previous studies have showed that there is a significant relation between health and safety trainings and accident rates. The majority of health and safety trainings given to construction workers consist of theoretical trainings. Since the majority of the construction workers have a low education level, learning the health and safety concepts with theoretical trainings are quite difficult for these workers. Therefore, the animations that have the potential to make trainings more attractive and enjoyable, can overcome this problem. In this project, health and safety trainings with these animations will be given in construction sites of companies in Turkey. The results of the project will be tested at these construction sites and the effects of these trainings will be examined.

Keywords: Animations, Cartoons, Construction Accidents, Health and Safety Training.

1. Introduction

The construction industry has been recognized as one of the most hazardous industries (Carter and Smith, 2001). It has a poor safety record when compared with other industries. Davies and Tomasin (1990) indicated that the risk of a fatality in the construction industry is five times more likely than in a manufacturing-based industry. The number of accidents according to some selected industries in Turkey is illustrated in Table 2 (Turkish Ministry of Labor and Social Security, 2007). As seen from this table, the construction industry has the highest number of fatal accidents in Turkey.

The factors causing construction site accidents have been addressed by several researchers. Toole (2002) listed the main causes of construction accidents as lack of proper training, deficient enforcement of safety, lack of safety equipment, unsafe methods or sequencing, unsafe site conditions, not using provided safety equipment, poor attitude toward safety, and isolated, sudden deviation from prescribed behavior. Previous researches have showed that the main causes of the fatalities in construction are due to falls, struck-by incidents, caught in/between incidents and electrocutions. It has been also indicated that the most significant factor in construction site accidents is the unsafe behavior (Dester and Blockley, 1995; Sawacha et al., 1999).

Table 1. Number of accidents according to industries in Turkey (2007)

Industry	Number of Accidents	Number of Occupational Illnesses	Number of Fatal Accidents
Mining	6589	997	45
Construction	7615	16	359
Food	2438	6	30
Metal Products	17147	61	60
Transportation	4483	13	146
Machinery Manufacturing	5497	10	19

Construction accidents result in great economic losses. In their study, Everett and Frank (1996) found that the total costs of accidents lies between 7.9% and 15% of the total costs of non-residential, new construction. Furthermore, Coble and Hinze (2000) showed that the average workers' compensation insurance costs could be estimated approximately 3.5% of the total project costs. Besides causing human tragedy and economic losses, construction accidents also affect the productivity and reputation of the construction industry (Kartam, 1997). Some examples are demotivated construction workers, delay of project progress, training of replacement personnel and equipment damage. In the study of Arslan and Kivrak (2009), lack of safety training was found as one of the important factors that can cause construction accidents in Turkey. One of the most important results of the study of Arslan and Kivrak (2009) was the significant relation between health and safety trainings and accident rates. Lack of training can be attributed to poor safety and health management by the companies. Thus, an effective training program implemented by the companies has a great potential to minimize these accidents.

2. Health and Safety Trainings in Construction

Health and safety training programs can provide several advantages in preventing possible accidents in construction sites. The importance of safety training for the safety performance in the construction industry has been addressed by many researchers (Huang and Hinze, 2003; Aksorn and Hadikusumo, 2008). Effective training of construction workers can be one of the best ways in improving site safety performance (Hislop, 1991; Tam et al., 2004). In the study of Zeng et al. (2008), it has been pointed out that some accidents such as falling from height and hit by falling materials in construction can easily be prevented by implementing effective training programs. In the same study, it has also been found that many workers in the Chinese construction industry had received limited education about safety issues (Zeng et al., 2008). Similarly, in the study of Dingsdag et al. (2008) construction workers identified training as a necessary element of safety performance.

Many studies have shown that there is a close relationship between individual safety behavior and safety performance (Tarrants, 1980; Sawacha et al., 1999). Effective training of workers can also significantly reduce unsafe behavior. As Fang et al. (2006) stated, workers with good safety knowledge have a more positive safety climate than those with poor safety knowledge. On the other hand, Mohamed (2002) found a significant relationship between the safety climate and safe work behavior. He stated that safe work behaviours are consequences of the existing safety climate. Safety climate is 'a summary concept describing the employees' beliefs about all the safety issues (Guldenmund, 2000). Langford et al. (2000) identified the critical factors that influence the attitudes of construction workers towards safe behavior on construction sites. According to the results of their study, training of operatives and safety supervisors are important to safety awareness and improved performance. Moreover, it has also been found that knowledge and competence influence personal safety performance. They also stated that companies must maintain and update their workers' skills and knowledge by training, skill updates and effective on-site communication (Langford et al., 2000). Besides minimizing construction accidents, successful training can also minimize project delays and damage to company image (Findley et al., 2004). On the other hand, lack of safety training of construction workers has been considered as one of the important causes of construction accidents (Gervais, 2003).

As mentioned before, construction industry is the most risky sector for industrial accidents and occupational illnesses all over the world. However, health and safety culture has not been established yet by many construction companies. Many researchers demonstrate that, especially in developing countries labor safety applications are insufficient. In Turkey, most of the construction projects are constructed by small or mid-size construction companies. In the majority of the firms there is a lack of safety culture. Moreover, the education level of workers is low and the majority of these workers have no safety training in the past. All these conditions increase the number of accidents. To prevent the accidents, labors must be well educated about safety.

As a result, effective safety trainings are critical for improving safety performance in the construction industry. There is a significant relation between health and safety trainings and accident rates. However, the majority of health and safety trainings given to construction workers consist of theoretical trainings. Since the majority of the construction workers have a low education level, learning the health and safety concepts with theoretical trainings are quite difficult for these workers. Using animations in health and safety trainings can be an effective method to overcome this problem and improve the safety performance in this industry.

3. Health and Safety Trainings Using Animations

In this part, an overview and the preliminary stages of the ongoing project which aims to prepare animations that show construction accidents are presented. These animations can be used as learning materials in health and safety trainings in construction industries to improve the trainings and therefore minimize accidents.

In the first step of the project, the current conditions of health and safety in construction industry in Turkey will be examined. The main causes of accidents, yearly accident statistics and the most frequently happened accidents in construction industry in Turkey will be determined using the statistical data from the Turkish Statistical Institute. The findings from the first step will be a basis for the second stage which is related about creating real accident scenarios.

The second stage of the project consists of the preparation of accident scenarios. The scenarios will be grouped according to their frequency as; the most frequently, frequently and rarely occurring accidents. Moreover they will also be grouped according to their severity as; fatal, severe injury, and minor injury accidents. These groupings will be based on the data that will be obtained in the first stage. The main aim of this stage is to prepare effective scenarios that will be the references for the animations. The basis for the animations will be constructed in this work package. In the scenarios, the definition of construction accidents, their frequency, place, severity, the cause of accidents and the possible precautions to prevent these accidents will be explained. An example of such an accident scenario from real cases is illustrated in Table 2. These scenarios will be used in the next stage of the project for the design of the animations.

After preparing the scenarios, animations that show construction accidents will be designed. Designing animations is the most important stage since it is the innovative part of the project. The learning materials for health and safety trainings will be created at this stage. In this stage, construction accident animations will be prepared based on the scenarios. While preparing animations, real cases from the scenarios will be used. Within the project, accident animations will be prepared according to high frequency, low frequency and seldom occurring accidents. Moreover, the animations will be categorized according to work types such as formwork, reinforcement, concrete and excavation. Table 3 illustrates some examples of these work types. The main purpose of categorizing the animations according to the work types is to create learning materials for specific trainings such as ‘work at height’. These groupings can help to provide effective training materials to the workers working in such areas.

For less educated employees, animation modeling can have a great potential in achieving efficient results in health and safety trainings. Computer animations can make trainings more attractive and enjoyable. According to previous studies, 80% of human memory skills and learning are developed by visual learning. Thus, animations can improve memory skills and provide an effective learning. Moreover they can significantly enhance the learning interest (Steven and Phillip, 1994).

Animations do not contain any spoken dialogue. Messages could be understood from images and rhythms of music. 3D Computer-based animations are nowadays used for training purposes in a wide range of industrial applications like assembly, maintenance and operations (Parisi et al., 2007). Some views of the sample animations prepared for this project are shown in Figures 1 and 2.

Table 2. An example of an accident scenario from real cases

Accident definition:	Fall from height
Category:	Construction site accident
Causes of accident:	Human behavior Lack of following Work at Height Procedure Lack of supervision Lack of covering of gaps Lack of tie off harness existing running line Lack of attention Choosing incompetent person for the risky activities
Place of accident:	Terminal building (Sunny day , Day light)
Frequency:	Most frequently occuring accident
Result of accident:	Severe injury
Description:	Generally roof employees have a Tool Box Talk with all roof employees two times in a week. The last Tool Box had been performed on 5th of June. The topic of Tool Box was edge works, gaps on the roof, carrying of materials and access to roofs. The accident occurred on 11th June 09. The roof employees started to perform their activities on R4 roof at 7am. The victim 22 years old who fell down from R3 Roof was a simple worker. While most of the team were working in R4 roof covering activity, the victim has decided to step on R3 roof. Nobody saw him at that moment. Despite his harness and existing life rope (running line) nearby dangerous zone he was not connected and continued his activity. He didn’t notice the gap which is smoke damper gap and then, somehow he lost his balance and fell down from R3 roof smoke damper’s gap to level +14.93. Firstly he hit to steel construction in level +18.00 and due to that his speed was reduced. Then he fell 4m more and hit to concrete surface.
Possible precautions to prevent the accident	Workers should wear proper safety equipments Specific Training should be implemented for all site workers on site such as (‘Work at height’, ‘Fall Prevention’…etc) Training should be implemented for all foremen, supervisors and engineers weekly

Table 3 Examples of groupings of animations according to work types

Animations		
Electrical	Masonry	Loud sound works
Plumbery	Plastering	Excavation
Transportation	Reinforcement	Heat and water insulation
Painting	Highway construction	Doors & Windows
Welding	Concrete	Hazardous materials
Soil	Machine-Equipment	Formwork
Site safety	Roof	Scaffolding

Figure 1: A view from sample animations – I

Figure 2: A view from sample animations – II

The next stage of the project is the application of health and safety trainings using these animations. The main objective of this stage is to test and evaluate the effectiveness of health and safety trainings using animations. For this purpose, the leading Turkish construction companies will provide technical support for this project. These trainings will be performed with Health and Safety Departments of these firms. Besides theoretical trainings, trainings with animations will be given at the construction sites of these companies. Using accident statistics, the effect of training with animations will be determined. To compare the results of the new method, accident rates will be compared with previous years using accident reports and accident data statistics. Thus the efficiency of animation project will be evaluated.

Methods used for comparing accident rates are; accident frequency, recurrence rate, number of accidents/ compensation payment per day rate of number of accidents/ number of worksite. Frequency of accidents method is the mostly used criteria for comparing different firms and sectors. Frequency of accident is the rate of accident for every thousand workers. ANOVA parametric test method will be applied in the analysis of the results. ANOVA examines the influence of variables to other variables. ANOVA is used to compare two or more groups and shows the differences between groups.

Moreover, to determine the success of trainings with animations, the perceptions of construction workers about safety culture will be assessed by a survey questionnaire both before and after trainings. The analysis of the data collected from the surveys will be evaluated using paired sample t-test.

4. Conclusions

This paper presented an overview of the ongoing project which aims to prepare animations that show construction accidents. These animations will be used as learning materials in health and safety trainings in construction industries to minimize accidents. The results of the project will be tested at construction sites and the effects of these trainings will be examined. In most of the countries, there is a vast need of effective health and safety training programs in construction sectors to reduce accidents. Therefore, a great impact is expected from this project.

Using animations will significantly facilitate learning about the health and safety issues in construction. Since now, although many significant improvements in health and safety trainings have been performed, there are still improvements needed to minimize accidents. Therefore, the training materials that will be established in this project will be very useful visual learning materials. The present project will strongly support the development of health and safety trainings in the construction industry. Moreover, in the future, the training materials can become an important visual material for health and safety courses in the universities as well.

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Teaching Safety Through Design Using a Social Sustainable Module

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Abstract

This paper documents the implementation of a social sustainability module for teaching Safety through Design to civil engineering seniors and graduate students in a Sustainable Construction course. Previous research has found that similar students focus on environmental and economical considerations when they refer to sustainability. This teaching module advances their understanding of social sustainability during the planning and design phases of construction projects, focusing on Safety through Design as well as Social Design, Corporate Social Responsibility, and Community Involvement. Trochim's and Novak's concept mapping techniques are used as assessment tools in this teaching module. The first is used to establish a group pre-assessment of student knowledge, serving as a point of discussion during the lesson. Novak's technique is then used as a post-assessment, identifying the knowledge gained by the students. The results of this educational experience show that both groups, seniors (N1=60) and graduates students (N2=25), developed a balanced view of sustainability. In particular, students became more aware that as future designers, they should ensure worker safety by eliminating potential safety hazards from the work site during the design phase. These results are encouraging in how to teach Safety through Design with other social sustainability categories.

Keywords: Safety through Design, Social Sustainability, Sustainable Construction, Concept mapping, Safety Education

1. Background

Civil engineers (CE) are in a key position to enhance the three pillars of sustainability given their broad roles, ranging from designing to deconstructing the built environment. While environmental and economic sustainability is receiving increased focus in CE programs (Woodruff, 2006; Grimberg et al., 2008; Chong et al., 2009), social sustainability receives little attention in the classroom (Klotz and Grant, 2009), the emphasis often on service-learning projects (Riley et al., 2007). Rather than a clear and agreed-upon focus on social sustainability, it is an evolving concept of interest, creating an opportunity to teach students its various categories.

When social categories are not considered, construction project performance measures such as schedule, budget, and safety are adversely affected. For example, safety accidents during construction impact a range of stakeholders by reducing team morale, productivity, and profitability, while at the same time increasing personnel turnover (Rechenthin, 2004). Making the situation more critical is the fact that these accidents negatively affect community perceptions about the profession and the industry. The public will view this industry as being indifferent to both safety concerns and long-term project viability, thus limiting the ability to attract qualified and diverse CE professionals and construction workers.

For social sustainability to be addressed fully by future CE professionals, students must be educated and trained to consider this concept in infrastructure projects. These students should begin thinking about their roles in the process to improve user/worker health, safety and well-being during the life cycle of projects. To accomplish this goal, this paper describes the implementation of a Social Sustainability teaching module taught in a Sustainable Construction course, an elective for seniors and graduates students in the Civil Engineering Program at Clemson University. This module was developed to help students consider social categories of sustainability during the planning and design of construction projects by focusing on Safety Through Design as well as Social Design, Corporate Social Responsibility, and Community Involvement. The learning outcomes of these four social categories were assessed through the evaluation of two concept mapping techniques (Novak, 1990; Trochim, 1989).

2. Safety Through Design as One of the Social Sustainability Categories

The sustainability literature suggests that safe and healthy living and working conditions are important components of social sustainability along with the impact of the project on the local community through the its lifecycle (Benoit and Mazijn, 2009). Based on the *Brundtland Report* (1987), *Agenda 21* (1992) and *Agenda 21 on Sustainable Construction* (1999), the construction industry considers social sustainability as a series of processes that improves safety, health and well-being during the life cycle of projects, including both current and future generations (Herd-Smith and Fewings 2008, Dillard *et al*. 2009). The teaching module proposed here is based on the four categories currently being applied through various processes and techniques in different phases of the delivery of construction projects (Valdes-Vasquez and Klotz, 2010). Each category is described briefly below:

- Community Involvement emphasizes public constituencies in governmental and private decisions
- Corporate Social Responsibility considers the accountability of an organization in caring for all of the stakeholders affected by its operations
- Social Design focuses on improving the decision-making process of the design team and the intended use of the project by the final users
- Safety Through Design ensures worker safety by eliminating potential construction /operation safety hazards during the design phase.

This last category, Safety Through Design, aims to reduce construction workers injuries and fatalities as well as increasing construction worker health. This concept, also known as Prevention through Design (PtD) or Design for Construction Safety, has been recognized by the National Institute for Occupational Safety and Health (NIOSH) as a key strategy for improving workplace safety. While this is a promising safety approach, one of the barriers for its implementation is the lack of education among designers concerning construction safety (Gambatese, 2003). However, as Toole (2005) documented, the possibility of adding another course in engineering programs to cover safety is limited due to accreditation requirements. Perhaps current sustainable construction courses could serve as an integration point for teaching safety to designers using a systems thinking approach. Such a pedagogy could help students learn to consider how design decisions can reduce construction hazards, helping to increase the social equity of a project. In addition, it will help them expand their perspectives about the social impacts of such hazards on the community, in particular when a high percentage of workforce may live in the surrounding area.

3. The implementation of the Social Sustainability Module

The implementation and assessment of the teaching module proposed here required four general steps, which include two class sessions as summarized in Figure 1:

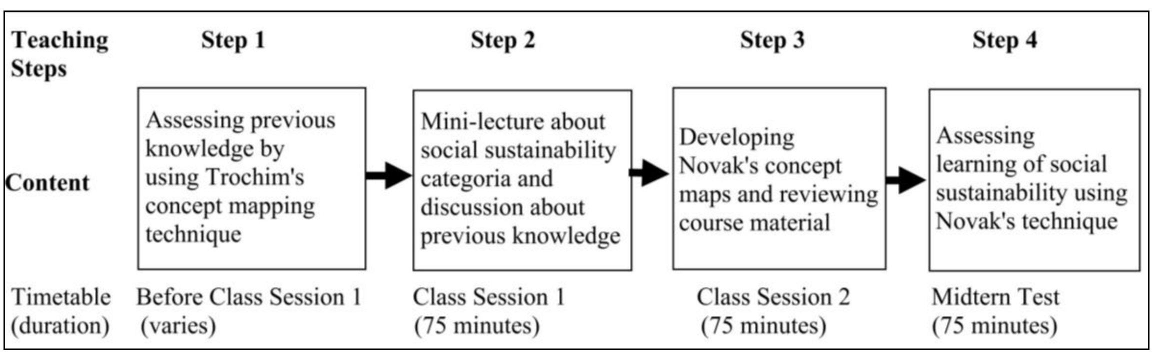

Figure 1: Teaching Approach for Social Categories of Sustainable Construction

Step 1: Assessing Students' Previous Knowledge of Social Sustainability

The first step assesses both the students' previous knowledge of social sustainability and their misunderstandings using Trochim's concept mapping technique (1989). This preliminary group assessment asks students to generate short statements describing specific processes of social sustainability that should be included during the planning and design phases of construction projects. Then, the final set of statements was later used for sorting and rating by graduate students.

The information collected from the students helped the instructor develop a group concept map representing a general conceptualization of social sustainability using the Concept Systems, a web-based software (Kane and Trochim, 2007). The objective of this report was to provide students with a graphic representation of their previous knowledge and to give them time to reflect on their misconceptions as group. In addition, a discussion topic about social sustainability was posted on Blackboard to prepare students for the next class period. For Safety Through Design, such discussion topics could include the effect of the design of skylights, footing and steel framework on occupational safety during construction and operation.

Step 2: Teaching Social Categories of Sustainability

The next class began with a discussion of the comments posted on the discussion forum on Blackboard. A copy of the concept map report was also given to the students to reflect about their misconceptions as group. Then, the Social Sustainability Model was presented so that students could apply theory to the practice of social sustainability concept, for instance how to integrate safety considerations during the design phase of construction projects. The importance of this mini-lecture is to emphasize that the social sustainability concept conveys multiple perspectives represented by various categories.

The students were then asked to find five aspects that they did not know about Social Sustainability based on the concept map report and the conceptual model presented. This in-class activity gave students an opportunity to convey and build knowledge in a cooperative environment since they worked in small groups. Past research has found that this combination of providing and receiving information from peers enhances the learning process since peer-feedback provides a different perspective and allows students to incorporate and internalize these new concepts (Nilson, 2003).

The class session concluded with a general discussion to help students clarify concepts and view different perspectives of the topic, with special emphasis on the fundamental concepts behind each social dimension. After this discussion, students were given instructions for incorporating the different categories of social sustainability in the midterm project, which was creating video tours featuring sustainability aspects of campus facilities. Finally, the instructor provided extra information to clarify some of the misconceptions found during the activity. After class, an e-mail was sent to the students providing extra resources such as documentation related to OHSAS, NIOSH and Safety through Design practices.

Step 3: Novak's Concept Mapping Practice

The information on social sustainability was reviewed again before the midterm along with other topics covered in the course. For this educational experience, Novak's concept mapping technique was used to assess the knowledge gained by each student (1990, 2010). In Novak's approach, the student writes ideas in boxes using lines to connect related concepts, often including labels, to show the type of connection to build meaning among a given set of concepts. This concept map technique has been successfully applied in other programs to measure understanding of sustainability (Borrego et al., 2009; Lourdel et al., 2007).

To practice, one class session before the midterm, students developed individual concept maps based on their understanding of the topics covered in the course to date. Although one of the main purposes of this step was to review the course content, it also allowed students to practice using the Novak concept mapping so that they were familiar with the technique. Students then shared their maps, reinforcing how to create concept maps. This technique is also a useful tool for understanding how students connect related information as well as the information they are missing at a specific point of time (Wiezel, 2006).

Step 4: Assessment of Student Understanding of Social Sustainability

During the midterm exam, the students developed individual concept maps. Students were required to construct a concept map of the social processes of sustainability that need to be considered during the design of construction project. Figure 2 shows one of the concept maps developed by the students:

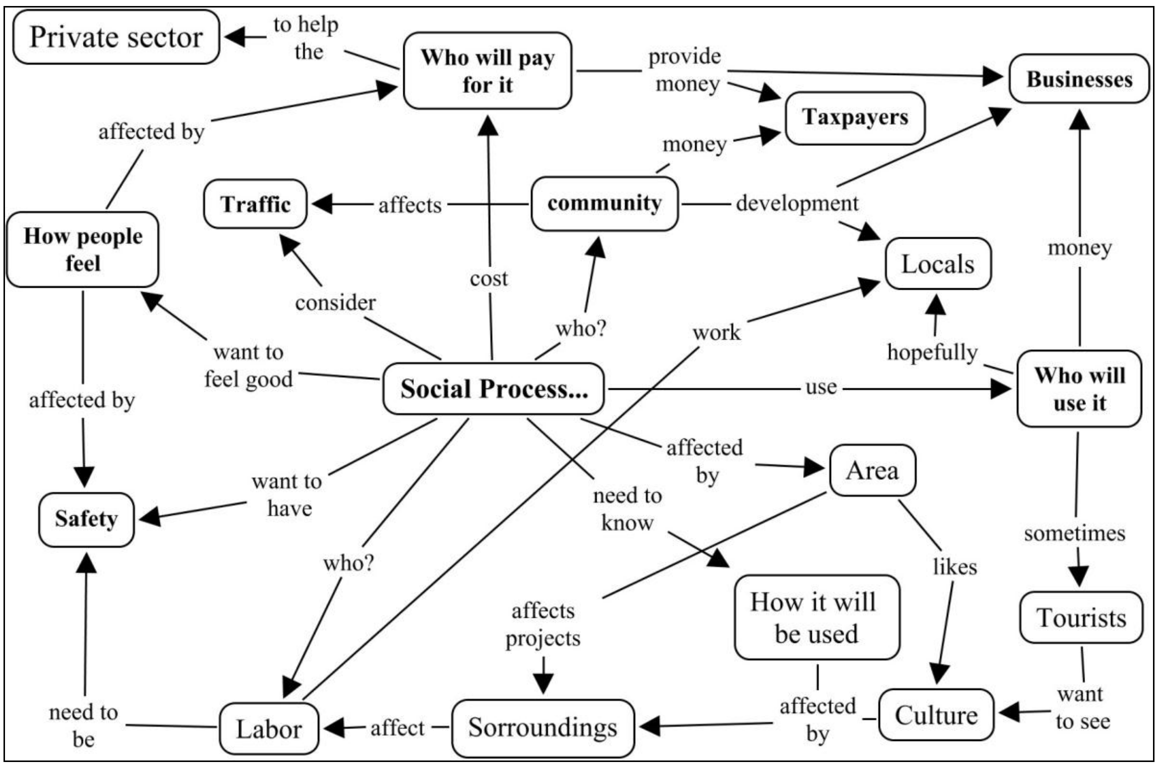

Figure 2: Concept map from a student.

A grading matrix for assessing these concept maps was adapted from Martinson (2004) and Besterfield-Sacre et al. (2004). Since one concern when using this rubric was the validation of the assessment tool, two other evaluators were asked to independently assess 17 randomly selected concept maps of the 85 collected. The instructor of record and another research graduate student with a sustainability focus served as these evaluators. These 17 maps were given to the evaluators without the names of students on them, and they were randomly arranged to eliminate individual bias.

The results of a linear correlation (r=.98) show a strong correlation between the principal evaluator's overall grades and the average overall grades of the two independent evaluators using the rubric. From these results, it was concluded that the rubric was a fair assessment tool to determine the level of understanding of students. In general, having two additional evaluators was important for the assessment of the maps because this process needs to be unbiased, especially when assessing some of the abstract topics related to social sustainability.

4. Results

Table 1 presents the results from the assessment of the 85 concept maps:

Table 1: Average Grade of the Concept Maps divided by Seniors and Graduates

Stratum (h)	Subpopulation (N_H)	Average Grade ($\bar{y}_h$)	Standard Deviation (s_h)
Seniors	60	88.4	5.0
Graduate	25	89.2	5.0

Since the levels of education of the students were different, it was expected that the results from the two groups would be different. However, these results show that undergraduate and graduate students have a similar level understanding of social sustainability based on the grades given using the assessment tool. The results do not support the hypothesis that Stratum One consisting of seniors would have a different average grade from Section Two, which includes graduate students.

While the results are encouraging, one of the primary limitations of using this technique was grading the maps. One of the independent evaluators affirmed that the task of grading was difficult, saying "grading concept maps is time-consuming and takes a fair job to do it." This comment is supported by another evaluator, who reported that grading conceptual ideas rather than concrete answers is difficult. The suggestion when grading concept maps is to compare the maps with similar scores to validate the consistency of the grades. Another recommendation to consider is to assess a large portion of the midterm as a concept map so that more time could be spent evaluating the knowledge gained by the students on different topics covered in the class.

Observations from Instructor of Record

One of the primary findings provided by the instructor of record was that having students construct individual concept maps is helpful since students work with the concepts rather than just listening to them. Primarily, writing the concepts forces them to reinforce and link the concepts discussed during the lecture. The instructor of record reflected that although a small group of students did not enjoy developing these kinds of maps, the majority found it useful. This reflection implies that these students saw their knowledge in tangible ways, connecting the different pieces. This process of developing the maps helped them to see the big picture, using a systematic approach rather than focusing on one narrow perspective, a key ability for future civil engineers designing sustainability infrastructures (Clough, 2005).

Feedback from Students

To supplement this classroom assessment, five students were formally interviewed three weeks after the midterm to obtain general feedback about the Social Sustainability teaching module. Three specific questions were asked: a) what do you think social sustainability means? b) can you explain how your understanding of social sustainability has changed, if it has, as a result of the teaching module?, and c) do you think it is important that social aspects are taught in this class? Why or why not?

The opinions obtained from the students provide additional perspectives that help to reinforce that the teaching module was successful in increasing the awareness of the students about Social Sustainability categories such as Safety Through Design. The following points are just a summary of the main findings from these interviews:

- Students clearly identified that social sustainability is about current people and future generations. While they did not recall fully the definition provided during the class session, they were aware this concept involves several stakeholders including the construction workers as well as the surrounding community, final users, and the design team.
- They stated that they have a better understanding of sustainability in general and that they now include not only the environmental concerns but also the social ones. Some of the comments shared were that "it is good to understand that the design is more than the safety of the structure itself. There are other safety considerations that affect sustainability of the project."
- All the students agreed that the teaching module helped them to integrate and see the various considerations that previously they did not think were part of the concept of sustainability such as preventing construction hazards during the design phase. One of the students stated that "I didn't really know anything about social sustainability; when I thought about sustainability, it was about saving the environment and recycling. I didn't realize that it deals with such aspects as safety and healthy places to live and work."

Based on the results obtained from individual concept maps and the feedback provided from students, the concept maps help students internalize and take ownership of the material by making them use the ideas discussed in class. These maps also reinforce conceptual understanding and enhance long-term retention by giving them options for organizing their knowledge. In particular, this technique helps to increase awareness among civil engineering students that preventing occupational hazards during the design phase is a fundamental concept of social sustainability.

In addition, using these techniques to teach safety concepts helped the students to conceptualize their ideas and the implications of Safety Through Design during the design of infrastructure projects. The same is applicable when learning about the other three categories: Community Involvement, Corporate Social Responsibility, and Social

Design. Future civil engineers must be able to design sustainable solutions that not only satisfy technical, economic and environmental requirements but also consider the social pillar of sustainability.

5. Conclusions

Although the results of this study may not generalize to other cohorts in other programs or institutions, it suggests trends in improving student learning of Safety Through Design as part of the social sustainability concept in the delivery of construction projects. Specifically, concept mapping techniques promote shared understanding and learning by looking at broader wholes and their parts, especially in teaching abstract concepts such as social sustainability as well as in providing feedback. In the future, the implementation of the teaching module can be enhanced by exploring how to assess the development of team concept maps rather than individual ones.

Further study based on other qualitative measures such as extensive personal interviews or essays is also required to investigate the different ways in which students experience or think about various aspects of social sustainability in relation to the delivery of construction projects. In addition, the implementation of this module can be applied in other programs and institutions to compare results and provide generalizations. The author welcomes other faculty members to be part of the implementation of this module. All of these efforts will serve the main goal of preparing CE future professionals for learning about the concept of sustainability beyond the classroom.

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An Investigation into the Legal Infrastructure Framework for Safety and Compensation Policies on Site Accidents

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Abstract

The nature of the physical construction process has been described as clearly distinguishing the industry to present safety challenges. Therefore, the risks associated with accidents on construction sites are inevitable. This phenomenon is more evident in developing nations where the provision of safety infrastructure is sometimes inadequate and substandard. It has been proposed in various literature that companies' safety policies and systems for risk management should include workers safety welfare broadly and also protect the contractors from the implications of the negligence of employees. However the contextual nature of various policies also suggests that there may be variations in the approach between countries. In this study, an investigative approach into the safety and compensation policies of construction firms in Lagos, Nigeria was made. Data collection was carried out using questionnaire surveys, structured interviews and documentary analyses. With a response rate of 75%, information was elicited on the safety and compensation policies and plans of construction firms in Lagos. Data was analyzed with relevant statistics. The research revealed areas of deficiency and loopholes in policy strategies. The results and recommendations from this research provide a guide for taking efficient and equitable policy decisions on the welfare of contractors and site workers.

Keywords: Construction site, developing country, legal infrastructure, organization, safety policy.

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~~I~~ 1 Introduction

The prospects of ever achieving ideal standards of health and safety in the construction will remain low where there is no formal organization policy on safety management. According to Adenuga, Soyingbe and Ajayi (2007) laws must protect the health, safety and welfare of construction workers. Generally, good health and safety policies set a clear direction for an organization to follow. They have also been described as cost-effective approaches to preserving and developing physical and human resources, which reduce financial losses and liabilities. Kuju-Ahmad (2000) explains that organizations that are successful in achieving high standards of health and safety generally have health and safety policies which contribute to their business performance. The formulation and implementation of such policies is particularly necessary in an industry that has generally been criticized for its poor performance in health and safety. Construction workers suffer far more serious injuries and fatalities than the general workforce population. (Buyite,

2007) .They die from work-related trauma at a rate three times the national average for workers in all industrial sectors; they suffer disproportionately from non-fatal injuries, from lung diseases, musculoskeletal disorders, hearing loss and dermatologic conditions. For the construction industry, the national cost from lost production, medical care, workers compensation and related claims is very high. Workers compensation insurance premiums alone cost $7 billion annually as they often work in the presence of excessive noise levels and with tools and equipment that produce potentially hazardous vibrations and perform repetitive, forceful motions. Workers also assume awkward working postures and frequently use a variety of toxic and volatile substances. Essentially, the construction sector stands out from most other industries to have one of the highest worker injury rates. Spangenberg (2010) also affirms that construction projects have resulted in impressive and useful structures, but at significant human costs and with numerous construction worker fatalities and serious injuries. In many developing nations, inadequate consideration has been given to the issue. Workers therefore remain prone to risks and uncovered even in the event of injuries and accident. Laryea and Mensah (2010) in their study on construction health and safety discovered a poor state of health and safety on Ghanaian construction sites. A primary reason for this was poor health and safety policies and procedures. Health and safety represents a great challenge and its management continues to be increasingly important in the construction industry. This study therefore adopts an investigative approach into the legal policy framework of construction companies in Lagos, Nigeria regarding safety and health of personnel on site.

~~II~~ 2 Literature

Safety and Health Policies in Construction

Safe and healthy working conditions do not happen by chance and any site safety approach recommended will remain in mere abstraction without its formal adoption into a policy. According to Ahmed, Roger, Martin and Terence (2001), employers need to have a written safety policy for their enterprise setting out the safety and health standards which is their objective to achieve. A health and safety policy is a written statement of principles and goals embodying the company's commitment to workplace health and safety (CSAO, 1993). It demonstrates top management's commitment to ensure safe working methods and environment at the construction sites (Dorji and Hadikusumo, 2009). Health and safety policy should influence the selection of people, equipment and materials, the way work is done and how service delivery occurs. A written statement on the arrangements for implementing and monitoring policy shows that hazards have been identified and risks assessed, eliminated or controlled.(Institute of Engineering technology, 2010), Identifying hazards and assessing risks, putting precautions in place and checking they are used protects people and safeguards production. A good comprehensive policy on the subject of safety will ensure that duties and responsibilities would not overlap thereby making safety management effective. This is due to the definitive roles of each actor in the process. Essentially, these policies serve as a blueprint and guide to safety management on site. Laryea and Mensah (2010) affirm that in developed nations, there are statutory instruments and legislative frameworks to govern construction operations on site and help in minimizing health and safety hazards for example, the Construction Regulations 2007 (S.I. 2007/No. 320) on Health and Safety in the UK construction industry. In Nigeria, there are no health and safety regulations developed specifically for the construction industry, though a number of occupational health and safety policies exist. Idoro (2011) explains that the existing Factory Act of 1990 in Nigeria is an adaptation of the UK Factory Act of1961. The Occupation Safety and Health Act of 1970- an American regulation. Others such as the Control of Substances Hazardous to Health Regulations of 1988; the Personal Protective Equipment at Work Regulations of 1992; the Management of Health and Safety at Work Regulations of 1999 are all British regulations and are applicable in European countries. The Manual Handling Operations Regulations of 1992 and the Construction Design and Management (CDM) Regulations of 2007 are also UK regulations. The Personal Protective Equipment (PPE) Regulations of 2002 were purposely formulated to regulate the use of PPE. Idoro asserts that the provisions of the Factory act of 1990 do not apply to the construction industry. Also, the provisions contained in the PPE regulations exclude construction sites and activities from its coverage, therefore the activities of construction contractors and workers on OHS are unregulated. Williams (undated) also confirms that it is only in Lagos State that there are some Local Government bye-laws that touch on the safety of workmen in this area.

The contents of safety policies of various countries may differ slightly or significantly depending on the orientation and adaptability of formulation strategies. Laryea and Mensah (2010) state that Health and Safety policies and procedures may vary and need to be contextualized as the characteristics of countries differ. In this context, Baloi and Price (2001) elucidate that an organization/project environment is a set of factors and their properties have the potential to impact on its operations and progress. Developing countries pose greater challenges to international construction contractors because of inherent risks such as government instability, shortages of adequately trained craftsmen, difficulty in acquiring needed materials, and lack of adequate infrastructure. In different regions, varying requirements for construction activities are put forth. Juodis, Siskina and Stalioratis (2005) identify the following major factors among those most often responsible for these variations: local/national regulations, rules and law, acts, climate/weather conditions; geological/ seismic conditions, price and productivity of labour force; quality of construction material, conditions of their provision and period; local traditions and festivals, local infrastructure; local communications lines and access to them; conditions of project financing and settlement for the works performed; taxes, insurance, Attitude of state institutions towards the companies from other countries etc. The management of construction organizations must therefore have a close relationship with the environment in policy formulation.

~~III~~ 3 Research Process

The initial stage of this research comprises the rationale for this study followed by literature pointing at various issues relating to policy use and formulation in construction health and safety. The insights into key performance criteria of established policies (some key factors were subsequently modified contextually and used in structured questionnaires to elicit information on the policy frameworks of construction companies in Lagos, Nigeria) .The questionnaires were designed as adapted from the policies of various construction companies in the United Kingdom to determine the state of the existence or non-existence of the performance contents in local policies. (Most governing frameworks in Nigeria are adaptations from the United Kingdom- Nigeria being a former colony of the United Kingdom). The variables were modified to suit the local criteria as discussed in the literature above. Figures from the current directory obtained from the council of registered builders of Nigeria practicing construction firms in Lagos put the size of the population of this study at 414. This population was derived from the current professional directory of the council consisting of various built environment professionals e. g builders, quantity surveyors, civil engineers, a etc, working within building and construction supply chains. The sample was systematically selected to obtain a sample size of 200 which constitutes approximately half of the total population. Follow-up documentary inspection was performed (where possible) to clarify claims made by the respondents. The respondents chosen were high ranking officers within the organizations surveyed. These included managing directors, project managers, engineers of the organizations surveyed as they were considered competent to give valid responses to the questions based criteria such as their positions in the organizations. The target respondents held positions of seniority within their organizations and were deemed the most adequate individuals to provide information required for this survey. The questionnaire was sub-divided into two sections comprising the following; background of the respondent in the organization, the background of organization itself and policy criteria. Lagos state was picked as study area due to the preponderance of these construction firms in the study area.414 firms in Lagos out of a total of 1200 in 36 states of the federal republic of Nigeria. Estimates put this value at about 30% of the total population of construction firms in Nigeria.

~~IV~~ 4 Research Findings

A sample of 150 firms yielded a response rate of 75%. This was considered adequate in view of usual difficulties encountered in data collection especially for research in Nigeria. The survey instrument was completed by respondents whom have been described in the table below. Questions asked in arriving at the aim of the study and responses are shown in subsequent tables.

Table 1: Characteristics of Respondents

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Gender	**Frequency**	**Percentage**
Male	147	98
Female	3	2
Academic Qualification		
HND/B.Sc	117	78
PGD	8	5.3
MBA/M.Sc	5	3.3

M.Phill	3	2.0
PHD	7	4.7
Others	10	6.7
Status in Organization		
CEO/Partner	3	2.0
Managing Director	7	4.7
Executive Director	5	3.3
Project Manager	95	63.3
Planning and Resource Manager	31	20.7
Others	9	6.0
Age of Organization		
Less than 1yr	2	1.3
1-3yrs	10	6.7
Between 3 and 5yrs	17	11.3
Between 5 and 10yrs	43	28.7
10yrs and over	78	52.0
Years of Working with Organization		
Less than 1yr	10	6.7
1-3yrs	39	26.0
Between 3 and 5yrs	29	19.3
Over 5yrs	72	48.0

Source: Field survey 2011.

The questions above sought to query respondents about their background. These responses confirmed that the respondents could be deemed fit to give valid responses in view of their education and experience levels mainly.

Respondents were further questioned about the frequency of occurrences on their sites. (51.3%) of the respondents agreed that site accidents/emergency occurred occasionally. About (34%) of the respondents also agreed that site accidents/emergency occurred rarely, while (8%), (4.7%) and (2%) of the respondents agreed that site accidents/emergency occurred 'frequently', 'very frequently' and 'never'.

Table 2: Rate of existence of written policies on Construction Safety and Health Management in organizations

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	Frequency	Percentage
Yes	89	59.3
No	11	7.3
It is currently being developed	37	24.7
Not Sure	13	8.7
Total	150	100

Source: Field survey 2011.

Table 1 above shows that 59.3% of the construction firms have written policies or formal blueprints on construction safety and health management in their organizations. 7.3% of the construction firms did not have any formal arrangement on health and safety of their workers at site. 8.7% of surveyed respondents said they were 'not sure', while a significant number (24.7%) explained that their policies were currently being developed, which implies that as at the time of collecting this data, they did not have any formal policy whatsoever.

Table 3: Rate of policy reviews

	Frequency	Percentage
Never	19	21.3
Bi-annually	6	6.7
Yearly	15	16.9
Once in two years	30	33.7
Once in three years	9	10.1
Others	10	11.2
Total	89	100

Source: Field survey 2011.

Table 2 shows that 33.7% of construction firms that do have any policy at all review their policies biennially. 16.9% of construction firms review policies annually, (21.3%) of firms have never reviewed their policies. 10.1% of firms surveyed review formal blueprint on construction safety and health management once in three years. While 11.2% of construction firms make reviews at the instance it is needed, or some other obscure time duration. Most firms though carry out reviews once in two years. This shows the level of importance placed on dynamism through policy amendments.

Table 4: Percentage of stakeholders/ staff equipped with the policy

	Frequency	Percentage
All employees	9	10.1
Most employees	31	34.8
Several employees	4	4.5
A few employees	31	34.8
Only employees who are interested	5	5.6
Only top management staff	9	10.1
Total	89	100.0

Source: Field survey 2011.

Table 3 above shows that 34.8% of construction firms issued 'most' members of their organizations copies of their policies, 34.8% also of construction firms issued 'a few' of their employees with the policies. 10.1% of construction firms issued 'all' members. 10.1% of construction firm issued only top management staff issued copies of policy. In the analyses, if organizations issued 'all staff' copies of their policies, then it was assumed that the organization issued approximately over 75% to 100% of their staff with these companies. If 'most employees' then between 50 and 75%. For 'only employees

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who are interested', this was assumed to carry a weigh of 0-25%. 'Only top management staff' was not weighted as the respective figures could be highly subjective and inconsistent with various staff strengths.

Table 5: Performance criteria status for construction health and safety policies in Lagos

	Construction health and safety Policy elements	P	NP	PP
1.	In your company policy, your company accepts formally and publicly its **collective / overall** role in providing health and safety leadership for the company.	58	26	5
2.	In the policy, each individual **member of the board** is to be assigned and is to accept his individual role in providing health and safety leadership for the company	85	1	3
3.	In the policy, the management requires all management functions within the company to be carried out in a manner that reflects the health and safety intentions of the policy statement.	63	16	10
4.	From your company policy, he board is to accept its role in engaging the active participation of workers in improving health and safety.	72	14	3
5.	From your company policy, the board is to appoint a Health and Safety Director who is to keep the board informed of, and alert to relevant health and safety risk management issues and who will assist in monitoring and reviewing health and safety performance.	53	-	36
6.	Your company policy ensures a place of work, systems of work and plant that are safe and do not create a risk to the health, safety and welfare of employees, independent contractors, members of associated companies and the general public, as far as it is reasonably practicable to do.	84	1	4
7.	Your company policy stipulates the issuance of appropriate information, instruction, training and supervision for all employees.	13	51	25
8.	Your company policy stipulates the allocation of sufficient funds/ resources to enable the health and safety policy to function effectively.	82	2	5
9.	Your company policy states that every individual concerned / employee must understand the contents of the policy for health, safety and welfare	89	-	-
10	Your company policy states that research must be carried out constantly to monitor Policy, review it and update it as appropriate. In order to take into account of any new Health and Safety legislation, new plant and equipment, new techniques and materials etc.	51	37	1
11.	In your company policy, specialist health and safety managers/advisors whose duties include monitoring on-going health and safety performance and providing advice in connection with establishing a healthy and safe place of work are suggested	67	18	4
12.	Your company policy stipulates regular consultation/ meetings with employees, contractors, trade union representatives, the Health and Safety Executive, Environmental Health Officers and other relevant organizations.	14	69	6
13.	Your company policy ensures that all on site workers, after proper	55	34	-

	training, assume personal responsibility and accountability for their actions, including knowing and observing safety rules and safe work procedures, wearing and using the required clothing, equipment and protective devices and being free from drugs and alcohol.			
14.	Your company policy stipulates the regular assessment of operational performance, incident investigation reports and audit information through a system of management review meetings in order to ensure continual improvement.	81	6	2
15.	The policy also stipulates the commitment to ensuring health and safety matters are an integral part of the business.	89	-	-
16.	The policy *alludes* to the commitment to complying with statutory requirements, approved codes of practice, recognized guidelines and other relevant industry standards.	29	28	32
17.	The policy stipulates commitment to the understanding of changes in working arrangements which have significant implications for Health and Safety	-	83	6
18.	Your company policy sets out that technical guidance notes and supporting information must be provided by relevant personnel in order to assist management in developing Risk Assessments and associated Method Statements.	6	62	21
19.	Your organization policy instigates **compliance** with the health and safety policy **by every member/employee** of the organization	89	-	-
20.	Your policy sets out Implications of non-compliance	11	71	7
21.	Your policy stipulates the availability of design or details of critical elements in any construction, such as, temporary construction, erection and lifting schemes, form work, scaffolding, and the use of lifting equipment and its supports as approved by a professional engineer**.**	16	49	24
22.	The policy identifies that the role of Health and Safety Manager is key to health and safety issues and reports to a Safety Director.	53	-	36

P- present, NP- Not present, PP- Partially present

Source: Field survey 2011

From 89 organizations with written formal construction safety polices, the table above shows the status of the contents in policies surveyed. Criteria 19 *'Your company policy sets out that technical guidance notes and supporting information must be provided by relevant personnel in order to assist management in developing Risk Assessments and associated Method Statements*' in the table above was found to be extremely lacking in many of the policies. 69.6% of the policies surveyed did not have this present at all. These companies therefore will likely lack information for the prevention development of associated hazards on their construction sites as well as key pointers on how to avoid such risks. The findings also show that most companies (58) openly accept their overall responsibility in providing health and safety leadership for the company. Other deficient areas in most policies include criteria 12 '*your company policy stipulates regular consultation/ meetings with employees, contractors, trade union representatives, the Health and Safety Executive, Environmental Health Officers and other relevant organizations'* as found in only 14 of the surveyed policies, and criteria 20 regarding the implications with non-compliance, only 11 firms had this criteria present in their policies. All the policies stipulated the commitment to ensuring health and safety matters as an integral part of the business

(criteria 15)

~~V~~ 5 Concluding Remarks

Most policies were found to be not as effective compared to accident rates which have not declined commensurately with policy formulations. (See Olatunji, Aje and odugboye, 2007). As observed from the findings in this study, the enforcement of organization policies still remains a major challenge as the implications of non-compliance were practically non-existent in many policies. The lack of a national act/ regulatory policy on construction health and safety has minimized the efficiency of individual policies in this regard. Bala, Kolo, Bello and Bustani (2009) in their study on factors inhibiting the growth of local construction firms in Nigeria ranked Government policies and support as the third out of 22 measures needed for optimal performance in the construction sector in Nigeria. A national regulatory policy will also ensure that individual organization health and safety policies (in line within statutory requirements) will be a pre-requisite to construction site operations. Communication also remains a veritable tool for organization performance. A few key staff of organizations were not well equipped with information as they were uncertain about the existence or non-existence of policies in their organization. Information stringency has been recognized as a clog in the wheel of industrial development as confirmed in this study. Areas recommended for further research included the sustainability of specific government policies for construction health and safety and a similar survey on the federation of construction industry members who are multinational and bigger contractors and are characteristically different in their organizational set up. This recommendation is advised for a comparative study.

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Reduction of Construction Project Risks to Pedestrians, Drivers, and Transit Passengers through Analysis of Historical Accident Records

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Reduction of Construction Project Risks to Pedestrians, Drivers, and Transit Passengers through Analysis of Historical Accident Records

Abstract

As the public agency responsible for the annual delivery of over three billion dollars in construction projects, the California Department of Transportation (Caltrans) has a tremendous responsibility to these deliver construction projects using project delivery processes and procedures that create the minimum risk to pedestrians, drivers, and transit passengers while also maintaining a safe working environment for all of its employees, consultants, and contractors. This study has introduces a methodology that uses the Pareto Principle and an accident chain analysis to analyze historical accident records. Analyses compare accident data and characteristics for accidents which do not occur in construction zones with accidents that did occur in construction zones. Using Pareto Charts to conduct these comparative analyses, recommendations to reduce accidents in construction zones are made. This work also includes accident chain analysis based on data identified from the Pareto analysis. The work presents mitigated accident chain diagrams to assist in determining how to reduce or eliminate the construction zone accidents studies in the chain diagrams. Conclusions include data collection suggestions for Caltrans, recommendations on how to implement research findings, and ideas for future research.

Keywords: Safety, Pareto, Construction; Transportation

1. Introduction

As the public agency responsible for the annual delivery of over three billion dollars in construction projects, the California Department of Transportation (Caltrans) has a tremendous responsibility to these deliver construction projects using project delivery processes and procedures that create the minimum risk to pedestrians, drivers, and transit passengers while also maintaining a safe working environment for all of its employees, consultants, and contractors. This study exams accident data from over 74,000 accidents that occurred on selected highways in Southern California. The objective of the analysis is to compare accident data and characteristics for accidents which do not occur in construction zones with accidents that did occur in construction zones. Using Pareto Charts to conduct this comparative analyses, recommendations to reduce accidents in construction zones are made. Potential accident chain scenarios based on the analysis are also developed as a tool to communication accident mechanisms.

Study of construction work zone accidents has become a nationwide and statewide priority. Title 23 United States Code (USC) 402, enacted in 1966 and administered through Title 23 Code of Federal Regulations (CFR) 1204.4, and California Vehicle Code

(CVC) Section 2900 et seq. requires the State of California to have a data collection system as part of the process to reduce the number and/or severity of accidents on roads in the State of California. In response to Title 23, USC 402, the State of California developed the Traffic Collision Reports (TCR's) used by police agencies to collect and compile accident data. When the State developed the TCR's, they also developed the accident database (SWITRS) that resulted from the data collected and compiled from the traffic collisions reports. The State also developed the Traffic Accident Surveillance and Analysis System (TASAS) used by the California Department of Transportation (Caltrans) to analyze accident, traffic, and highway data collected and compiled by Caltrans. The State of California has developed a process that utilizes the TASAS data base, including the accident information collected and compiled into it, to effectively reduce the number and severity of accidents on all highways under the jurisdiction of the State. This study to date has not extensively looked at accidents as related to active construction projects.

The Pareto Principle is based upon the observation of Vilfredo Pareto in nineteenth century Italy that 20% of the population controlled about 80% of the wealth. Researchers have applied Pareto's concept to many other topics other than wealth distribution and have found that in most cases, occurrences are distributed in a way such that a vital few make up the largest portion of the population of outcomes – but not always strictly in a 20-80 relationship (Juran 1989). The Pareto diagram is a graphic representation of this concept. The Pareto diagram itself is a histogram with the categories of data arranged in order from the largest the smallest and a cumulative curve for all outcomes. Used in research applications, Pareto diagrams graphically allow the separation of the vital few items from which the majority of occurrences are generated from the trivial many. Resources are then directed to the vital few, thus maximizing the effective use of available resources. Used in such a fashion, Pareto diagrams have been used or proposed in a number of applications such as quality control (Kuprenas and Kenney 1999), engineering management (Graves 1993), and safety (Kuprenas et al 1999, Kuprenas and Nasr, 2000).

Accident chains are a simple graphical tool used to represent the condition of events that result in an accident. Each circumstance / event is illustrated through a box. Arrows connecting the boxes indicate a relationship between the circumstances / events. The final box in the chain is the accident. Items immediately preceding the accident are the direct cause of the accident, but the value of the accident chain is beyond these events. The chain identified events prior to these direct cause events that if eliminated would prevent the accident preceding event from happening. In many cases, removal or mitigation of these earlier events is significantly easier (effort, cost, time, etc.) than removal of later events. This work will create accident chains based on data identified from the Pareto analysis. The work will also create mitigated accident chain diagrams to assist in determining how to reduce or eliminate the construction zone accidents studies in the chain diagrams.

2. Analysis

Data used in the analysis is all accidents in Caltrans District 7 for the three year period from 10/01/00 to 09/30/03 on the five state routes 005, 010, 101, 110, 405. Accidents in all directions (northbound, southbound, eastbound, and westbound), all times of day, and all conditions are included. The TASAS database includes several data fields. The TASAS data fields used in this study are

- Number of vehicles
- Type of vehicle / party
- Type of accident
- Movement proceeding accident
- Primary collision factor (including construction activity)
- Other associated factor
- Sobriety / drug use

The data set is subdivided into two groups – all accidents (including accidents in construction zones) and accidents that specifically occurred in construction zones. Table 1 summarizes the data to be used in the analyses. Note within column 4 of the figure the large variation in number of accidents in construction zones. Note that this variation is less a function of the road, but rather more a function of whether construction took place over the three year period. Series of figures showing Pareto charts with two pieces of information for each accident attribute studied. The x axis on the chart represents the attribute outcomes and the y axes showing percentage. The left axis is the percentage of each individual outcome (measured as a bar) and the right axis is and the cumulative percentage for all listed outcomes (measured as a curve). Each figure shows information on two sets of data, a dark grey set of frequency bars and curve (representing accident data for all accidents) and a light grey set of frequency bars and curves (representing accidents that happened in construction zones).

TABLE 1. Accident Data

Route (1)	Total Number of Accidents (2)	Number of Accidents Not in Construction Zones (3)	Number of Accidents in Construction Zones (4)
005	16,562	16,207	355
010	18,306	17,194	1,112
101	13,169	12,938	231
110	10,555	10,480	75
405	15,894	15,715	179
TOTAL	*74,486*	*72,534*	*1,952*

Table 2 summarizes the number of injuries and of the number of accidents per injury. Note within columns 3 and 5 of the figure a lower number means that the accident would be more likely to result in injury – a value of one would mean every accident resulted in an injury. The table shows a 4.2% increase in the average of accidents per injury when the accident occurs in a construction zone.

Table 3 summarizes the number of fatalities and of the number of accidents per fatality. Note within columns 3 and 5 of the figure a lower number means that the accident would be more likely to result in fatality – a value of one hundred would mean every one hundred accidents resulted in a fatality. The table shows a significant difference between the averages shown in columns 3 and 5. The table shows an increase of 37.4% in the average of accidents per fatality when the accident occurs in a construction zone.

Within the TASAS database one fundamental piece of information is the primary collision factor to each accident. The Pareto chart showing the primary collision factor in each accident of the study is shown in Figure 1. The dark bars show the non-construction zone accidents; the lighter bars are the construction zone accidents. The figure shows the most common primary collision factor to be “speeding” with “other violations” and “improper turn” also relatively common factors (~20% and ~10% respectively). The figure shows differences in collision factors based on construction zone accidents.

TABLE 2. Accident Data – Injuries

Route	Accidents Not in Construction Zones		Accidents in Construction Zones	
	Number of Injuries	Accidents per Injury	Number of Injuries	Accidents per Injury
(1)	(2)	(3)	(4)	(5)
005	4,098	3.95	93	3.82
010	4,418	3.89	319	3.49
101	3,584	3.61	68	3.40
110	2,722	3.85	20	3.75
405	4,475	3.51	50	3.58
Average	-	*3.76*	-	*3.61*

TABLE 3. Accident Data – Fatalities

Route	Accidents Not in Construction Zones		Accidents in Construction Zones	
	Number of Fatalities	Accidents per Fatality	Number of Fatalities	Accidents per Fatality
(1)	(2)	(3)	(4)	(5)
005	89	182.10	3	118.33
010	55	312.62	2	556.00
101	30	431.27	4	57.75
110	38	275.79	1	75.00
405	42	374.17	1	179.00
Average	-	*315.19*	-	*197.22*

Figure 2 is a Pareto chart primary collision factors but with the “speeding” and “other violations” factors removed and the chart recalculated. The figure is of value because it clearly shows a substantial difference in collision factors based on construction zone accidents – the most striking in the collision factor of “influence of alcohol”. Based on figure 1 (all factors) the data shows alcohol to be the primary collision factor in 7.3% of accidents in construction zones and only 4.7% in accidents in non construction zones. This 56% increase for construction zone accidents due to the influence of alcohol is a key finding representing about 150 additional accidents in District 7, resulting in 40 injuries and 1.3 fatalities over the three years of the study.

The TASAS database collections collision factors other than the primary collision factor. This field is called “Other Associated Factor”, and Pareto chart for these other associated factors is shown in Figure 3. As in the other figures, the dark bars show the non-construction zone accidents; the lighter bars are the construction zone accidents. Many of these factors are common to the factors shown in Figures 1 and 2. Speeding is identified as another associated collision factor in 16.6% of accidents in non-construction zones and 22.4% of accidents in construction zones.

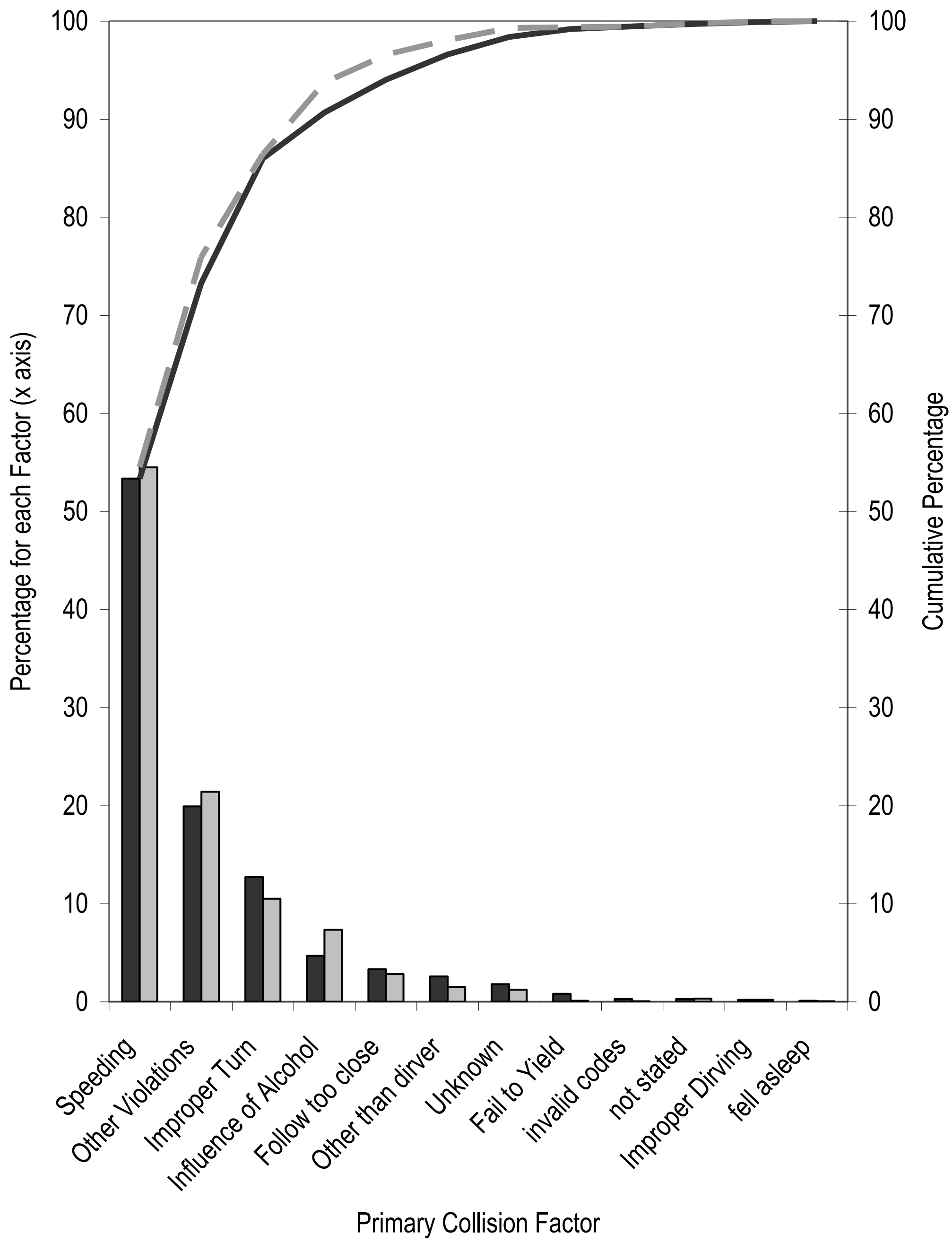

FIGURE 1. Pareto Chart – Primary Collision Factor

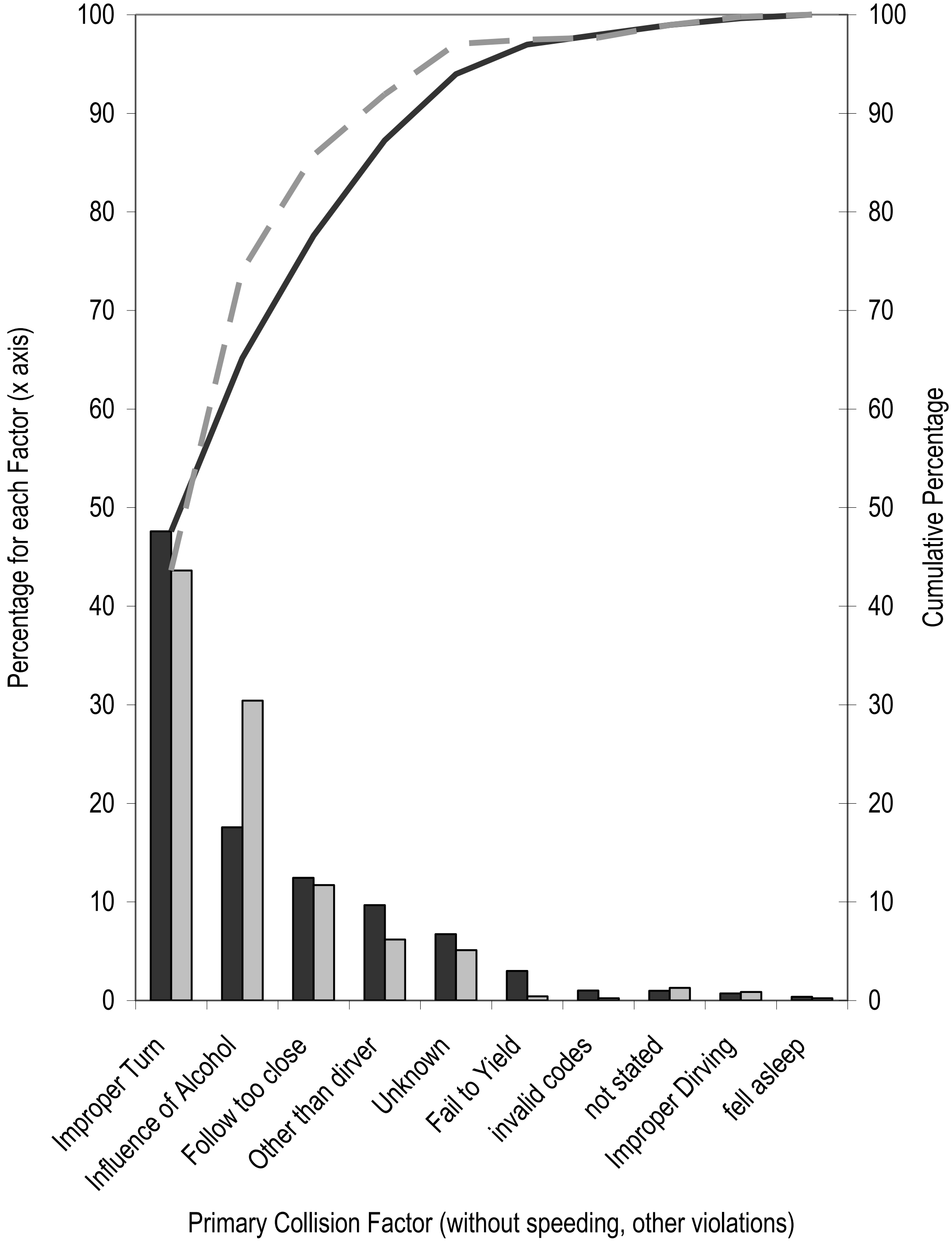

FIGURE 2. Pareto Chart – Primary Collision Factor With "Speeding" and "Other Violations" Removed

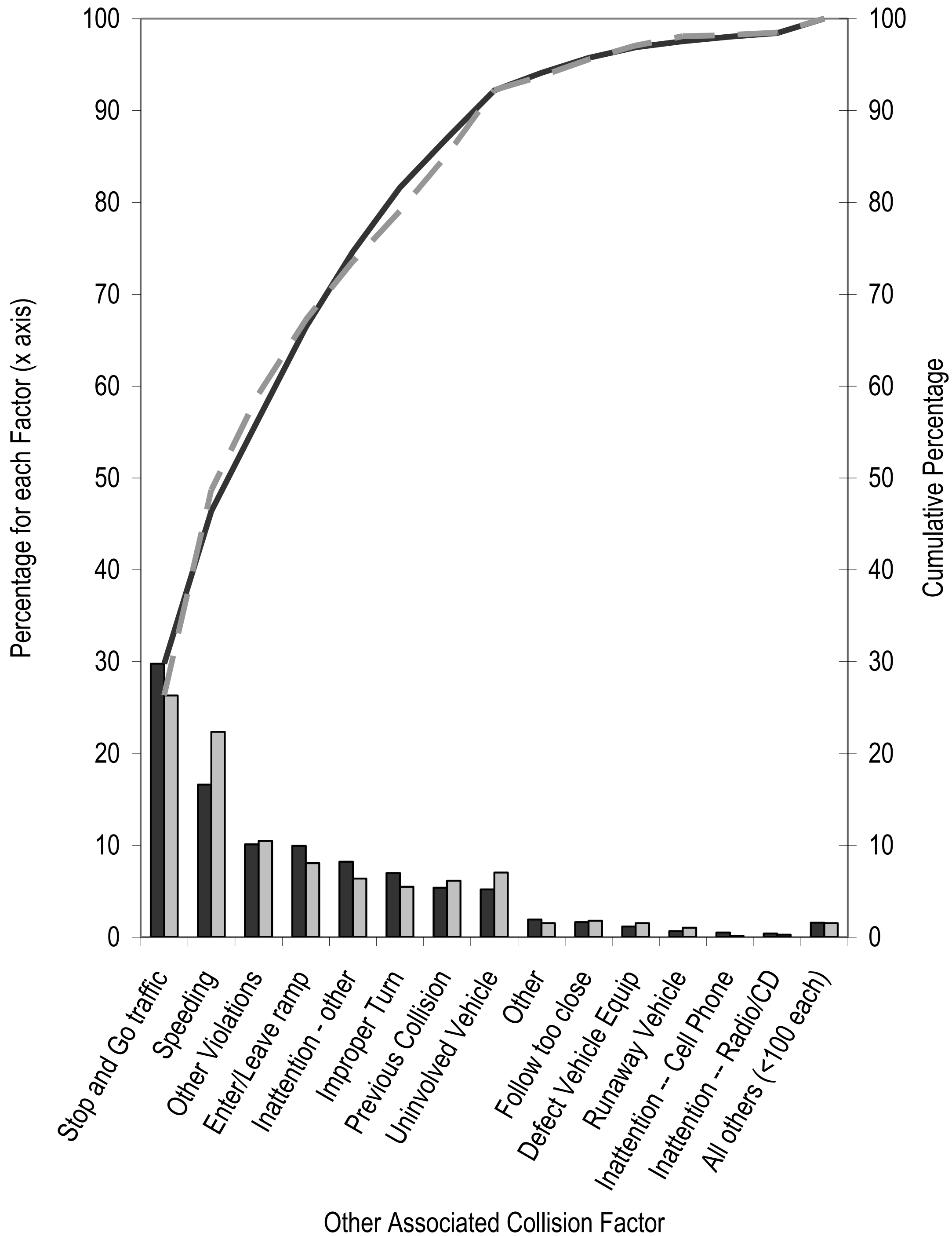

FIGURE 3. Pareto Chart – Other Associated Factor

3. Accident Chains

Accident chain analysis will focus on construction zone accident scenarios identified through the Pareto chart analyses. Accident chains will illustrate how sideswipe / drinking accidents could possibly occur. Mitigated accident chains are also created for each scenario in order to understand how to eliminate these types of accidents.

Figure 4 shows the accident chain for one finding from the analysis of the TSAS Construction Zone data analysis. The figure shows how the hypothetical Construction Project of a center median improvement project requires traffic controls, specifically lane traffic controls. The figure also shows the hypothetical case of a driver who had been drinking arrived at the area with lane traffic controls. The combination of these two events results in a sideswipe accident (shown to be 12% more likely in a construction zone).

Figure 5 shows one simple mitigation for the accident shown in Figure 4. Again, the figure shows how the hypothetical Construction Project of a center median improvement project requires traffic controls, specifically lane traffic controls. Again, the figure also shows the hypothetical case of a driver who had been drinking arrived at the area with lane traffic controls. Figure 4 also shows an external influence in the accident chain – law enforcement in place. The addition of the law enforcement removes the drunk drivers from the roadway and eliminates the combination of the two critical events that resulted in a sideswipe accident.

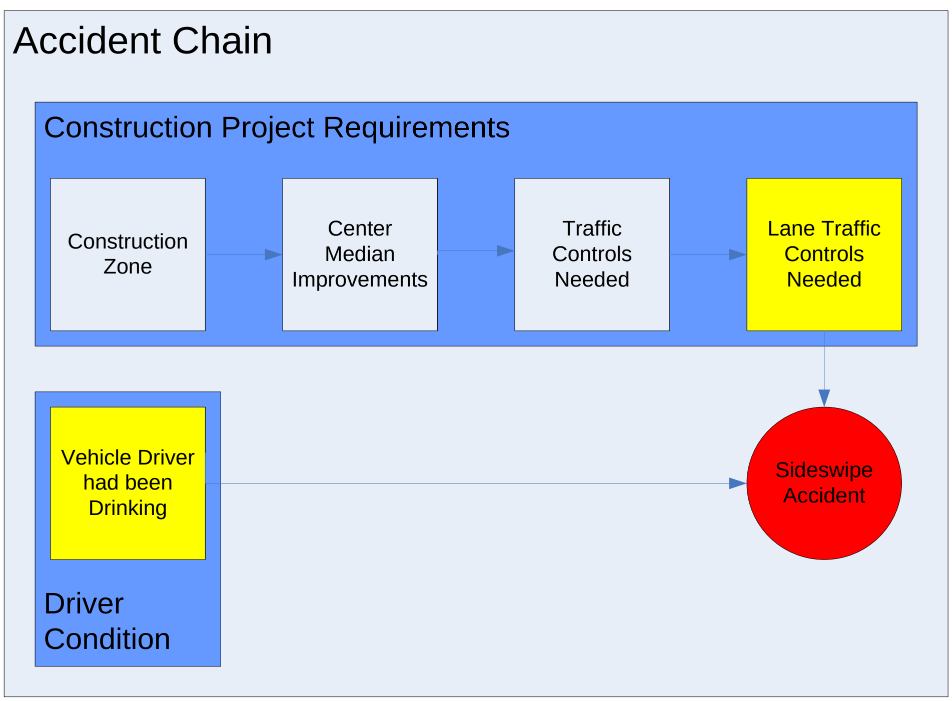

FIGURE 4. Accident Chain – Sideswipe / Drinking

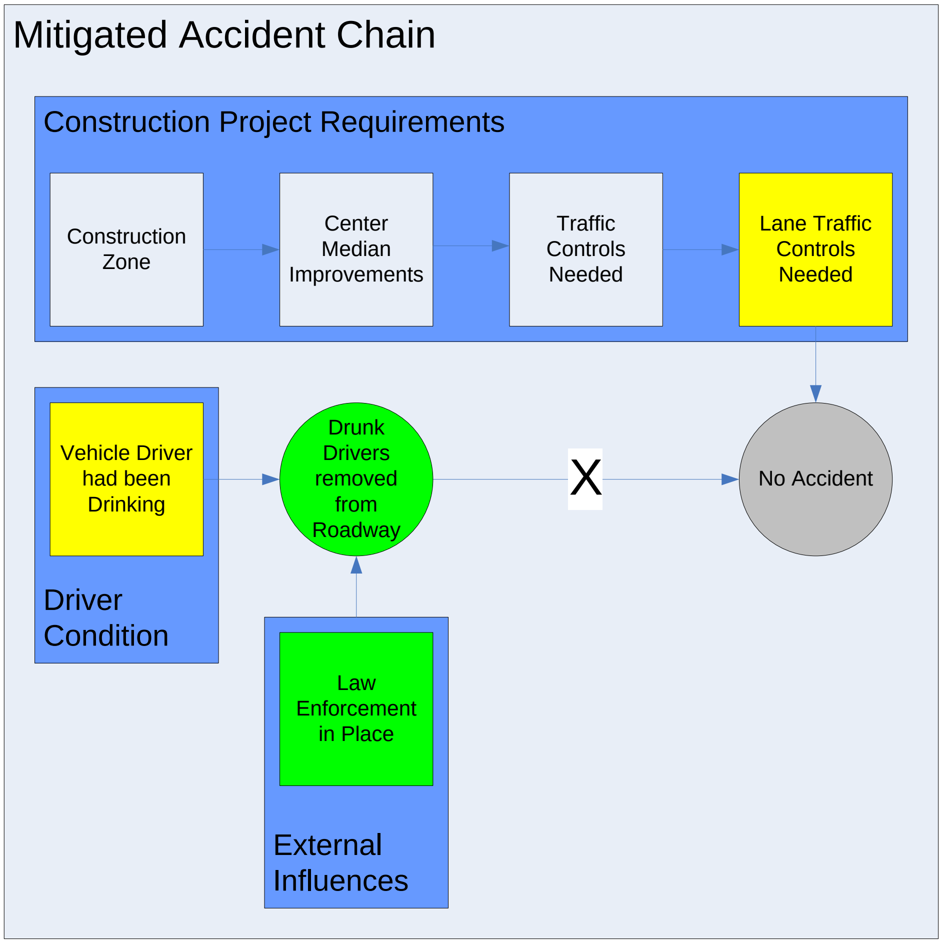

FIGURE 5. Accident Chain – Sideswipe / Drinking – Mitigated

4. Conclusions and Recommendations

As the public agency responsible for the annual delivery of over three billion dollars in construction projects, the California Department of Transportation (Caltrans) has a tremendous responsibility to these deliver construction projects using project delivery processes and procedures that create the minimum risk to pedestrians, drivers, and transit passengers while also maintaining a safe working environment for all of its employees, consultants, and contractors. This study has introduced a methodology that uses the Pareto Principle and an accident chain analysis to analyze historical accident records.

This study has examined accident data from over 74,000 accidents pulled from the TASAS database that occurred on selected highways in Southern California between 10/01/00 to 09/30/03 on the five state routes 005, 010, 101, 110, 405. The analysis has compared accident data and characteristics for accidents which do not occur in construction zones with accidents that did occur in construction zones. Using Pareto Charts to conduct these comparative analyses, recommendations to reduce accidents in construction zones are made. Potential accident chain scenarios based on the analysis are also developed as a tool to communication accident mechanisms. Specific findings of the analysis were found to be:

- A large variation exists in the number of accidents in construction zones. Note that this variation is less a function of the road, but rather more a function of whether construction took place over the research period.
- There is a 4.2% increase in the average of accidents per injury, when the accident occurs in a construction zone.
- There is an increase of 37.4% in the average of accidents per fatality when the accident occurs in a construction zone.
- The historical data shows the most common primary collision factor in construction zone accidents is “speeding” with “other violations” and “improper turn” also relatively common factors (~20% and ~10% respectively).
- When the “speeding” and “other violations” factors removed, “alcohol” is the primary collision factor in 7.3% of accidents in construction zones and only 4.7% in accidents in non construction zones.
- This 56% increase for construction zone accidents due to the influence of alcohol is a key finding representing about 150 additional accidents in District 7, resulting in 40 injuries and 1.3 fatalities over the three years of the study.
- Speeding is identified as another associated collision factor in 16.6% of accidents in non-construction zones and 22.4% of accidents in construction zones.
- The three “Had Been Drinking” subcategories (“under influence”, “not under influence”, and “impairment unknown”), increase in frequency by 69.8% in construction zone accidents (from 5.19% to 8.82%).

Future California Department of Transportation construction safety research should focus on two approaches – breadth and depth. Breath means to expand the data set. The TASAS database is a significant research resource for dozens of purposes. With respect to construction safety, future research should duplicate the analyses of this work but include all freeways within the state. This analysis would

1. Confirm the findings of this work
2. Allow comparison of findings across Caltrans Districts
3. Identify relationships between variables that were not identified in this work
4. Allow statistical verification of result

Depth means to dig deeper into the current data. Every record in the TASAS database has a specific accident record associated with it. The accident records are only summarized in the database. Future research could make use of these records and would

1. Allow specific understanding of conditions (roadway, traffic, construction, etc.) at time of accidents
2. Allow specific understanding of drivers’ thoughts at the time of the accident
3. Enhance accident chain analyses by using actual case studies (as opposed to hypothetical cases)

It must be noted, however, that privacy issues associated with use of the records would need to overcome. Future Caltrans construction zone research beyond the TASAS database can be accomplished. Rather than focus on the accident after it happens, future research should also look at near misses. Through documented records of near misses and / or through the use of stationary video cameras over construction zones, Pareto analysis of near misses and their root causes can be identified and accidents reduced.

The implementation of the research findings could be immediate value. It is recommended that Caltrans use the results of the Pareto charts presented to create additional accident chain diagrams to supplement the initial diagrams presented in this work. Based on these diagrams, Caltrans can review existing construction work zone policies with respect to law enforcement, signage, work hours, etc. and determine if any additional accident mitigations beyond their current systems are potentially possible. Timeframes for this implementation could be immediate. Implementation cost would be expected to negligible since safety analysis of projects and policies is a routine element of the business of Caltrans.

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Prevention through Design Tool for High Performance Sustainable Buildings

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ABSTRACT

Recent research has revealed that there are many aspects of the design and construction of high performance, sustainable buildings (HPSB) that lead to a more hazardous work environment. As the trend of building 'green' continues, it is becoming increasingly important to understand how injuries can be prevented for HPSBs. One promising strategy that promotes lifecycle safety on these projects is prevention through design (PtD). Since sustainable building elements are largely dependent upon the spatial layout, products, technologies, and methods specified by designers, PtD is a logical technique that can be used to reduce safety risk for construction workers. The objective of this paper is to describe a tool that has been created to facilitate PtD on HPSBs. The tool, created in Adobe Live Cycle, assembles PtD strategies identified in recent research.

Keywords: Safety; Prevention through Design; Sustainability

1. INTRODUCTION

In the past forty years substantial improvements in construction worker safety and health have been made and safety management has become an integral component of project management. Among the strategies that have been implemented to prevent injuries, Szmberski (1997) claims that those that occur during design and preconstruction planning are most effective. Prevention through design (PtD), also known as design for safety and safety constructability, has been shown to be especially effective (Behm et al. 2005). PtD is the deliberate consideration of construction worker safety and health in the design of a permanent facility, which may involve altering the features of the building so that they are safer to construct and maintain (Gambatese et al. 1997; Behm 2005; Toole et al. 2006). The process requires that designers consider if (1) the design safe to build; (2) modifications can be made to permanent features remove potential hazards; and (3) the plans and specifications be prepared in such a way that promotes site safety and health. Fortunately, PtD has gained momentum in the past two decades. In fact, in some countries (e.g., UK, Australia) PtD has become a legal requirement.

Another trend in the architecture, engineering and construction industry is the increasing adoption of sustainable building designs and construction practices. The most recognized green building initiative is the US Green Building Council's Leadership in Energy and Environmental Design (LEED). This program provides certification at various levels using a standardized credit-based system. Since its inception in 1998, LEED has grown to encompass more than 14,000 projects in all US States, 3.6 billion square feet of developed space, and is expected to increase to $60 billion in value in the coming decade (USGBC 2009).

Though the rapid growth of LEED is exciting, there are several studies that have shown a negative impact of sustainable design and construction on construction worker safety and health (Rajendran et al. 2009; Fortunato 2010; Dewlaney 2011). These studies have shown moderate statistical evidence for a higher OSHA recordable injury rate for LEED certified projects, specific increases in risk and exposure due to the design elements and means and methods of construction implemented to achieve LEED credits, and innovative methods that can be incorporated during design and construction to mitigate these risks. The purpose of this paper is to present the results of a study that attempted to validate previous research studies and organize the validated results into a user-friendly tool that can be used to prevent hazards on LEED projects.

2. LITERATURE REVIEW

Literature in two main areas was reviewed to develop context: prevention through design and the safety and health impacts of LEED design and construction.

Prevention through Design

As previously indicated, PtD has gained momentum in the research community because of the perceived benefits; however, there are significant barriers to widespread and successful implementation, particularly in countries such as the US that do not have PtD legislation. This literature review focuses on the evidence for the viability of PtD, the identified barriers, and resources available to facilitate implementation.

Effectiveness. There have been a substantial number of studies that investigate the impact of design on safety and the viability of PtD. These studies are summarized below:

- A study of 100 construction site accidents found that changes in the permanent design elements would have reduced the likelihood of the accident occurring in 47 of the accidents (Gibb et al. 2004).
- A study of musculoskeletal injuries to construction workers, showed that design is a strong contributors to working conditions that pose risks of injuries during the construction process (Hecker et al. 2001).
- Behm (2004) found that the design was linked in approximately 22% of injury incidents and 42% of fatalities in the study sample.
- 50% of the 71 general contractors responding to a survey of the construction community in South Africa identified the design as an aspect or factor that negatively affects health and safety (Smallwood 2004).

Barriers to PtD. In order to effectively implement PtD, it is vital to understand the barriers to implementation. Once the barriers have been identified, countermeasures, financing arrangements, and management strategies can be formed. First and foremost, the OSH Act of 1970, which places the responsibility of construction safety and health on the employer, almost completely absolves designers from legal responsibility for construction worker safety. Second, the prevailing project delivery method (i.e., design-bid-build) financially discourages PtD unless the owner has set aside specific funds for implementation. Third, there is a lack of construction safety and PtD education and resources for designers, which makes PtD infeasible even if designers have the best intentions (Toole 2005). Fourth, a study performed by Gambatese et al. (2004) revealed that 5 out of 19 designers (26%) cite fear of increased liability as a primary barrier to implementation.

Available resources. When design firms are willing to invest in the PtD technique, there are three notable tools available. First, Gambatese et al. (1997) created a design tool, the DfSH ToolBox, that provides designers with hundreds of specific design suggestions for improving construction safety and health. Second, the National Institute of Steel Detailing (NISD) and Steel Erectors Association of America published a document that provides guidance for detailing for steel construction (NISD 2001). This publication is unique because it includes a specific section for detailing steel for construction safety. Lastly, Toole (2005) outlines the process of reviewing for safety. Together, these three publications provide designers with basic guidance for navigating the PtD process. Though these decision support systems and guidance documents are helpful, they do not specifically address the hazards that are unique to LEED projects.

LEED and Safety

Several recent studies have been performed to investigate the relationship between the LEED and safety. The impetus for these studies was the moderate statistical evidence that the recordable injury rates were higher for LEED certified projects (Rajendran et al. 2009). Following this original work, Fortunato (2010) identified specific hazards that resulted from individual LEED credits. Out of the fifty-five applicable credits, he found that sixteen had an impact on construction worker safety and health when compared to traditional design and construction. Twelve of these credits involved additional hazards that increase safety risks, five decrease hazardous exposures, and two credits had mixed impacts. Subsequently, Dewlaney (2011) quantified the increase or decrease in safety risks for the credits highlighted by Fortunato (2010) and identified numerous PtD strategies, specific to LEED projects, which can be used to mitigate risk. Table 1 provides a sample of the design and construction strategies employed to achieve LEED credit from USGBC (2009) and the safety hazards identified in various literature.

Table 1 – Hazards associated with LEED credits

	Design and construction strategies employed to achieve LEED credit (USGBC 2009)	**Increased hazards when compared to traditional designs and means and methods of construction (Fortunato 2010, Gambatese et. al. 2009, Rajendran, Gambatese 2009)**
Heat Island Effect- Roof	Specify thermoplastic polyolefin (TPO) materials that have a solar reflectance index (SRI) equal to or greater than 78 for low-sloped roofs (slope less than or equal to 2:12) or 29 for steep-slope roofs (slope greater than 2:12).	TPO membranes tend to be heavy, slippery, and 'blindingly' bright when compared to ethylene propylene diene monomer (EPDM) These material properties were found to lead to slips, trips, falls to lower levels, and eye strain
Innovative Wastewater Technologies	Reduce the use of potable water building sewage by 50% through water-conserving fixtures or the use of non-potable water (e.g. captured rainwater, recycled gray water, on-site treated wastewater)	These methods increase in the time that workers are installing electrical and mechanical systems at height, which increase the exposure to falls from working at height and on ladders.
On-Site Renewable Energy	Specify photovoltaic (PV) panels or the requisite infrastructure for future installation of PV panels.	PV panels tend to be installed on roof surfaces, which increase the time that work with heavy and unwieldy objects is performed near exposed edges.
Enhanced Commissioning	Begin the commissioning process early in the design process and execute additional activities after systems performance verification has been completed.	On-site visitors who may not be familiar with the specific means and methods of construction, increasing the probability of injury for such individuals.

3. VALIDATION

To supplement and validate Dewlaney's (2011) PtD strategies, eleven interviews were conducted by six independent but well-informed graduate student researchers. Interviewers were instructed to review (1) the credits that Fortunato (2010) found to have an impact on safety; (2) the typical design strategies and means and methods of construction implemented to achieve these credits; and (3) the specific hazards identified in Table 1. Interviewees were asked to identify PtD strategies that may be implemented to reduce the risks associated with these credits that are specific to the methods used to achieve the credit. In other words, the interviewees were asked to identify specific elements that can be incorporated into design that would be unique to a particular credit.

One-hour interviews were conducted over the phone with four designers and seven general contractors. Though the focus was on PtD, the research team found from previous research that contractors have an excellent perspective on how the design affect construction safety and have novel PtD ideas. Interviewees were selected from contacts held by the University of Colorado's Construction Engineering and Management Program. In this respect, the interview sample can be considered to be a convenience sample. The interviewees averaged 13 years of industry experience and, collectively, the group had been involved in a total of 550 traditional projects and over 100 LEED certified projects. All interviewees were either superintendents or design managers.

The validation effort revealed that the original dataset published by Dewlaney (2011) is, indeed, accurate but was not complete despite the original convergence. Nearly 90 percent of the original PtD strategies were identified and discussed in the validation effort. Additionally, twelve new PtD strategies were identified. A sample of these new PtD strategies is provided, by credit, in Table 2.

Table 2 – Sample PtD strategies from validation efforts

LEED Credit	**PtD Strategies**
Heat Island Effect- Roof	Specify high traction roofing membranes. Install coverings that reduce brightness for workers during construction.
Innovative Wastewater Technologies	Design piping to run in locations with access points that are easily accessible during construction and maintenance (e.g., above ground and not in confined spaces).
On-Site Renewable Energy	Locate PV panels and other solar collectors away from exposed openings and edges.
Enhanced Commissioning	Run basic diagnostics of all the controls and programs before fully loading the system. Avoid need for maintenance and construction work on ladders by locating filters and controls at lower levels or under floor systems.
Daylight and Views	Design skylights on curbs or with handrails that assist in fall protection for installers and maintenance staff.

4. PREVENTION THROUGH DESIGN TOOL

Once the data from Dewlaney (2011) and Fortunato (2010) had been validated, they were assembled into PtD tool using Adobe LiveCycle. The user interface was specifically designed to emulate the LEED scorecard published by the USGBC. This scorecard includes checkboxes for each of the possible credits and helps owners and design teams to track the credits earned and level of certification achieved. The PtD tool was designed to integrate with this scorecard as shown in Figure 1. As one can see, the user simply checks the boxes for 'yes' indicating that the credit will be pursued on the project or 'no' indicating that it will not. Once this scorecard has been completed by the user, the system provides several forms of output based on previous research.

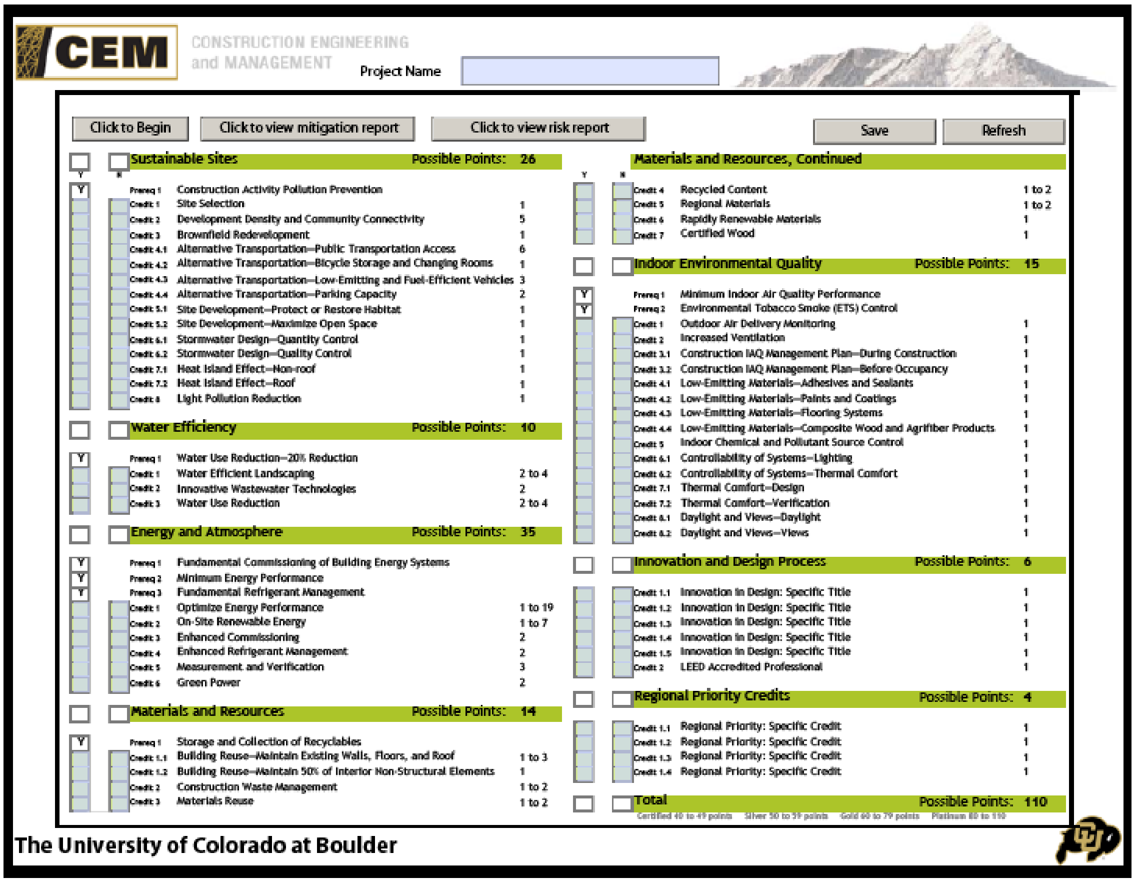

Figure 1 – Tool Input

The tool has output that can be used by both designers and contractors. The first form of output includes the typical methods used to achieve the credits selected and the hazards identified by Fortunato (2010). Second, a module provides PtD suggestions and construction management strategies, including those identified in the validation study described here. The output is only provided for the selected credits to ensure that the feedback is clear and concise. A sample output of the tool is provided in Figure 2, which shows specific strategies for the LEED credits that are not available in other PtD tools such as Gambatese et al.'s (1997) Design for Safety ToolBox and subsequent revisions.

It should be noted that not all suggestions will apply to all projects. Rather, the PtD suggestions apply specifically to the means and methods of construction *typically* used to achieve the credit. Thus, a user needs to be aware that the tool may not provide useful output in cases when new products, processes, or technologies are included to earn a credit.

CEM CONSTRUCTION ENGINEERING and MANAGEMENT

SAFETY RISK MITIGATION TECHNIQUES FOR SELECTED CREDITS

LEED Credit	Increased hazards	Design for safety mitigation strategies	Construction management plan mitigation strategies
Brownfield Redevelopment	Exposure to and handling of hazardous substances. Additional hazards due to excavating transporting dangerous substances. Fall and collapse hazards.	Avoid brownfield sites if possible.	Use impermeable plastic liners in beds of equipment. Wash equipment after use to avoid contamination spread and reduce exposure. Adding training and safety planning specific to tasks involving chemicals. Provide breathing apparatus and other PPE.
Stormwater Quality Control	Increased exposure to on-site excavation and trenching specifically with the use of on-site detention ponds used to achieve credit, which may increase the number of falls and trench collapses.	Design detention ponds with vertical cuts simliar to a "zero-entry pool" (i.e. gradually sloping entry in manner of natural beach). Ensure proper sloping in design for safety of workers.	Pre-construction planning: avoid concurrent activities near excavation (sequencing and site-layout planning). Schedule excavation to limit exposure. Use combination of flagging, barricades and signage. Ensure accuracy of as-built documents and adequate utility surveying (potholing).
Heat Island Effect- Roof	TPO membranes tend to be heavy, slippery, and 'blindingly' bright when compared to ethylene propylene diene monomer (EPDM) These material properties were found to lead to slips, trips, falls to lower levels, and eye strain.	Specify tan or light grey membranes (still achieve high SRI but lower glare and brightness). Adjust top's reflectivity. Include dull peel-off cover that could be prefabricated onto the TPO to lessen brightness and provide traction-recyclable material that would be removed and disposed upon completion of roof work. Texturize surface or include more rubber walkpads on high traffic areas.	Mandatory break rules. Ensure tinted eyewear. Provide warning signs at entrance to roof. Purchase higher number of smaller rolls from supplier to reduce weight and therefore minimize overexertion. Also, contractor may provide temporary walkpads if not in design.

The University of Colorado at Boulder

Return to Checklist

Figure 2 –Tool output

5. APPLICATIONS AND RECOMMENDATIONS

The validation results and PtD tool presented in this paper can be used by practicing professionals to support PtD efforts on LEED projects. Such safety interventions are particularly important for LEED projects because they have been shown to include additional risks and increased exposures to known hazards (Rajendran et al. 2009; Fortunato 2010). The tool described has output that is useful to architects and engineers who design and specific 'green' building components and the contractors who must respond to the building's design.

The writer recommends that this tool be designer controlled when it is implemented on active projects. Ideally, a designer will use this tool as part of an iterative process as credits are selected for implementation. A designer could select an initial group of credits based on architectural and economic preferences and use the tool to evaluate the safety impacts. The user could then consider safety as a competing criterion along with aesthetics, cost, time, etc. when final decisions are made. Once credits are selected, the design firm can consider implementing the PtD strategies suggested by the tool to mitigate hazards. Finally, once technologies, products, and construction methods are specified, the contractor could use the tool to identify the best safety strategies to manage the hazards associated with the selected credits.

Future research is warranted to continually improve the tool as new methods are introduced to improve building performance. Additionally, researchers may wish to pilot test the tool on active projects to determine the perceived benefits and shortcomings. Finally, additional research is needed that investigates the lifecycle safety impacts of sustainable high performance buildings so that impacts to suppliers and maintenance workers can also be considered.

6. ACKNOWLEDGEMENTS

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APPRAISAL OF SAFETY LEVEL IN THE USE OF EQUIPMENT IN SELECTED CONSTRUCTION INDUSTRIES IN NIGERIA

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Abstract

The use of construction equipment has been identified as a major contributor to occurrence of accidents in construction industries in Nigeria. This results in fatal and severe injuries leading to huge financial losses. In this study, safety practices in the use of construction equipment were investigated. Data were collected on injury and accident occurrence on the use of selected equipment from four multi-national construction companies with organized safety programmes. The commonly used construction equipments investigated are bulldozers, graders, excavators and pay loaders through the use of structured questionnaire, interview, technical checklist and physical observation.

Four causes of accidents were identified as equipment design, maintenance, human/personal factors and work issues. Classical statistics, chi- square and ANOVA were performed on the data collected. The results showed that majority of the equipment being used are of age. It was also found that inadequate Protective Personal Equipment (PPE), low literacy level of operators, excessive overtime, inadequate safety training, inefficient work supervision and poor maintenance culture are prevalent in all the industries considered. The safety practices in the four companies exhibit similar traits.

It was concluded that safety regulation enforcement is essential to prevent alarming accident occurrence in construction sites.

Keywords: Safety, Equipment, Construction industry, Accident, Injury.

1. Introduction

Occupational health and safety (OHS) is a multi-disciplinary field concerned with protecting the health, safety and welfare of workers engaged in employment. The goal of OHS programs is to foster a safe working environment by protecting the health and safety of workers and other members of the public who are impacted by the workplace environment (Wikipedia, 2010).

The rate of industrial growth and development is directly proportional to the increase in the use of mechanical equipment in most countries today. Most industries, especially the construction industries make major and frequent use of mechanical equipment. This is associated with resulting mechanical injuries and fatalities.

The construction industry has certain peculiarities among which are the facts that work is carried out in the open and subject to the vagaries of weather (Newcombe et al., 1988; Fellows et al., 1990). Owing to the uniqueness and complexity of the industry, it has a high rate of accidents, and this constitutes a constant drain on the industry's scarce resources (Oyediran, 1989; Illingworth, 1993).

Attempts to change the safety culture in the construction industry has been an uphill struggle and of limited success for a number of reasons. The approach has been to legislate, to provide training to end users and to endeavour to improve the safety culture on sites (Roughton, 2002). In addition to these, a longer term strategy for reducing these accidents would be to design inherently safer machinery and to evaluate the safety condition before putting machinery into use in order to reduce the risk of accidents. It is expected that this will require a change in the safety culture and a greater awareness of the human factors pertaining to mechanical design. If human factor issues are properly accounted for, then the resultant designs will provide a best fit to all the circumstances of human use (and misuse), providing a safer environment, resulting in a fewer accidents (Crabb, 2000).

Several researches had been done on accidents in the construction industry (Sidwell, 1983; Oyebuchi, 1990; Raheem and Wabara, 2001; Raheem, 2004; Adebiyi, 2009). These studies considered activities on construction sites (for buildings and road construction works) and the likely accidents the workers may be involved with. The present study is particularly interested in accidents that are related to the use of mechanical equipment which are a must on construction sites especially the large ones.

Over many years, a great deal of effort has gone into reducing the number of injuries and fatalities as a result of use of mechanical equipment (Gardner, 1999). Researches and initiatives from all sides of the industry have produced a long-term reduction in the number of injuries and fatalities; but recently their effects have diminished and numbers of deaths have even risen.

The safety of a worker also involves his/her good health (Gibson, 2002). A healthy and contented work force gives back to the employer, a number of very tangible benefits in terms of high productivity, high product quality, lower rate of absenteeism, fewer disputes and increased loyalty and a stable workforce which also means less training expenses for new staff (Akpokoje, 1998). Many people already recognize that good health and safety is not only morally right, but also makes good business sense.

International agencies, nations, private and public organizations have been investing enormous human and material resources on construction safety (Wikipedia, 2002). In construction industries, the use of mechanical equipment is involved and of course, injuries resulting from such equipment can be very fatal and severe. The importance of safety therefore, cannot be overemphasized due to the fact that accident, no matter how minor it may be, will definitely have negative effect on productivity and output. Thus in any industry such as that of construction where financial, mechanical and human inputs have been invested, there is need for safety evaluation in order to effect a desirable output. This study therefore investigates the safety practices in the use of mechanical equipment in construction industry with express purpose of evaluating the level of safety programme in the industry.

2. Methodology

For the purpose of this study, data on some selected mechanical equipment – related injuries were collected from selected construction industries in Oyo, Kwara and Lagos states in Nigeria. The mechanical equipment investigated is the most widely used equipment in the industry. These were mainly earth-moving equipment such as bulldozers, graders, excavators and pay loaders. In the survey, injury data over a period of five years was collected with the aid of structured interviews, questionnaire, documentation and technical checklist.

Structured Interviews

Interviews were conducted with varying responses from workers ranging from the project manager to the operator. The interviews involve using mostly, open-ended questions which allowed detailed and qualitative information to be collected, that supplemented and in some cases clarify data collected by the questionnaire and technical checklist.

Documentation

Records were collected from industries usually from the human resource department. The record includes – nature of mechanical equipment injuries, operator's age, experience and literacy, maintenance interval and availability of personal protective equipment (PPE).

Technical Checklist

A technical checklist was used to rate the mechanical equipment observed in each workplace. The checklists assessed were:

- (i) Machine / equipment and tool design
- (ii) Machine guarding
- (iii) Personal protective equipment
- (iv) Site environment

Questionnaire

Self administered questionnaires were given to managers for distribution to employees. Completed questionnaires were returned. The questionnaire employ Likert scale, ranging from 1 (strongly agree) to 5 (strongly disagree) which indicated respondent agreement with each item.

The questionnaire was in four different sections, each indicating what could be responsible for cause of accident in the industry. The sections are explained as follows:

Machine Design. This section had a number of questions trying to clarify whether the causes of accident usually experienced were as a result of the machine design.

Machine and Equipment Maintenance. This section contains questions which were used to determine the relationship between injuries and accidents witnessed and the maintenance practices on mechanical equipment.

Human Factors. This section evaluates the unpredictability of human attitude, behaviour and response as related to safety in industries.

Work Issues. This section contains questions which determine how external factors affect safety in industries.

Four hypotheses were formulated to measure the effect of the above four factors on the safety of mechanical equipment. The null hypotheses and the alternative hypotheses are based on the four factors being considered as follows:

H1a: Present machine design is adequate for the safety of mechanical equipment.
H1b: Present machine design is inadequate for the safety of mechanical equipment.

H2a: Present maintenance level is adequate for the safety of mechanical equipment.
H2b: Present maintenance level is inadequate for the safety of mechanical equipment.

H3a: Present human/personal factors are adequate for the safety of mechanical equipment.
H3b: Present human/personal factors are inadequate for the safety of mechanical equipment.

H4a: Work issues do not affect the safety of mechanical equipment.
H4b: Work issues affect the safety of mechanical equipment.

3. Analysis of Data

Of the 200 questionnaire that were distributed to operators of earthmoving equipment in the four construction companies, 165 completed questionnaires were returned representing 82.5% response rate.

The data collected from each construction industry were analysed and entered into contingency tables using the chi-square (x^2). The null hypothesis was tested whether to be accepted or rejected at a particular probability to arrive at a reasonable conclusion. ANOVA was performed to assess the variability in the results obtained from the four construction industries investigated.

4. Results and Discussion

Number of Mechanical Equipment Injuries

Of the 165 people who returned questionnaires, 73 (44%) reported that they had experienced an injury while 92 (56%) said that they had seen someone else injured. There were differences in the way these questions were answered, because some viewed some injuries as minor compared to others and therefore chose not to account for such. It was observed that most responses are not genuine enough as the respondents view the true response as threat to the work. This shows the level of poverty and insecurity of jobs

Nature of the Mechanical Equipment Injuries Reported

Through the oral interviews and the self-administered questionnaires, 124 incidents of injuries were reported. In 23 cases, the interviewee could not recall the nature of injury. For the 101 accidents, for which the nature of injury was recalled; open wounds were the most common injuries (63), followed by crushing (22) and amputation (12).

Factors Associated with Mechanical Equipment Injuries

Operator Age and Experience. The mean age of workers that are allowed to operate machines in all the companies observed was found to be 26.5 years. The number of experienced workers was also very minimal as the management of these companies makes too much frequent changes in machine operators. Of the 165 operators who retuned questionnaires, only 30 have worked for a particular company for more than 10 years. There was a strong correlation between the operator age and experience as well as the frequency of mechanical equipment injuries. Companies with higher average age and higher level operator experience had lower number of accidents as viewed from the accident records of the various companies.

Operator Literacy. Of all the 165 operators interviewed, none has a tertiary education. Very few of the operators completed their secondary education. Most are either primary or secondary school drop-outs. Some did not even have any form of education. There was a great link between the level of operator literacy and the mechanical equipment injuries encountered.

Machine Age and Model. The mechanical equipment in the various companies were examined and checked. Enquiries as to the age of machine (from manufactured date), the years of usage (years for which it has been involved in continuous use) and the condition of purchase (new or used) were made. Of the companies visited, 192 various types of earthmoving equipment were in constant use. Enquiries showed that the average age of machines was 35 years. The average years of use of the machines was found to be 15 years. It was observed that most of the machines used are old models of between 1976 and 1984. The latest model of earth moving equipment found in use was 1998 model. It was gathered that new models are too expensive and requires high level of technological know-how which may not be readily available in the country.

Machine Design. A large proportion of machines observed were poorly designed. Of the 192 numbers of machinery examined. 150 (78%) were rated as having poor design for safety, 25(13%) were rated as having satisfactory safety design and 17(9%) were rated as having good safety design.

The most serious design problems identified were the lack of emergency stops, absence of guards for rotating parts including gears, wheels shafts and spindles. The companies having the best machine design tended to have the lowest number of mechanical equipment injuries.

Machine Guarding. Of the 192 machines observed, 171 (89%) were considered to require guards on account of exposed moving parts and other hazards but only 95(50%) require guards actually on them. However, there was no significant correlation between the existence of guards and the number of accidents reported. Some of the machines with guards have the guards being poorly designed.

Guards were frequently removed; the most common reason given for removal was that it was difficult to do the job with the guards in place. Several tasks were observed where the work necessitated removal of guards. Employers and employees discussed the difficulty they had finding or making new guards for old machines which were not built with guards.

Maintenance of Equipment. Of the 192 pieces of equipment checked, 88(46%) were rated as being in poor condition, while 104(54%) were rated as having satisfactory or good condition. This data was supported by questionnaire findings regarding maintenance. Machine condition was significantly associated with the number of mechanical equipment injuries. The extent of use of machines is also a very important factor considered. Machines used beyond their working limits or used inappropriately are more likely to develop faults which may affect the occurrence of accidents. It was also reported that when low grade machine parts are used to replace worn out ones, such results into faulty machine operation which often caused accident in construction companies. Companies which use adequate machine parts and does not work the machines beyond their limit tended to have low injury frequency.

Personal Protective Equipment (PPE). During the examination of the workplace, items of PPE were assessed. It was also noted whether or not workers were actually wearing PPE. There was significant correlation between the condition of PPE and the number of mechanical equipment injuries reported. Results from interview revealed that the managers find it difficult to make employees wear PPE. Employees on the other claimed that necessary PPE were not provided for by the management. It was however observed that only few apprentices make use of PPE, while experienced employees were working without PPE. Some workers also claimed that the use of PPE makes them uncomfortable and inconvenient.

Respondents report of causes of accidents

The respondents report based on completed and returned questionnaires were also analyzed using the chi-square (X^2) method of analysis. Tables 1, 2, 3 and 4 shows the descriptive and independence statistics of raw scores of factors in the four companies examined. The tables give the mean value, the calculated and table value of chi-square (X^2) for each company under the four factors considered as the possible cause of accidents.

Table 1: Descriptive and independence statistics for Company 1 (n = 42)

	Factors	Means	X^2 (calculate)	X^2 (table value) $p<0.05$
1	Machine Design	2.33	551.18	36.42
2	Maintenance	1.99	612.99	40.11
3	Human / personal factors	2.88	475.68	47.44
4	Work issues	2.87	230.34	25.00

Table 2: Descriptive and independence statistics for Company 2 (n = 56)

	Factors	Means	X^2 (calculate)	X^2 (table value) $p<0.05$
1	Machine Design	2.16	550.18	36.42
2	Maintenance	2.10	516.20	40.11
3	Human / personal factors	2.81	338.44	47.44
4	Work issues	2.88	236.84	25.00

Table 3: Descriptive and independence statistics for Company 3 (n = 32)

	Factors	Means	X^2 (calculate)	X^2 (table value) $p<0.05$
1	Machine Design	2.31	190.67	36.42
2	Maintenance	2.30	505.86	40.11
3	Human / personal factors	2.42	134.70	47.44
4	Work issues	2.50	60.85	25.00

Table 4: Descriptive and independence statistics for Company 4 (n = 35)

	Factors	Means	X^2 (calculate)	X^2 (table value) $p<0.05$
1	Machine Design	2.10	112.56	36.42
2	Maintenance	2.00	114.42	40.11
3	Human / personal factors	2.46	114.86	47.44
4	Work issues	2.52	72.00	25.00

Considering the calculated values and table values of chi-square (X^2) obtained at 5% level of significance for the factors, for all the four companies, the calculated values exceeds the table value. All the null hypotheses will therefore be rejected while the alternative hypotheses will be accepted.

The mean of values obtained for the factors of the various companies also shows that based on machine design and maintenance, the mean approaches the value of 2 while for human / personal factors the mean approaches the value of 3.

The following set of figures shows the model for the four companies with their mean values expressed as percentage.

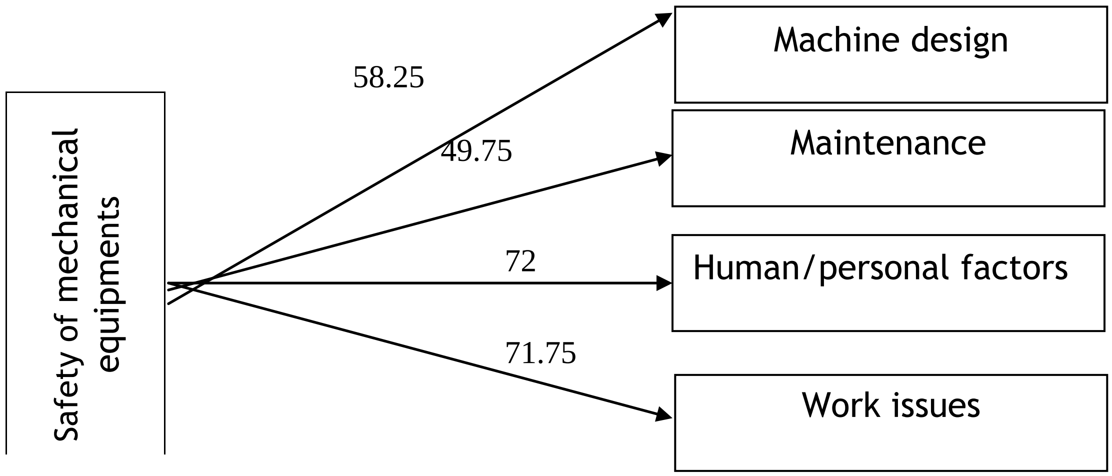

Fig. 1 – The modified structural model of Company 1 with the mean of each factor expressed as a percentage.

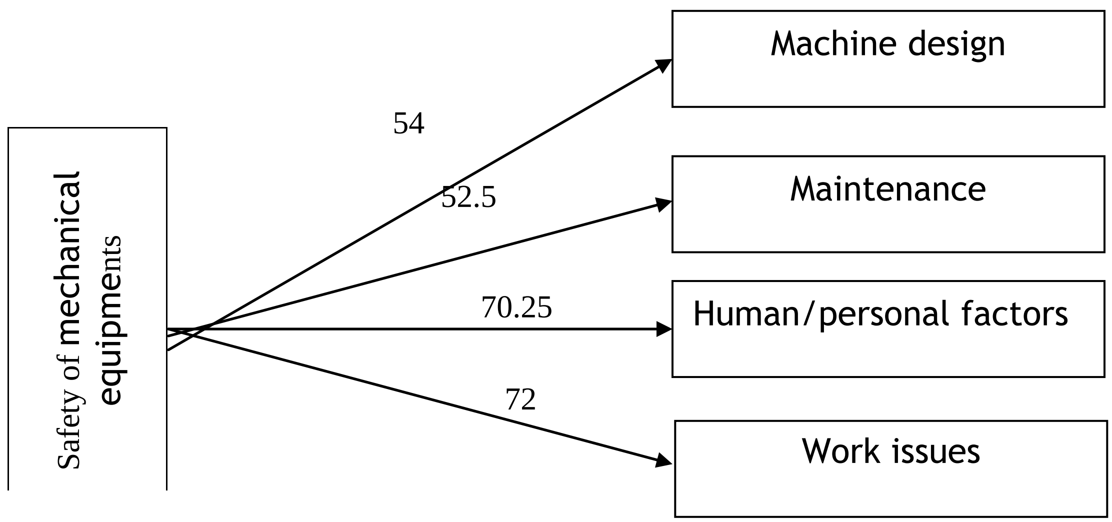

Fig. 2 – The modified structural model of Company 2 with the mean of each factor expressed as a percentage.

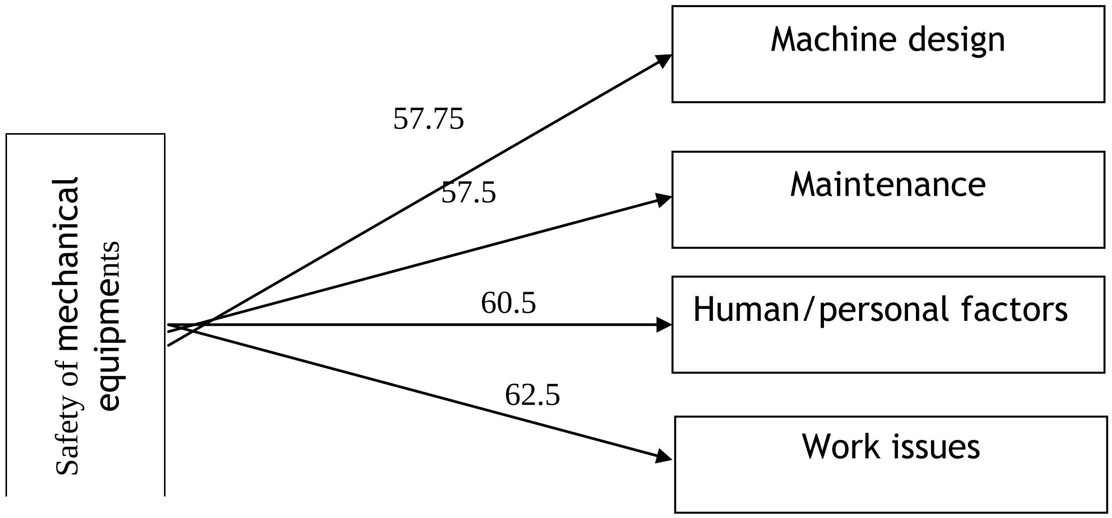

Fig.3 – The modified structural model of Company 3 with the mean of each factor expressed as a percentage.

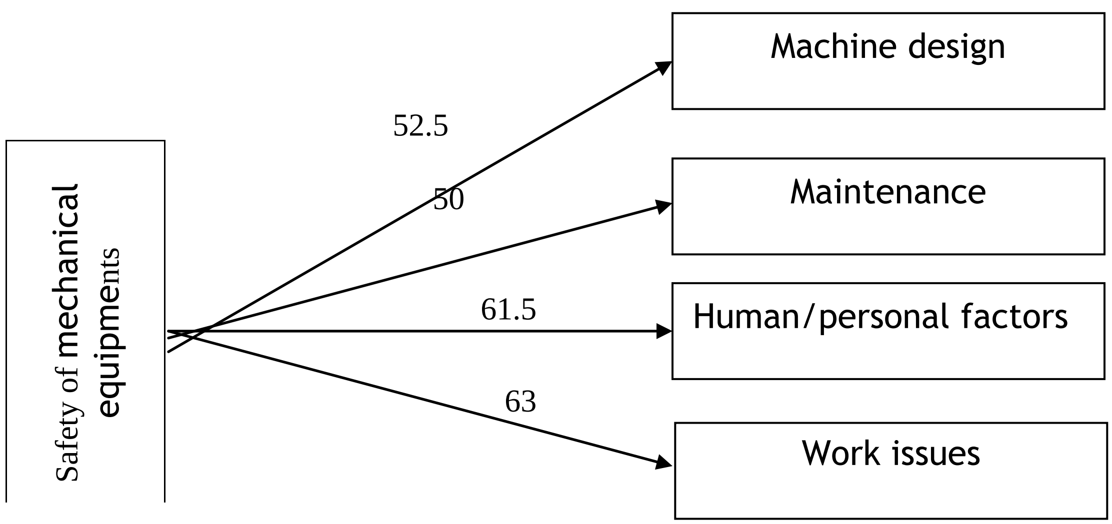

Fig.4 – The modified structural model of Company 4 with the mean of each factor expressed as a percentage.

The analysis of variance (ANOVA) of the results for the four companies is presented in Table 5.

Table 5: ANOVA of the results of the four companies.

Source of error	Sum of squares	Variance estimate	Df	F (cal)	F (table)
Between the group	94.61	31.53	3	0.4137	3.49
Within the group	820.14	76.23	12		
Total	914.75		15		

For ANOVA, the following hypotheses were proposed:

H_0: there is no significant difference between the data obtained from the four companies.

H_1: there is significant difference between the data obtained form the four companies.

From Table 5, the value calculated for 'f' is less than the table value obtained for 'f' at 5% level of significance. Consequently, the null hypothesis H_0 will be accepted and the alternative hypothesis (H_1) will be rejected.

5. Discussion

The study shows that machinery in construction companies were generally old, damaged and not well maintained. Most of the machineries assessed had poor or non-existence safety features, particularly relating to guarding and emergency stops. Lack of safety features was related to the age of the machinery. Older equipment was often manufactured without safety features and as machines became older, guards were more likely to be lost or damaged. Although for some machines, low cost guards could be devised which would not hinder operation, often improving the poor design features or adding guards would not be a cheap or easy exercise.

Guards were frequently removed, the most common reason given by respondents was that it was difficult to do the job with the guards in place and several tasks were observed where the work piece was not suitable for the machine or necessitated removal of guards. The study also indicated that personal protective equipment was not in full use in construction companies. The main reason given by the respondents was inadequacy of the PPE and the discomfort available ones cause.

The interviews conducted with managers of the construction companies indicated that new and improved models of machines are now being manufactured with high safety standards. Such machineries are however not in use in these companies because they are very expensive and also require high level of technological know-how for their operation and maintenance, which may not be readily available in the country. The literacy level of operator also does not support the use of more sophisticated machinery.

Poor machine condition was perceived by interviewees to be one of the most important causes of mechanical equipment injuries and observation of machine condition confirmed this is a major problem. The age and condition of the machineries used in construction companies also contribute to machine malfunctions which in turn lead to unsafe conditions. There were also indications that most of the machineries purchased are second hand.

The analysis of questionnaire using the chi-square (X^2) also shows on the average for the four companies that the present machine design, maintenance level, human/personal factors and work issues in the companies are not adequate enough and does not encourage safety. The mean of the factors expressed as a percentage shows that for machine design and maintenance, the rating is still at the average (between 50 – 60%) while human /personal factors and work issues are still satisfactory (60 – 70%).

Finally, the ANOVA analysis shows that the data obtained from the four sample companies are very similar reflecting that almost the same approach is given to safety in the companies.

6. Conclusions

The study evaluates the safety of mechanical equipment in four construction companies. With reference to the results obtained, the following conclusions can be drawn:

(i) Old machineries whose design still poses safety threats are in use and therefore create an unsafe environment in the workplace.
(ii) Maintenance culture in construction companies is still not adequate in the country. With increased maintenance level, the workplace environment will be made safer.
(iii) Safety of mechanical equipment greatly depends on human factors relating to its operation and use. Non adherence to the safety regulations pertaining to the use of mechanical equipment is one important factor responsible for the unsafe condition in workplaces.
(iv) Pressure on operators and inadequate safety awareness programmes by the management also influences the continued unsafe conditions in companies.

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Development of a System to Enhance Residential Construction Ergonomics and Productivity Using Wall Panels

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Abstract

Premanufacturing (or industrialization) is a contemporary trend in residential construction, one important aspect of which is the use of panelized walls (aka panels) that are generated by a designer. While this approach provides increased efficiencies, the centralization of design provides an opportunity to promote ergonomics in the design process and is critical given the physical demands involved in building with panels. There are also opportunities for even greater efficiencies (e.g., reduced safety & health costs, increased productivity) and effectiveness (e.g., fewer incidents and injuries). We have developed a prototype decision support system (DSS) for panelized design and construction. This software system facilitates a more proactive approach to ergonomics in panelized construction, consistent with the philosophy of prevention through design (PtD). A primary advantage in our approach is the inclusion of both ergonomics and productivity as fundamental components that are both improved. As such, it addresses the need to support the economic and/or business case for PtD, specifically by providing information relevant to necessary financial considerations in decision-making and an understanding of the financial implications of PtD. The DSS logic can be expanded to other circumstances within and beyond construction in which a central designer or design process exists.

Keywords

Ergonomics; prevention through design; lean; residential construction

1. Introduction

Compared to the general workforce, occupational injury rates are high in construction, and this sector accounts for ~10% of all non-fatal occupational cases requiring days away from work (BLS, 2009). Roughly 20% of these were attributed to overexertion and repeated motion, and work-related musculoskeletal disorders (WMSDs) overall are more common in the construction industry than in any other sector except for transportation in the U.S. (Weinstein et al., 2007). Occupational injury costs are particularly high in residential construction and among laborers and carpenters. When examined by the nature of injury, muscle strain is identified most frequently among all other mechanisms, and except for minor injuries, the back and shoulders are by far the most frequent sites of injury (Dement and Lipscomb, 1999; Waehrer et al., 2007; Lipscomb et al., 2008a, b). Hence, ergonomics issues are particularly relevant in residential construction.

Controlling WMSDs in construction involves several particular challenges (e.g., Vedder and Carey, 2005; Ringen and Stafford, 1996; Forde and Buchholz, 2004), which as a whole may account for why the construction industry has been somewhat slow to address ergonomics issues. While the industry is complex, it is not unique either in terms of the potential benefits from incorporating industrialization and reducing ergonomic exposures, both of which can be obtained through improved design.

Indeed, Prevention through Design (PtD) – aka Construction Hazards Prevention through Design (CHPtD) and Designing for Construction Safety (DfCS) – has received increasing attention as a means to reduce safety hazards. A primary goal is to encourage designers and architects to consider safety early in the project life cycle (e.g., Behm, 2008; Schulte et al., 2008; Toole and Gambatese, 2008). While roles for contractors and employees later in the life cycle are still acknowledged, PtD is justified by the lost opportunities when interventions are considered only later in the life cycle (e.g., Fadier and De la Garza, 2006). Safety in (construction) design has been promoted and studied in the construction industry by several groups, in which primary attention is given to eliminating hazards through changes in work practices, substitution, or redesign (Gambatese and Hinze, 1999). Our approach (described below) is consistent with this concept, but focuses on ergonomic concerns (i.e., exposures and risks).

Given the potential for design impact in safety (and arguably ergonomics), it is unfortunate that there is not more substantial designer involvement, and several explanations have been identified (Gambatese et al., 1997; Gambatese and Hinze, 1999; Hecker and Gambatese, 2003). Generally, construction designers have limited education and experience related to construction processes and safety, and comparable results have been reported with respect to ergonomics (Kim et al., 2008). One particular barrier is the lack of tools or guidelines (Gambatese et al., 2005). Though such tools exist, most of which address safety hazards related to acute trauma (e.g., falls), they do not include ergonomic issues, however, and none address aspects related to production.

2. Panelized Construction

Our efforts to facilitate ergonomics in residential construction design are focused on the development of a PtD tool to enable designers and other decision-makers to incorporate ergonomics (and production) issues into their design process for one aspect of residential construction. We have focused on construction using panelized walls because of the complexity of the construction process, increasing adoption of panelization, and existence of a central designer. In contrast to traditional stick-built walls, panels arrive at the work site more completely assembled and are typically delivered on pallets containing 15-40 panels stacked 1-3 meters high. A panel designer, working from an architect's drawing, specifies panel sizes and several aspects of preassembly. A carpentry crew then transfers and erects the panels at required locations on site.

Existing evidence suggest that panelized construction reduces construction time, material use, waste, and labor and material costs, and the need for skilled labor (NAHB, 2009; SBCA, 2009; Shepard, 2000). While the panelized approach provides clear savings in many areas, present construction methods may also result in greatly increased risk of worker overload and injury (Kim et al., 2011). Since panels are produced in a factory, production- and transportation-related objectives are typically employed. As a result, panels can be either too large for workers to handle, or too small, resulting in increased material handling. Further, since the current approach involves a separation between design and onsite activities, process efficiency is not as high as it could be otherwise.

3. An Approach to PtD in Panelized Construction

Our approach encompasses panel design and all downstream activities up to and including on-site construction. These activities include determining how panels will be arranged into stacks for delivery to the job site, when stacks are to be shipped, where they are to be placed on arrival, what tasks should be used for each panel, which workers should work on each panel and when. Thus, we have a sequence of related design and planning problems to solve, and implement PtD at each step of the process. Broadly, two approaches are possible: (i) model mathematically and attempt to solve optimally, or (ii) develop approximate solution methods (*heuristics*) and use computer simulation to generate alternative, feasible solutions. Mathematical models explicitly considering the human worker are almost nonexistent, due to the inherent difficulty in predicting human motion and behavior. Additionally, preliminary mathematical modeling efforts have shown that the problems are both too complex for accurate solution and too large for optimal solution in reasonable amounts of time. Thus, we take the second approach involving heuristics and computer simulation.

The problems of designing panels, determining how they are to be erected, and controlling the construction processes are very similar to product design, process planning, and operations planning in the manufacturing industry. The latter have been widely studied, and heuristic solution methods (many incorporating computer simulation) are well established. In product design, for example, design-for-manufacture/assembly (DFM/A) has been used for many years to design products that are easy for workers to fabricate and/or assemble. Typically, a set of DFM/A "rules" (heuristics) are invoked during product design and used to guide the design process. Computer-automated process planning (CAPP) has been available since the mid-1980s to automatically generate process plans in specific manufacturing applications. One method, generative process planning (GPP), utilizes a set of sequential decision rules for generating process plans automatically, based upon the product drawing. In many manufacturing facilities, production is controlled by local decisions based upon rules that have been shown to perform well. One excellent example is the use of dispatching rules, whereby workers select the next job to run at their machine in real-time, based upon pre-specified criteria. Each of the noted manufacturing problems has been successfully addressed using heuristics. In a similar manner, we are developing a set of "design-for-construction" rules (heuristics) for panelized residential construction.

A decision-support system (DSS) is the best choice for the above approach since multiple users will be involved during different PtD activities and users will require the ability to test various alternatives and adjust final solutions. To evaluate a given set of rules for a particular building, the resulting construction process is simulated on a computer. Data obtained from laboratory-based experiments are used to generate predictions of ergonomic risk (e.g., of a low-back disorder) when that construction process is employed. While it is possible to generate such risk predictions directly via computer simulation, such methods do not general reasonable levels of accuracy except under limited conditions. Thus, laboratory-based data is believed to be the best choice for generating estimates of ergonomic risk associated with a given construction process.

In addition to using computer-based simulation to evaluate the construction process, we also use it to generate a three-dimensional simulation animation of the process. This animation can aid construction designers, managers, and others in visualizing how a given structure is to be erected in the field. Such visualization not only improves understanding of the process, but aids in subsequent evaluation and decision-making. Use of simulation animation for this purpose is well established in manufacturing, but has only recently been seen in the construction domain. In construction planning, implementation of PtD will be greatly facilitated through the use of tools that aid the visualization of hazards (Gambatese, 2008).

Overview and Preliminary Results

Overview of the DSS. Given the building plan (blueprint) for a home, we divide the required decision-making into three steps. The first is concerned with establishing the panelization design, i.e., what panels to employ (dimensions, quantity of and location of openings) for a given plan. Next, we establish the stacking plan, which involves how panels are to be arranged into stacks, the stack delivery locations, and the stack delivery sequence. Finally, we generate the construction plan: how panels are sequenced for construction followed by which construction tasks are to be used and which workers perform which tasks.

To establish how good a particular solution (panelization design, stacking plan, and construction plan) is, three measures are employed: 1) some aggregate measure of overall ergonomic risk, 2) the quantity of workers used, and 3) total construction time. The overall objective in design and planning is to minimize one of the three measures, subject to specified constraints on the other two. Thus, ergonomic aspects are considered directly in formulating the panelization design, stacking plan, and construction plan, an approach that should improve worker health, safety, and performance (van der Molen et al., 2005). Previous efforts to develop computer-aided software tools for construction planning have separated ergonomic aspects from construction planning and scheduling. However, our goal is to *address ergonomics in both design and planning*, consistent with the PtD concept and approach.

We assume that a finite set of alternative materials and configurations are available for panelization and that a finite set of generic construction tasks are identified and quantified with respect to ergonomic exposures (e.g., postures, spine loads) and performance (e.g., task time). Furthermore, the generic construction tasks and exposures are used to predict ergonomic risk (e.g., of a low-back disorder) and performance for any particular construction task and panel definition.

We employ heuristic (approximate) solution methods and then *simulate the entire construction process*, from panel stacks arriving at the construction site through completed construction of the panelized building. Such simulation has been shown to be an effective technique to evaluate decision-making on construction sites (Shi, 2003; Gambatese, 2008). Detailed output (ergonomic risks, worker utilization, etc.) is generated from the simulation, and a simulation animation allows the user to “see” the construction process in action and assess, for example, how the workers must work together and how the various construction tasks are performed. Of note, while the construction tasks for each panel and construction schedule are established as part of construction planning, simply providing these items to workers and expecting them to follow them is not the intent. Workers may be unable and/or unwilling to work in this manner or tasks may be short and numerous enough that time is wasted checking the schedule. Additionally, emphasizing adherence to a rigid construction schedule can result in reduced productivity and quality, such that the actual schedule benefits may be barely worth the effort. Our approach is to instead provide workers with a set of construction rules; when followed, the rules result in the desired assignment of construction tasks and construction schedule. (Note that our approach, including the use of construction rules, does not rely on English fluency among workers, but does assume that an accurate translation is available and that the rules are transmitted and employed.) Our approach also has the advantage of allowing workers (and supervisors, contractors, designers, etc.) to react to changes and unplanned contingencies that might quickly invalidate plans made in advance.

In practice, each of the involved parties (panel manufacturer, transport company, contractor) can use the DSS to establish the design rules to use for their associated activity (panelization, stacking, and construction). These design rules can either be completely specified by the users or a small subset can be provided and the DSS will select the rest automatically (to minimize overall ergonomic risk, the quantity of workers needed, or the total construction time). Either way, the results are used as follows. The panelization design and stacking plan are provided to the panel manufacturer and transport company (if an external agent is used), so that panels can be manufactured and delivered accordingly. Construction rules are provided to the job site and communicated to the workers, who then perform their own decision-making during the building process. To check that construction is proceeding according to plan, the construction schedule can also be provided.

Exposure and Risk Assessments. We use relatively high-fidelity lab-based task recreations (mock-ups). By assessing exposures in the lab, detailed measures of exposure can be obtained that would have been quite difficult to gather in the field. Note that *exposures* here refer to contact with risk factors associated with WMSDs (e.g., postures, forces). The lab studies are designed to achieve two goals. First, tasks are reproduced with a reasonable level of detail and accuracy. Only the fundamental tasks identified from field observations are included, as these were identified as the most physically demanding. Alternative methods used by actual workers are included (e.g., horizontal and vertical lifting), with the final set of tasks based on observed frequencies. Second, exposures are measured to facilitate subsequent ergonomic risk assessment. Lab-based measurements provide the necessary input to these tools, but also fairly extensive additional information to anticipate future risk assessment tools. Multiple and diverse ergonomic risk assessment methods are available, where *risk assessment* refers to the qualitative or quantitative value of risk associated with a given task. We have incorporated a set of existing tools in the DSS to achieve three ends, specifically ease of implementation, common use, and relevance to panelized wall erection. These methods are not intended as complete, but rather as broad and representative of both application-oriented and research-based tools.

Preliminary results indicate potential implications for panelized design, and support the need for the DSS (or a similar system-level approach to CHPtD). WMSD risks (specifically for low back injury) were quantified for several fundamental panel tasks (lifting, carrying, erecting, and moving) and using several panel sizes and weights (Kim et al., 2011). Such risks were quite high overall, with the majority of tasks and conditions imposing unacceptable levels of risk. Initial vertical panel placement, size, and weight had the most consistent and substantial effects on risks. In addition, use of an additional worker consistently reduced risks across several panel sizes and weights, though the benefits differed substantially depending on the specific tasks performed. While such findings indicate potential control approaches (e.g., use smaller panels and more workers), they may adversely affect productivity. A more systematic approach, facilitated by the DSS, will thus be needed to address ergonomic and productivity jointly.

Panelization Construction Design and Planning Algorithms

The overall design and planning process for panelized residential construction can be divided into three closely related problems: panelization, stacking, and construction planning. Our approach is based upon lean manufacturing and stems from several fundamental concepts:

- Stacking is based upon build order. In other words, the “top” panel of each stack is always the next one needed/used. Workers no longer slide panels off to the side or onto the floor to get to the panel they need. Only those panels being worked on are out of the stack, and the work area is kept neat and tidy (lean principle: 5S). This accelerates construction and also eliminates safety hazards resulting from panels left lying on the ground or tipped against walls.

- Once a panel is removed from a stack, it is processed in one continuous operation (barring a change of workers) until it is fixed at its final position (lean principles: one-piece flow, minimize setups).

- Workers involved with a given panel can change between construction tasks (e.g., from lifting the panel off the stack to carrying it) to best suit the requirements of a given panel/task combination (lean principle: shojinka).

- Connectivity is maintained to the extent possible – each panel, save the first, is preceded by ≥ 1 connecting panels. This simplifies positioning and minimizes the need for temporary bracing of stand-alone panels; thereby panels are installed quickly and correctly the first time (lean principle: jidoka).

- A single build pattern is used (e.g., left-to-right and front-to-back), as much as possible, to avoid workers being trapped or boxed-in.

- Upon delivery, all stacks are dropped off along the same edge of the structure ("dropping edge”).

Panelization. Panelization consists of “breaking up” the walls or dividing them into panels. The process employs three parameters: stud spacing, preferred panel length, and maximum panel length. Based upon these parameters, walls are divided into panels. The build direction is taken into consideration to ensure smooth construction in the field and to minimize ergonomic impact. Of note is that the panelization plan (and hence stacking formulation, construction sequence, etc.) varies with build direction. Thus, a panelization plan is created for each feasible build direction (input by the user). Remaining problems are then solved for each panelization plan, and the best overall solution is selected.

Stacking. A heuristic method employing a staged approach has been developed for stacking. In brief, we divide the building into zones running parallel to the dropping edge. Each zone has an unload area along the dropping edge – where panels can be unloaded from a stack without interfering with any finished panels – and one or more associated build areas. Stacks are dropped off at each unload area in turn. Panels within the associated build areas then form a continuous build sequence (and connect with the previous build areas). Once zones are established, the corresponding build area panels are assigned to stacks by moving through the build areas according to the build direction and selecting panels based upon their final location in the build area. This approach ensures that panel connectivity is maintained as much as possible and that a feasible build sequence results. Stack locations and delivery sequence are automatically generated, and the results minimize move distances for panels within each stack. Delivery of select stacks can be overlapped, if desired, to allow two stacks to be worked on simultaneously. Compared to the traditional approach (fill stacks as much as possible to minimize trips to the worksite), our methods can yield a larger quantity of stacks, each filled to a lesser extent. More trips are not a necessary outcome, however, as multiple, partially filled stacks can be loaded onto the same truck. Computational evaluations have indicated that our current algorithms, compared to current methods (using commercial software and manual adjustments), can concurrently reduce the number of stacks and material handling requirements (i.e., weighted distances).

Construction Planning. The stacking heuristic assigns panels to stacks to maintain connectivity and provide a feasible build sequence. Thus, no on-site construction sequencing is necessary. To get each panel from its initial location/orientation on a stack to its final location/orientation in the building, a sequence of construction tasks is required. These are based upon a construction task taxonomy developed from analysis of extensive field observations. In addition, there is a set of possible task sequences, along with the allowable worker quantities for each task. As previously described, we allow the workers involved with a panel to vary from one task to the next.

The construction task planning, scheduling, and worker assignment problems are difficult to solve. Construction scheduling alone closely resembles traditional *job-shop scheduling*; as such, the three problems together will be at least as hard to solve as job-shop scheduling problems. One widely used and well-studied approach for job shop scheduling is the use of dispatching rules: whenever a job is completed at a machine a simple rule (e.g., shortest processing time) is used to select the next job to run. We employ this same approach via the use of construction rules that can be easily employed by workers in the field. Such rules are needed to establish (i) *what panel* to work on next, when a worker becomes available, (ii) *how many* workers to use for each panel task, and (iii) *which* workers to use for each panel task once the quantity has been established. For example, we may elect for a worker to always go to the nearest panel being worker on, select the maximum quantity of workers for each panel task, and then select the actual workers to use to balance workload (utilization).

4. Summary and Future Work

There is an increasing trend toward premanufacturing in construction, including the use of panelized walls. Current panel design approaches lead to both inefficiency and WMSD risks, negating some of the expected cost reductions intended by panel use. The centralization of panel design, however, provides an opportunity to enhance such efficiencies and reduce ergonomic exposures. We have developed a prototype DSS for panelized residential construction that facilitates a proactive approach to ergonomics and addresses the ongoing need for appropriate design tools to facilitate PtD. As it incorporates ergonomic aspects throughout the construction process, the overall impact of DSS use is expected to be more efficient and effective than reactive, site-based interventions applied only later in the product life cycle. A primary advantage in our approach is the inclusion of both ergonomics and productivity as fundamental components and the joint improvement of both. As such, our approach addresses the need to support the economic/business case for PtD, specifically by providing information relevant to necessary financial considerations in decision-making and an understanding of the financial implications of PtD. Our system also serves as an "integrating mechanism"; from a sociotechnical systems perspective, such mechanisms help overcome the traditional challenges involved when there are multiple functional units (Hendrick and Kleiner, 2001), such as architects, engineers, and builders in construction. Finally, several authors have noted current research and practice needs related to interventions, specifically the dearth of available solutions and the lack of high-quality evaluative studies (van der Molen et al., 2007; Watterson et al., 2007; Lehtola et al., 2008; Rinder et al., 2008). Our DSS, from conception, was intended to address these needs by facilitating the development and assessment of interventions to reduce ergonomic exposures and risk.

Much additional work is needed, however, and is proceeding in several directions. First, the decision-making logic in the DSS and the ability to simulate and visualized tasks is being improved and evaluated. Use of the DSS requires specific design/construction rules, and simulation is then used to establish how panels are design and shipped and how construction proceeds. Based on lean principles and input from panelized construction workers and supervisors, a wide variety of such rules will be evaluated. To improve usability and validity, detailed simulation input data are being compiled from field observations and lab studies, and WMSD risks are being estimated for a wider range of construction activity using lab-based task simulations. Second, there is a need to determine effective strategies for implementing the DSS in practice and improving the business case for its actual use. This will involve consultations with potential users (panel designers, manufacturers, and contractors). Computer-based cases studies will be conducted to compare panelization and stacking plans generated using the DSS vs. those from the "traditional approach. A more "upstream" focus is also needed, to determine the impacts of DSS use on panel manufacturers and shippers. Third, a field study is planned to demonstrate and quantify the potential and actual benefits of using the DSS.

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Behavioural and Cultural Safety Programmes: Evaluation from the UK Site Perspective

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Abstract

The UK construction industry has made a step-change in its approach to safety management on sites. Larger contractors with established safety management systems have looked to behavioural and cultural safety programmes to take incident and accident prevention to the next stage. Such programmes have been implemented in various forms over the last twenty years in the UK; however there is a lack of evidence of their success. This study examines the perspective of those directly affected by these programmes: construction operatives, tradespeople and supervisors. It explores potential issues and areas of concern, as well as examining positive changes that may have occurred. Six in-depth interviews were undertaken, transcribed, and the results coded to allow a narrative to be drawn out. The findings indicate that despite the desire for change and positive improvements on UK construction sites, there is conflict in the way work is carried out; the use of 'pricework' for companies and individuals, and the perpetual pressures of time and cost are seen as causing disharmony with the safety programmes. In applying the theory of complex systems to safety on construction sites, these conflicts can also be seen as latent defects which will require resolution in development of policy rather than at site operational level.

Keywords: Construction Sites, Safety, Safety Programmes, Human Factors

1. Introduction

UK construction is statistically a dangerous industry in which to work: 2.0 workers per 100 000 were killed during the period 2009/10, making construction work four times more dangerous than the average job in the UK (Health and Safety Executive (HSE), 2010a). Understandably, this situation is not tolerated by the UK government nor by the UK construction industry itself. Focus on improving the safety record of the industry has been continuous, and success can be seen in the statistics, from 1974 where 166 workers lost their lives, to 1986/7 where 125 were killed, to 96 deaths in 1996/7 (HSE, 2010b) and now to 41 worker fatalities in 2009/10 (HSE, 2010a). The safety record of the UK industry is undoubtedly improving, although there is still the eminently justifiable belief that '*one death is too many*' (Donaghy, 2009).

It would be an error to assume that fatalities now only occur on small sites, with poor adherence to basic health and safety, possibly due to cost of compliance or failure to wear personal protective equipment (PPE). There are still incidents on large, well managed construction sites; the death of a worker in 2004 on the Jemstock Project in London's Docklands area is a prime example (HSE, 2009a; McMeeken, 2010). This was a large project run by a member of the UK Contractor's Group, with an established safety management system, which has regularly won gold awards for its safety procedures (RoSPA, 2008). During the official investigation, the HSE found that whilst risk assessments and method statements had been undertaken for the work, the checks identified as necessary in the assessments had not been adequately carried out, and the hole through which the worker fell had been covered with poor quality plywood, although by whom was never established (HSE, 2009a). This incident illustrates that the human factor is still critical in construction work, regardless of the size and management of the construction site itself. Why were the checks not done? Who was it that decided the plywood was acceptable to cover the hole? Who put it there? It is unsurprising, therefore, that an approach directed towards human factors, in terms of behaviours and the culture created by these behaviours, has come to the fore in UK construction health and safety management.

This study forms an initial exploratory part of a larger project, which seeks to examine the cultural and behavioural change safety programmes currently in use on large UK construction sites, and to begin to explore their impact, effectiveness and how they are perceived by those who work there. In order to appreciate these programmes and the factors they seek to change, examination must first be made of the literature and theory of the programmes themselves, as well as the context of the construction site setting.

2. Literature Review

Behavioural and Cultural Safety Programmes in the UK Construction Industry

The construction industry has devoted considerable effort to improve health and safety performance (HSE, 2009b). Investment in innovative programmes for change, over and above adherence to legislation, has frequently occurred amongst larger contractors (Donaghy, 2009), and a variety of safety programmes have been established on UK sites (Rawlinson and Farrell, 2009). The programmes can be broadly categorised along the two directions of approach made within them; one type of programme is focused specifically on targeted behaviours, whilst the other attempts to make more holistic changes (IOSH, 2006; Spanswick, 2007).

The first to be established in the UK were the Behavioural Safety Programmes (BSPs), which have been in operation in a number of guises since the mid 1980s (HSE, 2008). BSPs focus on the reduction of specific behaviours that have been shown to be high risk, and create the desired safety culture from within (Dingsdag *et al* 2006). These programmes have indeed been shown to reduce injuries and therefore minimise accidents (Roughton and Mercurio, 2002). However lack of any continuing improvements, if less training or monitoring is carried out (Channing, 2008), lends weight to the argument that these BSPs are simply another form of superficial behaviour management, rather than catalysing any deeper cultural change. BSPs have been proven to work well within fixed work environments with an unchanging workforce (HSE, 2002; Roughton and Mercurio, 2002). This environment is a stark contrast to the construction site, where work often involves chains of complex and often unique behaviours in an ever-changing environment (HSE, 2009c), undertaken by a transient, subcontracted and often casually employed workforce (Department for Business, Innovation and Skills, 2007; HSE, 2009c).

The most vocal criticism of BSPs, both in the UK and North America, is that these programmes 'blame the worker' rather than focus on potential hazards and unsafe conditions (Frederick and Lessin, 2000) that are often the root causes of site accidents (Lessin, 2002). Indeed, this is supported by researchers of complex systems, who agree that attempts to discover and neutralise latent failures in systems will be of greater benefit to safety than efforts focused on minimising front line operator errors (Reason, 1990). There is also the opinion that, certainly in more complex and changing environments, BSPs should only be used as one element of safety systems and not as a standalone solution (Roughton and Mercurio, 2002). Indeed, Balfour Beatty's Zero Harm campaign is an example of a combined safety programme; in 'identifying and planning out hazards', establishing 'behavioural protocols...to eliminate fatal risks' the programme looks to the BSP aspects of safety management, but in 'making safety personal' the fundamentals of the Cultural Safety Programme (CSP) are also apparent (Balfour Beatty, 2010).

CSPs are based on the concept of an organisation's safety culture, defined by the HSE (2005) as a combination of workers' attitudes and perceptions regarding health and safety management; the workers' actions and behaviours with regard to workplace health and safety, and the management in terms of policies and procedures. It has been established that people respond to the work culture in which they find themselves (Wong, 2002) and the CSPs aim to change and improve that culture.

CSPs, first implemented on UK sites in the late 1990s (HSE, 2008), employ a top-down change model to alter the norms, values and attitudes of companies as a whole, leading to desired behavioural changes on sites. The CSPs aim to 'make safety personal' and asks people to take responsibility for their own safety on sites (CIOB, 2006). Although research has shown that giving people this responsibility can in some instances be inadequate, depending on other factors such as comfort when wearing required PPE or beliefs about the risks involved for the task in hand (Cameron and Duff, 2007). The CSP programmes also attempt to win the 'hearts and minds' of the site workforce by creating a shared sense of responsibility between them and site management, promoting a caring attitude on sites (AGC, 2006). However, this could be seen as conflicting with the macho culture found on UK construction sites and at odds with the swearing and banter normally found there (Bird, 2003; Jordan *et al*, 2005). One key aspect of CSP programmes is the no-blame culture, the elimination of any retribution or punishment that may be associated with accidents, ostensibly to encourage reporting and enable sites to be 'truly safe environments' (AGC, 2006). This blanket no-blame approach has led to criticism from the Institute of Occupational Safety and Health (IOSH), who feel this negates the fact that some acts will inevitably deserve sanctions and a distinction should be made between wilful acts and accidental occurrences (IOSH, 2004).

Examples of the CSP model can be seen in the Laing O'Rourke and Bovis Lend Lease 'Incident and Injury Free', or IIF, programmes. As Laing O'Rourke states, 'IIF represents a step-change in attitudes to safety...underlining the personal responsibility we each have to ourselves and each other' (Laing O'Rourke, 2010), a philosophy echoed by Bovis Lend Lease, stating that IIF requires '...individuals to take a personal stand …with a mindset intolerant of any injury or incident ...' (Bovis Lend Lease, 2010).

The success of these programmes has still not been determined, and whilst there have been positive reports about implementation on large sites, there has been a lack of direct evidence (HSE, 2008). Certainly, it must be recognised that culture changes slowly, and fundamental change requires time (IOSH, 2004). The effectiveness of implemented programmes may yet be unrealised (Dingsdag *et al*, 2006), although it has also been suggested that there is the potential for conflict with the other key characteristics of UK construction sites (Rawlinson and Farrell, 2008).

Human Factors: Human Error

These programmes are based on a variety of cognitive theories that drive human behaviour (Fiske and Taylor, 2008; Hardman, 2009). For example, the CSP programmes are in part based on the theory of cognitive dissonance (Festinger, 1957) and seek to challenge the mind-set of the operatives by bringing their personal and family lives into the work environment, creating a dissonance with unsafe behaviours, motivating the operatives to reduce this conflict by acting safely.

This focus on the operatives and people of the construction sites, and their behaviours, as the root cause of health and safety accidents and incidents builds on the work of Heinrich (1959) in his seminal examination of accidents at work and the conclusion that 88% of workplace injuries were due to unsafe acts on the part of the operator. This study has since been criticised for the choices made in data classification, possibly leading to this high figure (Woodcock, 2007), and using source data from supervisor reports which could arguably be seeking to shift blame onto operatives (USOA, 2000); however the perception of human error as a major cause of accidents arguably remains (IOSH, 2006; Wilson, 2007; HSE, 2009c). Blame is still frequently assigned to human factors; inaccurate assessments, bad decisions and poor judgements often remain high on the list of causal factors (Perrow, 1999; Dekker, 2006).

However, this view has begun to change following research into accidents within complex systems. The construction industry and, more specifically, construction sites can be described as complex systems (Winch, 2003); many people come together performing different tasks, interacting at many different times and places to ultimately create the end product, employing the complex 'system' of sites. When the time pressures of construction (Loosemore *et al*, 2003; Spanswick, 2007; Rawlinson and Farrell, 2008) are also taken into consideration, the system arguably becomes 'tightly coupled' (Perrow, 1999) which can further enhance and link incidents ultimately resulting in accidents.

Within complex systems, the simple explanation of 'human error' as the cause of accidents is no longer taken at face value; human error is itself now seen as a symptom of trouble deeper within the system. It is now argued that people have made incorrect assessments or taken incorrect action as a result of failures in the systems which have created situations which dictate a certain course of action (Perrow, 1999; Dekker, 2006). The new perception of human error does not accept that the system will work correctly but for the behaviour of some 'bad apples'; rather it requires that safety be instilled at all levels of the organisation (Dekker, 2006), including within management, who may unwittingly instil latent failures within the system by the choices made in the offices and boardrooms (Reason, 1990; Kletz, 2001). Cultural influences have also been suggested to affect people working within complex systems, and therefore can influence its safety in terms of acceptance of authority, need to conform to the social groups within organisations as well as overall organisational culture (Strauch, 2004).

This study therefore begins to ask those who work on UK construction sites how the BCPs and CSPs 'fit' with the highly complex construction site systems they operate within every working day. Could the choices and decisions made by the construction site operatives be driven by factors inherent in the construction site system itself?

3. Methodology

This paper summarises an initial investigation made under the umbrella of a much larger study, examining construction site culture as a causal factor in health and safety incidents on site. This study has its foundations in an interpretivist epistemology (Dainty, 2008; Sutrisna, 2009) and is using several data gathering techniques, including interviews, photographs, artefacts and participant observation, to collect a rich variety of data. These initial interviews were carried out to start to bring the picture into focus (Fellows, 2008), rather than take the finished photograph, and the findings herein will be used to inform and develop further lines of enquiry within the study.

The sample for the interviews was one of convenience (Fetterman, 2010), necessary in part to fulfil the requirements of the wider study and the criteria necessary to ensure relevance of the data. The sample criteria were that the interviewees were working on large sites (value £15m+) for members of the UK Contractors Group (UKCG), they had all worked in construction for over five years, and had also received some form of behavioural or cultural safety training within the last two years. Three semi-structured interviews (Silverman, 2001; Fetterman, 2010) were undertaken with construction site operatives and three with construction site supervisors. The interviews were digitally recorded, transcribed and subsequently coded, which highlighted themes, consistencies, inconsistencies, patterns and irregularities (Silverman, 2001; Langdridge, 2005) when the data was viewed through the lens of the literature.

Whilst this small sample size and selection process does not allow for generalisations to be made from the findings of this paper, it does provide some insights as to the site perspective of these programmes and their relevance and integration with UK construction site life. These insights can then direct further research in this area, although it can also be argued that given the transient nature of the UK construction workforce, their experiences, perceptions and attitudes are likely to be common within the industry as a whole.

4. Findings: Narrative

The Programmes

The cultural and behavioural programmes are felt to be a positive step for the construction industry to make. Increased awareness of health and safety is seen as the outcome, and people can be seen to change their attitudes and approach to health and safety during training. Under the programmes, improved communication on sites, both amongst operatives and also between operatives and site management, is seen as a very positive result. Operatives feel able to speak up and comment on the health and safety of sites, and this is often responded to with action from management. The no-blame culture was also seen as a positive step:

> *"...if I did something, like knocked a handrail and the bracket came loose, I'd have far more inclination to go up to the foreman, supervisor, whoever and tell him it was unsafe."*

However, specific concern was raised about the longevity of the training; it was felt that although the training did work, the improved behaviours were not seen to last for too long once people returned to the workplace. It was seen to only temporarily increase awareness, although estimations on this timescale varied from the rest of that day to 3-4 weeks:

> *"...a week or two down the line and it's forgotten."*

Refreshers were seen as necessary to stop this occurrence, and in some cases main contractors had used focused tool box talks to reinforce the key messages. Consistency of approach was also seen as critical, and the need to implement the programmes to all on the sites. Inconsistencies had been found by the interviewees as they moved from site to site even within the same companies, and this was seen as creating a very difficult environment to work within. The early, American, versions of the Incident and Injury Free CSP were remembered with some amusement by the operatives, the language and approach seeming a little different to the usual UK construction site training:

> *"Let's all have a big group hug every morning...yeah right!"*

Whilst it was felt that the BSPs and CSPs have made a difference, there was no consensus that improvements in health and safety can be attributed solely to the presence of the programmes. Management of the site was often seen to be more influential than the safety programmes that were in place:

> *"I don't think that necessarily just because you've seen a video and had a bit of a chat about it, I don't think it necessarily instructs you to be safety conscious."*

The People

The very nature of the industry means it attracts people who take more risks:

> *"...the people in the industry want to get on and do things, they are do-ers, not pen-pushers…people who want to physically do something and achieve something... they think 'I can do that', rather than 'maybe I shouldn't'."*

Appreciation of human factors was commonplace; the understanding that people are all different and there will always be people who do not seem to care about their own or anyone else's safety. Others are seen to judge their situations on what they are capable of and act accordingly

> *"People being people want to do things as fast as they can and as easy as they can and that's never going to change no matter what procedures you put in place."*

Perception of risk was also seen as very important, and this was seen as one of the reasons people still took risks on sites. People are seen to evaluate what they can and what they cannot get away with on a particular site and act accordingly.

> *"...people will push it as much as they can."*

Unwillingness to change was also seen as a factor that would influence uptake of the programmes, especially for some older and more experienced individuals, and it was thought that following training sessions, people eventually return to type and go back to their old ways of doing things.

Time and Money

The industry itself was seen as affecting the overall attitude to health and safety. Contractual requirements such as completion dates and penalty clauses were seen to be influential in adding time and cost pressures to work environments, meaning people work faster or take risks to get the work done.

> *"...it's got to be a quick, cheap price job and if you can get away with doing something slightly unsafe but you get the job done and it's done a little quicker...your firm will make a bit more profit out of it...and you're seen as a better prospect..."*

Main-contractor/subcontractor conflict still exists to some extent, and this had influenced the overall uptake of safety programmes. Whilst some subcontractors participated in the programmes, others did not, and even when operatives were trained, it was not further encouraged or enforced by the sub-contractors' contracts managers.

The subcontractor propensity to work on price was also felt to influence implementation of the safety programmes; for these operatives it was felt that their first priority was to make money on the job, with health and safety coming second.

> *"...it all comes down to earning money...the bottom line."*

Other aspects of the industry system were also voiced as reasons for working around health and safety on sites, the pressures of the job and the realities of daily working life were seen to affect the longevity of the safety programmes' influence:

> *"...you need to get a permit which takes half an hour, then find the ladders to work from, or you can nip in and stand on a box for a five minute job..."*

The fragmented nature of the industry was also felt to be an influential factor to the maintenance of the approach to health and safety at work. One week operatives can be working on a large well organised and trained site, and the next on a small site with far less controls, making a consistent implementation of the safety programmes difficult.

> *"...next week they're on Joe Bloggs house builder down the road, in trainers and shorts."*

Overall there was a positive feeling that changes for the better are inevitable on construction sites in terms of improvement in site health and safety:

> *"10 years down the line we'll probably be saying - how did we used to work like that?"*

5. Discussion and Conclusions

Whilst the BSPs and CSPs have been welcomed on UK construction sites and people are keen to participate in improving the health and safety on their sites, agreement that the programmes 'fit' or 'work' within the site environment is often followed by a 'but...'. There is concern about the long term effectiveness of the training as well as inconsistency in implementation which together have created some uncertainty as to the overall success of the programmes. Site management was seen as a highly influential factor in the success of the programmes and the overall standards of health and safety on site.

Most significantly, when viewed as complex systems, the construction industry has clearly built in several latent defects which result in failures at the site end; the focus on price and deadlines, the fragmentation of the industry and the continued reliance on subcontracting and pricework were all seen as influencing factors on the success of the health and safety programmes on sites.

This paper has sought out and established several key areas for further research and investigation. Although the industry has made significant efforts to improve health and safety through the implementation of these programmes, there appear to be a variety of factors limiting their success. Fundamental issues such as consistent implementation and full workforce training appear to be of concern, and the factors that are limiting this training within the industry and its sites should be examined further. In addition, there are also factors fundamental to how industry operates its sites. When viewed as complex systems, these industry factors, or latent defects, within the system are highly likely to cause operative error on site 'front lines'. Either an appreciation of how these defects influence the site operatives in terms of human factors is required to tailor the change programmes to focus on these areas, or, arguably a more effective solution, these latent defects in the industry systems need to be examined further and ultimately resolved at source.

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Using Bayesian Network to Develop an Approach for Construction Safety Risk Assessment

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Abstract:

Risk assessment for construction safety is critical for effective project control. Traditional risk assessment approaches mostly rely on expert opinion because of limited accident data. Therefore, assessment results may lack precision because of experts' subjectivity and limited cognition when multiple safety risks are assessed simultaneously. This study developed a new assessment approach based on the Bayesian Network for construction safety risks. Both expert opinion and real data were incorporated by this approach. The approach has been developed for major safety risk events (Scaffolding Collapse, Fire Disaster, Falling, Machinery Injury, Electric Shock and Strike By/Against) based on expert opinion from construction companies and real accident data in Beijing. Risk probability analysis was based on both subjective and objective information, while risk influence analysis was based on objective information from real accident data. The assessment results could be updated easily as new data was collected. Using this approach, project managers could comprehensively assess risks or understand the causes of accidents where there were complex interrelationships between safety factors and events.

Keywords: Construction safety; Bayesian Network; Risk assessment

1. Introduction

Safety is one of the most critical aspects for construction management. Accidents can result in dramatic cost as well as low morale; therefore, both industrial practice and academic research emphasize safety management of construction projects.

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Unfortunately, accident rate in the construction industry ranks highly in comparison to other industries. Hence, risk assessment has been used for decision making of safety management such as confirming relative importance and possibility of risks, providing a consolidate foundation for strategic planning. Thus, an appropriate approach for risk assessment is critical to safety risk control (Fang, D. et al., 2005).

Subjective methods which are based on expert opinions and objective methods which are based on real data analysis are the two normal types of methods for assessing safety risks. In many studies, Subjective approaches are utilized for risk assessment. Expert opinion is one of the most prevalent approaches to address possibilities of safety risks. Many researchers use experts' subjective opinions to assess construction safety risks, such as risk assessment matrix (Hallowell, M. R., Gambatese, J. A., 2005), AHP method (Shapira, A., Simcha, M., 2009), safety index with fuzzy logic (Grassi, A., 2009), and so forth. However, different experts may have different understanding on subjective descriptions. For example, 'very possible to happen' and 'possible to happen', these are two descriptions on possibility of risks that every expert may have different standards when evaluating risks. Although some researchers tried to avoid this problem by using scientific methods while studying (Patt, A. G., Schrag, D. P, 2003), however, assessment methods based on real data are more objective and persuasive

Nonetheless, safety records such as near-misses, injury, even fatality are not easily obtained and thus few safety risk assessments are based on real data (Mcdonald, N., Hrymak, V., 2002; Hinze, J., Bren, D., 1996; Abdelhamid, T. S., Everett, J. G., 2000). Objective methods are used only when a high quality accident statistics database can be accessed. For instance, Aneziris (2008) and Papazoglou (2007) have established an objective evaluation model according to the database of Netherland occupational safety and health accidents between 1998 and 2004, which they obtained through GISAI. Today in China, the Ministry of Housing and Urban-Rural Development and the State Administration of Work Safety have started to standardize the report schedule of safety accidents and are establishing a database. However, it is still not easy to obtain a complete safety accident database. As a matter of fact, it is important to take into account both subjective evaluations from expert opinions and objective evaluations from accident database when carrying out risk assessments. So far, there are no methods to solve this problem.

This study develops a new assessment approach based on Bayesian Network for construction safety risks. Both expert opinion and real data can be incorporated by this approach. Relationships between safety risk events, risk settings and risk factors can be modeled as a complicated network. Bayesian Networks, broadly implemented for academic research in the recent decade, is a probabilistic graphical model that represents a set of random variables and their conditional dependencies via a directed acyclic graph (Heckerman, D., 1997) to develop reasoning construct on uncertain knowledge, specifically dealing with the uncertainty resulting from various conditional constraints（Pearl, J., 1988). It is also utilized to develop a network to assess a complicated relationship model consisting of risk events and risk factors.

Bayesian Networks are widely used in areas like ecology, environment, economy, geology, safety and so on (Walton, A., Meidinger, D., 2006; Marcot, B. G., Steventon, J. D., 2006; Marcot, B. G., et al., 2001; Zhu, J. Y., Deshmukh, A., 2003; Rivas, T. , et al., 2007; Zhou, Q., et al., 2008). It is also used for construction safety risks. Martin, et al. (2009) identified main risk factors of fallings at construction site from previous studies and used Bayesian Networks to model falling risks by relating them to risk factors. He also identified the most important safety risks at various levels. Matias, et al. (2008) evaluated the precision of risks prediction using Bayesian Networks with comparison to other approaches. He concluded that Bayesian Networks have the following advantages: 1) they simulate risks under different conditions and carries out probability analysis on each variable simultaneously; 2) they can be used to construct a model with discrete qualitative variables (e.g. all kinds of parameters relate to accident); and 3) they predict risk probability more accurately.

2. Methodology

This research developed a Bayesian Network risk assessment model in order to assess the safety risks on construction site. As such, causal relationships between safety risk events and risk factors were establishing the Bayesian Network method as follows:

1) The authors established the structure of construction safety risk Bayesian Networks.
2) The Conditional Probability Tables (CPTs) of the nodes of construction safety risk Bayesian Networks were developed.
3) The authors assessed the average probabilities of construction safety risk factors. The probabilities of the risk events were assessed based on the risk Bayesian Networks.
4) The probabilities of the nodes (risk factors, risk settings and risk events) in the risk Bayesian Networks were updated by the real accident database.
5) The influences of the risk events were assessed based on the real data.
6) The levels of the risk events were assessed based on the results of the probabilities and the influences of the risk events.

Data analysis was conducted with the software package Netica® (2007). The subjective data in this research was obtained from the questionnaires for experts or workers with rich safety management experience. The accident database was obtained from the government.

Establishment of the causal model for safety risks with Bayesian Networks

Many studies developed Bayesian Networks and concluded with a large dataset (Russell, et al., 1995). However, accident data in the construction industry is relatively limited in China. The structures of Bayesian Networks can be also built up based on logistics and expert opinions in the previous studies (Zhu, J. Y., Deshmukh, A., 2003; Rivas, T., et al., 2007; Zhou, Q., et al., 2008). Therefore, the identification of risk factors, the relationships among risk factors and events and the development of the safety risk Bayesian Networks are mainly based on previous studies and experts' experiences in this research.

The Bayesian Networks consist of three layers including Risk event, risk settings and risk factors, as shown in Figure 1. For example, the risk event "fire" may be directly caused by various settings such as improper storage of inflammable and explosive materials, welding close to inflammable materials, etc. Risk factors are the main causal origins of a specific setting. For instance, lack of training is one of the main factors which lead to workers welding beside inflammable materials.

In this model, each setting or factor is treated as a node which has two states: occurred or not. Here Y denotes that the event takes place and N indicates that the event does not occur.

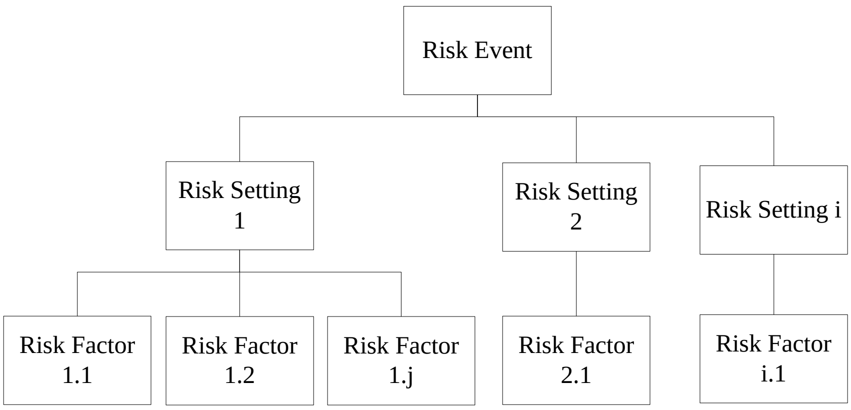

Fig. 1 Structure of risk Bayesion Network

Identification of the conditional probability tables (CPTs) of parent nodes

After developing the structure of the Bayesian Network, the Conditional Probability Table (CPT) of each parent node (risk setting or event) is required for further analyses.

Parent nodes in the Bayesian Network are classified into two groups: the M type and the N type. Their difference is depicted with the CPTs of their child nodes. The M type nodes only occur in the probabilities of 0% or 100% when their parent nodes occur or not occur which were obtained by logical deduction. On the other hand, the

N type nodes occur in the probabilities of any value between 0% to 100% when their parent nodes occur or not occur which was obtained by machine learning with a set of data or by the experts' experiences. Users should recognize nodes as M or N type in order to collect corresponding information for the Bayesian Network.
An example of logical deduction in a Bayesian Network is presented in Fig. 2. C is the parent node where A and B are child nodes. Using the M type node to illustrate their relationships, AND and OR can be applied to the parent node as shown in Figure 3 and Figure 4. Both of the logical relationships have logic gate in fault tree while their CPTs differ. Figure 5 shows the CPT of the parent node C in terms of logical AND. The logic delineates that only if both A and B occur, C occurs. Figure 6 demonstrates the CPT of the parent node C in terms of logical OR. This logic indelicate whenever A or B occurs, C occurs.

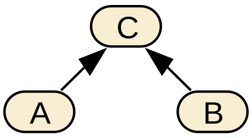

Fig. 2 Bayesian Network

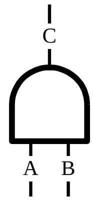

Fig. 3 logical AND

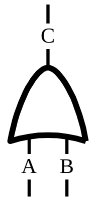

Fig. 4 logical OR

Node: C

Chance | % Probability

A B	Y	N
Y Y	100.00	0.000
Y N	0.000	100.00
N Y	0.000	100.00
N N	0.000	100.00

Fig. 5 CPT of logical AND

Node: C

Deterministic

A B	C
Y Y	Y
Y N	Y
N Y	Y
N N	N

Fig. 6 CPT of logical OR

Node: C

Chance | % Probability

A B	Y	N
Y Y	100.00	0.000
Y N	100.00	0.000
N Y	100.00	0.000
N N	1.000	99.000

Fig. 7 CPT of modified logical OR

For research purposes, the CPT of the parent node in logical OR can be rectified. Providing all the risk factors in the Bayesian Network do not occur in Figure 2, the risk event may least likely to occur, resulting in extremely low probability. Using the logic OR to delineate this relationship, the child nodes are both assigned with an extremely small probability value (for instance, 1%) to indicate low probability of the existence of their parent nodes (Figure 7). With different expert opinion, the rectified probability values of the child nodes can be adjusted accordingly.

CPTs of N type nodes can be established with both data simulation and expert experience. When the amount of accident data is insufficient or unreliable, the CPT will weigh more on experts' experiences than simulated results. At the commencement of the research, expert opinion can be weighed much higher than practical data because of its small sample size. Conducting data simulation to develop CPTs with limited sample size may produce misleading results. Thus, the CPTs are mainly determined by experts' experience. With growing sample size, practical data can be weighted equally with or higher than expert opinion in the future. The questionnaires need to be developed and distributed to obtain expert opinion for CPTs of the N type nodes of Bayesian Networks. As shown in Table 1, the entire probability distribution is categorized in seven intervals as the qualitative probability description of IPCC (Intergovernmental Panel on Climate Change). Patt (2003) considered the categorization reasonable and suitable for a description of risks probabilities. In this research, the questionnaires are very similar to the CPTs shown in Figure 5. The respondents are asked to choose one of the seven categories to assign the probability value in CPTs of each node in the Bayesian Network except the nodes without any parent node. Probability descriptions are then converted to numerical probability values. For example, if a respondent chooses 'very small possible' on behalf of the probability range of '1%-10%', the probability of the risk factor should be 5.5%. Then the probability values of all the respondents are averaged to obtain the final probability values. In order to maintain data quality, all the respondents need to be instructed to answer every question in advance.

Table 1 Qualitative Probability Description of IPCC

Probability Interval	**Description**	**Probability Interval**	**Description**
＜1%	Extremely unlikely	66–90%	Likely
1–10%	Very unlikely	90–99%	Very Likely
10–33%	Unlikely	＞99%	Virtually certain
33–66%	Medium likelihood		

Evaluation of probabilities of construction safety risk factors and safety risk events by expert opinions

The probabilities of risk factors can also be established with both accident data and experts' experience. Nonetheless, Real accident data are nor easily available in China; therefore, the probabilities of the risk factors were determined by experts' experience. The questionnaires need to be developed and distributed to obtain expert opinion regarding the probabilities of the risk factors. Respondents are asked to choose one of the seven categories (shown in Table 1) to assign the probability value for each risk factor. Then the probabilities of risk events are calculated via the Bayesian Network. The results are assessed by the experts. If the results of the probabilities of risk factors as well as risk events are considered unacceptable, the Network need to be further reviewed and modified. Then the values of the probabilities of risk factors are inputted into the risk Bayesian Networks.

Update the probabilities of construction safety risks by real accident data

First, the real accident data from the government is transferred into the format of Netica®. Second, the data is inputted into the Bayesian Network. Then the software calculates the data using "count-learn" method (Netica, 2007). The CPTs of the nodes of the Bayesian Network are updated in the software. The new probabilities of construction safety risk events can be obtained automatically. The weights of the information from experts and from real accident data can be set up. When the database is small, the weight of the information from experts is relatively higher than real data. When the database is big enough, the weight of the information from experts can be very small or even zero.

Evaluation of the influences of construction safety risks

In this research, the influences of construction safety risks include an index. One is measured by monetary lost. The second is the casualty in the accident. Casualty can include the number of injuries and fatalities. In China, the numbers of injury are very hard to obtain, so the fatality is used to measure the severity of the casualty in the accident.

Evaluation of construction safety risk levels

Construction safety risks are defined as the product of the probabilities and the influences of the risks. The risk levels are decided according to the risk level matrix as presented in Table 2. The green area means low risk level, the yellow area means medium risk level and the red area means high risk level. The threshold values can be changed according to the risk bearing capability of the users. In this research, the threshold values are obtained based on the opinions of the experts.

Table 2 The matrix of risk levels

Economic lost / Fatality	$0 \leqslant e < 10$ (10 thousands RMB)	$10 \leqslant e < 20$ (10 thousands RMB)	$e \geqslant 20$ (10 thousands RMB)
$0 \leqslant n < 0.3$			
$0.3 \leqslant n < 0.6$			
$n \geqslant 0.6$			

3. Practical application of the assessment methods

Establishment of the construction safety risk Bayesian Networks

Risk events were firstly identified from previous studies (Huang, J., 2008; Li, X., et al., 2008; Zhang, G., 2003; Zhang, J., Tao, R., 2004), including Scaffolding Collapse, Falling, Machinery Injury, Electric Shock, Strike by Large-scale Object, Strike by Small-scale Object, Strike by Flying Object, Fire Caused by Electricity, Fire Caused by Naked Flame, Fire Caused by Moving Combustion Source and Fire Caused by Extreme Weather. The structures of the risk Bayesian Networks at construction site were developed with respect to their risk factors. One safety supervisor and five safety managers of China State Construction Engineering Corp. (CSCEC), who have at least ten-year experience in safety management, were interviewed to adjust the structure of Bayesian Networks. One example of the construction safety risk Bayesian Networks is presented in Figure 8.

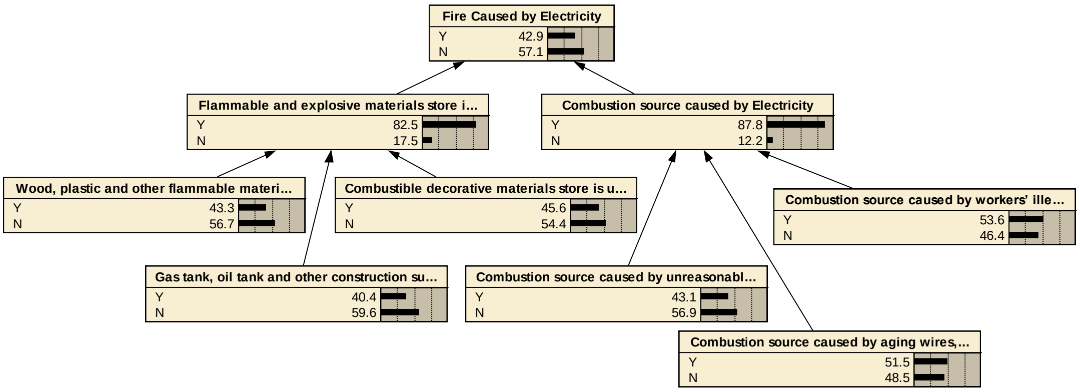

Fig. 8 Bayesian Network of Fire Caused by Electricity

Evaluation of the probabilities of construction safety risks

The CPTs of M type nodes of construction safety risk Bayesian Networks were logically deducted directly. A survey was conducted on six safety managers from five subsidiary companies of CSCEC to obtain the CPTs of N type nodes of construction safety risk Bayesian Networks. The authors distributed the survey to the experts and explained the structure, definitions of terms, and related protocol. The recovery rate of the questionnaire is 100%.

A detailed survey was then developed and conducted broadly on more than 400 project managers or safety managers of Beijing Construction Engineering Group (BCEG) to obtain the probabilities of risk factors. The survey which took 20 minutes to complete was conducted during the group training. A total of 388 responses were received which represented a survey recovery rate of 97%. The CPTs and the probabilities of construction safety risk factors at the jobsite were then calculated.

Then the construction accident database (2006-2009) obtained from Beijing Administration of Work Safety were inputted into the construction risk Bayesian Networks. The probabilities were updated by the real data. The probabilities of construction safety risk events were prioritized in the order of their average probabilities as shown in Table 3.

Table 3 Rank of the probabilities of construction safety risk events

Number	Construction safety risk events	Probabilities from expert opinions	Updated probabilities by real data
1	Falling	40.1%	78.0%

2	Machinery Injury	50.2%	50.2%
3	Strike by Large-scale Object	41.4%	43.9%
4	Fire Caused by Electricity	42.9%	42.9%
5	Fire Caused by Naked Flame	41.6%	40.6%
6	Electric Shock	34.9%	35.4%
7	Scaffolding Collapse	34.6%	34.6%
8	Strike by Small-scale Object	30.5%	31.1%
9	Fire Caused by Moving Combustion Source	27.0%	27.0%
10	Strike by Flying Object	19.2%	25.2%
11	Fire Caused by Extreme Weather	6.9%	6.9%

Evaluation of the influences of construction safety risks

The average economic lost and fatality of construction safety risks were obtained from the construction accident database (2006-2009) from Beijing Administration of Work Safety, as presented in Table 4.

Table 4 The influences of construction safety risk events

Construction safety risk events	**Risk influences**	
	Economic lost (10 thousands RMB)	Fatality
Falling	28.2	1
Machinery Injury	47.5	1
Strike by Large-scale Object	33.1	1
Fire Caused by Electricity	0.58	0
Fire Caused by Naked Flame	0.58	0
Electric Shock	34.2	1
Scaffolding Collapse	67.3	2.3
Strike by Small-scale Object	33.1	1
Fire Caused by Moving Combustion Source	0.58	0
Strike by Flying Object	33.1	1
Fire Caused by Extreme Weather	0.58	0

Then the risk value of construction safety risks were calculated based on the probabilities and influences of construction safety risks, as presented in Table 5.

Table 5 The construction safety risk values

Construction safety risk events	Risk Value Economic lost (10 thousands RMB)	Fatality
Falling	22.0	0.78
Machinery Injury	23.8	0.50
Strike by Large-scale Object	14.5	0.44
Fire Caused by Electricity	0.2	0.00
Fire Caused by Naked Flame	0.2	0.00
Electric Shock	12.1	0.35
Scaffolding Collapse	23.3	0.80
Strike by Small-scale Object	10.3	0.31
Fire Caused by Moving Combustion Source	0.2	0.00
Strike by Flying Object	8.3	0.25
Fire Caused by Extreme Weather	0.0	0.00

The risk levels of construction safety risks were obtained according to Table 2, as presented in Table 6.

Table 6 The construction safety risk levels

Construction safety risk events	Risk Level
Falling	High
Machinery Injury	High
Scaffolding Collapse	High
Strike by Flying Object	Medium
Electric Shock	Medium
Strike by Large-scale Object	Medium
Strike by Small-scale Object	Medium
Fire Caused by Electricity	Low
Fire Caused by Naked Flame	Low
Fire Caused by Moving Combustion Source	Low
Fire Caused by Extreme Weather	Low

According to the results, Falling, Machinery Injury and Scaffolding Collapse were the most serious safety risks on construction sites in Beijing. The project managers and safety supervisors should be more careful about the control of the risk factors related to these three risk events, for example, strengthen the site protection facilities management, strengthen the personal protective equipment regulation, strengthen the inspection and maintenance of machines, double check the scaffolding design scheme, and so on.

4. Conclusion

The major construction safety risk Bayesian Networks (Scaffolding Collapse, Fire Disaster, Falling, Machinery Injury, Electric Shock and Strike By/Against) were built up based on expert opinion from the construction companies and the real accident data in Beijing, China. The information from both expert opinion and real data were incorporated in the construction safety risk Bayesian Networks. The assessment results could be updated easily when new data was collected. The results showed that Falling, Machinery Injury and Scaffolding Collapse were the most serious safety risks on construction site in Beijing. With this approach, project managers could comprehensively assess risks or understand the causes of accident with complex interrelationships among safety factors and events. In the future, the construction risk assessment approach needs to be validated among different regions and different companies when more data is obtained.

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Implications of ignoring HIV and AIDS by the construction industry: The South African experience

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ABSTRACT

Purpose: This study discusses why the construction sector should address HIV and AIDS against the background of the South African construction industry experience.

Design/methodology/approach: The research design included a review of relevant literature and a comparison of the construction industries in the United States of America, India and the Russian Federation. Interviews were conducted with Human Resource managers of construction companies in South African to understand the implications of ignoring HIV and AIDS in construction.

Findings: HIV and AIDS in the construction industry cannot be ignored or overlooked. The implications of no action include among others threats to profitability, corporate social responsibility and increased mortality of the workforce.

Practical implications: The global construction industry needs to heed of the threat and serious implications of HIV and AIDS. The implementation of workplace HIV and AIDS prevention and care programmes can improve the health and wellbeing of affected employees, as well as encourage them to access HIV-related treatment.

Originality/value: By taking an interest in the health and welfare of their employees, construction firms are able to reduce their vulnerability to the financial and human resource implications of the pandemic.

Keywords: HIV and AIDS, construction industry, lessons learned, South Africa

1. Introduction

The sustainability of companies is at risk due to the threats posed by HIV and AIDS (Dickinson, 2004a). HIV and AIDS endanger the lives of the economically active population, affect investor confidence and impact negatively on the economic market (Dickinson, 2004b, UNAIDS 2000; Whiteside and Sunter 2000). HIV and AIDS can raise business costs due to decreasing productivity, and increase labour costs as a result of absenteeism and illness and the loss of skills and experience. The human rights of workers at work are often violated due to stigma and discrimination targeted at employees living with and affected by HIV and AIDS (Dickinson, 2004b; International Labour Organisation, 2010, Karim, 2010 and The International Bank for Reconstruction and Development /The World Bank, 2004).

This paper looks at the reasons why the construction industry should address HIV and AIDS against the background of the South African construction industry experience.

2. Review of Literature

The construction industry needs understand that it makes good business sense to address HIV and AIDS in the workplace because failure to do so results in decreased productivity due to increased absenteeism and also because sick workers are less productive. Fatigue results in frequent accidents in the workplace. The loss of employees to the disease results in increased costs to the company in terms of replacing those skills lost and /or training new employees.   Ultimately the declining population growth rate will result in companies having a smaller skills base from which to choose their employees. Labour costs will also increase as company's have to increase their contributions for medical aid and life and/or disability coverage (Dickinson, 2004b; ILO, 2010; Rosen, *et. al.*, 2003; Whiteside and Sunter, 2000).

Having considered the reasons why firms should address HIV and AIDS this paper will briefly look at three countries and how they can learn from the approach that the South African construction has taken in terms of addressing HIV and AIDS.

Table 1 provides key information in terms of population numbers and relevant statistics on HIV and AIDS in various countries.

Table 1. HIV and AIDS statistics by country.

	South Africa	India	Russia	USA
Population	49,991,300	1,151,751,000	143,221,000	302,841,000
Estimated number of people living with HIV and AIDS	5,700 000 (11.4%)	2,270,000 (1.97%)	370,000 (0.25%)	1,106,400 (0.37%)
Number of new infections	497,000	1,200,000	58,400	56,300
AIDS related deaths	360,000	170,000	40,000	18,000

Source: (South African Institute of Race Relations 2010a; UNAIDS/WHO, 2009; WHO, 2011)

Overview of HIV epidemic in South Africa

The HIV and AIDS and STI Strategic Plan for South Africa 2007-2011 aims to reduce the number of new infections by 50% and increase access to treatment and support and care by 80% to all people diagnosed with HIV (SANAC, 2007). In order to meet these targets, the National HIV Counselling and Testing (HCT) Campaign was launched on 25 April 2010 with the aim of mobilising 15 million South Africans to know their status. Additionally, a massive male circumcision campaign was launched as clinical trials have shown that male circumcision reduces transmission of HIV among men (UNAIDS/WHO, 2009). In the hardest-hit province, KwaZulu-Natal (KZN), the plan is to circumcise 2.5 million men (UNAIDS, 2010).

South Africa with only 0.7% of the global population has the highest prevalence of people (5.7 million people) living with HIV. With the largest antiretroviral therapy programme in the world, South Africa is experiencing substantial public health benefits associated with improved treatment access (UNAIDS/WHO, 2009 and UNAIDS, 2010) but for every two people who start antiretroviral therapy, five individuals were newly infected with HIV (UNAIDS, 2009). South Africa had a declining population growth rate between 2001 and 2008 suggesting a possible link to the HIV and AIDS pandemic. In 2001 the HIV and AIDS infection rate for the South African population was 8.8%. This had increased to 11.6% in 2008 (South African Institute of Race Relations, 2008). KwaZulu-Natal (KZN) is the "worst afflicted province" (Thurlow, 2009:1). The prevalence rate varies among the nine provinces, with recent studies indicating that 26.4% of KZN's working age population is HIV positive, compared to 15.9% in the Western Cape (Matthews *et al.*, 2008). By 2025, two-fifths of the KZN adult population would have died from HIV and AIDS (Thurlow, 2009). The concentration of the pandemic on the economically active population will have grave implications for South Africa's workforce (*ibid*).

According to the Department of Public Works (2004) the construction industry has the third highest incidence rate of HIV and AIDS compared to other industrial sectors in South Africa. The workplace provides an ideal platform to reach workers through the development and implementation of workplace policies and programmes on HIV and AIDS (ILO, 2010). But, the important role that companies play in addressing the pandemic has not been optimally utilized. In fact the response of corporate South Africa to HIV and AIDS has been slow, partial and erratic (Dickinson, 2004b). In a study conducted by Harinarain and Haupt (2010) it was found that only 10% of 123 building contractors in the KwaZulu-Natal province of South Africa had an HIV and AIDS policy in place.

The South African construction industry employed over 1.1 million people in 2009 almost double the number of people employed in the industry since the early 2000s. After two decades of decline, activity in the building industry saw rapid growth from 2004 mainly due to increased spending for the preparation for the FIFA 2010 World cup (International Organization for Migration, 2010).

The greatest barriers that South Africa faces are a low uptake of HIV counselling and testing, weak integration of tuberculosis–HIV services and poor access to antiretroviral therapy. (UNAIDS, 2010). In order to combat these barriers, the South African government has dramatically increased its funding for HIV and AIDS with commitments in excess of $ 718 million a year ($1=R6.9639[1]) to finance healthcare (South African Institute of Race Relations, 2010b).

Overview of HIV epidemic in India

The construction industry in India employs 31.46 million people making it the most labour intensive industry and the biggest employer in the country. The development of physical infrastructure in the country has grown at the rate of over 10% annually during the last five years (Planning Commission-Government of India, 2008)

India, with a population of more one billion people, has an estimated 2.27 million people between the ages of 15 to 49 years living with HIV (PLHIV), equating to 1.97% of the total population (UNGASS, 2010a). The epidemic in India shows a declining trend overall with the HIV prevalence among the adult population decreasing from 0.34% in 2007 to .029% in 2008 (*ibid*). Even though India is considered a low-prevalence country, it is ranked third behind South Africa and Nigeria in terms of the HIV burden. Stigma and discrimination continue to pose significant barriers to accessing services. India has strengthening its AIDS response in terms of treatment and care and prevention programmes and scaling up HIV testing and counselling services. India has committed 67% of its national AIDS budget for prevention, distributed 245 million condoms and increased access to antiretroviral therapy from 32% in 2008 to 45% in 2009 (UNAIDS, 2010).

[1] Exchange rate as at 12 May 2011

Overview of HIV epidemic in Russia

The Russian construction industry has recovered from an industry downturn in 2010 mainly due to high government spending. The industry employs 4.9 million people which is approximately 7.3% of Russia's total workforce (Full-Advice, 2011 and PMR, 2011).

The HIV epidemic in the Russian Federation is increasing, while many other areas in the world have managed to stabilise their HIV epidemics (Avert, 2011; (UNAIDS/WHO, 2009). A very serious obstacle is insufficient access to information on HIV, mainly due to cuts in funding for HIV prevention activities resulting in an increase in the number of new HIV infections (UNAIDS, 2010). The epidemic is heavily concentrated (78%) among injecting drug users. In 2009, for every four patients enrolled on treatment, eleven were newly infected with HIV. An estimated 400,000 HIV-positive people will require antiretroviral therapy by 2015, but funding trends suggest that there will be a shortfall in those accessing treatment (UNAIDS, 2010). Russia is will experience the greatest number of AIDS-related deaths between 2009 and 2015. In order to prevent thousands more AIDS related deaths, stigma and discrimination needs to be adequately addressed (AVERT, 2011). Government financing also needs to be increased for primary prevention, public information and education on HIV (UNAIDS, 2010).

Overview of HIV epidemic in USA

The construction industry in the USA is one of the largest industries with 7.2 million jobs. It is divided into three major segments; the construction of buildings (residential, industrial, commercial, and other buildings), heavy and civil engineering construction (sewers, roads, highways, bridges, tunnels, and other infrastructural projects) and specialized activities related to all types of construction (such as carpentry, painting, plumbing, and electrical work) (Bureau of Labour statistics, 2010). Growth of 19% is expected in the construction industry.

HIV incidence in the USA has remained relatively stable (UNAIDS/WHO, 2009), largely attributable to the medical benefits of antiretroviral therapy, prevention and treatment programmes. The USA is categorized as having a concentrated/low-prevalence epidemic (UNGASS, 2010b). The Center for Disease Control and Prevention(CDC) of the Department of Health and Human Services (HHS) estimates indicate that 1,106,400 people were living with HIV in the United States in 2006 (UNGASS, 2010b) with 14,581 AIDS-related deaths in 2007. (UNAIDS/WHO, 2009).

3. Research Design

Interviews were conducted with Human Resource/Wellness managers of construction companies in KwaZulu-Natal, South Africa to determine the current state of HIV and AIDS policies and practice as well as the implications of ignoring HIV and AIDS in this sector.

From a list of contractors downloaded from the Master Builders Association (MBA) website, 123 contractors were telephonically contacted to determine if they had a HIV and AIDS policy in place. Of these contractors only 10% had a HIV and AIDS policy in place. Of the 12 contractors that had HIV and AIDS polices 67% (8) agreed to be interviewed.

In 2002, the South African Business Coalition on HIV and AIDS (SABCOHA) reported that the majority of companies in South Africa had yet to assess the risk of HIV and AIDS within their workforces and begin to mount a response to this risk. Not much seems to have changed nine years later as ninety percent of contractors still do not intend implementing a specific HIV and AIDS policy even though they are aware of employees who have died from AIDS and that some of their current workforce are HIV-positive. The reasons given were that they considered themselves a "small company, and do not have the resources to implement an HIV and AIDS policy which probably be too expensive and time consuming". This is in line with other studies conducted by Connelly (2004); Stevens, Weiner & Mapolisa (2003) and SABCOHA (2004).

The response of the South African construction industries to HIV and AIDS started late in the epidemic, with only 12.5% of the companies implementing an HIV and AIDS policy 8 years ago. The majority of the firms (75%) have their respective policies in place between 3 to 5 years and 12.5% have only starting implementing their policy as recently as one year ago.

Dickinson (2004b) offered two explanations for the slow response of South African business to the threat of AIDS; the first of which was the failure of the South African government to lead and co-ordinate a national response to AIDS and the second reason being that senior managers believed that AIDS would not have a significant impact on their operations.

A majority of the firms (75%) conducted a policy review via an internal audit. The absence of an evaluation and review by an external party implies that the companies are working in isolation and probably not in line with 'better-practice'.

All the firms reported that standard workplace programme elements were the distribution of condoms and promotion of condom use, HIV and AIDS awareness programmes and HIV and AIDS counselling. These are usually followed by focused education and training programmes which included information booklets and brochures, posters, peer educators, counsellors and workshops, minimizing stigma and discrimination and wellness programmes. Although employees were encouraged to get tested, testing was not conducted at the workplace. Disclosure of HIV positive employees was encouraged via education and training programmes and even though stigma and discrimination was catered for in all policies, employees did not disclose their status due to fear of the reaction from co-workers. Although discrimination against employees on the basis on their status is illegal in South Africa, it is still very prevalent in the workplace.

All the firms interviewed assisted and continue to assist in communities in which they worked. This attitude shows an understanding of the need to protect their workforce and the surrounding communities.

These firms had active Peer educators communicating and guiding co-workers, but they did not actively involve people living with HIV in the delivery of the programmes. Peer educators also assisted with treatment referral systems to employees. UNAIDS (2010) reported that the visibility and involvement of people living with HIV and AIDS has helped in reducing stigma and discrimination in organisations. This strategy is one that firms should use more frequently.

Even with workplace policies and education and training programmes in place, the managers interviewed, still expected future increases in HIV and AIDS prevalence and incidence rates but did not have any contingency coping plans in place.

While all the firms interviewed had HIV and AIDS policies none of them provided Anti-Retroviral therapy (ART) to their employees even though the cost of drugs had substantially reduced. Two of the more important reasons given were that ART required the availability of medical personnel and disclosure that might result in discriminated. No voluntary counselling and testing (VCT) programs were being run. This absence is cause for great concern since VCT is seen as an important part of any effective response to HIV and AIDS as it encourages employees to know their status.

Eighty percent of the interviewees were unsure what percentage of the company budget was spent on the implementation of HIV and AIDS programmes. It is possible that funds were not being utilised or insufficient funds had been allocated. The majority of firms (60%) placed a greater emphasis on employee health and wellness programmes, which incorporated other illness such as tuberculosis and diabetics.

4. Discussion

The construction industry employs millions of people worldwide. The USA construction sector employs 7.2 million people, the Russian construction industry employs 4.9 million people and 31.46 million people are employed by the construction sector in India. Although the South African construction industry only employs 1.1 million people, it is important that other countries understand the steps the industry has/has not taken in this fight against HIV and AIDS.

The South African construction industry failed to realise the importance of understanding the risk that HIV and AIDS posed to their workforce. This resulted in the implementation of workplace HIV and AIDS policies at a very late stage in the epidemic. This will be a point of interest to the Russian construction industry as Russia is experiencing an increase in the number of new HIV infections and is facing the problem of government withdrawing a majority of its support.

Numerous attempts were made by the South African construction industry to address stigma and discrimination to very little success. The industry failed to reassure its employees that disclosure with not result in discrimination from fellow workers. This is important for India, because stigma and discrimination is concerned a major stumbling block in fighting the disease. Research has shown (UNAIDS, 2010) stigma and discrimination can be addressed by education and the assistance of people living with HIV and AIDS as role models. To date both South Africa and India have yet to carry out this.

A strong response from the South African construction industry was the educational programmes run in local communities. The socio-economic upliftment of these communities is needed to protect the workforce that ultimately comes from and returns to these communities.

Active involvement and participation of Peer Educators should be encouraged and supported by management in the Russian and Indian construction industries as the South African industry has successfully managed to do.

A downfall of the South African construction industry is that they do not conduct voluntary HIV counselling and testing. VCT is important and should be used as part of a wider workplace programme. VCT is most effective if employees who test positive can access antiretroviral drugs. This then leads to the second problem faced by South African companies as they do not provide ART to employees. In order to curb the epidemic in Russia and India VCT and the provision of ART is very important.

5. Conclusion

The failure of the South Africa government to effectively co-ordinate a national response to HIV and AIDS resulted in a reactive response from business rather than a proactive response. The private sector in countries across that global need to understand the extent to which they will be able to shoulder the greater responsibility that goes with addressing HIV and AIDS.

Although HIV and AIDS is not curable, it can be prevented and treated. But only a small percentage of construction firms in South Africa appear to be responding to the current impact of HIV and AIDS. However there are still areas for concern and room for improvement in terms of ART provision and assistance with VCT. The workplace also needs to be an environment that is free from stigma and discrimination. HIV and AIDS has a significant impact on profits and it needs to be a strategic part of managements decision-making. Ultimately, firms should try to support employees living with HIV and AIDS for as long as possible and encourage those that are negative to stay negative through behaviour change.

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A Case Study of Real-time Exposure Training in Construction.

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Abstract

Current technology exists in roadway construction to control respirable dust and silica exposure for many tool-specific applications, but under-utilization of dust suppression systems and a lack of tool-specific training are leading to unnecessary exposure within the industry. A case-study of cut-off saws in roadway construction was performed 1) to collect and evaluate real-time inhalation exposure data for a silica-producing operation, 2) to create training materials using a side-by-side visual comparison of known dust control options, and 3) to survey construction supervisors in regards to the effectiveness and usability of the training materials produced from this assessment.

A real-time aerosol monitor was used to measure respirable dust levels during concrete cutting, revealing a respirable dust reduction of 80.9% for wet suppression (n=3) and 78.6% for local exhaust ventilation (LEV) (n=3) when compared to cutting without dust control (n=3). A task-based analysis of each dust control determined that these controls were less effective during vertical cuts versus flat cuts (i.e. 67% less effective for LEV controls and 76% less effective for wet suppression). Best work practices were derived from this data along with real-time side-by-side exposure videos of each control method, which were then compiled into tool-specific training materials. Construction supervisors (116) at a local contractor were trained using these materials, followed by a 27 question survey regarding the effectiveness of this training. Of the 101 returned surveys, 85% of supervisors answered “yes” when asked if they would consider changing current uncontrolled work practices after receiving the training.

Keywords: Construction, Training, Silica, Health

A Case Study of Real-time Exposure Training in Construction.

1. Introduction

Crystalline silica is a constituent of many common building materials such as concrete, stone, and masonry (NIOSH, 2002; OSHA, 2008). Manipulation of these building materials during construction and demolition generates airborne crystalline silica particles (OSHA, 2008). Inhalation of resirable-size, silica particles is a causal agent of progressive lung fibrosis, lung cancer, and other serious autoimmune diseases (NIOSH, 2002; IARC, 1997). According to the World Health Organization (WHO), thousands still die annually from these exposures (WHO, 2000). In 2009, the Occupational Safety and Health Administration (OSHA) released a guidance document regarding known control options for tool-specific operations in construction including cutting, grinding, hammering, and drilling (OSHA, 2009). The latest National Occupational Research Agenda (NORA) agenda for construction has requested research to explore methods to "increase awareness about silica hazards and known solutions among construction workers, contractors, owners, and suppliers" (NIOSH, 2007). The objectives of this case study were 1) collect and evaluate real-time dust exposure data during hand-held concrete cutting, 2) create training materials using a side-by-side visual comparison of known dust control options for hand-held saws, and 3) survey local construction supervisors in regards to the effectiveness and usability of the training materials produced from this assessment.

2. Background

Cutting concrete produces elevated levels of respirable dust containing crystalline silica (Croteau et al., 2002; Flanagan et al., 2006; Thorpe et al., 1999). Silica-related lung diseases are completely preventable by controlling inhalation exposure (OSHA, 2008). Engineering controls such as wet suppression and local exhaust ventilation (LEV) are preferred over administrative control and respiratory protection because they reduce exposure at the source (AIHA, 2003). More importantly, a survey conducted in the U.S. indicated that less than 45 percent of construction contractors require respiratory protection during the course of work (U.S. Bureau of Labor Statistics, NIOSH, 2003).

"The workers' knowledge of risks associated with their tasks, and perhaps more importantly, how these risks can be controlled, is essential to improve their health" (Rosen et al., 2005). Video exposure monitoring (VEM) combines video footage of a process familiar to the worker with the corresponding instantaneous measurements of exposure. VEM can be used to show workers or management where exposures occur and how they can be controlled (McGlothlin, 2005). Research regarding the application of VEM techniques in construction has been limited, with even less research evaluating the effectiveness of these techniques as a component of training.

3. Materials and Methods

In this case study, real-time exposure monitoring was performed during the cutting of expansion joints in concrete curbs. The study evaluated exposure during hand-held cutting without dust control and with two exposure control methods; wet suppression and local exhaust ventilation. Personal real-time respirable dust monitoring was accomplished using one DustTrak real-time aerosol monitor (model 8520; TSI, Inc.) in conjunction with a 10 µm inlet adapter connected to a 10 mm nylon Dorr-Oliver cyclone. The aerosol monitor was zeroed before calibration, and pre-calibrated to a flow rate of 1.7 liters per minute. The operator wore the monitor on his lower back with the cyclone placed on the left lapel. Before the commencement of each sampling period, the time on the DustTrak was synchronized with the time on a site laptop and filmed with a video recorder (Rosen et al., 2005). Respirable dust concentrations were then logged every second for the duration of each sampling period.

Three saw joints were cut consecutively by the operator to assess dust concentrations as the process progressed. Three consecutive samples were collected for each exposure control method on the same length of curb within a two hour time period. After the data was collected, the individual video frames were analyzed with the real-time exposure concentrations using the reference time filmed at the beginning of each sample. The real-time exposure videos were rendered using Adobe Photoshop CS4 and Microsoft Visual Basic v6.5 in Microsoft Excel. Video from one sample for each exposure control method was rendered into a video with a graph of the streaming concentration below the camera footage. A combined side-by-side video was also created using the individual rendered videos for all three control options. The cutting process was then broken into 10 individual subparts, which were then assessed individually for both peak concentration and exposure contribution (See Table 1). For each exposure control method, peak exposure was expressed as the median concentration of the individual peak sample concentrations and mean concentration was expressed as the overall or grand mean of the individual mean sample concentrations.

After the exposure assessment was complete, a tool-specific training presentation was developed using these results. Construction supervisors (116), employees of a local roadway construction contractor, were trained using the materials as a component of an internal annual safety refresher. The presentation was followed immediately by an anonymous 27 question survey regarding the effectiveness of the training and its components. The 15 minute training presentation first included a brief introduction to silica, a video of the process without control (video 1), a video rendered with real-time exposure for the process without control (video 2), and a side-by-side video rendered with real-time exposure for each control option (video 3). The presentation was concluded with an explanation of best work practices derived from the task-based, real-time analysis.

Table 1. Overview of Task-Based Analysis.

Task	Task Descriptions	
1) Start	Begin:	Sample commencement.
	Task:	Worker preparation for first cut.
2) Flat Cut 1	Begin:	Cutting commences for the first saw joint.
	Task:	Cut front, flat section of the curb.

3) Head Cut 1	Begin:	Cutting commences on incline of the back, head of the curb.
	Task:	Cut vertical head of curb for the first saw joint.
4) Walk 1	Begin:	Cutting is terminated for the first saw cut.
	Task:	Move equipment approximately 10 feet to second curb joint.
5) Flat Cut 2	Begin:	Cutting commences for the second saw joint.
	Task:	Cut front, flat section of the curb.
6) Head Cut 2	Begin:	Cutting commences on incline of the back, head of the curb.
	Task:	Cut vertical head of curb for the second saw joint.
7) Walk 2	Begin:	Cutting is terminated for the second saw cut.
	Task:	Move equipment approximately 10 feet to third curb joint.
8) Flat Cut 3	Begin:	Cutting commences for the third saw joint.
	Task:	Cut front, flat section of the curb.
9) Head Cut 3	Begin:	Cutting commences on incline of the back, head of the curb.
	Task:	Cut vertical head of curb for the third saw joint.
10) Finish	Begin:	Cutting is terminated for the third saw cut.
	Task:	All immediate actions following the last cut.

Notes: The completion point of each task is the time immediately before the commencement of the next task. The last task is defined as a fifteen second period.

4. Results

Real-Time Exposure Assessment

The respirable dust reduction was very similar between wet suppression (80.9 percent) and local exhaust ventilation (78.6 percent) (See Table 2). The wet suppression control proved to be more effective in reducing peak exposures. The reduction in peak exposure was 70.0 percent for wet suppression and only 54.6 percent for local exhaust ventilation. Wet suppression also appears to be more consistent in reducing peak levels of dust throughout the saw process (See Appendix 1). Regardless of reductions in peak exposures, local exhaust ventilation still appears to be similar in its overall dust reduction capabilities to wet suppression.

A detailed, task-based analysis of the cutting process provided additional information regarding when the highest exposures occurred during cutting. Without dust control, both the peak concentrations and the mean concentrations appeared to be much higher during the head cuts and the walk time following the head cut (See Appendix 2). Wet suppression also displayed the highest peak and mean concentrations during either the head cut or the walk time following the head cut (See Appendix 3). LEV revealed similar results with the exception of the third flat cut (See Appendix 4). Overall, these controls were less effective during vertical cuts versus horizontal cuts (i.e. 67% less effective for LEV controls and 76% less effective for wet suppression).

Table 2. Summary Statistics for Exposure Control Methods.

			Respirable Dust Concentration (mg/m^3)				
Control	Trial	T	AM (SD)	Maximum	Median Peak	μ^A	Reduction (%)^B
None	1	74	2.51 (3.71)	14.2			
Wet	1	86	1.76 (3.75)	17.4			
LEV	1	84	3.16 (5.37)	26.0	17.4	2.48	
None	2	88	0.38 (0.52)	2.09			
Wet	2	99	0.34 (0.74)	5.77			
LEV	2	107	0.70 (1.13)	5.20	5.20	0.47	80.9
None	3	137	0.51 (1.07)	8.87			

Wet	3	118	0.57 (1.05)	7.89			
LEV	3	117	.0.51 (0.63)	3.00	7.89	0.53	78.6

Notes: LEV= Local Exhaust Ventilation; Wet=Wet Suppression; T=time in seconds; AM (SD)= Arithmetic Mean (Standard Deviation); μ=grand mean.

[A] 1**Error! Objects cannot be created from editing field codes.**

[B] $\% = (\mu_{None} - \mu_{Control}) / \mu_{None} \times 100$

A visual analysis of the recorded videos revealed similar results as the quantitative measurements. For all exposure control methods, the worker was required to bend closer to the curb during the head cut. During the head cut, the dust was not ejected cleanly behind the worker, and it was deflected off the ground and towards the worker. This resulted in a visible cloud of dust around the worker during this task. As the worker turned to walk, the dust appeared to trail the worker for at least half of the distance between cuts. As a result, the worker was exposed to the deflected dust as they walked to the next cut.

Construction Supervisor Survey

The quantitative and visual results from the real-time exposure assessment were used to develop the training presentation for the supervisor survey. The appropriateness of the three videos (See Appendix 5) incorporated in the training presentation was assessed and confirmed using both the quantitative and visual results. For the 116 construction supervisors trained, 101 (87 percent) returned the voluntary survey. Fifty-one percent of participants considered themselves an onsite worker, 24 percent as an onsite supervisor, 8 percent as upper management, and 17 percent as other (e.g. safety professional). Ninety-three percent of these workers reported that they were aware that dust exposure and a variety of its components were regulated by law prior to the training. Ninety-seven percent of workers also understood that overexposure to dust was a significant health concern in construction. The participants were then asked to rank cost (operation and capital), usability (ease of use), productivity (operational efficiency), and safety (employee acceptance, exposure reduction, additional PPE requirements) in order of importance when selecting a tool. Only 66 percent of participants believed safety was the most important.

When asked whether the addition of the exposure graphic below the video changed their perception of dust levels during this operation, seventy-five percent of participants answered “yes”. Eighty-five percent of participants also answered “yes” when asked if they would investigate changing current uncontrolled work practices after watching the third side-by-side video. Finally, 90 percent of participants would consider using a video-based training library to train workers for other work processes. When asked what would utilize free safety training materials, approximately 31 percent preferred professional organization endorsements, 29 percent preferred placement on a government website, 27 percent preferred the first return on a search engine, and 13 percent replied with other methods.

5. Discussion

The quantitative real-time concentration values clearly correlated with the visible dust in the videos. In the side-by-side rendered videos, participants were able to visualize a very evident dust reduction for both wet suppression and local exhaust ventilation when compared to no control. In addition, the participants were also able to visualize the cutting process and the requirements of each control. Seventy-five percent of workers did feel that the rendered video impacted their perception of exposure magnitude, and approximately 85 percent would investigate changes to this process after watching the side-by-side video. Perhaps, most importantly, participants exhibited interest in using similar videos of other processes to train workers.

In collaboration with NIOSH's workplace solutions database, the Center for Construction Research and Training (CPWR) currently provides a comprehensive database of solutions to control hazards for specific tasks in construction (The Center for Construction Research and Training (CPWR), 2009). The database is searchable by construction task, listing hazardous exposures, risks, and practical control measures for each process. Currently, the database does not include multimedia for worker training, but could easily be adapted to include exposure monitoring videos. Inclusion of these videos would be helpful for the contractor during equipment acquisitions and tool-specific training exercises.

6. Conclusions

Interestingly, this case study exhibited that construction supervisors were knowledgeable in the risks associated with silica exposure, but many still prioritize by cost, usability, and productivity above safety and exposure when selecting a tool. The case study reaffirms the importance of incorporating these factors in control design and conveying this information appropriately to contractors. An accurate perception of exposure is critical to the use and implementation of hazard controls. It is recommended that an electronic library of exposure monitoring videos be developedl to provide contractors with this valuable tool-specific information. The use of these real-time videos could also play an important role in analyzing motion and time of processes extending beyond safety and health hazards.

7. Acknowledgement

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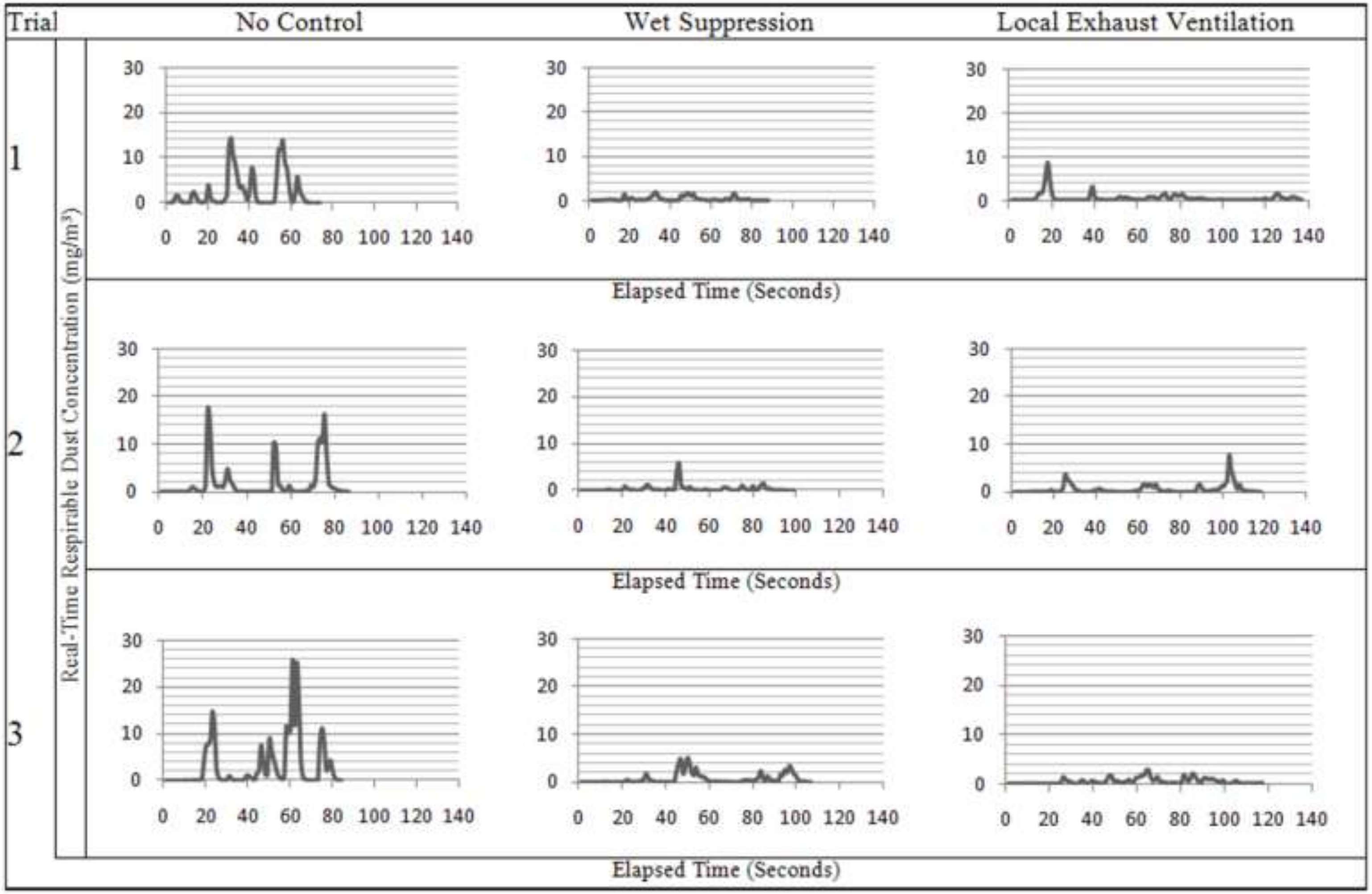
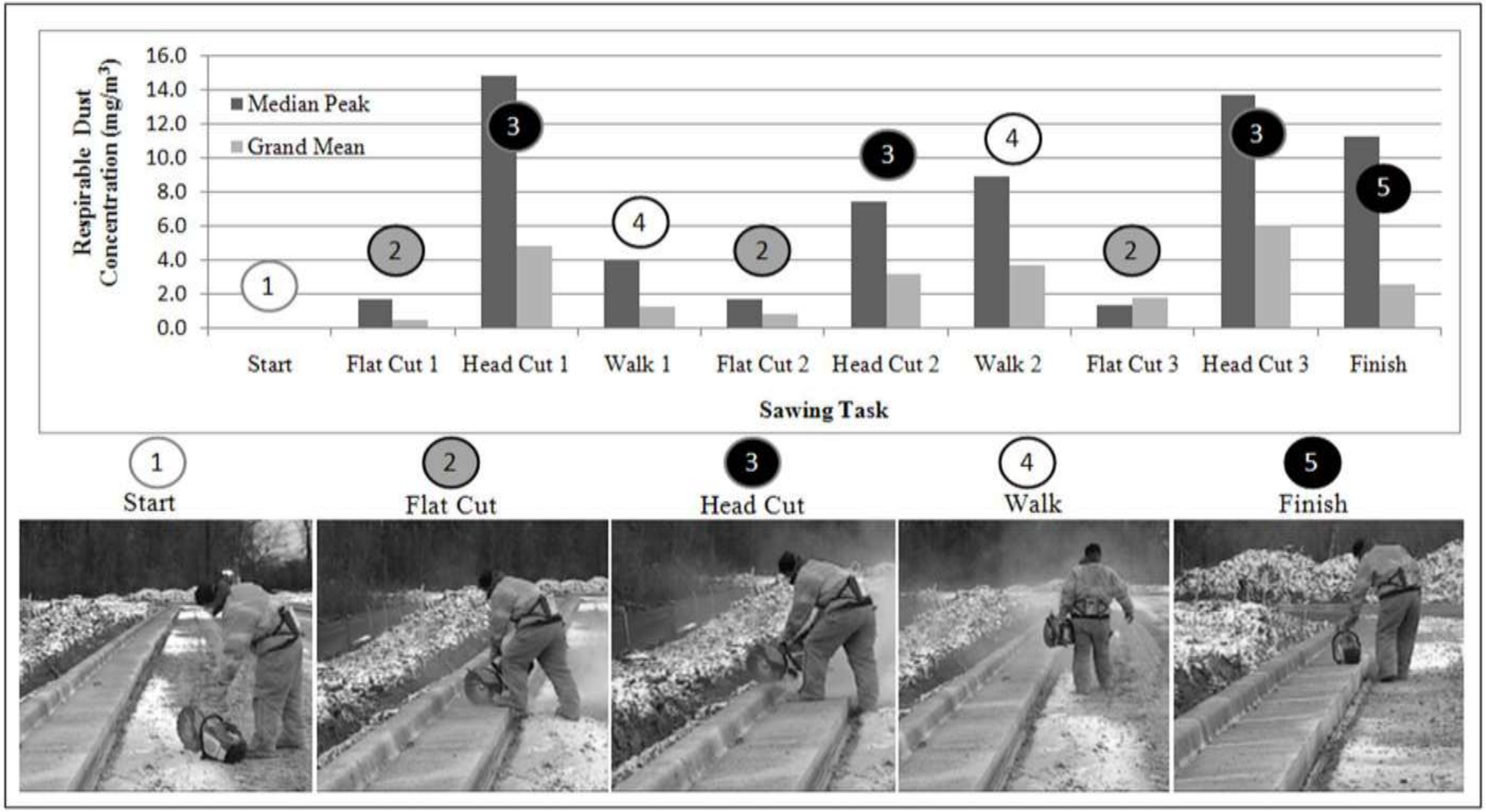
Appendix 1. Instantaneous Respirable Dust Exposure for Sampling Periods.

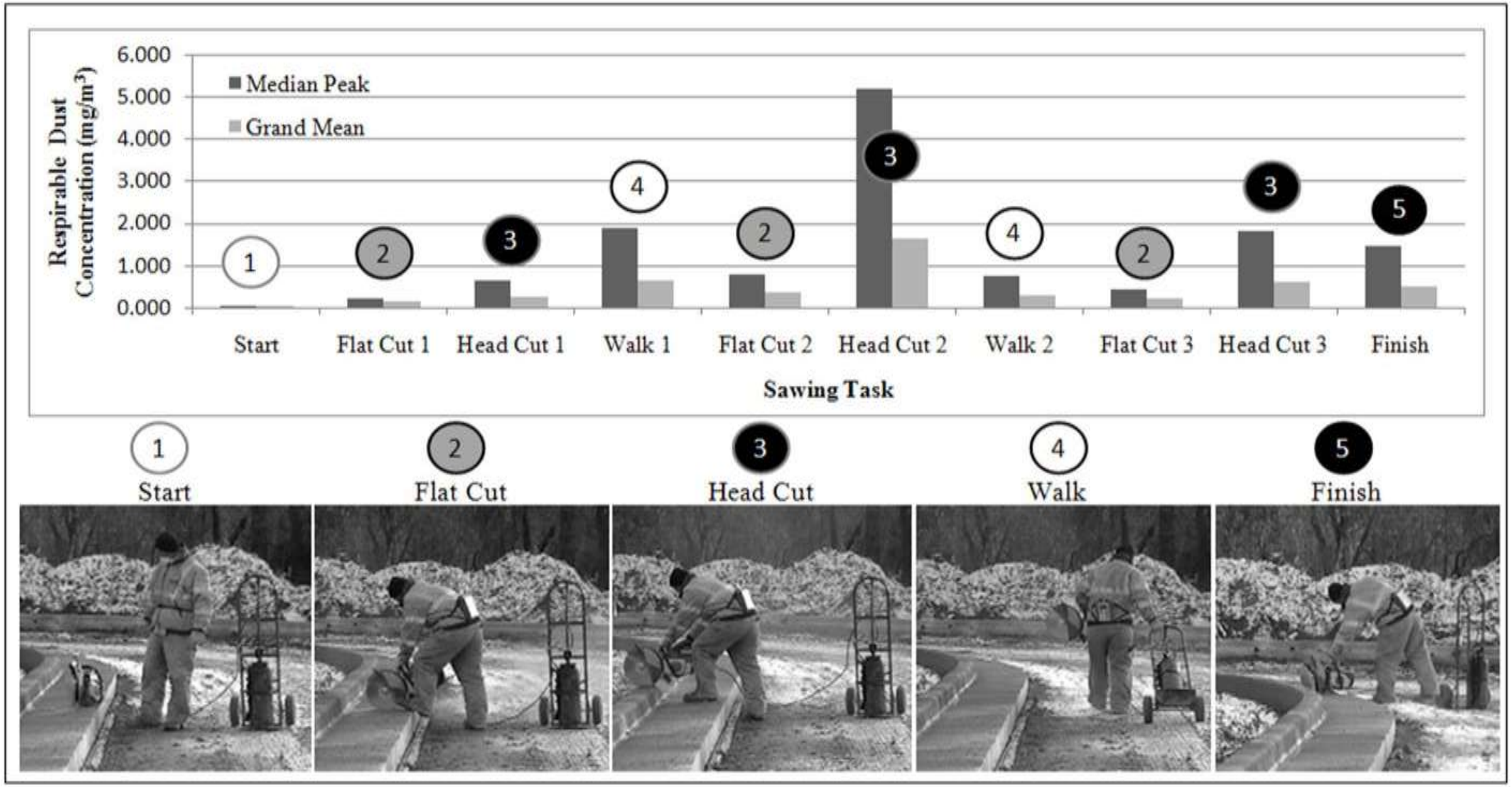


Appendix 2: Task-based Analysis of Cutting Process without Exposure Control.



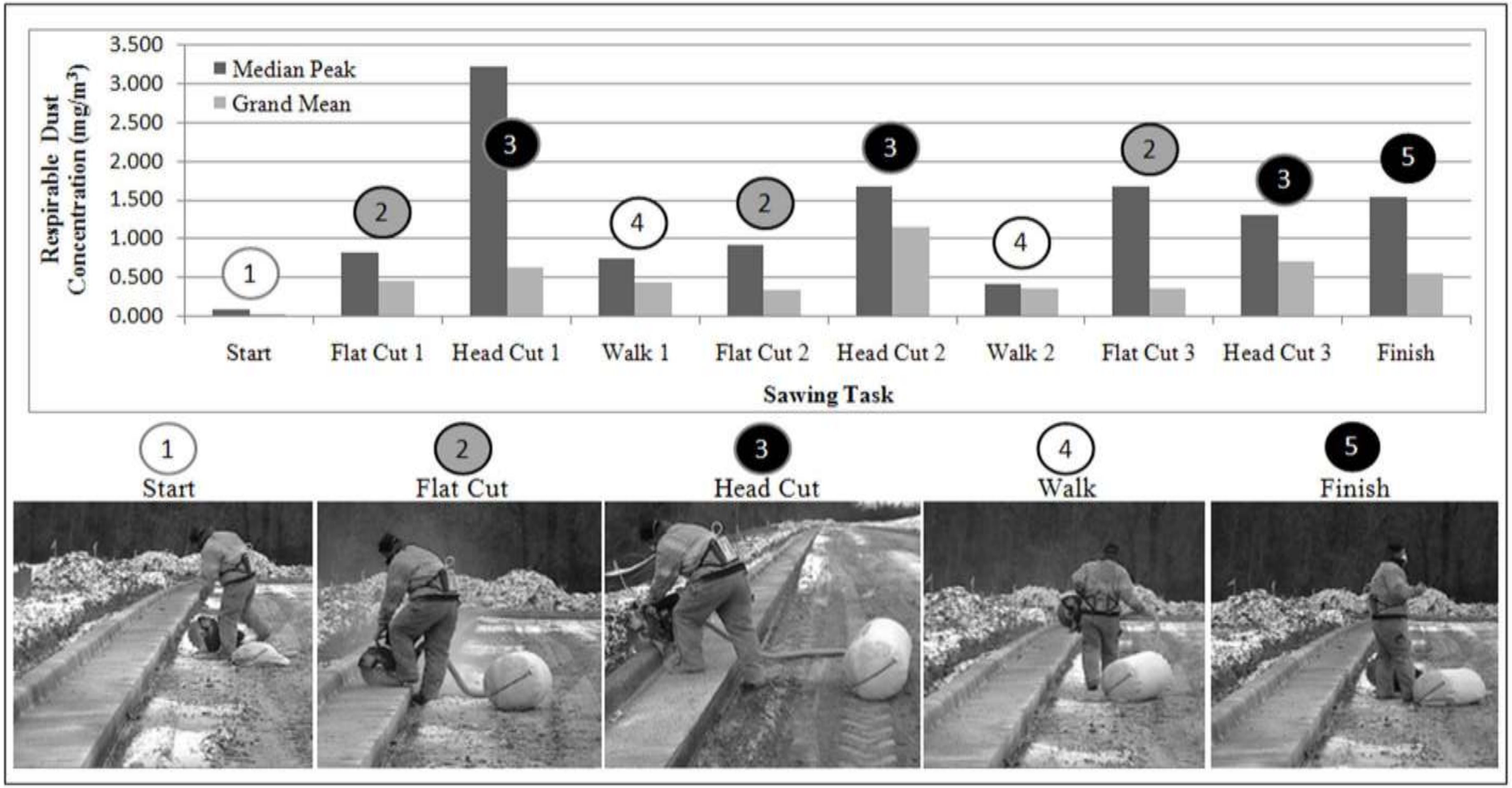
Notes: See Table 1. for detailed task descriptions.

Appendix 3. Task-based Analysis of Cutting Process with Wet Suppression.



Notes: See Table 1. for detailed task descriptions.

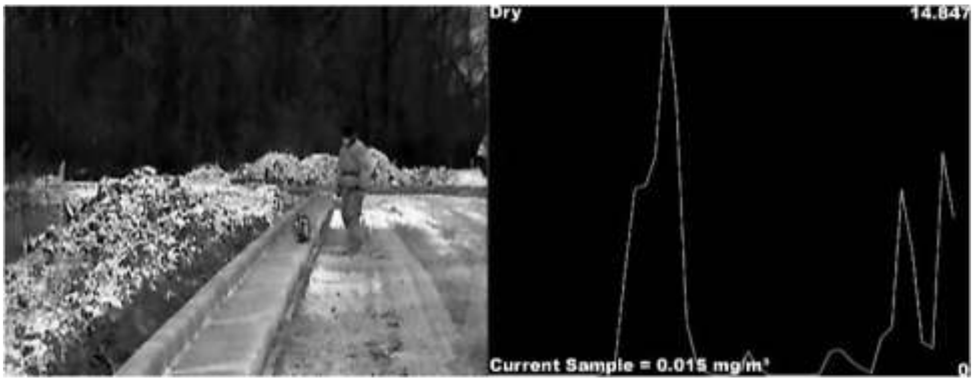
Appendix 4. Task-based Analysis of Cutting Process with Local Exhaust Ventilation.

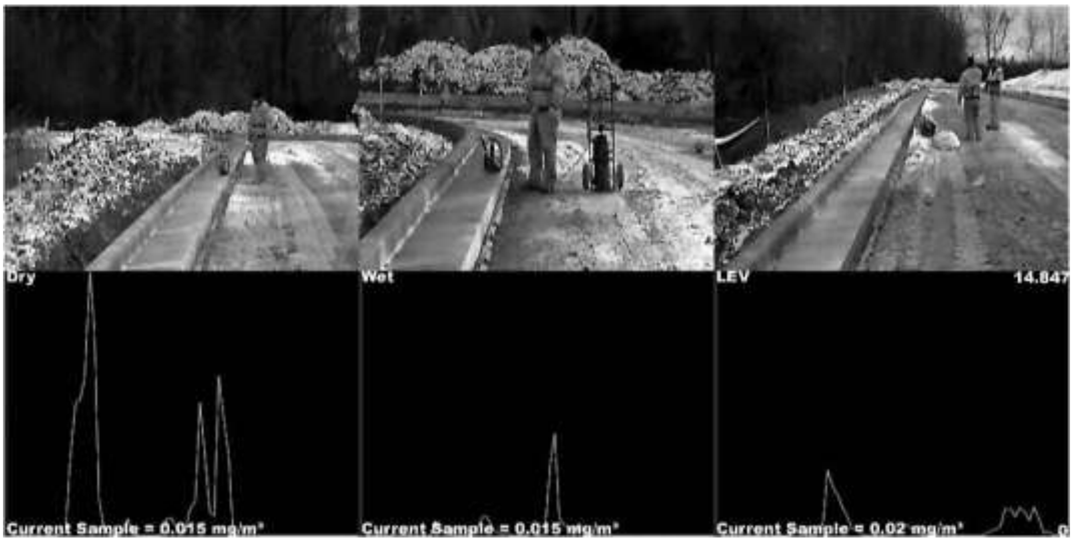


Notes: See Table 1. for detailed task descriptions.

Appendix 5. Supervisor Training Videos.

1. 

2. 

3. 

Notes: Video 1: Video of cutting process without dust control. Video 2: Rendered video of cutting process without dust control. Video 3: Side-by-side rendered video of all three dust control options.

Prevention through Design: Use of the Diffusion of Innovation Model to Predict Adoption

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Prevention through Design: Use of the Diffusion of Innovation Model to Predict Adoption

Abstract:

The Diffusion of the Innovation Model has been widely used to study the adoption of new innovations in many industries. The use of this model can provide valuable insight into the diffusion of Prevention through Design (PtD) health and safety technologies within the construction industry. This paper reviews the Diffusion of Innovation (DOI) literature; its applications for construction; and, specifically, for Prevention through Design (PtD) adoption within the construction industry. The importance of technology champions is reviewed. Technology champions can be used to aid in the adoption of PtD technology. However, the false identification of technology champions for PtD innovations can lead to the misuse or disuse of controls that have been developed. This paper examines the criteria that exist for the identification of champions and asserts that safety and technology championship are both critical elements of adoption of prevention through design innovations.

Key Words: Diffusion, Technology, Adoption, Prevention, Safety, Intervention

1. Introduction

Diffusion of innovation is the process through which an innovation, whether an idea or product, is communicated over a period of time in a social system and involves some degree of uncertainty (Rogers, 2003). Innovation is defined as a significant improvement in a product, process or system that is actually used and which is new to those who will be developing or using it (Manseau and Shields, 2005). One of the necessary components of an innovation is the ability of the innovation to improve some aspect of the adopter's performance of a work task (Toole, 1998). Two important factors that are involved in the diffusion of innovation are the discovery of the innovation and the diffusion of it (Ball, 1999). Diffusion involves communication about the innovation to the target adopters (Koebel, 1999). The Four main elements compose the general diffusion model as outlined in Rodgers 5th Edition of Diffusion of Innovations (2003) include: the innovation, communication channels, time, and a social system.

An **innovation** can be any idea, product, process or object that is perceived as new to an individual or group (Rogers, 2003). Innovation can take many forms and can be incremental, in which small changes occur based on current experience, radical, where a breakthrough in science or technology provides a new change, or modular, where there is a change in concept within a component of a larger system (Blayse, 2004). For a product, process or idea to be considered an innovation, it does not need to be something new pertaining to the time when it was created, but rather the newness of the innovation can be measured if it is new to the individual or adopting unit. The newness of an innovation is often gauged on a person's knowledge, or decision to adopt (Rogers, 2003). The characteristics of innovation that are the most responsible for influencing adoption are:

a. Relative advantage- Relative advantage is perception that the innovation is better than the idea, product or process that already is in use by the potential adopter. If a potential adopter can readily see the benefits of using an innovation there is greater likelihood for adoption. The greater degree the adopter perceives the advantage, the more likely they are to adopt.
b. Compatability- Compatability is the degree to which an innovation is perceived as being consistent with the needs of the potential adopters. Adopters are looking for products they can incorporate into their systems without much effort and without having to change values.
c. Complexity- Complexity is the degree to which the potential adopter views the innovation in terms of how difficult the innovation is to understand or the ease of use of the innovation. If an innovation is easy to understand and use then the likelihood of adoption increases.
d. Triability- Triability of an innovation is the opportunity given to use an innovation on a trial basis before wholly committing to adoption.
e. Observability- Observability is the visible results of the innovation in practice. If observers can readily see the results of an innovation, the likelihood of adoption increases. (Rogers, 2003)

These five characteristics should be considered in Prevention through Design (PtD) innovations because they can aid in adoption. If aspects of these elements are not met, the missing pieces could represent barriers to adoption of innovation.

Communication is the second main element of diffusion. Diffusion of innovations is facilitated by tapping into many sources of communication and information (Toole, 1998). The process of communication through diffusion includes the innovation, an individual or group that has experience using the innovation or a knowledge of the innovation, an individual or group who does not yet know about the innovation or has not experienced it, and a way for these two parties to communicate with each other (Rogers, 2003). Many methods of communication are available for use in the diffusion process including the use of mass media, inter-organizational networks, educational institutes, research institutions, and professional associations (Sexton, 2004). Different kinds of communication channels have differing effects on the diffusion process and rate of adoption. Mass media provides an efficient channel for communication while interpersonal interactions remain the most important channel for providing information about innovations and influencing the adoption process (Lin, 1975, Rogers, 2003).

Time is a third element of diffusion of innovations. Time is a variable that is used to measure the rate of diffusion of an innovation and is one of the strengths of the diffusion of innovation model. Time is involved in diffusion in three major functions. The first is in measuring the time that passes from the time knowledge of an innovation is introduced to an individual or group and the time they adopt or reject the innovation. The second function time is the time in which an innovation is adopted by an individual or group in relation to the introduction of the innovation into society. For example a person can adopt in the early introduction stages of an innovation or can wait and become a late adopter after seeing others adopt the innovation and use it successfully. A common element of the Diffusion of Innovation model is the graph of Everett Rogers for Technology Adoption Lifecycle that shows the distribution of adoption in relation to time shown in Figure 1. The third function of time in the innovation process is the rate of adoption that reflects the number of members in a system that adopt the innovation in a given time period (Rogers, 2003).

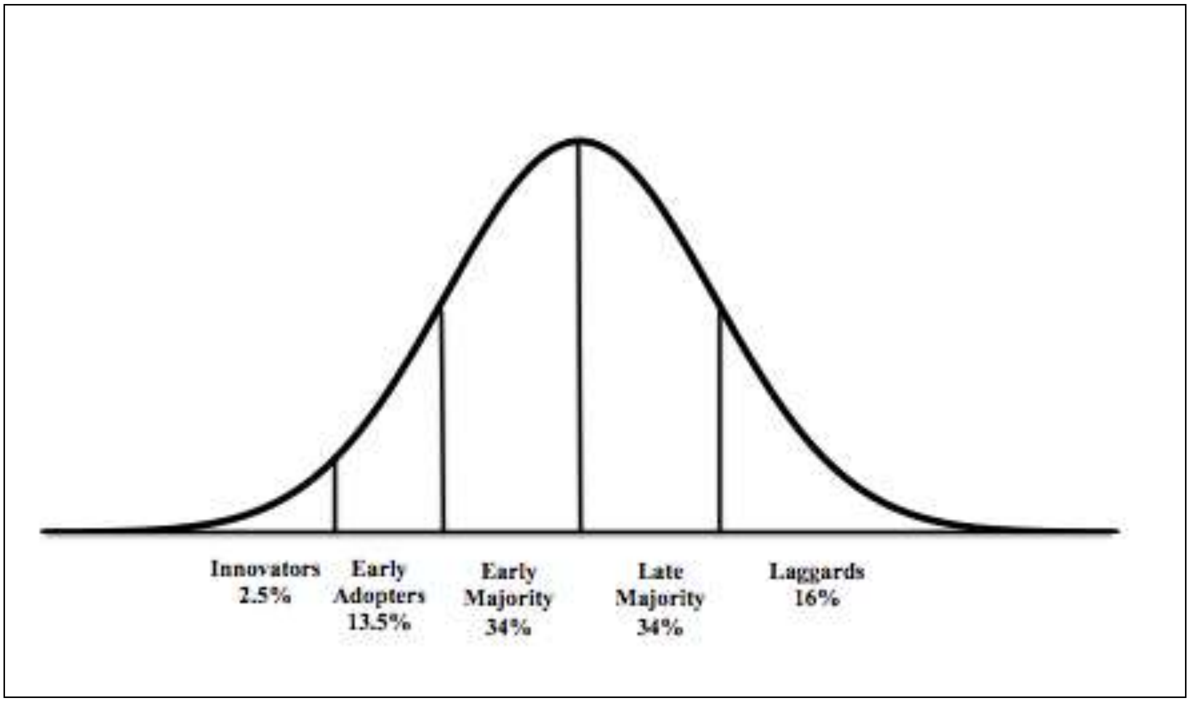

Figure 1: Bell Shaped Graph Depicting Levels of adopters (Rogers, 2003)

Social systems are the fourth element of diffusion of innovations. Social systems could be individuals, groups or members of organizations. The social system affects the diffusion of an innovation depending on the social system structure, processes, roles of members, types of innovation decisions and the consequences of adoption (Rogers, 2003). Innovative individuals known as opinion leaders or change agents are able to influence other individuals' attitudes and behaviors (Rogers, 2003). These opinion leaders also often referred to in innovation discussions as champions can come from formal leaders or informal leaders in a social system (Howell and Higgins, 1990, Markham, 2001). Social systems can also influence the adoption of innovation by deciding to adopt innovations by collective or authoritative decisions. Decisions to adopt innovations in a social system may be optional decisions that are left up to an individual, or collective decisions, which the decision to adopt or reject innovations is based on the consensus of the group. Social systems might also affect the adoption of innovations through the use of authority innovation decisions in which the decision for adoption lies with a few individuals who possess power. The fastest rate of adoption comes from authoritative decisions (Rogers, 2003).

Diffusion in Construction

Innovation in construction offers potential for significant company, social and industry benefits (Slaughter, 1998). The construction industry has been viewed as an industry that is resistant to technology and slow to adopt new innovations (Koebel, 1999). Innovation occurs in construction more than what is recognized by those outside the construction industry. A lot of the innovations done in construction are done by people working on site as opposed to large manufacturers (Slaughter, 1993). The importance of PtD innovation in the construction industry is recognized as a means to improving the quality of life, productivity and safety (Arditi et al., 1997). The amount of information presented to the potential adopter can greatly influence the decision to adopt. Innovations can be categorized into high uncertainty and low uncertainty innovations. High uncertainty innovations are those in which potential adopters are missing substantial information relating to for example, long-term performance, total installed cost, safety, and acceptance by customers. Low uncertainty innovations are those which potential adopters are missing relatively little information pertaining to these criteria (Toole, 1998).

Much of the research on innovation in the construction industry has focused on the barriers in the industry (Slaughter, 1993). Adoption of innovations in construction are defined as occurring when a firm uses a technological innovation in at least 25% of the cases in which it has an opportunity to use it (Slaughter, 1993). Frequent downturns in the construction market may deter firms from adopting innovations (Blackley and Shepard, 1996). Regulatory bodies in construction can also have an impact on the successfulness of innovations. The development of new products or processes in construction is not always be welcomed by all parties (Oster, 1977). Stringent standards for product performance, safety and environmental impacts can create pressure for firms to innovate improve quality and upgrade technologies (Gann et al., 1998). Unions may resist innovations that are viewed as labor saving or eliminating products or processes (Blackley and Shepard, 1996).

Cost, risks, uncertainty and control over limited aspects of the way that construction work is performed and the products that are chosen makes diffusion of PtD innovations in the construction industry difficult (Manseau and Shields, 2005). Barriers that affect the implementation of innovations also include forms of contracts, the cost of research, lack of information about the innovation or being unaware that one exists and not realizing the potential cost savings of adoption (Ling, 2003). Many of those in the construction industry are looking for proof that products and processes will provide an advantage over existing methods and products (Toole, 1998). Builders are frequently unwilling to adopt innovations because of the risks that fall on the builder without capturing the benefits (Manseau and Shields, 2005).

One significant barrier to adoption for PtD methods in the construction industry is that there is a lack of belief among the users that a hazard actually exists or they lack the confidence that they are able to control the hazard (Kramer et al., 2009). The lack of understanding that hazards exist or that controls are available can influence the decisions of managers. Managers tend to devote more attention to items that are failing than items that are meeting their targets (Mitropoulos and Tatum, 1999). If a manger doesn't perceive there is a problem then they are unlikely to adopt innovations.

2. Using Diffusion Theory to Understand the Adoption-Use of New PtD Technologies in Construction.

The use of the diffusion model can help in understanding the adoption use of new PtD technologies in construction. Using the diffusion model as a guide and focusing on the four elements of the diffusion model, researchers can determine the most effective ways to increase diffusion of PtD innovation in the construction industry. A review of the four elements of the model as it pertains to PtD innovation diffusion in construction companies will be outlined to help understand the barriers that exist to increased use of new PtD safety technologies in construction.

The Innovation

The four elements of the diffusion model can be used to examine the understanding of adoption. The five characteristics of an innovation are important determinants in the decision to adopt PtD technologies in construction.

1. Relative Advantage- The use of PtD technologies must provide the potential adopter with the perception that the use of the technology is better that the current method of doing work. This relative advantage could be described as having a greater advantage in terms of cost, production or safety. An innovation must allow the adopter to execute actions that increase the organization's performance (Toole, 1998). Construction firms tend to innovate when there is a clear potential for increased profits (Utterback, 1974).

2. Compatability- The use of PtD technologies needs to be presented to the adopter as consistent with the desired outcomes that current methods produce. Some innovations can disrupt the working system which could result in delays or reduced quality creating additional costs (Toole, 1998). Technologies which construction companies tend to adopt are those that can contribute to the business quickly with visible results (Sexton, 2004).

3. Complexity- The PtD safety innovations needs to be easy for the user to understand and the tools need to be easy to use to increase the likelihood of adoption. New technologies acceptance is helped by the availability of properly trained and skilled people (Arditi et al., 1997).

4. Triability- Letting companies have hands-on experience using the PtD method prior to adoption will allow for a risk free trial and improve self-efficacy in the use of the innovation and will increase the likelihood of adoption. Builders responses to innovations are considerably different when presented the

opportunity to view and touch the product (Toole, 1998). A high degree of user involvement is needed in the construction industry innovation process (Manseau and Shields, 2005).

5. Observability- The innovation needs to be presented in a way that the results of using the innovation are observable to others. PtD innovations can benefit multiple trades on site and will be visible to others who will encourage adoption. Innovators have their eye on advantageous innovations and ones that are easy to implement (Manseau and Shields, 2005).

Communication

Communication channels can be used in the construction industry to increase adoption of PtD innovations. Construction safety innovations including PtD innovations face obstacles due to the limited knowledge of the innovation and the benefits it may provide (Nooteboom, 1994). Potential adopters of innovations in construction are missing a tremendous amount of information (Toole, 1998). In the diffusion model, communication is distributed in different ways. Information concerning the benefits of the usage of PtD innovations could be achieved through training and re-training courses, as well as training manuals or distributed informational materials (Gherardi, 2000). Diffusion of innovation can not be achieved unless others transfer knowledge and diffuse information about innovations to others (Peansupap, 2005). Knowledge and competence are key elements that influence the personal safety performance of construction workers (Langford, 2000).

Time

Time is used in the diffusion model to understand the rate of adoption of innovations. The time an innovation is introduced to the time it is adopted can be the result of how ready to adopt the firms may be (Rogers, 2003). Construction innovations tend to face obstacles that delay the diffusion of innovation due to liability, regulatory codes and the lack of information (Manseau and Shields, 2005). When presented with innovations, people may expect that something better will come along shortly so they wait and watch the experience of others before adopting which is a retarding factor in the time element of diffusion (Ball, 1999). The relative newness of a PtD innovation may have an effect on the adoption rate among construction companies. As time goes on and information increases diffusion is expected to increase.

Social System

Diffusion of innovation in construction firms requires addressing the social system of the industry. The norms of a social system are the established patterns of behavior for the members of the system. Norms set the standard and relate to individuals what behavior is expected (Rogers, 2003). Introducing changes into a construction social system can create ripple effects that can be difficult to anticipate (Manseau and Shields, 2005). The culture of a company can play an important role in the adoption of innovations within a social system and innovations should try to be compatible with the normal behaviors that are in place. Structural barriers such as building codes, and construction safety and health regulations can constrain or drive innovations. Safety and environmental factors can apply pressures for firms to adopt innovations or upgrade technology (Manseau and Shields, 2005). The use of safety and health information dissemination and the enforcement of regulations is an effective way to increase PtD innovation adoption among construction companies as well as other innovations in the construction industry that increase worker safety and health. The use of regulations creates an administrative innovation decision where the decision is made by those with authority and takes away the optional innovation decision of the individual (Rogers, 2003).

Another import aspect of the social system element of diffusion of innovation that can be used to help in the adoption is the use of technology champions to influence other individuals' attitudes towards adoption. Interventions have often used a champions to provide education, champion a product, or to give support for the innovation. Reviews of interventions using champions have been found to be moderately successful (Thompson, 2006). The use of champions could be beneficial in the diffusion of PtD technology usage by using persuasive people to increase the recognition of the innovation and share experiences. Champions provide a transfer of knowledge at an interpersonal level that plays an important part in adoption (Koebel, 2008)

Using the four elements of the diffusion model, the innovation, communication, time and social systems as a guide can influence the adoption of new PtD innovations in construction. It is recommended that the elements discussed herein be considered and incorporated into the design of an PtD interventions to increase diffusion of innovation in the construction industry.

Technology Champions

Frequently the term technology or innovation champion is used to label an individual who is a leader in the innovation process (Nam and Tatum, 1997). There are many terms in diffusion research for an individual who acts as a champion, champions are also called opinion leaders, facilitators, linkage agents or change agents (Rogers, 2003, Thompson, 2006). Research has found that about 70% of construction firms have technology champions who keep others in the company aware of new products and processes. The role of champions varies between small and large firms (Koebel, 2008). Champions are individuals who influence innovation in their organizations or areas of influence (Lin, 1975). The role of a technology champion is to drive innovation and be able to absorb the risk of adopting innovations. A technology champion can be delegated only if the person has slack resources and enough power to implement innovations (Ling, 2003).

Champions need to have past experience and resources as in time or money (Nam and Tatum, 1997). Champions act as gatekeepers of knowledge who help transfer knowledge and diffuse innovations to others (Lin, 1975). Champions aren't usually assigned and can be formal leaders with titles and positions or informal leaders who others look to for information (Howell and Higgins, 1990). Technology champions feel that using interpersonal relationships is a key to influencing innovation and understand that diffusion is a social process (Thompson, 2006). Studies of product innovation success have shown that champions are influential in overcoming barriers to adoption within organizations. Champions who promote innovation can influence the organization to learn about new niches and to develop new processes by fostering communication within firms and stimulating managers to make decisions about innovation (Howell et al., 2005).

Identifying Innovation Champions

Based on a review of literature, many identifying factors are exhibited by technology champions. Some of the identifying factors of champions as found in the literature are:

- Highly enthusiastic people who are willing to make special efforts and take risks to implement innovations, and individuals who have slack resources. (Nam and Tatum, 1997).
- A champion is someone who is open to new ideas (Kramer et al., 2009)
- Champions need to have: a technical competence and understanding of how the innovation works, a knowledge of the company so they can identify relevant ideas, a knowledge of the market, a personal drive to push the idea ahead and get decisions made, and a champion needs to get along with different people and communicate well (Chakrabarti, 1974)
- Champions are persistent even in the face of obstacles. They exhibit self confidence in their own ideas and are highly motivated to influence their followers (Howell and Higgins, 1990)
- Champions are persuasive and willing to take calculated risks and adopt products as their own to promote them. Personal ownership of an idea is a critical quality of a champion (Thompson, 2006)
- Technology champions are indispensible sponsors, protectors, and promoters of innovations who are able to negotiate and balance the opportunities of new approaches with the risks of departing from the tried and tested (Manseau and Shields, 2005).

A champion is an individual who recognizes a new technology as having a significant potential, adopts the project as their own, commits to the project, and seeks to generate support from other people in the organization. A champion can arise from any level of an organization, they get resources to keep the innovation alive, they support projects when there is potential to benefit the champion’s own department and are just as likely to promote innovation that are failures as they are to promote successful innovations.

Identifying a champion can be difficult but similar qualities exist in the various definitions of champions. People who are enthusiastic, committed people who are willing to take risks to implement innovations should be sought out as champions. A person may view themselves as a champion but a good way to identify a champion is through peers and senior managers (Howell et al., 2005, Thompson, 2006). These qualities can be used as good indicators to identify existing champions for new PtD technologies in the construction industry as well as promoting new champions in the intervention process.

False Champions of PtD Innovation

It is essential to ensure that observed behavior is truly indicative of technology champion-ship and not some other construct. Management commitment is a strong indicator of the success of any safety intervention. If manager is not a true champion for a safety innovation, then the likelihood of the intervention having and impact on worker safety is diminished because workers can see that safety is not important to the management's goals (Marsh et al., 1998). There is a natural tendency for a champion to want to select out the desirable parts of an innovation to adopt and to reject the rest. This is often caused by a lack of efficacy of certain elements of an innovation, personal preferences of champions or strong organizational norms (Bresnen, 2001). An unbalanced pursuit of purpose shows how in business situations driven by profit and production, destructive behavior can actually be incentivized. Decision making of champions can be motivated by market approval, government regulations, and safety threats that are ethically inadequate since some organizations never take the time to look at the overall purposes of their chosen practices (Goodpaster, 2000). The problem with falsely identifying a innovation champion for a PtD innovation is that the champion might champion the wrong behavior and the intervention may lose its original meaning and the impact might be lessened (Bresnen, 2001).

Interventions should be aimed at introducing PtD innovations to prevent future potential injury and illness among workers. Preventative safety innovations have been perceived as having low relative advantage as compared to other innovations that are designed to create a profit (Rogers, 2002). Perceived relative advantage has been found to be the most important predictor of the rate of diffusion causing preventative innovations to be slowly adopted. Increasing the rate of preventative innovation adoption can be helped by increasing the perceived relative advantage (Rogers, 2003). If safety prevention is the only perceived relative advantage then the innovation will be unlikely to be adopted (Rogers, 2002). The encouragement of true champions in PtD interventions will to help diffuse information through social networks.

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Respirable Crystalline Silica Dust Exposure during Concrete Breaking and Drilling in Hong Kong Construction Industry

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Abstract:

Construction dust is one of the most concerned pollutants presenting risks to human health. Dust from construction activities, particularly true for silica dust, have an adverse effect on the local environment and on the health of local residents, as well as on those working on the site. There is a long-term concern about the over exposure of construction workers to respirable crystalline silica. The high exposure to silica, even over a short period, can lead to silicosis. No comprehensive study has been conducted in a holistic way to evaluate the effectiveness of current dust control practices in Hong Kong's construction industry. Therefore, the authors proposed this research aims to evaluate the effectiveness of construction dust control practices in Hong Kong. The current dusty work processes and trades were firstly identified through a series of interviews and focus group meetings. Personal respirable samples were then collected and analysed based on NIOSH 7500 method. This paper presents the staged outcome of this research on the concrete breaking and drilling process. 48 samples have been collected and analysed. The results showed that the concentration of silica dust in more than half of the samples exceeded the current recommended threshold limit value of 0.05mg/m^3. The main dust control measures during concrete breaking and drilling process are wet methods and fans, and the respiratory protection was also inadequate. Therefore, there is a strong need to devise methods for controlling workers' exposure to crystalline silica dust during concrete breaking and drilling activities in Hong Kong construction industry.

Key words: Dust control, Silica dust, Silicosis, NIOSH 7500, Concrete breaking and drilling.

1. INTRODUCTION

Dust is defined as all particulate matter up to 75 µm in diameter according to BS6069 and comprising both suspended and deposited dust (British Standards Institution, 1988). Dust from construction activities, particularly true for silica dust, have an adverse effect on the local environment and on the health of local residents, as well as on those working on the site. There is a long-term concern about the over exposure of construction workers to respirable crystalline silica (Chisholm, 1999; Flanagan et al., 2003; Valiante et al., 2004). The high exposure to silica, even over a short period, can lead to silicosis. In Hong Kong, silicosis has been the most common occupational disease for the past several decades. According to a report published by Occupational Safety and Health Branch (Labour Department, 2010), around 100 new cases of silicosis were reported each year during the period of 2000-2009. Construction dust and its impact on the local environment, as well as health and safety, have come into the focus of various concerned parties including workers, clients, contractors, and the general public.

It appears that no comprehensive study has been conducted in a holistic way to evaluate the effectiveness of current dust control practices in Hong Kong's construction industry. Ng et al. (1987) and Wong et al. (1995) investigated the silica hazard of caisson construction in Hong Kong, which has contributed to knowledge of silica hazards in Hong Kong's construction sector. But the construction practices have changed a lot since then, evidenced by the ban of hand-dug caissons in 1995 and the promulgation of the Air Pollution Control (Construction Dust) Regulations in 1997. It is vital that the current dust control practices are closely monitored, and their effectiveness is presented unambiguously to various concerned parties.

In order to better understand current dust control practices in the construction industry in Hong Kong, a study is now conducted to investigate the current practices in dust control and their effectiveness in the Hong Kong construction industry. This knowledge should in turn lead to better practices of dust control in this region and highlight the areas where improvements are needed.

As part of the above study, this paper mainly focused on dust exposure situation during the process of concrete breaking/drilling. The major research methods were NIOSH 0600 and 7500. Following these methods, personal respirable samples were collected and analysed to determine the respirable dust and silica dust exposure of workers during the process of concrete breaking/drilling.

This paper first lists the current dusty work processes/trades and the corresponding dust control measures taken in Hong Kong construction industry which were identified through interview and focus group meetings. It then turns to present the analysis results of personal respirable samples. Discussions and future works are briefly introduced at the end of this paper.

2. CURRENT DUSTY WORK PROCESSES IN HONG KONG CONSTRUCTION INDUSTRY

In order to identify the current work processes and work trades that general most dust and silica dust in the construction industry in Hong Kong, a thorough literature review was conducted first to produce an initial list of dusty work processes and trades in the construction industry worldwide. The Initial List was then scrutinized and verified through two interviews with Registered Safety Officers (RSOs) from Hong Kong construction industry. A focus group meeting was then designed and conducted with two professional associations in Hong Kong: the Construction Industry Safety Management Association (CISA) and Society of Registered Safety Officers (SRSO). The meeting lasted for around 2 hours and total twenty-one RSOs joined this focus group meeting, including 2 CISA members and 19 SRSO members.

During the focus group meeting, a brief introduction to dust control and this research project was first presented. Since the top five work processes from each type of projects that generate most dust were planned to be identified for sampling purpose, each participant was then given 5 red dots (for work processes) to "spend" on the Initial List of work processes based on frequency of occurrence and expected level of dust/silica dust produced. Then, each participant was asked to stick all their dots to the processes/trades which they thought were dusty. Then, the work processes/trades were ranked based on the dots they received. A questionnaire survey was then conducted to collect the views from the participants on the dust control measures taken for the selected dusty work processes and trades. After the focus group meeting, seven more interviews with RSOs were held, together with two focus group meeting: one with HKOSHA (Hong Kong Occupational Safety and Health Association) members and the other with SRSO committee members, to further verify and validate the results. The interviews were conducted in the interviewee's offices and each lasted for 1.5 to 2 h. The Final List of dusty work processes and corresponding dust control measures are shown in Tables 1.

Table 1. Dusty work processes and the corresponding dust control measures

	Work processes	Dust control measures
P1	Excavation	wet methods/ respirator/isolation
P2	Rock drilling & breaking	wet methods/respirator
P3	Loading & Unloading construction waste (rock)	respirator
P4	Soil nail/ Rock bolt	wet methods/respirator
P5	Cement mixing for Shotcreting/grouting	wet methods/ respirator/isolation
P6	Cutting (e.g. concrete, brick and other similar	wet methods/respirator

	materials)	
P7	Grinding (e.g. concrete, marble, granite)	wet methods/respirator
P8	Concrete breaking and drilling	wet methods/respirator
P9	Debris removal	respirator
P10	Drywall finishing (Sanding)	respirator
P11	Manual demolition (concrete structure)	respirator
P12	Heavy equipment demolition (Hydraulic hammer breaking/crusher)	respirator
P13	External wall tile removal	wet methods/isolation

3. RESEARCH METHODS TO IDENTFIY THE DUST EXPOSURE DURING CONCRETE BREAKING/DRILLING

This paper focused the staged outcome of this research on the concrete breaking and drilling process. The main research methods taken were NIOSH 0600 and 7500 methods. Following these methods, personal respirable samples were collected and analysed to determine the respirable dust and silica dust exposure of workers during the process of concrete drilling.

3.1 Sampling Methods

Personal respirable samples. Personal respirable dust samples were collected using pumps (GilAir-3) connected to 10 mm nylon cyclones, as shown in Fig. 1. Each set of sampling equipment was calibrated to a recommended flow rate of 1.7L/Min using an airflow calibrator. The sampling medium was a 37 mm, 5.0 µm pore size PVC filter, supported with backup pad in a two-piece cassette filter holder. This 10 mm nylon cyclone with its attachments was a light weight, size-selective particulate collector recommended by NIOSH (NIOSH, 1998).

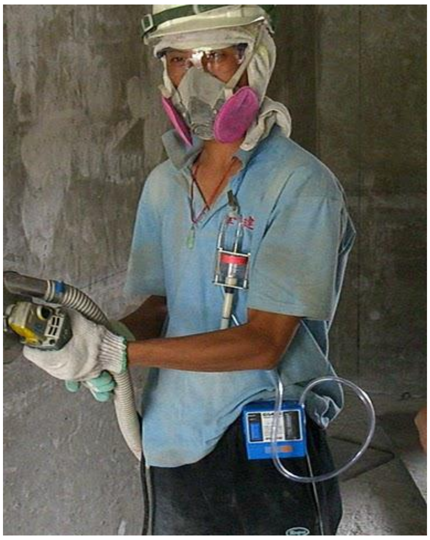

Fig. 1 A worker wearing the sampling pump

The duration of samples were determined by the limit of detection (LOD) parameters of laboratory analysis and the actual operational time of each work process/trade. From LOD perspective, the duration of samples should be longer enough for the laboratory analysis to detect the presence of silica, which gives the duration a lower duration limit (LDL). The LDL could be calculated by the following equation:

LDL= LOD/REL (NIOSH)/Flow rate = 118 min

(LOD: 0.01mg, REL (Recommended Exposure limit) by NIOSH: 0.05mg/m3, Flow rate: 1.7 l/min)

Therefore, the duration of samples should be more than 118 mins. For the samples collected during the process of concrete breaking/drilling, the duration of samples varied from 155 to 270 minutes.

The environmental conditions were measured using a 5-in-1 weather meter (MODEL: AZ 8910). Humidity, temperature, wind direction and velocity were recorded at the beginning, middle and end of each sampling processes. If a subject's orientation to the wind direction was observed that the wind blew dust away from the worker, "Upwind" was then recorded; otherwise, "Downwind" was recorded.

Bulk samples. In order to determine the presence of silica and the relative percentage of different forms of silica (quartz, cristobalite, tridymite), one bulk sample was collected for each work process/trade at each site, which means at least one bulk sample was collected for each different material. Since the bulk sample should be representative of the airborne dust to which the workers are being exposed, settled dust was collected as the bulk sample (NIOSH, 1998).

3.2 Laboratory Analysis

Two different analysis methods were used for personal samples and bulk samples. All analyses were conducted by a laboratory at Hong Kong Polytechnic University. The LOD and LOQ (limit of quantification) were 0.01 mg and 0.03 mg respectively.

Personal samples. All personal samples were firstly analyzed for total weight according to NIOSH 0600 method using Mettler-Toledo XP 26 balance, which gave the concentration of total respirable dust. The samples were then analyzed by X-ray following NIOSH 7500 method.

Bulk samples. A quick qualitative analysis on the bulk samples using x-ray in accordance with NIOSH 7500 method was conducted to determine the presence of silica and the relative levels of the three silica forms. If the presence of silica was confirmed and the major percentage of silica is quartz, the personal respirable samples collected for this work process/trade were only analyzed for quartz.

4. RESULTS AND DISCUSSIONS

48 personal samples have been collected from 6 sites which were operated by 4 different contractors (two large and two small contractors). Four bulk samples have been collected and tested. The results showed that the settled dust contained silica and more than 92% existed as quartz (as shown in Table 2). Therefore, only the quartz was tested for all the samples during the X-ray analysis.

Table 2. Component percentage of crystalized silica in bulk samples

Sample code	Quartz (%)	Cristobalite (%)
S3B1	99	1
S3B2	95	5
S17B1	98	2
S13B1	92	8
Note: S-Site; B-Bulk sample		

4.1 Calculation of Equivalent 8-hour TWA

Since the concrete breaking and drilling process is usually performed for a whole working day, the concentrations of the process specific samples were taken as the 8-hour TWA results with the assumption that the concentration during the whole exposure period stays the same as the concentration during the sampling period. The limitation is that other potential exposures during working time other than the sampling period have not be taken into consideration.

4.2 **Analysis Results**

Forty-eight personal respirable samples have been collected and two out of them were not valid for NIOSH 0600 analysis, for the net weight values of the filter papers were below or equal to zero. Out of the 48 valid samples, 46 were analyzed for the total respirable dust and respirable quartz concentrations. The results showed that one of the measurements taken during the process of concrete breaking/drilling exceeded the exposure limits for the respirable dust concentration (5 mg/m^3) and twenty samples exceeded the respirable quartz limit (0.05 mg/m^3) (See Table 3).

The hypothesis of normal distribution could not be rejected for logarithmically transformed respirable dust concentration values (Kolmogorov-Smirnov test, p=0.702>0.05). Therefore, it could be assumed that the respirable dust concentration values followed a lognormal distribution. Since less than the half of respirable quartz concentration values (20 out of 46 samples) were below LOD, the non-detectable values were replaced as follows: LOD/(√2*Volume) for the GSD were less than 3 (Hornung and Reed, 1990). The GMs were calculated as shown in Table 3.

Table 3. Respirable dust and respirable quartz exposure by construction workers during the concrete drilling/breaking process

Site (Size)	N*	Sampling duration, min (min-max)	Respirable dust, mg/m^3			Respirable quartz, mg/m^3			
			AM (min-max)	GM (GSD)	Above Limit, 5mg/m^3	GM (GSD)	Below LOD (%)	Range ^	Above Limit, 0.05 mg/m^3
Site 2 (Large)	15	171-230	0.50 (0.11-2.60)	0.35 (2.22)	0	0.03 (1.89)	10 (66.7)	0.04-0.16	4
Site 13 (Small)	15	170-240	1.19 (0.45-2.34)	1.06 (2.22)	0	0.07 (2.21)	3 (20)	0.03-0.17	11
Site 14 (Small)	1	155	0.17	0.17	0	0.03	1 (100)	-	0
Site 17 (Large)	15	165-270	1.25 (0.13-11.71)	0.51 (2.98)	1	0.03 (1.95)	6 (40)	0.03-0.12	4
Total	46	155-270	0.96	0.56	0	0.04	20	0.02-	19

			(0.11 -11.7 1)	(2.58)		(2.19)	(43.5)	0.63	
N*: Number of valid samples analyzed Range^: Range of remaining samples									

Respirable Dust and Respirable Quartz Dust. Table 3 shows that only one of the total forty-six valid samples collected during the process of concrete drilling/breaking were below the exposure limit for respirable dust (5 mg/m^3). The AM and GM of the total samples were 0.96 mg/m^3 and 0.56 mg/m^3, which suggests that the dust exposure levels of workers during the concrete breaking/drilling process were relatively high.

There were nineteen samples that were above the exposure limit of 0.05 mg/m^3, and the GM and peak values of total samples were 0.04mg/m^3 and 0.63 mg/m^3. It indicated that the quartz exposure level were high during the concrete breaking/drilling process.

4.3 Comparison between Large Contractors and Small Contractors

There were two major tools involved: hand drills and pneumatic drills. Since the tools were not exactly the same, the comparison studies between large contractors and small contractors have not been conducted.

Dust control measures & PPE. Since different tools were used during the concrete drilling/breaking process, they were introduced respectively in the following section:

- Pneumatic drills (as shown in Fig. 2). Pneumatic drills were used at site 2 (large contractor) and site 17 (large contractor). At site 2, workers used pneumatic drills to remove the unwanted pile-top. As shown in Table 3, the total respirable dust concentrations were blow the limit. However, there were 4 samples that exceeded the quartz exposure limit with a range from 0.05-0.16 mg/m^3. Among the 15 samples, different dust control measures were used: water spray only (11 samples), fans only (2 samples), fan and water spray (2 samples). All workers wore PPE for respirable protections (half-face respirator or N95), which were adequate to reduce the exposure level to below the limit. It could be concluded that the dust control measures together with the PPEs (if properly worn) at site 2were effective. At site 17, pneumatic drills were involved in 13 samples. As shown in Table 16, the total respirable dust concentrations were relatively high. 25% samples were over the exposure limit of respirable quartz with a peak value of 0.11 mg/m^3 (2.2 times of the limit). However, there were no dust control measures. Respirable protection was not enough either. Workers were only found to wear N95 or half-face respirators during fours samples. Wet towel were used by workers during two samples the quartz concentration values were 0.11 and 0.04 mg/m^3 respectively. It could be concluded that the dust control measures and PPEs were inadequate at site 17.

Fig. 2 Pneumatic drill (left) & Hammer drill (right)

Table 4. Respirable dust and respirable quartz exposure at site 17

Site (Size)	N*	Tools	Respirable dust, mg/m^3			Respirable quartz, mg/m^3			
			AM (min-max)	GM (GSD)	Above Limit, $5mg/m^3$	GM (GSD)	Below LOD (%)	Range^	Above Limit, 0.05 mg/m^3
Site 17 (Large)	12	Pneumatic drill	1.46 (0.16-11.71)	0.61 (2.90)	0	0.03 (1.80)	4 (33.3)	0.03-0.11	3
	2	Hand drill	0.53 (0.13-0.92)	0.35 (3.99)	0	0.05 (3.55)	1 (50)	0.12	1
	1	Hammer and chisel	0.14	0.14	0	-	1	-	-
Total	15	-	1.25 0.13-11.71	0.51 (2.98)	0	0.03 (1.95)	6 (40)	0.03-0.12	4

N*: Number of valid samples analyzed
Range^: Range of remaining samples

- Hand drills. Hand drills were used at site 13 (small contractor) and site 17(large contractor). As shown in Table 3, both the total respirable dust and respirable quartz dust concentrations were high. 73.3% samples exceeded the quartz concentration limit, and the range was 0.07mg/m^3 (1.4 times)-0.17mg/m^3 (3.4 times). According to Appendix 7, the only control measure was using fans for ventilation. Workers wore N95 during the majority samples, however, workers were found to wear surgical masks during three samples. Surgical mask is not an effective respirator for dust. It was suggested workers should wear respirators with Assigned Protection Factor (APF) =10 (e.g. N95) when using hand drills. At site 17, two samples were collected and the concentrations of quartz were 0.12 mg/m^3 and below LOD. The PPE was N95. The above results showed that workers could exposure to high level of dust and silica dust when using hand drill to break or drill concrete. Usually, there are no control measures taken. Fans are used sometimes to control the dust. Therefore, it is strongly recommended that the workers should wear appropriate respirators (APF=10). Surgical masks and wet towels must not be used as respirators.

5. CONCLUSIONS & FURTHER RESEARCH

The analysis results suggested that both the respirable dust and respirable quartz dust concentrations were high. The GM and peak quartz concentration values of total samples were 0.04mg/m^3 and 0.63 mg/m^3 (12.6 times of limit). The dust controls measures were also inadequate. There were three common methods: fans (33%), 27% (wet methods) and respirators (73%). None of them were using LEV system to control dust. Some workers were still using wet towels or surgical masks as respirators. Appropriate dust control measures (wet methods, LEV and respirators) are highly recommended for the contractors during the concrete breaking and drilling processes.

This paper only presented staged outcomes on the processes of concrete breaking and drillings in Hong Kong construction industry. More than 500 personal samples have also been collected on other dusty work processes listed in Table 1. All these samples will be analysed to evaluate the effectiveness of current dust control practices in Hong Kong construction industry.

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Design for Construction Health, Safety, and Ergonomics: Encouraging Architectural Designers

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Abstract

A prior exploratory survey demonstrated, inter alia, that architectural designers: perceive H&S to be the contractor's problem; do not adequately conduct hazard identification and risk assessments during the design process; concur that appropriate design and specification can mitigate health, safety, and ergonomic risks; concur that design education is inadequate in terms of construction health, safety, and ergonomics, and further concur that associated risks can be mitigated through improved design education.

This paper presents the findings of a quantitative pilot study conducted among a regional group of architectural designers registered with the South African Council for the Architectural Profession (SACAP) to determine what would encourage architectural designers to proactively mitigate construction hazards and risks through design.

The salient findings are: architectural designers need 'designing for construction health, safety, and ergonomics' competencies; a guiding approach or model should be developed and incorporated into architectural education and ongoing training; the guiding approach or model should be technologically grounded and should not stifle architectural freedom.

The findings, although arising from a pilot study, will contribute significantly toward questionnaire development for a PhD study, which ultimately aims at mitigating construction health, safety, and ergonomic risks through architectural design.

Keywords: architectural designers; construction: health, safety, and ergonomics.

1. Introduction

The South African construction industry, as worldwide, is dangerous. The outdated Compensation for Occupational Injuries and Diseases (COID) report (Compensation Commissioner, 1999) suggests that of the listed 24 industries, Building and Construction ranks ninth in terms of accident frequency rate, fifth in terms of accident severity rate, and third in terms of accident fatality rates.

The South African Construction Regulations were promulgated in 2003 and require a multi-stakeholder approach to construction health and safety, inclusive of designers (Republic of South Africa, 2003), while SACAP expects "... registered persons to competently carry out their duties with integrity." (Goldswain & Smallwood, 2009) The impact on 'designing for construction health, safety and ergonomics' remains questionable. The traditional 'cost, quality and time' project success measurement tool is no longer applicable and needs to embrace construction health, safety, and ergonomics (Mroszczyk, 2005; Schneider, 2006; Smallwood, 2006). Numerous studies suggest that half of construction accidents can be eliminated through proactively 'designing for construction health, safety, and ergonomics' (Health and Safety Executive (HSE), 2003; Beam, 2006; Toole and Gambatese, 2006).

The literature review considers a range of factors, which can exacerbate construction hazards and risks leading to accidents. It identifies predominant accident types leading to construction related illness, injuries and fatalities. A discussion on 'mitigation of hazards and risks through design' suggests that up to half of construction accidents could be avoided through design, and entertains separate discussions on construction health, construction safety, and construction ergonomics. Approaches toward mitigation of construction hazards and risks are exposed in the form of lists of recommendations and models which have been devised to engage, inter alia, designers in the process of 'designing for construction health, safety, and ergonomics'. In closing, relative perceptions of architectural designers are exposed through a prior exploratory survey.

This qualitative pilot study forms part of a PhD (Construction Management) study, which ultimately aims to realise a paradigm shift relative to construction health, safety, and ergonomics. The objectives are to determine the perceptions of architectural designers as to:

- Whether they engage in 'designing for construction health, safety, and ergonomics' or not, and to establish the need for development of competencies;
- What mechanisms could be introduced which would promote engagement and commitment to the process, and
- What format the introduced mechanisms should take.

2. Review of the literature

Accident factors and causes of illness, injuries and fatalities

A convergence of factors leads to construction accidents. Firstly, ‘proximal factors’, which include the attitude, ability, awareness, health and fatigue status of workers, as well as site hazards created in the absence of suitable planning, management and supervision. Secondly, ‘distal factors’ include issues surrounding design, in terms of choice of material and equipment and the application of the design situation. Similarly, these factors can be grouped as worker factors, site factors and material / equipment factors, which stem from ‘originating influences’, such as permanent works design, inter alia, which in turn are affected by client requirements, economic climate and the education, knowledge and experience of the people involved (Health and Safety Executive (HSE), 2003; Gibb *et al*., 2006).

The main causes of illness, injuries and fatalities in South African construction and internationally are ‘falls onto different levels’, ‘motor vehicle accidents’, ‘struck by’, ‘inhalation, absorption and ingestion’, and ‘work-related musculoskeletal disorders’ (WMSDs) or ‘body stressing’ (The Health and Safety Executive (HSE), 2006; Penny, 2007; Weitz and Luxenberg, 2008; Bureau of Labour Statistics (BLS), 2008; Construction Industry Development Board (cidb), 2009; Safe Work Australia, 2010).

Mitigation of hazards and risks through design

Toole and Gambatese (2006) suggest that mitigating hazards and risks can be achieved by conducting reviews at various stages of the design process, while Beam (2006) suggests that one third of the hazards and risks “... could have been eliminated or reduced if design-for-safety measures had been implemented”. The HSE (2003) suggests that up to 50 of 100 studied cases could have mitigated the hazards and risks through alternative design.

Construction health hazards and risks include inhalation, absorption and ingestion of hazardous chemical substances (HCSs), which can lead to a range of illnesses and ultimately death (Smallwood and Wheeler, 1999). Cowley *et al.* (2000) advocate Bender and Hadley (1994) and suggest more pressure be applied on manufacturers of HCSs to improve hazard information on packaging to make ‘upstream target groups’ more aware of the risks presented by using specific products.

Construction safety hazards and risks include ‘motor vehicle accidents’, ‘falls onto different levels’ and ‘struck by’ possibilities, as well as electrical contact, contact with moving parts of machinery and vehicles, fire and explosion, excavation collapse, and working in confined spaces (Deacon and Smallwood, 2010). Cowley *et al*. (2000) advocate The Consultancy Company (1997) suggesting that by the time hazards are assessed it is usually too late to intervene.

Deacon and Smallwood (2010) suggest that construction ergonomic hazards and risks include repetitive movements, working in awkward positions, climbing, heavy equipment and material handling, bending or twisting, reaching overhead or away from one's self, noisy and vibrating tools, use of body force, working in limited space, reaching away from the body, working in a varied range of weather conditions, and working while injured. Rotation of activities and rest periods can alleviate problems, however ultimate risk mitigation can be achieved through avoidance of labour intensive construction (Deacon and Smallwood, 2010).

Approaches toward mitigation of construction hazards and risks

Beam (2006) presents a list of design suggestions originally developed by Gambatese (1996) suggesting modifications to permanent features of projects. For example: *Design the parapet to be 42 inches tall. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or future roof maintenance.*Beam (2006) created a new list of design suggestions. For example: *When design features, such as ventilation systems, trash chutes, chimneys, and elevators, cause floor openings to occur during construction, provide a warning in the plans and specifications for construction, and design in permanent guardrail systems and sequence them in early in the construction process for use by all contractors;*

Numerous researchers contend that up to half of construction accidents can be mitigated through design, which can be enhanced by conducting construction H&S reviews throughout design stages (Toole *et al*., 2006; Toole and Gambatese, 2006; Beam, 2006; HSE, 2003). To this end two models come to the fore, namely the United Kingdom's Gateway model (HSE, 2004) and the Australian CHAIR model (WorkCover NSW, 2001). These differ and are not elaborated here, but focus on a multi-stakeholder approach requiring interim assessments of designer's work, inter alia, with construction health, safety and ergonomics being an inclusive factor.

Perceptions of architectural designers

A prior quantitative exploratory survey was conducted to determine the perceptions of architectural designers with regard to the mitigation of construction health, safety, and ergonomic risks through appropriate design (Goldswain and Smallwood, 2009).

The paper is not elaborated here, but the most significant findings include: *architectural designers do not adequately conduct hazard identification and risk assessments during the design process; appropriate design and specification can mitigate health, safety and ergonomic risks; design education inadequately prepares architectural designers in terms of construction health, safety, and ergonomics and associated risks can be mitigated through improved design education.*

It recommended additional research with regard to 'designing for construction health, safety, and ergonomics', which should be fully integrated into appropriate tertiary education design programmes, as well as Continuing Professional Development (CPD) courses.

3. Methodology

A quantitative pilot study was conducted among a regional group of architectural designers registered with the South African Council for the Architectural Profession (SACAP) to determine what would encourage architectural designers to proactively engage in mitigation of construction hazards and risks through the design process.

The process involved development of thirteen semi-structured interview questions in order to determine the perceptions of architectural designers as to:

- Whether they engage in ‘designing for construction health, safety, and ergonomics’ or not, and to establish the need for development of competencies;
- What mechanisms could be introduced which would promote engagement and commitment to the process, and
- What format the introduced mechanism should take.

Approximately 60 telephone calls were made to set up interviews. Of these, twelve interviews were secured and only 10 took place due to two cancellations. Interviews were recorded and corresponding hand written notes were captured.

4. Findings

The data gathered is too rich for inclusion in a concise paper, but will serve toward the greater PhD study. Only responses to the more pertinent questions are included here.

To the question ‘*Do you believe that construction hazards and risks can be mitigated through alternative design?’* 80% of respondents confirmed their belief, with commentary suggesting that:

- Everything has risks, which can be minimised through design and material choice;
- It is the responsibility of the architect to understand construction technology;
- Risks need to be identified and managed correctly;
- There are definitely ways, but the form of buildings should not change;
- Construction methods should take safety and worker ability into account;
- Risks can be reduced by pre-manufacturing and spending less time at high levels;
- One should mitigate risks, but this should not become a driver for design, and
- There is a lack of awareness and the profession should advise and set out preambles.

20% of respondents do not believe that mitigation of hazards and risks is a design issue. Commentary includes:

- It doesn’t really matter as the risks and dangers are contractor responsibility, and
- It is not so much design as management of site procedure.

To the question '*Do you actively engage in 'designing for construction health, safety, and ergonomics'? (Please support your answer with an explanation of 'how' or alternatively with 'reasons' for not engaging)'* 60% of respondents suggested that they do actively engage, yet the responses suggest that the understanding and level of engagement is minimal. Some selected commentary suggests:

- Some design occurs with health and safety in mind but it cannot be specified on drawings;
- Not when taking form into account, but maybe when starting to detail things;
- It is kept in back of mind, but is not a sole reason;
- To a certain extent, risks are noted and sorted out;
- I think I do ... it's not at the forefront of one's mind, and
- One does or should ... we don't think about it enough.

40% responded to the negative, with commentary including:

- I don't think one can ... don't consciously think about it;
- I wouldn't say we actually design for it ... the challenge is to look at how it can be done;
- Inspectors check on how a contractor manages his staff, and
- Not specific, it depends on the project.

To the question *"Is there 'something' which could be introduced that would encourage architectural designers to engage in 'designing for construction health, safety, and ergonomics'?"* 60% of respondents offered positive suggestions, which include:

- Educating people ... tedious to implement ... should not limit design;
- Ongoing education to keep it at the forefront of one's mind ... it's becoming more visible as a topic;
- It is more a case of awareness, even at university level ... it stems back to Architectural School days;
- One may be able to make up manuals ... needs to be brought to our attention ... an awareness is needed;
- Training should include on site experience ... mentorship is lacking, and
- Architects should have hands on knowledge of what the contractor encounters.

40% of respondents were less forthcoming with suggestions and commentary including:

- Nothing specific ... think it's logic;
- Wonder if it happens in high architecture ... nothing off hand;
- No – dangers come more from under-design by engineers, and
- Can't think of anything off hand ... would hate design to be stifled. Is there a design criteria? ... I don't think there can be.

To the question *"In terms of your recommendation, is there any specific means or format which could be integrated into the design process in order to promote 'designing for construction health, safety, and ergonomics'?"* 80% of respondents offered positive input, while 20% did not respond. Commentary includes:

- Find out how to do it safely ... stipulate how it's got to be done;
- Education ... consulting agents or representative visits ... buy-in is required;
- An ongoing process to sensitise people ... CPD makes it easier to introduce;
- Some sort of methodology is crucial ... a method or awareness of the building programme;
- Not sure of a format (earlier suggested manual) ... it should make a worthwhile contribution ... something which reminds one to think about it all the time;
- More time spent on the design development stage could benefit ... to build it in, we do Advanced Technologies as part of our design course ... it's glanced over ... we don't fully understand how things are put together;
- It should be integrated into the training process ... in terms of the architect going through six years of training, and
- Architects need to understand how buildings are put together and how methodologies are spelt out ... but the contractor is the expert in building.

To the question *"How could the aforementioned means or format be integrated into your everyday design process?"* 70% of respondents offered positive commentary:

- It should be part of integral thinking ... part of design and documentation;
- Architects should build up specialist knowledge over time;
- It is up to the professional... we need to educate the client to trust the professional;
- The fundamentals of health and safety should be discussed, even at university, and should be monitored and recorded;
- Keep it real and honest – practical and buildable. Do not simplify form and make architecture less exciting and stimulating ... methodology should check and double check your decisions as you proceed;
- Education must be relevant and must address the real problems of design, and
- What must not happen ... we must be very careful with any manual ... it must not be prescriptive and must invite deeper thinking ... if you start closing doors, your design process will be stunted and you can't have that.

30% of respondents did not contribute effectively:

- Never really thought of it;
- We do specify that contractors should conform to safety standards; and
- Accidents seen are due to on site carelessness ... no problems where architectural designs are not safe.

To the question *"Do you feel you have the necessary competencies to 'design for construction health, safety, and ergonomics', and how could these competencies be* *enhanced?"* 40% of respondents felt that they have the necessary competencies, although commentary suggests otherwise:

- Must do ... most definitely ... working with an engineer the combined effort must cover those sort of things;
- I believe I've got the competencies ... to enhance those competencies one would need to interact with contractor to find out how things could be improved;
- Yes, but we must understand our limitations ... ask for help when we need it and consult with specialists. Experience helps – and do the research, and
- We have the competencies because we are designers ... we can design anything. The only way to enhance those competencies is by being made more aware.

50% of respondents did not feel they had the necessary competencies, while 10% of responses could not be deemed valid. Commentary received includes:

- I don't believe any of us do – we were never taught. What is known is purely through experience – if a detail causes a big problem it won't be used again;
- No, I'm not a health and safety 'fundi'. Aware, but learning as we go;
- No ... interaction of the team to thrash out ideas. Awareness is needed ... goes back to 'varsity' days;
- Not something we factor in enough ... but we don't want it to govern form totally. Architects take thousands of different influences to determine form ... this needs to be one of them, and
- It would be arrogant to say that – maybe adequate but never enough. Education is needed to enhance competencies ... there's a chasm between the two. We actually need to marry the thought processes.

To the question *"If 'designing for construction health, safety, and ergonomics' could somehow be incorporated into tertiary education for architectural students, then how do you think it could be integrated?"* 80% of respondents offered a way forward:

- It needs to be instilled from basics. It's difficult, but there must be a way to define objectives ... to fit into Building Construction – the nuts and bolts – not into Design ... must be non-restrictive;
- Alternative construction usage could be enhanced ... risks are not clear. It could form a module with OHS incorporated ... or a subsection of Materials and Methods – what materials, how to use them ... what to use where;
- It will have to fit somewhere between Building Design and Construction, which run parallel ... the Building Construction component. How do we put a building together and how do we document it? It needs to be an integral component – a separate course won't receive the emphasis it deserves. In the early years of architecture it needs to create awareness for architects;
- There must be a rational way of thinking ... even as simple as once drawn, imagine building it. Architectural education discourages it ... forget how, it doesn't matter how it gets built ... at what point do we bring it into detail technology ... the subject Building Technology;

- It should be taught by an architectural professional, not a health and safety officer;
- It should start at root level – day one. Design and methodology go hand in hand like form and structure ... ‘varsity’ projects – how is it going to be built ... feasible, viable or too risky?;
- Incorporate it into Design and Construction courses – how to put it together. Architects can become more aware, but are not health and safety officers, and
- We need the correct packaging ... there is too much emphasis on spatial rather than detail. Incorporate it into a design problem – link into the detail – talk to the curriculum to decide what year to introduce it.

20% of respondents did not offer a way forward, with comments such as:

- Wouldn’t know, and
- It relies on common sense.

To the final question *“Do you have any other comments or ideas in general with regards to ‘designing for construction health, safety, and ergonomics’?”* 70% of respondents offered commentary:

- It’s important ... an awareness needs to be made;
- One does not really think about it – it needs to be taught and awareness raised;
- The trade is becoming more aware of the problems;
- We need to understand alternative methods of construction. Recycle and re-use ... reduce manpower and reduce risk;
- Awareness and fairness – people doing a hard job – how do we make their day more comfortable. If teams are happy, they will be more aware and careful;
- Something can be developed. Hopefully we’re doing it anyway ... it’s something we need to be aware of, and
- It’s a new field ... not widely explored. We need research and new ideas brought to us. Information needs to be increased at tertiary education level and workshops held for the professionals.

5. Conclusions

Given the objectives and methodology of the study, it is likely that the more committed architectural designers made themselves available for interviews.

80% of respondents believe that construction hazards and risks can be mitigated through alternative design and 60% of respondents suggested that they do actively engage in designing for construction health, safety, and ergonomics, yet commentary suggests that the understanding and level of engagement is minimal. This is supported by the responses received relative to having the necessary competencies.

In terms of encouraging architectural designers to engage in designing for construction health, safety, and ergonomics, and the possible means or format thereof, the arising themes strongly suggest the need for appropriate and ongoing education and training to create awareness and that designers need ‘hands on knowledge of what the contractor encounters’. It was also suggested that a manual could be introduced to guide designers through the process, which would make a worthwhile contribution.

The responses to the question of how designing for construction health, safety and ergonomics could be incorporated into education, as well as into the everyday design process, position themselves somewhere between design and technology, with the majority leaning toward the nuts and bolts – as suggested, ‘how do we put a building together and document it?’ When to introduce this into education remains questionable, but suggestions of creating awareness ‘in the early years of architecture’ is inspiring.

An additional important theme running throughout the responses is that designing for construction health, safety, and ergonomics must not stifle the design process and should ‘invite deeper thinking’, rather than being prescriptive.

6. Recommendations

In order to encourage architectural designers to design for construction health, safety, and ergonomics, further research is necessary. Such research should focus on development of a guiding approach or model – or a manual – suitable for integration into architectural education and continuous professional development (CPD) programmes. The approach or model should be geared toward the early years of architecture and related technologies, and should invite deeper thinking, rather than stifle architectural freedom.

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Proactive Monitoring of Health and Safety Performance in Small and Medium Construction Enterprise Using Leading Health and Safety Indicators

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Proactive Monitoring of Health and Safety Performance in Small and Medium Construction Enterprise Using Leading Health and Safety Indicators

Abstract

Traditional measures or indicators of workplace health and safety (H&S) performance reflect unrecognized hazards, unsafe conditions, reckless behaviour and other H&S program shortcomings. This happens only after a worker is injured, falls ill or a fatality occurs. In contrast to traditional or lagging indicators, leading indicators (LIs) can predict poor H&S performance to ensure that H&S program failings are addressed before occupational injury, illnesses or fatality actually occur. This research project has identified a variety of proactive H&S management practices, and activities shown to influence workplace H&S performance. The researchers have proposed a comprehensive framework of subjective and objective LIs, based on literature review that small and medium construction enterprises (SMEs) in South Africa can use to proactively gauge H&S performance. SMEs could then address unrecognized hazards, unsafe conditions, reckless behaviour and other H&S performance deficiencies at their project level before injuries, illnesses and fatalities occur. The framework consists of ten main elements: upper management commitment, worker/employee involvement, appointment of H&S staff, formal and informal written communication, formal and informal verbal communication, project planning of H&S, H&S resources, H&S policy, training in H&S and project supervision.

Keywords: health and safety; leading indicators; small and medium; performance

1. Introduction

Every employee has a right to a healthy and safe working environment which enables them to live a socially and economically productive life (Loosemore and Andonakis, 2007). While recent South African government initiatives to improve safety and quality performance on construction sites have reduced accidents, construction sites continue to be among the most dangerous workplaces in the economy, and rework levels are comparably high (Construction Industry Development Board, CIDB 2004). In South Africa, the Compensation Commissioner and Federated Employers Mutual Assurance Company Ltd (FEM) indicated approximately 25,500 reported accidents per annum at a total direct cost (compensation) of approximately R200 million in construction industry (CIDB, 2004). In terms of fatalities, cited in CIDB, (2008) report 160 deaths occurred on site in 2007/2008, while CIDB, (2004) report indicated the construction industry was ranked third after mining and transport with 74 deaths recorded on site in 2003.

The continuing poor H&S performance of the construction industry in the form of fatalities, injuries, and disease, the number of large-scale construction accidents, and the general non-participation by key project stakeholders such as clients and designers, provided the catalyst for a new approach to construction H&S. This led to the promulgation of consolidated construction H&S legislation in the form of the Construction Regulations 2003. It requires a range of new multi-stakeholder interventions, inter alia, that designers substitute less hazardous materials, amend designs that necessitate the use of hazardous processes, and consider ergonomics during commissioning and other phases of projects (Smallwood and Haupt, 2005).

CIDB (2004) revealed that there is a very limited commitment to comply with basic requirements, let alone promote a culture of H&S. Employers views H&S as a cost in the system. Small contractors can barely maintain tools and regard safety equipment as luxury items. Even where protective clothing and equipment are provided, workers often avoid their use, including the use of safety goggles and masks when working with grinders and asbestos. Aside from the direct compensation and medical costs associated with accidents, the costs to the economy are immense and include rework, lost time, damage to plant and equipment, disruption, productivity loss, and loss of skills to the economy. These views highlight the importance of identifying proactive measures for monitoring H&S in SMEs projects in the construction industry in South Africa.

2. Measurement of construction health and safety performance

Health and safety performance measurement allows comparison of H&S performance between projects. Also, measurement can be used by organizations internally to maintain line accountability for H&S and to pin point problem areas. Health and safety performance measurement can be broadly classified in terms of two types of indicators, namely lagging indicators such as accident rates, and LIs or positive performance indicators (PPIs) that address H&S climate (Flin et al. 2000) and H&S culture (Grabowski et al, 2010). Grabowski, et al. (2007) asserts that leading indicators can either be subjective or objective indicators. Unfortunately, the construction industry continues to rely heavily on traditional measures such as accident and workers compensation statistics (Mohamed, 2002). This implies that measuring PPIs in construction industry are in their infancy and needs to be addressed especially in SMEs.

When using LIs a more thorough and constant surveillance is required than when using lagging indicators (Hinze, 2005). The real value of using H&S leading indicators on the construction project is that changes can be made early. An intervention can be devised that can address the weakness before there is an accident. Hinze (2005) advocates the need to use LIs in H&S performance, rather than using lagging indicators. A literature review was conducted to identify the H&S leading indicators.

3. Literature review

The Occupational Health and Safety Act (OH&S Act) 1993, mandates that the employer i.e. the principal contractor creates a conducive, environment for the employee and reaffirmed in Construction Regulation 2003. Based on the aforementioned, Levitt and Parker (1976) studied the role of top management in construction firms in reducing construction injuries. They established that: companies whose top managers talked about safety when they visited jobsites had lower Experience Modification Rating (EMR’s) than companies in which safety was not mentioned during these events. They also found that companies with formal orientation programs had lower EMR’s compared to companies with no orientation programs. Cooper (1998) indicated the importance of communication in influencing H&S performance improvement and categorized communication into formal and informal, verbal and written communication. Kheni et al. (2006) further indicated the need for verbal communication as a good measure for safety management practice. Sawacha et al. (1999) established that the most important factors to improve H&S performance under organization safety policy are: management communication in regards to safety, provision of safety booklets, provision of safety equipment, assuring a tidy site, appointing safety representatives and training of operatives on safety.

Jaselskis et al. (1996) assert that to achieve better construction safety performance at the company level the related H&S factors/elements to be in place are: upper management support, time devoted to safety issues from company safety coordinator, number of informal safety inspections made by the company coordinator, meetings with field safety representatives and craft workers, length and detail of company safety program, and safety training for new foremen and safety coordinators. The authors also indicated that at the project level, the H&S factors/elements that are important for achieving better safety performance are: increased project manager experience level, more supportive upper management attitude towards safety, reduced project team turnover, increased time devoted to safety representative, more formal meetings with supervisors and specialty contractors, more informal safety meetings with supervisors, a greater number of informal site safety meetings with supervisors, a greater number of informal site safety inspections, reduced craft worker penalties, and increased budget allocation to safety awards. Toellner, (2001) established LIs that are essential to improving safety performance. These measures are: safety walkthroughs by management, barricading a given place, tool box talk meeting and housekeeping. Jannadai et al. (2002) revealed that management involvement, personal protective equipment, and emergency planning and preparation were considered to be extremely important factors in influencing safety performance as they reveal the greatest impact.

Fernandez-Muniaz et al. (2007) developed a positive safety culture model that consisted of management commitment, employee involvement and safety management system (SMS). The SMS included safety policy, incentives, training, communication, planning, and control. Their model was generic to represent industries of different types and sizes. Their results indicated improvement when these elements are used, and especially when top management and employees are involved. Aksorn et al. (2008) in a validated study revealed 16 critical H&S factors that will influence H&S performance improvement. The factors were later categorized into four major dimensions namely; 1). Worker involvement, 2), safety prevention and control system, 3), safety arrangement and 4), management commitment.

In a recent study by Rajendran et al. (2009), the authors identified 50 elements considered essential by experts. These were categorized into 14 categories i.e.; project team selection, contract safety requirement, safety and health professionals, safety commitment, safety planning, training and education, safety resources, drug and alcohol program, accident investigation and reporting, employee involvement, safety inspection, safety accountability and performance measurement and industrial hygiene practices. The literature result synthesized is tabulated in Table1, based on the authors' interpretation of the meaning of core elements and leading indicators. This comprehensive framework of LIs comprises of both subjective and objective indicators.

Table 1: Framework of H&S leading indicators

Core elements	***Leading indicators***
Appointment of H&S staff, Sawacha et al., 1999; Vredenburgh, (2002)	Employing at least one qualified manager with H&S training to oversee H&S [*on multiple projects]* At least one staff member with H&S training is employed on each project Employing at least one H&S representative on each project
Formal and informal written Communication Cooper, (1998); HSE, (2008)	Provision of written information about H&S procedures Provision of written information about the correct way to perform tasks Written circular/brochure that informs workers about the risks associated with their work Written circular/brochure that inform workers about the preventive measures to reduce risk Provide clear verbal instructions to both literate and illiterate employees about H&S H&S information verbally communicated to workers before changes are made to the way their work activities are executed Organize regular meetings to verbally inform workers about the risks associated with their work Organize regular meetings to verbally inform workers about the preventive H&S measures of risky work
H&S resources Abudayyeh et al., (2006); Rajendran et al., (2009)	Provision of personal protective equipment (PPE) Training in H&S through attending seminars/workshops Material schedule data sheets provided for all hazardous materials on site Employing technically skilled employees with H&S training Adequate information brochures given on H&S Provision of a budget for H&S Provision of correct tools, equipment and plant to execute construction Provision of good welfare facilities such as showers, canteens, toilets
Project planning of H&S Sawacha et al., (1999); Rajendran et al., (2009)	Ergonomics is considered when deciding the method of construction Reengineering is considered to reduce hazards When head office decides on the method of construction H&S is included in decision making process Each project has a site-specific H&S plan Layout of the site considers H&S aspects Use hazard identification procedures Constructability of project is reviewed Scheduling for H&S

Continued Table 1: Framework of H&S leading indicators

Project supervision/inspection Rajendran et al., (2009)	Proper supervision by staff trained in H&S Identification of hazards by at least (*one staff member trained in H&S)* Results of inspections discussed at H&S meetings H&S inspections done at least daily Local authorities and H&S enforcement agencies visit sites for inspection Ad hoc informal H&S inspections of work place Regular H&S audits of projects
Training in H&S Sawacha et al., (1999); Fernandez-Muniz et al., (2007)	Workers undergo induction on H&S before commencing work on a particular site Workers trained in proper care of personal protective equipment Workers trained in proper use of personal protective equipment Workers are regularly trained in H&S Instruction manuals or safe work procedures are used to aid in preventive action Employer helps employees to train in-house (study leave, grants) Workers are given time off for training
Worker/employee involvement in H&S Aksorn et al., (2008); Fernandez-Muniz et al., 2007)	Workers…… are involved in production of H&S policy provide written suggestions on H&S kept informed of provisions of H&S plan are involved in H&S inspections are consulted when the H&S plan is compiled are involved in development of H&S rules and safe work procedures have the explicit right to refuse to work in potentially unsafe, unhealthy conditions
Upper management commitment in H&S Levitt et al., (1976); Fernandez-Muniz et al., 2007)	Managers….. encourage and support worker participation, commitment and involvement in H&S activities encourage and support training of employees in H&S communicate regularly with workers about H&S actively monitor the H&S performance of their projects and workers take responsibility for H&S actively and visibly lead in H&S matters regularly visit workplaces to check work conditions or communicate with workers about H&S encourage and arrange meetings with employees & other managers to discuss H&S matters conduct toolbox talks themselves ensure that the H&S budget is adequate recognize and reward outstanding H&S performance of workers
H&S policy Shannon et al., (1997); Fernandez-Muniz et al., 2007)	Proper implementation of safety management system Company has H&S policy Written in-house H&S rules and regulations for all workers reflecting management concern for safety, principles of action and objectives of achievement The firm coordinates its H&S policies with other human resource policies to ensure the well-being of workers

4. Problem statement

The challenges and the current state of poor H&S in the construction industry in South Africa advocates for better ways of monitoring and measuring H&S in SMEs projects in order to reduce occupational injuries, illnesses and fatalities in their projects. The overarching research question is:

> *What are the core H&S elements and leading indicators that will be used to monitor H&S performance at project level of SMEs?*

In order to achieve the stated research question the following specific objectives were set:

- To identify core H&S elements through literature;
- To identify H&S leading indicators through literature; and
- To develop a proactive H&S framework based on the identified core elements and leading indicators.

5. Discussion of Results

A number of H&S studies (Levitt et al., 1976, Askorn et al., 2008) have established that management commitment to H&S is a major factor influencing the success of an organization's safety program. Management commitment is monitored when managers encourage and support worker participation, further encourage and support training of employees in H&S (Abudayyeh et al., 2004) and communicating regularly with workers about H&S (Toellner, 2001). Management should be seen to actively monitor the H&S performance of projects and workers, taking responsibility for H&S, be actively and should visibly lead in H&S matters. The literature further advocates for regular workplace visits by management to check work conditions arrange meetings with employees and other managers to discuss H&S issues. Toolbox talks should be monitored if they are conducted and ensuring adequate H&S budget. The recognition and reward of outstanding H&S performance of workers should also be monitored.

Involving and empowering employees provides them with authority, responsibility and accountability. It has been established that in order for employees to be involved and empowered they should be allowed to participate in the H&S policymaking i.e. developing the H&S safety rules and procedures, provide written suggestions on H&S, the employees are updated on H&S plan, be involved in H&S inspections, consulted when the H&S plan is compiled, and refuse to work in potentially unsafe, unhealthy conditions these indicators need to be monitored to improve H&S performance.

The H&S policy allows an organization to follow a set of rules and regulations in order to operate efficiently. The monitoring of organizational H&S policy and proper implementation of safety management system should be undertaken; further monitoring is on the comprehensive written in-house H&S rules and regulations for all workers reflecting management concern for safety taking into consideration the, principles of action and objectives to be achieved. It is also essential that the firm monitor its coordination of H&S policies with other human resource policies to ensure the well-being of workers health and safety.

Planning for H&S has been considered vital in influencing H&S performance improvement. For H&S planning to be able to influence H&S performance, SMEs, will have to monitor if ergonomics is considered when deciding the method of construction and considering reengineering to reduce hazards, on the other hand head office should decide on the method of construction considering H&S in their decision making process. It has been implied in literature that each project should have a site-specific H&S plan to enhance H&S performance improvement. The layout of the site should consider H&S aspects, taking into consideration the use of hazard identification procedures and risk assessment procedures. The constructability of project should be reviewed and monitored to enhance H&S performance of the workers and finally, the scheduling for H&S is monitored to ensure H&S activities are programmed in the project to enhance improvement.

Appointing H&S staff according to Sawacha et al. (1999) and Vredenburgh, (2002) is important in influencing H&S performance. Monitoring those getting employed by ensuring at least one qualified manager with H&S training to oversee H&S [on multiple projects], employ at least one staff member with H&S training on each project and employing at least one H&S representative on each project.

Formal and informal written communication is the transfer of information through writing to employees about the possible risks in the workplace and the correct way to combat them. Necessary written information about H&S procedures should include, correct way to perform tasks, information about risks associated with their work, materials necessary to reduce risks with job.

Formal and informal verbal communication is the conveying of information verbally to employees. This requires clear verbal instructions to both literate and illiterate employees about H&S. It is necessary to convey H&S information verbally to workers before changes are made to the way their work activities are executed. The need to organize regular meetings and verbally inform workers about the risks associated with their work and about the preventive H&S measures of risky work are indicated to be effective in monitoring H&S.

In order for H&S to be effective, occupational H&S training is required according to (Sawacha et al., 1999; Kheni et al., 2006). Monitoring effective training in H&S can reduce the number of injuries and fatalities. Monitor when workers undergo induction on H&S before commencing work on a particular site they are aware of H&S. It is also essential that workers demonstrate proper care and use of personal protective equipment as this has been proved to influence H&S performance improvement and further ensuring workers are regularly trained in H&S. The issuing of instruction manuals or safe work procedures to aid in preventive action is deemed to be essential in construction projects and ensuring workers are given time off for training in H&S will further assist workers to understand the importance of H&S.

Supervision of construction projects is vital (see OH&S Act 1993 amendment Construction Regulation 2003). The need for proper supervision by staff trained in H&S is required taking into consideration the, identification of hazards by at least (one staff member trained in H&S), and allowing results of inspections to be discussed at H&S meetings. The study has revealed that, H&S inspection should be done at least daily on projects and allowing local authorities and H&S enforcement agencies to visit sites for inspection. Due to the nature of the construction projects the study further revealed *ad hoc* informal H&S inspections of workplace should be conducted and allow regular H&S audits of projects to monitor H&S performance.

According to Abudayyeh et al. (2006), Rajendran et al. (2009) they assert that H&S resources are important in influencing H&S performance. The monitoring of the provision of PPE, training in H&S through attending seminars/workshops, ensuring material schedule data sheets are provided for all hazardous materials on site to improve H&S performance. The employment of technically skilled employees with H&S training, and providing adequate information brochures on H&S needs to be monitored, further monitoring of the provision of H&S budget, correct tools, equipment and plant and the provision of good welfare facilities, such as showers, canteens, toilets, need to be undertaken to improve H&S performance.

6. Conclusions

The 64 leading indicators identified were either subjective or objective indicators and were categorized in 10 elements which will need to be monitored to indicate early warning before an accident occurs. The elements were upper management commitment, worker/employee involvement, appointment of H&S staff, formal and informal written communication, formal and informal verbal communication, project planning of H&S, H&S resources, H&S policy, training in H&S and project supervision. The framework of LIs in Table 1 will be used to develop a conceptual model for H&S performance improvement. The results are based on literature review and hence might be biased. It is worth noting this is a research project in progress.

7. Further studies

The effectiveness of using H&S leading indicators to reduce injuries, illnesses and fatalities is a logical area for further studies and verifying the importance and impact of these LIs in improving H&S performance at project level of SMEs is advocated.

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The Evolution of Legislation on Health and Safety on Construction Sites in Italy

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ABSTRACT

Starting in 2007, with the approval of law 123, the Italian government has proceeded to reorganize the law summary in the matter of health and safety in the workplace, highlighting important observations in respect to previous regulatory framework.The first concerns the reunification of set standards, ending the existing distinction between the construction site and other workplaces.

The second concerns the complete abandonment of logic on which the norm in the 1950's was based on, which are *obligations* and *prohibitions*, in favor of evaluative logic introduced in the EU Directives in the 1990's.

The paper examines in detail the path taken by Italy starting from the first legislation in the end of the 19th century until today highlighting the following stages:
- Damage preventions
- Risk preventions
- Safety planning
- Safety management

The differences found in the law summary highlight the difficulties of this route that is due to the particular situation that the construction industry is experiencing in Italy.
An element of no lesser importance, for example, is given by the excessive fragmentation of productive infrastructure of construction sector.

Keywords: Legislation, Health and Safety, Coordination, Construction site

The Evolution of Legislation on Health and Safety on Construction Sites in Italy

1. The Socio-Cultural Italian Context

Italy was among the first countries in the world to adopt specific legislation on the protection of workers' safety. The aspects of health and social work, in fact, have always been studied and analyzed carefully by the Italian medical and scientific world. It is no accident that, historically, the Italian, Bernardino Ramazzini was recognized as the founder of occupational medicine, who at the beginning of the eighteenth century inserted a new question into the Hippocratic anamnesis: "et quam artem exerceas? – What is your occupation?" Author of "De morbis artificum diatribe" (Padua, 1700), Ramazzini identified through an analysis of sixty categories of workers, the harmful effects of work and "the nature of harmful utilized substances."

Another Italian record is the development of occupational medicine as an independent clinic branch. In 1902 the "The Labour Clinic" was founded, the first institution in the world dedicated to this discipline, which was completed in 1910. In 1906, in Milan, the first international congress of occupational medicine took place and the International Commission on Occupational Health (ICOH) was founded.

In this cultural and scientific climate, the Italian regulations to protect workers, were developed. At the end of the nineteenth century in the middle of the Italian industrial revolution, theconcept of work was profoundly different from today. Environmental resources and human labor-power itself were seen as unlimited resources and inexhaustible assets to the industry that could exploit them at will, without any concern for their protection. The worker's protection, prevention of injuries and work related illness issues were not taken into consideration. Unlike the artisan, in fact, the worker was more often than not qualified, because the tasks carried out in the factories were often characterized by a low level of qualification. The worker, therefore, was interchangeable and his state of health was not a concern for the employer, who could easily be replaced. With the birth and the organization of the first unions, specific norms to protect workers came about. After the Crispi Pagliani Law of 1888 a system based on worker's insurance began to develop in Italy. A few years later, in 1899, the first laws dedicated to a specific work activity, work in mines and quarries, were enacted.

The health insurance system has gradually extended to new categories of workers. In the fascist period, within a social model based on corporations, health care coverage shifted from a voluntary to a mandatory regime, first for individual categories and individual illness, and later in a generalized form with the creation of the "The Workers Health Care Institute". During the same period, with the enactment of the Civil Code (1942) and the Penal Code (1930), the concept of "corporate responsibility" on the civil and criminal matters, recognizing that "the employer is required to adopt the necessary measures to protect the physical health and mental health of workers", began to develop. This concept was reinforced a few years later giving it constitutional value. In fact in 1948, in Article 35 of the Constitution work protection in all its forms was laid down.

The socio-economic change in Italy in the following years led to the need of developing a legal system to protect workers based on imposing company restrictions and constraints. The companies did not apply, therefore, the regulations in accordance with a real interest in the health of its workers, but rather to avoid fines and penalties resulting from their breach. Between 1955 and 1956, with full industrial development of post-war reconstruction, a series of measures (the Act No. 547/55, 164/56 and 303/56) were issued, aimed at identifying the hierarchy responsible for safety to provide specific sanctions and to supervise their implementation. The legislation of the fifties still had many limitations within.

No information/formation activities for workers were provided, as a preventative intervention; the identification of specific exposure limit values lacked; identified remedies were too generic and, finally, the workers and their representatives were still poorly involved in prevention. The recognition of the necessity for direct participation of workers in the process of protecting their own health happened at the end of 1969, when the working population realized, that only direct experience of those who worked daily in hazardous environments would be efficient for assessing working conditions and the impact on the health of the workers. The "Workers' Statute" then introduced the rights of workers to control, through their union representatives, the implementation of standards for the prevention of accidents and occupational illness.

At the same time the claim to pay full wages and maintenance of the workplace in case of injury, occupational disease, maternity and sickness in general until complete healing was made. With the creation of the National Health System (Act No. 833/78), specific "environmental health services and occupational medicine" were set up, organized within each of the local health units to which the powers of the department of Health and Safety were progressively transferred in terms of injury prevention and safety at work. A personal health record to be distributed to all citizens, including possible exposure to risk in the conditions of life and work was also established. Moreover, within the same regulation, a consolidated safety and hygiene rule should have been included by the end of 1979, however, it was not added until 2008.

Since the early nineties health issues began to become intrinsic and strategic aspects of production processes as an indicator of quality. After the inception of the European Union (Treaty of Maastricht, 1992), Italy began to implement the EU directives in the field of health protection at work. The Act No. 626/94 was issued after a long process, preceded a few years earlier, by Act No. 277/91 on protection against risks of exposure to chemical, physical and biological (specifically lead, asbestos and noise).

The Act No. 626/94, in applying "to all public and private sectors," accepted seven EU Directives (workplace, use of work equipment, DPI use, cargo handling, use of display screens, safety to carcinogens and biological agents). This legislation introduced new provisions on risk assessment, information, complete and regular training of workers and their health inspection.

Specifically, in the construction sector, European law is applied in the Act No. 494/96, in which, for the first time, a system of analysis, design and safety planning was constructed within a specific safety management on construction sites document

2. Development of Italian health and safety regulation

Developments in Italian legislation and regulations on health and safety covered four basic stages, which are summarized as follows;

- Damage prevention
- Risk prevention
- Safety planning
- Safety management

Period 1865-1942: Damage Prevention

The first important provision in Italy in health and safety at work, laying the groundwork for future legislation, is that established art. 2087 of the Civil Code which provides: "The entrepreneur has the duty to adopt measures in the performance of the company, according to the particularities of the work, experience and techniques are necessary to protect the physical integrity and moral personality of the employee."
The diagram below illustrates the results obtained, namely:

- compulsory insurance for workers against the contractor
- the obligation of prevention and protection for workers
- the burden of proving possible negligence of the worker
- the compensation for damage suffered by the worker

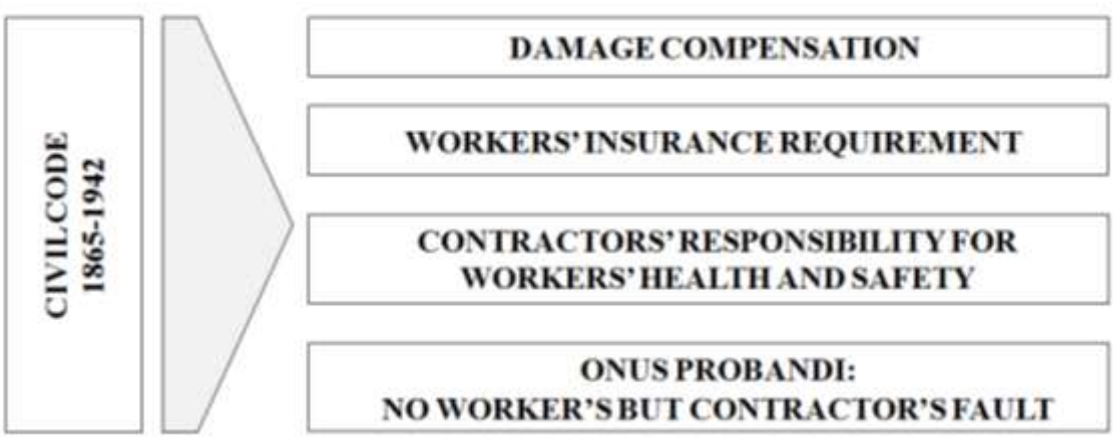

Fig. 1 – Summary diagram of the damage recognition in the Civil Code

Period 1955-1978: risk prevention

The subsequent provisions date back to the 1950's with the legislation concerning the prevention of accidents at work or the Act No. 547/55 and hygiene of work, the Act No. 303/56. Such laws are the pillars of accident prevention in Italy, along with the Act No. 164/56 on construction and emphasize the prevention of intrinsically safe mechanical systems and dictating prevention rules specific to each individual machine, or for any single working environment, allowing limited freedom of choice to the employer who is obliged to comply, for detailed and specific penalties for each breach, in fact, "Employers, managers and those responsible for carrying on, manage or supervise the activities of the company, within their respective functions and responsibilities are:

- take the safety measures provided in the relevant acts;
- warn employees of specific risks they face and make them aware of the ways to prevent damage due to such risks;
- provide workers with the necessary means of prevention;
- require those who have individual workers follow the rules of hygiene and safety and apply the protections available to them."

Such detailed and specific regulations to define specific rules do not allow room for interpretation and discretion to the employer who, within the enterprise, is not free to choose and adopt a preventative system but is obliged to comply with specific rules; A repressive system whose judgment is therefore delegated to the monitoring party that must ensure compliance to the obligations of the legal system. Only with the enactment of the Workers' Statute (1970) a new policy is established, compared to the above provisions, giving workers the right to "monitor the implementation of standards for the prevention of accidents and occupational illnesses and to promote research, development and implementation of all measures to safeguard their health and physical fitness."

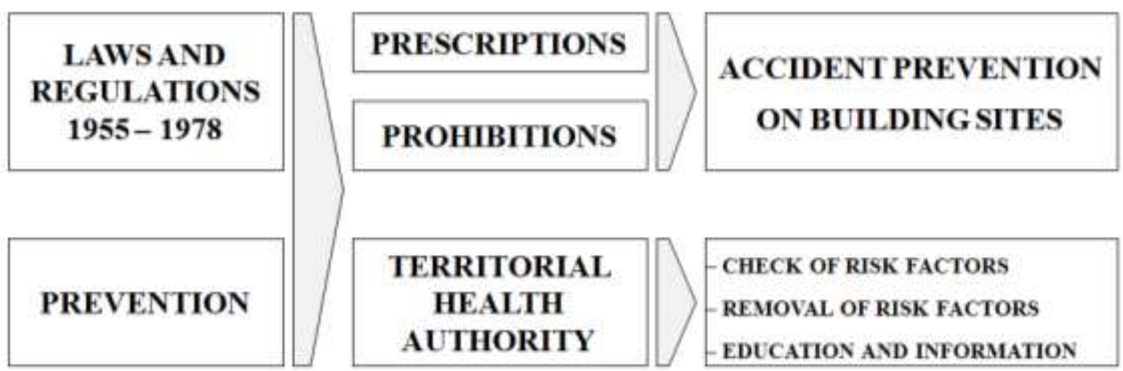

Fig. 2 – Summary diagram of the risk prevention in Acts from 1955 to 1978

Period 1980-1992: safety planning

In the 1980's a gradual change of the original setting of the 1950's was recorded, with the introduction of the laws on protection of the worker from chemical and physical agents in the workplace with the issue of Directives 80/1107/EEC, 82/605/EEC, 83/477/EEC, 86/188/EEC, 88/642/EEC, in which a prevention system is imposed to all the involved subjects and not just the workers and criteria for risk evaluation and prevention and protection measures are defined.

The Act No. 277/91, which establishes requirements on risks related to chemical, biological and physical agents and is the first norm that reverses the previous of the above requirements, indicating among the prevention measures, training for workers, health surveillance, the exposure limit values, the emergency measures and consultation of workers through their representatives. With Act No. 13/82 of the Ministry of Labour is introducing the concept of accident prevention plans for the assembly of heavy prefabricated structures:

"Before beginning assembly the following technical documentation must be made available to those responsible for the work, the workers and controllers:

- work plan that clearly describes the execution assembly operations and their order;
- safety procedures to be adopted in the various phases of work;
- in the case of more companies working in the worksite, a specific scheduling regarding the various companies involved.

In the absence of this documentation it is forbidden to perform assembly operations."

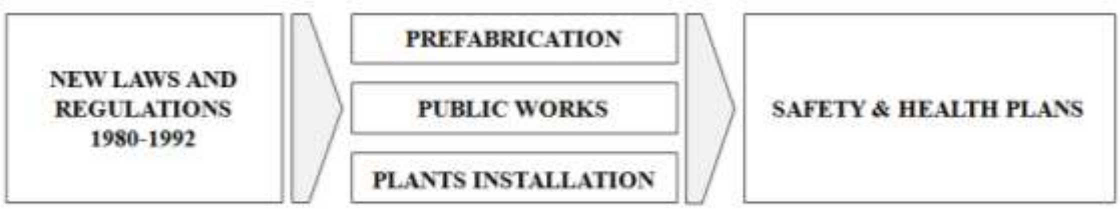

Fig. 3 – Summary diagram of the safety planning in Acts from 1980 to 1992

Period 1994-2009: safety planning and management

The most important revelation in health and safety at work in Italy came with the enactment of Act No. 626/94 which gave effect to EU Directive 89/391/EEC and other seven EU Directives details such as 89/654/EEC, 89/655/EEC, 89/656/EEC, 90/269/EEC, 90/270/EEC, 90/394/EEC and 90/679/EEC.

In the Act No. 626/94 the institution of the *Prevention and Risk Protection Service* is a novelty compared to the Italian legislative landscape prior to the 1990's. The most important Italian reference regulations, the Acts No. 547/55, 164/56 and 303/56 do not cite the *Prevention and Risk Protection Service*. With this Act Health & Safety is not more a technical issue. From technical prescriptions we passed to a new concept of prevention through risk assessment and involving all actors (client, contractor, workers, controllers, unions, etc.) of construction process.

The Act No. 494/96 gave effect to EU Directive 92/57/EEC (Temporary or mobile construction sites). This Act has introduced the obligation to draft a Safety & Coordination Plan for the client and the nomination, by client, of two Coordinators of Health & Safety: one during the design phase, the other for the execution phase.

The Act No. 222/03 clarifies in detail the minimum contents of the Safety & Coordination Plan (drafted by Coordinator) and the Safety Operating Plan (drafted by contractor or subcontractor).

The *Prevention and Risk Protection Service* could be or inside the structure of the company, either managed by professional consultant's experts in Health & Safety.

The Act No. 123/07 had founded the base for the reunification of the entire legislation corpus regarding Health & Safety.

This Act had consolidated a couple of principles: the first concerns the risk assessment approach; the second principle underlines the important of involving all actors of construction process during the various phases.

It was confirmed that Health & Safety must be treated and designed from first steps of all process.

In Act No. 123/07, an important aspect is the amendments to art. 7 of Act No. 626/94, with the introduction of a requirement for the client, in case of contract, the drafting of a single document relating to the evaluation of the risks of interference. This document must contain both the risks of the activities of the client in respect of subcontractors, both of the latter towards the client and those generated by the overlap and interference of the activities of the contractors themselves. This document must be drafted not only in the presence of contracts characterized by many overlapping businesses or self-employed workers, but also and especially in the work site environment.

In reality, however, the obligation was already expressed in Act No. 494/96, which said that the Safety & Coordination Plan was intended to assess and prevent risk interference between contractor, subcontractors and one-man companies.

On April 30, 2008, was published the Act No. 81/08, based on principles of Act No. 123/07, setting the following three objectives:

1. The revised laws and regulations regarding Health & Safety in the workplace, through the reorganization and coordination of the same in a single piece of legislation on Health & Safety in a single text;
2. Simplifying compliance for smaller companies: the Act introduces some simplifications for the self-employed and family businesses and other simplifications in the risk assessment;
3. More effective implementation: the legislature has suggested to achieve this objective through the establishment of coordination committees, the introduction of trade unions in a strong figure of the representative of the workers' safety, the organization of a retrieval system and management of information on the matter from the health information written by physicians for each company and, ultimately, through the reorganization and strengthening of control institutions.

The Act No. 106/09 modifies some detail elements regarding responsibilities and sanctions.

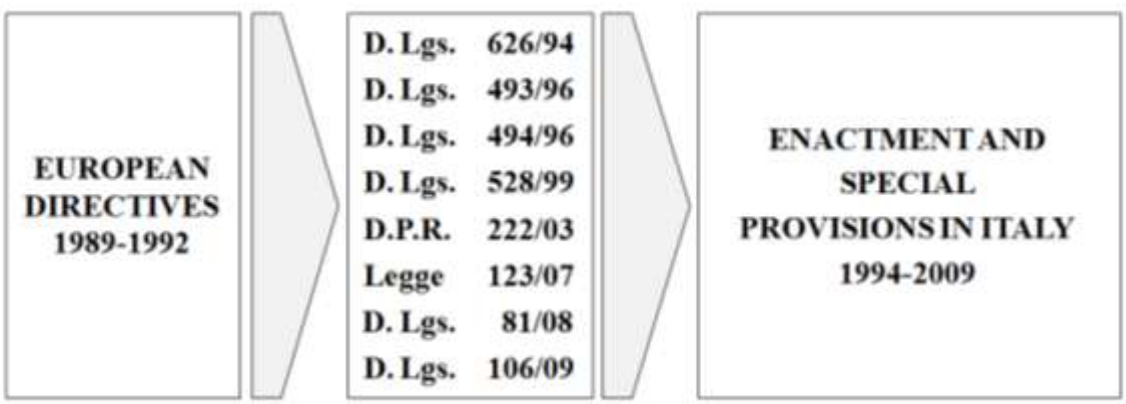

Fig. 4 – Enactment of EU Directives in Acts from 1994 to 2009

3. The management of safety on construction sites

In the first implementation of Directive 92/57/EEC (Act. No. 494/96), the Italian legislation has in fact kept contractors out of the safety process. Contractors were bound to implement the Safety & Coordination Plan (S.C.P.) through a deed of acceptance.

The Act 528/99 has introduced the Safety Operating Plan (S.O.P.) to be drafted by the contractor and subcontractors.

This plan gives a factual response to the requirements expressed by the Safety Coordinator at the design phase in the Safety & Coordination Plan.

Through the enactment of Act No. 222/03 and Act No. 81/08, the legislator meant to complete the reference grid for drawing up the Safety & Coordination Plan and the Safety Operating Plan.

The Act No. 222/03 further highlights the need to develop real interaction between the Safety Coordinator at the design phase and the contractor.
The Safety Coordinator at the design phase is actually asked to specify the detailed procedures in connection with the Safety & Coordination Plan. From the other side the contractor's own choices have to be detailed in the Safety Operating Plan.

Another issue that has turned out to be essential in safety management is determining the costs involved in its implementation; the latter regulation has made all the difference between the costs implied in each process and the costs for the safety procedures to be carried out on each site.

For the first time, the Italian legislator acknowledged that the working conditions of the construction sites had to be recognized at the very start of the design process, thus bringing together the earlier two Acts: Act No. 494/96 and the following amendment Act No. 528/99.

The regulations define, as "design and organizational choices" all of the choices made by the work designer in close co-operation with the safety engineer in order to ensure that the risks associated with each process are removed or minimized. To this effect, the Safety & Coordination Plan cannot but be site-specific and so it cannot help refer to the site features, the site organization and the processes that are to be carried out there.

The regulations recognize that it is essential for safety management that the design of the work and the Safety & Coordination Plan evolve together, in close connection, so as to highlight the preventative choices integrated by the designer in different phases: the design and the spatial, temporal and economic planning of the work.

The Safety & Coordination Plan might solve those problems that cannot be managed at the design phase, or cannot be tackled before the execution of the work.

The Safety & Coordination Plan must be drafted to reflect the peculiar features of the construction site, the layout and organization and the processes carried out during the productive cycle of the site.

The Safety Coordinator at the design phase should divide each process in specific parts (a kind of W.B.S.).
For each hazard/risk associated with the specific construction project, the Safety & Coordination Plan must contain:

- design and organizational choices, procedures, preventative and protective measures required to remove or minimize work-related risks;
- coordination measures required to implement the foregoing with special reference to the common usage of systems, equipment, facilities, joint safety equipment.

Another important step regards the spatial and temporal planning of the execution phases and the management of any interference during the construction. The introduction of the requirement to specify the operating prescriptions also in graphic design terms and time schedules make the Safety & Coordination Plan more integrated in the process and more legible by the site operators.

The principle underlying the site design should be Coordination, and this is why the site design must be broken down into several steps, so that the information can be adjusted to the development of the site phases.

The level of detail of site design should be fit for facilitate coordination so as to remove or minimize any interference between the various workers present on site.

At the design phase, the Safety Coordinator is responsible for describing an appropriate scenario so that site activities can be carried out, while the contractor is responsible for the site organization and the management of the Safety Operating Plans.

The primary goal of the Safety & Coordination Plan is to prevent accidents associated with interfering and/or overlapping process steps.

To prevent interfering and overlapping process steps from increasing the risk level, the Coordinator should plan works at the design phase through a time schedule, citing the duration of processes, divided into steps and any process priority.

The entire legislation corpus is involving in one main direction: prevention of Safety & Health risks through a better education, information, better organization and management. The *person* is to be considered before any technical or economical reason.

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IMPACT SIGNIFICANCE OF CONSTRUCTION CLIENTS ON DESIGNERS' AND CONTRACTORS' HEALTH AND SAFETY (H&S) CULTURE- AN EXPLORATORY DELPHI STUDY

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ABSTRACT:

Designers and Contractors' top management have been identified in many studies to be of great importance to health and safety performance and its continual improvement. Therefore developing strategies that support and motivate designers and contractor top management to implement health and safety elements would ensure a gradual and sustained improvement of health and safety in the construction industry.

In order to determine the impact significance of clients/owners on designers and contractor top management, a Delphi study was conducted.

Findings from the study where that client culture has critical impact significance on designers and contractors' top management culture. Further findings were that implementation of health and safety elements by designers and contractors were 'very likely to occur' with clients influence.

This paper reports on findings from an analysis of impact significance of clients on designers and contractors. It will underscore the point that has been made before using different methodologies that client health and safety culture is critical to designers and contractors' health and safety culture. The paper argues that an improved client health and safety culture will result in an improved health safety culture of designers and contractors. Pursuing this strategy can result in prevention of many accidents and incidents.

Keywords: Clients, Contractors, Culture, Designers, Health and safety, Impact significance, improvement,

1. INTRODUCTION

Construction H&S performance improvement has in recent years become a priority and thus has gained industry-wide attention (Cheung, Cheung and Suen, 2004 and Hamalainen, Saarela and Takala, 2009) because of the economic benefits, the need to improve construction industry image, the need for organisations to be socially responsible and the need for an improved general regard and respect for people working in the construction industry. In addition, the legislative pressure coupled with debate concerning the personal responsibility that senior managers should bear for their organisations on health and safety failures (Fitzgerald, 2005) has contributed to most organisations to focus on health and safety improvement. However improving health and safety performance in the construction industry has proved to be somewhat challenging partly due to the industry's complex character. Despite this complexity of the industry, health and safety performance improvement remains a crucial issue and its importance or need has been demonstrated in numerous studies (Smallman and John, 2001; Lee, Halpin and Chang, 2006; ILO, 200; and Hoonakker et al, 2005).

A number of ways to improve and promote H&S performance in the construction industry have been suggested. Some of the suggested methods to improve or manage H&S in the industry include designing for construction worker safety (Gambetese and Hinze, 1999; Gambetese, Behm and Hinze, 2005; Hecker, Gambatese and Weinstein, 2005), continual improvement of safety management systems (Chua and Goh, 2004), addressing H&S culture (Molenaar, Park and Washington, 2009; Parker, Lawrie and Hudson, 2006; Chinda and Mohamed, 2007), adopting the model client framework (Lingard, Blismas, Cooke and Cooper, 2009), use of incentives and disincentives (Tang, Qiang, Duffield, Young and Lu, 2008), multi-stakeholder involvement (Suraji, Sulaiman, Mahyuddin and Mohamed, 2006) and many other strategies that have not been mentioned above. However, although many ways of improving H&S have been suggested, there has not been much study on approaches that advocate for a holistic approach to achieve a multi-stakeholder involvement and objective identification of each party's capacity to influence H&S outcome and thus attain the desired H&S improvement in the industry.

This paper presents an analysis of clients' impact significance on H&S performance of designers and in the construction industry. Based on this analysis, the extent to which clients can influence designers and contractors H&S performance and which client cultural aspects are essential to influence H&S performance will be established. These can then be used as an H&S assurance or leading indicator of contractor H&S performance.

The importance of designers and contractors to project H&S performance has been recognized in many studies (Suraji et al 2006 and Gould and Joyce, 2002). Designers and Contractors H&S performance is therefore very important. Crucially therefore, the knowledge on the impact significance of clients on designers and contractors' H&S performance is essential as it can aid in formulating targeted strategies to assure designer and contractor H&S performance.

2. THE STUDY

A Delphi study method was used to explore the impact significance of the identified stakeholders on project H&S. The Delphi method was preferred to common survey methods as the current study was addressing the 'what could' kind of questions as opposed to the 'what is' kind of questions (Hsu and Sandford, 2007). The Delphi methodology was also considered to be a much stronger methodology for its rigorous query of experts which is achieved through many iterations and feedback.

The Delphi study involved invited panellists and it retained 11 active members. This number of panellists was considered adequate based on what other Delphi studies have used and recommended. Delbecq, Van de Ven and Gustafson (1975) suggest that 10 to 15 panellists could be sufficient if the background of the panellists is homogenous. A review by Rowe and Wright (1999) indicates that the size of a Delphi panel has ranged from three to 80 in peer reviewed studies. Okoli and Pawlowski (2004) and Skulmoski, Krahn and Hartman (2007) also mention a panel size of about 10 to 18 members. Hallowell and Gambatese (2010) suggest a minimum of eight panellists. Based on the above and the fact that the Delphi method does not depend on the statistical power (Okoli et al, 2004), but rather on group dynamics for arriving at consensus among experts, a panel of 11 members was considered adequate.

The selection of panellists was based on criterion sampling. Panellists were selected for a purpose to apply their knowledge to a concept raised in the study based on the criteria that was developed from the research questions under investigation. A Delphi study does not depend on a statistical sample that attempts to be representative of any population. It is a group decision mechanism requiring qualified experts who have deep understanding of the issues (Okoli et al, 2004). Therefore, one of the most critical requirements is the selection of qualified experts as it is the most important step in the entire Delphi process because it directly relates to the quality of the results generated (Hsu and Sandford, 2007). In view of the above, successful panel members had to meet at least four of the following criteria adopted from Skulmoski et al (2007) and Hallowell et al (2010):

- Knowledge and experience in construction H&S;
- Knowledge and experience in construction project management;
- Have appropriate academic qualifications;
- Professional registration with a recognized built environment or H&S registration body;
- Have published articles in peer reviewed journals, books and or conferences;
- Industry experience of at least five years;
- Capacity and willingness to participate;
- Sufficient time to participate;
- Effective communication skills

Panel members were identified from three sources. The first source was the CIB W099 register of members located on the CIB WO99 website (CIB W099-Safety and Health in Construction, 2010). The CIB W099 is a working commission that was set up on royal appointment to enable researchers on construction H&S in the world collaborate as well as protect H&S. The second source was the conference proceedings of the CIB WO99 from year 2005 to 2009. Individuals who had frequently appeared as authors or keynote speakers were identified as potential experts on the study. The third and last source was identifying through references of individuals working in the area of H&S in the local construction industry in Southern Africa.

The panel consisted of two members from South Africa, three each from United States of America (USA), and the United Kingdom (UK), one each from Singapore, Hong Kong, and Sweden. Of these one of the panellists had a Doctor of Science (DSC) Degree, six had a Doctor of Philosophy (PhD) degree, two had a Master of Science (MSc) degree, one had a Bachelor of Science (BSc.) degree and the last one had a Diploma in safety management. All the panellists specialized in construction safety. In terms of their current occupation, three of the panellists were employed by contracting organizations, one by a consulting organization, and six by Universities. All panellists held very senior positions in their organizations and were involved in community service.

The panel had a cumulative of 243 years of experience. The lowest number of years of experience was seven and the highest was 45 years. The calculated mode of years of experience was 15, the mean was 22.1 years and the median was 15 years. Experience was an important factor in determining who an expert was and therefore a minimum number of years was set to be five years. In terms of publications, 10 of the panellists had published in peer reviewed journals, conference proceedings and books. Between them, they had published 57 books and monographs, 19 chapters in books, 187 peer reviewed academic journals, 345 recent conference papers and 341 other publications comprising of articles in professional journals, technical reports, policy papers, expert witness documentation and key note addresses. In addition to their publication, the panel had led and managed 108 funded research projects. Three panellists served on editorial boards of 43 peer reviewed journals and conference proceedings. The bar chart labelled figure 1.0 below shows the contribution of panellists to the above mentioned publications.

Table 1: Panellists publications

Panel publications	No. of publications
Books and monographs	57
Chapters in books	19
Peer reviewed Journals	187
Peer reviewed Conference proceedings	345
Funded research	108
Other publications	341
Editorial board membership	43
Referee for journals	22
Referee for Conference proceedings	30

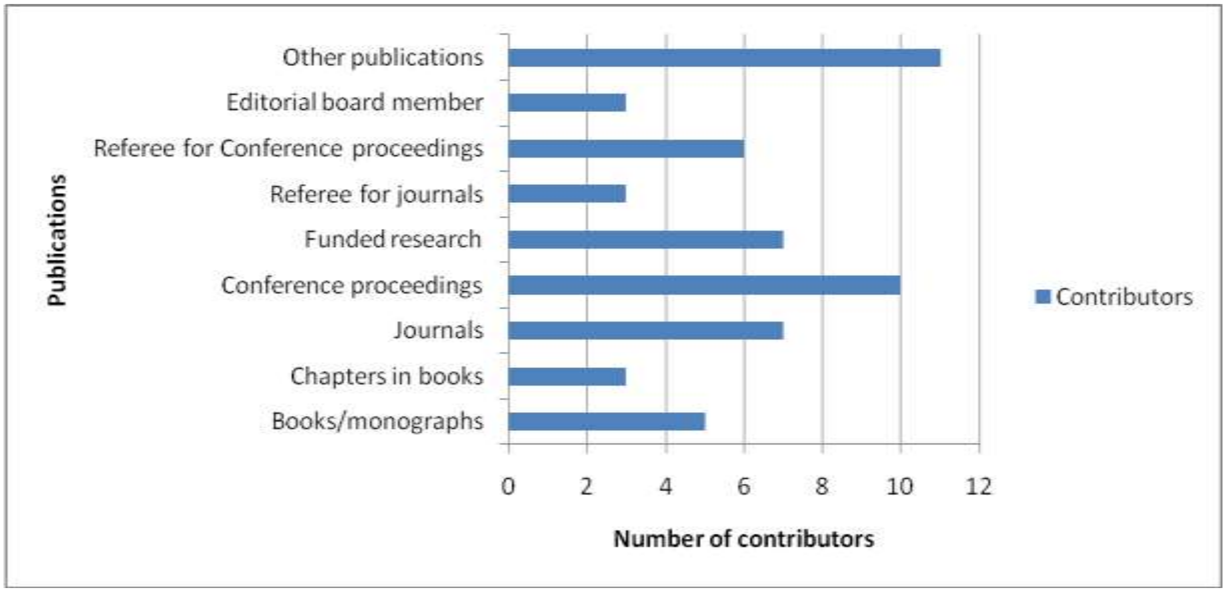

Figure 1: Publications by panel members

The current Delphi study involved three rounds of an iterative process with the view of achieving consensus between the panel members on the impact significance of clients and designers on H&S consideration at various project phases. Panellists were requested to rate the probability that H&S would be considered at project phases as a result of clients and designers H&S cultural influence. The probability scale ranged from 1 to 10 representing 0 to 100%. Further, panellists were requested to rate the negative impact that would result if a particular stakeholder's cultural element was absent. The impact scale was based on a 10 point rating scale ranging from low to critical. This aspect indicated the severity of the culture or cultural element.

A two stage analysis of data from the Delphi was conducted using Microsoft office Excel, a spreadsheet software program. The first stage involved analysis to establish or confirm consensus on responses to the predetermined criteria. This involved determining the group median responses for each question. After the third round of the Delphi, absolute deviations (D_i) about the group medians ($m(X)$) of each rating for every question were calculated using equation 1.0. In addition, mean absolute deviations (MAD) were calculated for every question. This is a calculated mean of all absolute deviations for all panellists about the median on each question. Further analysis involved determining the statistical range in ratings by panellists on each question and the percentage of panellists with a similar opinion inclination on each and every question. Consensus was determined to have been achieved when the MAD was less than one unit below or above the group median, the range in ratings on each question between all panellists was below 4.0 and the percentage of panellists that were of a similar inclination in opinion was 60% and above on a particular question.

$$D_i = \lfloor x_i - m(X) \rfloor \quad \text{Equation 1}$$

Where:

D_i = Absolute deviation

x_i = Panellist rating

$m(X)$ = Measure of central tendency

The second stage of Delphi data analysis, involved determining the impact significance of clients' cultural factors on contractors' top management, H&S performance. The significance of the impact of various factors associated with the clients' H&S culture was categorised as critical, major, moderate, minor or low. The categorisation was helpful in determining which client factor was key and relevant for contractor H&S performance. The impact significance of a factor was obtained as a product of the overall rated probability (likelihood) that a client factor would influence contractor to implement H&S elements and the rated negative impact (severity) on the contractor implementing the elements that would result if the client factor was absent. This relationship is illustrated in equation 2.0 below.

$$\text{Impact Significance} = \text{Likelihood factor} \times \text{Severity factor} \qquad \text{Equation 2}$$

3. RESULTS

Designers' role has been recognised as important to health and safety performance on construction projects. However some studies have suggested that designers are unwilling to participate fully through their designs or taking up a leadership role for example in managing health and safety and this has in a way inhibited a better project H&S performance. It seems as though, designers can only fully participate in H&S performance with external influence apart from their own motivations which should include ethics. Although the situation is somewhat different for contractors, optimal H&S performance from contractors is also far from the desired level. Contractors too require external pressure or motivation for them to perform better.

One such external influence is the clients' influences who in fact are their employers. It was therefore determined to establish the impact significance of the clients' influence on designers and contractors to implement certain important H&S elements. The impact significance of factors of client H&S culture of *commitment, involvement, competence* and *leadership* was evaluated. In addition, the resultant likelihood of designers and contractors implementing H&S elements as a result of client culture influence was also determined.

Findings were that the average impact significance of factors of client culture on designers was determined to be 6.45. This is slightly lower than the client culture influence on contractors of 6.60. There is however more variability in the impact significance values with the standard deviation of 0.8 compared to 0.34 for the impact significance of clients' influence on contractors'. This was suggestive of the fact that some factors of client H&S culture have more influence than others. *Client involvement* in H&S performance was considered to be more critical to designers at 7.31 compared to clients' *competence* which was determined to be 5.42. Clients' *leadership* was the second rated factor followed by *commitment*. These were rated at 6.75 and 6.30 respectively (Figure 2.0).

The impact significance rating of the factor, '*client involvement'*, was found to be 'critical' to designers' H&S performance whilst all other factors were found to be of 'major' impact significance.

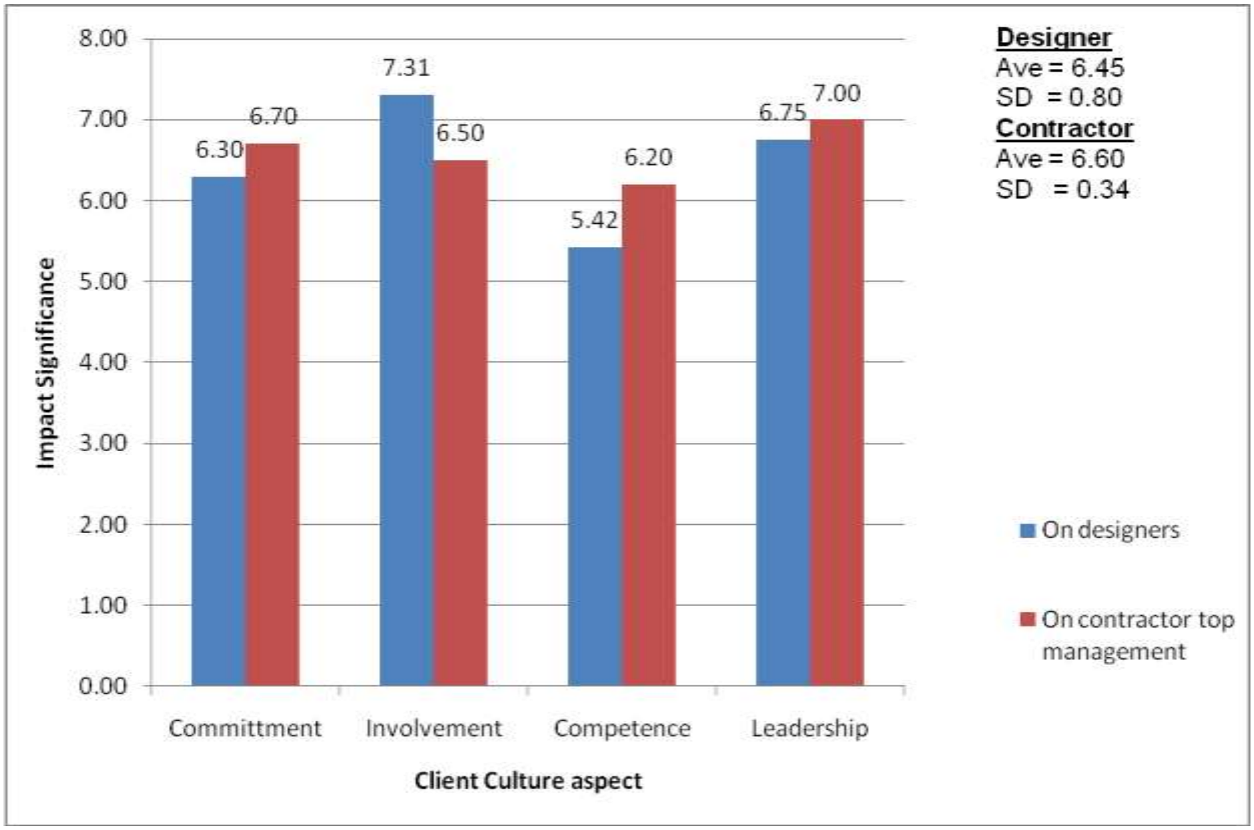

Figure 2: Impact significance of clients' factors of H&S culture on designers and contractors

All the impact significance values of client culture were above 5.0 suggesting that their impact significance's criticality to designers' and contractors' H&S performance was 'major'. As observed earlier, client *competence* was found to be the least rated factor even on influence to contractors' H&S performance. Notwithstanding, client *competence* was rated higher at 6.20 to contractors' whilst to designers, it was rated at 5.42. This suggested that client *competence* was slightly more critical to contractors than designers.

The factor of client H&S culture with the highest impact significance to designers was found to be '*client involvement*'. The impact significance rating on designers' H&S performance for '*client involvement'* was determined to be 7.31. This was suggestive of the fact that *client involvement* in H&S management is crucially important to motivate designers to implement and be committed to H&S performance.

From the results shown in figure 2.0, all factors of client H&S culture are seen to be of critical importance to influencing designers and contractors to implement H&S elements.

The likelihood of designers implementing H&S elements identified as important to H&S culture of designers was an average of 78% with a standard deviation in the likelihood values of 0.04. The 78% value suggested that the implementation of all H&S elements by the designers was 'likely to occur' with clients influence. The elements with the highest likelihood i.e. those elements with the likelihood of above 80% of being implemented by designers as a result of client influence were found to be:

1. Involving contractors in design reviews;
2. Undertake hazard identification and risk analysis;
3. Designing for H&S and
4. Establish effective H&S policies, procedures and goals.

According to the scale used in this study, the ratings for all scales above suggested that with clients' influence, the implementation of the above elements was 'likely to occur'. In other words, clients' influence is a leading indicator of designers' possibility to involve contractors, undertake hazard identification and risk assessment, and design for H&S and also to establish effective H&S policies, procedures and goals.

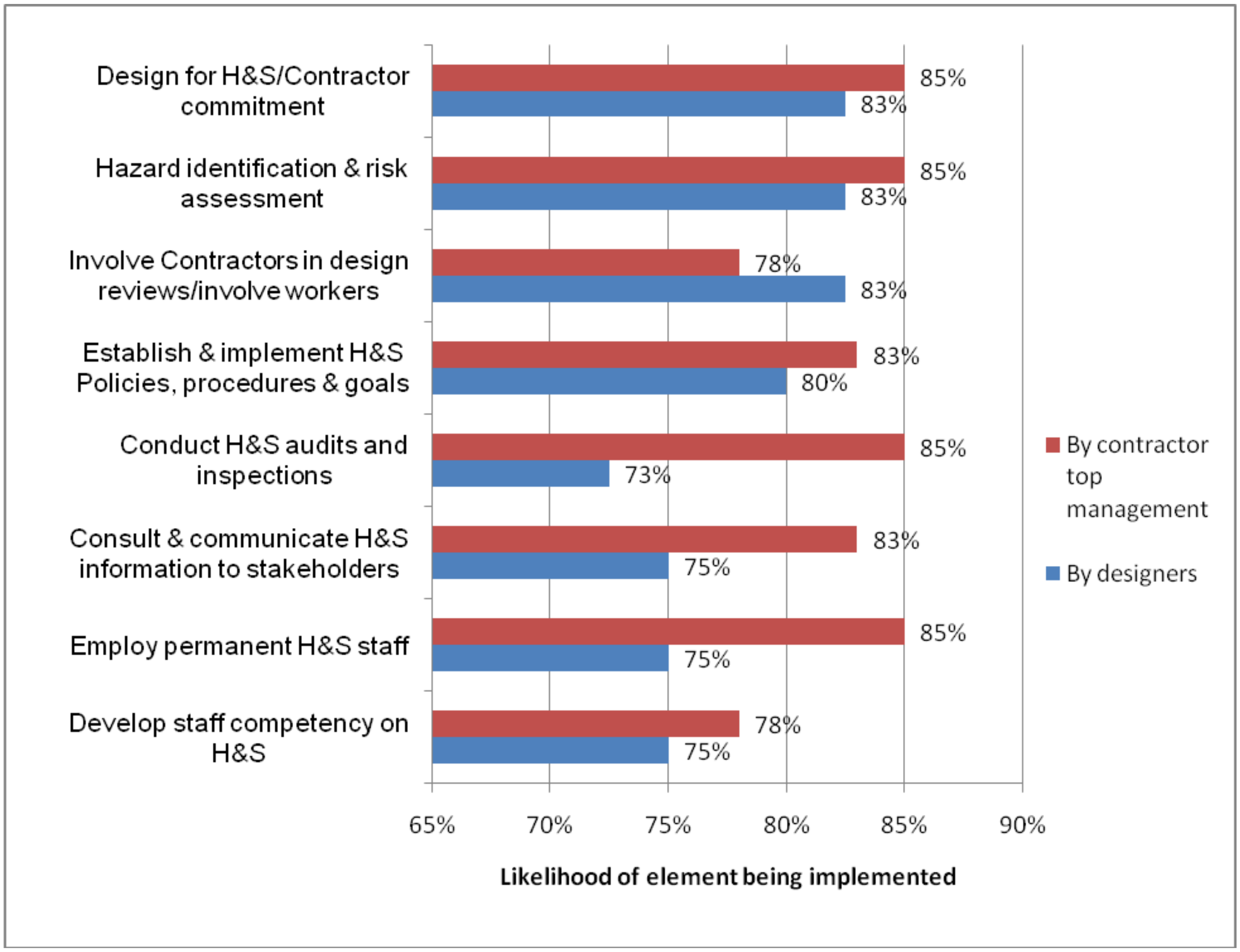

Figure 3: Designers' and Contractors' likelihood to implement H&S elements as a result of clients' influence

Developing staff competence, consult and communicate H&S information and employing permanent H&S staff were the second most likely elements to be implemented by designers as a result of client influence. All these H&S elements had a likelihood of 75% which was described as ‘likely to occur’.

The least likely H&S element to be implemented compared to all other elements was found to be ‘*conducting H&S audits and inspections’*. This element had a likelihood of 73%. Although this is a low likelihood compared to others, it is actually a high likelihood and the implementation of the elements by the designers is described as ‘likely to occur’.

The largest disparity in the likelihood between contractors and designers was observed in the following elements:

1. Employ permanent H&S staff;
2. Consult and communicate H&S information to stakeholders;
3. Conduct H&S audits and inspections.

In all the, above the likelihood was higher for contractors’. The difference between the two was found to be about 10% points i.e. contractors were more likely to implement the H&S elements than designers. The rating relating to contractors' was described as 'very likely to occur' whilst implementation by designers of the elements listed above was described as 'likely to occur'.

With the exception of the H&S elements of '*involving contractors in design reviews'* or '*involving workers in H&S management'*, the likelihood of contractors implementing all elements was consistently higher than that of designers. On average, the likelihood of contractors' implementing the elements was found to be 83% whilst that of designers was about 78%. This is about 5% percentage points higher for contractors.

4. DISCUSSION

Improving H&S performance on a construction project has to do with the extent to which designers and contractors perform in terms of H&S. The aspect of designer and contractor H&S performance is therefore an important aspect to improving H&S performance in an overall construction project. Therefore measures should be in place to ensure that designers and contractors' H&S performance was encouraged. The question however is, 'how do we assure designer and contractor H&S performance?

The current study was therefore a response in part to the above question and sought to determine the impact significance of clients on designers and contractors' H&S performance.

The consensus among panellists regarding the likelihood of contractors implementing identified H&S elements as a result of client influence was an average of 83% whilst that of designers was found to be 78%. The panel determined that contractor H&S performance i.e. implementing the identified elements was 'very likely to occur' with clients' influence and designers' implementation was 'likely to occur'. This finding is in agreement with other studies that have alluded to the fact that clients can influence H&S performance (Huang et al 2006). The current finding in addition, estimates the extent to which clients could influence contractor H&S performance.

The panel determined that the severity of clients' H&S culture on H&S consideration was 'critical'. Panellists indicated that the negative impact on contractor performance if factors of clients' culture were not apparent was determined to be above 8.0.

The resulting client culture impact significances to designers and contractors' H&S performance ranged from 'major' to 'critical'. The suggestion was that clients' influence would assure designers and contractors H&S performance. The client cultural factor of *leadership* was rated to be more critical compared to other client cultural factors to contractor H&S performance. On the contrary, the client factor, *involvement*, was the most critical to designers The suggestion was that in order to ensure contractor H&S performance, clients need to provide visible leadership on H&S and a motivation for designers, was client involvement.

4. CONCLUSION

Findings from the study reviewed the following:

- Clients H&S culture influence on designers and contractors H&S performance has a high impact significance;
- All clients H&S cultural aspects of involvement, commitment, competence and leadership have impact significance ranging from ‘major’ to ‘critical’;
- Contractors were on average ‘very likely’ to implement H&S elements with clients’ influence;
- Designers were on average ‘likely’ to implement H&S elements with clients’ influence;
- In order to assure designers and contractors H&S performance, client H&S culture and influence is necessary.

It was observed that Clients’ influence would cause designers’ and contractors’ implementation of H&S to ‘likely to occur’ and ‘very likely to occur’ with a likelihood of 78% and 83% respectively. The significance of this finding was that with the influence of clients, there is an assurance of a better designer and contractor H&S performance and thus may achieve the desired H&S performance. Positive clients’ H&S culture could therefore be taken as a leading indicator for a better designer and contractor H&S performance.

In conclusion, generalisability of the current study is limited as validation of the Delphi findings has not been done. The validation is however currently under way using the structural equation modelling (SEM).

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Research-to-Practice (R2P) Tools for Improving Safety in Nighttime Highway Construction Work Zones

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Abstract

The safety of workers in nighttime roadway work zones has become a major concern for state transportation agencies due to the increase in the number of work zone fatalities. During the last decade, several studies have focused on the improvement of safety in nighttime roadway work zones; but the element that is still missing is a set of tools for translating the research results into practice. This paper discusses: 1) the importance of translating the research results related to the safety of workers and safety planning of nighttime work zones into practice, and 2) examples of tools that can be used for translating the results of such studies into practice. A tool that can propose safety recommendations in nighttime work zones and a web-based safety training tool for workers are presented in this paper. The tools were created as a component of a five-year research study on the assessment of the safety of nighttime roadway construction. The objectives of both tools are explained as well as their functionalities (i.e., what the tools can do for the users); their components (e.g., knowledge base, database, and interfaces); and their structures (i.e., how the components of the tools are organized to meet the objectives). Evaluations by the proposed users of each tool are also presented.

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1. Introduction

Nighttime construction and maintenance work on highways is becoming very common in the U.S. Most of the U.S. highways were built in the 1960s and 1970s with a design life of 30 years, and it is estimated that about 33% of the nation's highways have exceeded their design lives. According to the Federal Highway Administration (FHWA) in 2007, the estimated cost to maintain U.S. highways and bridges in order to ensure an efficient roadway system for the use of the traveling public over the 20-year period from 2005 to 2024 would be about US$78.8 billion, stated in constant 2004 dollars.

Construction and maintenance work on highways is now being performed at night in order to reduce the inconvenience that daytime construction causes for the public, especially the problem of traffic congestion. While beneficial to the traveling public, the practice of conducting nighttime highway operations forces contractors to work in an environment which is very different from their usual daytime operations. Based on the data on fatal accidents in highway work zones in the State of Illinois in the five-year study period of 1996–2001, Arditi et al. (2007) concluded that nighttime construction is about five times more hazardous than daytime construction. Safety is one of the major concerns of the contractor while deciding to work at night, and the work may be performed differently from identical daytime operations due to safety reasons (Hancher and Taylor 2001).

To respond to the safety concerns presented by nighttime highway construction and maintenance operations, several research studies exploring different aspects of the safety of nighttime operations have been conducted. For example, El-Reyes and Hyari (2002) developed a decision support system (DSS) to optimize the lighting variables in work zones; Holguín-Veras (2003) emphasized the significance of lighting for the improvement of safety of nighttime work zones; Ellis et al. (2003) assessed appropriate levels of illumination of nighttime work zones; Bryden and Mace (2002) assessed traffic control practices in nighttime work zones; El-Reyes and Hyari (2005) developed a tool called CONLIGHT to assess the performance of lighting in nighttime work zones; Hyari and El-Reyes (2006) developed a framework for evaluating the lighting requirements of nighttime work zones; Burgess et al. (2007) assessed the effectiveness of different traffic control strategies for nighttime operations; Miller (2007) and Miller et al. (2009) assessed different speed control practices in nighttime work zones; and Valentin (2007) and Valentin et al. (2010) assessed the effectiveness of various personnel protective equipment (PPE) used in nighttime highway operations.

As shown in Figure 1, the knowledge management cycle for new information development includes four fundamental phases: observation and analysis, theory generation, testing and application, and consolidation (Silver and Shakshuki 2002). The last two phases of KM (i.e., testing and application and consolidation) are considered to be the research to practice (R2P) phases and have not gained sufficient attention in the area of safety of nighttime operations. Testing and application refers to the application of the findings of the research studies in practice, and knowledge consolidation refers to the diffusion of new information and knowledge into the current body of knowledge and practice. The information and knowledge generated from research studies should be processed and transferred into practice so that the practitioners benefit from it. So far, many of the research studies on the safety of nighttime highway operations have covered the first two phases of knowledge management (KM) cycle: observation and analysis (e.g., Burgess et al. (2007), Miller (2009), and Valentin (2010)) and theory generation (e.g., Hancher and Taylor (2001), Holguín-Veras (2003), and Arditi et al. (2007)).

Figure 1- Knowledge management cycle (Silver and Shakshuki 2002)

Knowledge management systems (KMS) have gained popularity in implementation of KM. There are different forms of KMS: knowledge databases, decision support systems, web-based learning, training tools, etc. KMS are useful in transferring the findings of research studies into practice. This paper discusses three R2P tools that were developed as part of a research study (Grant No.1 R01 0H07553, Safety of Nighttime Construction Operations) funded by the National Institute of Occupational Safety and Health to bridge the gap in the KM cycle in the area of safety of nighttime highway construction and maintenance operations: (1) a tool for developing safety recommendations for nighttime highway operations, (2) a web-based training tool for nighttime highway operations, and (3) course modules for undergraduate students in the area of construction safety. The goals, functionalities (i.e., what the tools can do for the users), the components (e.g., knowledge base, database, and interfaces), the structures (i.e., how the components of the tools are organized to meet the objectives), and the evaluations of each tool are explained in the following sections.

2. Safety Recommendations Tools for Nighttime Highway Operations

The objective of the safety recommendations tool is to provide recommendations regarding the safety of nighttime highway operations based on different project characteristics and activities. The recommendations are a compilation of applicable standards, such as the Manual on Uniform Traffic Control Devices (MUTCD), and the findings of research studies such as Bryden and Mace (2002), Miller (2009), and Valentin (2010). The recommendations tool facilitates the application and consolidation of the findings of prior research studies regarding the safety of nighttime operations into practice. The recommendations provided are based on general conditions typically present at job sites and are not specific to any particular job site. Therefore, it is not intended for the tool to provide a decision for the project engineer, but rather to assist in the consideration of the safety aspects, which are dependent on the type of activities to be performed and on the characteristics of specific projects operating at nighttime.

The tool is not intended to replace any existing safety training and/or manuals but to complement them instead.

Structure and components

The safety recommendations tool consists of a knowledge database that stores information in different categories, an interface engine to receive the user input, and a report generating algorithm to print the recommendation reports. Figure 2 shows the structure of the recommendation tool. The tool can provide one of two types of recommendations; (1) site-based and (2) task-based, depending on the type of project, as shown in Figure 3. The site-based recommendations consider the type of site, based on whether maintenance activities or construction activities will be performed during the nighttime operation. Four different activities for both maintenance (i.e., asphalt resurfacing, concrete repair, bridge repair and crack sealing) and construction operations (i.e., hot-mixed asphalt paving, concrete paving, concrete barriers, and bridge construction) were included in the tool. Each one of these activities was divided into sub-activities. Task-based operations consider three typical activities performed as part of highway operations: (1) closing lanes, (2) flagger operations, and (3) shoulder operations.

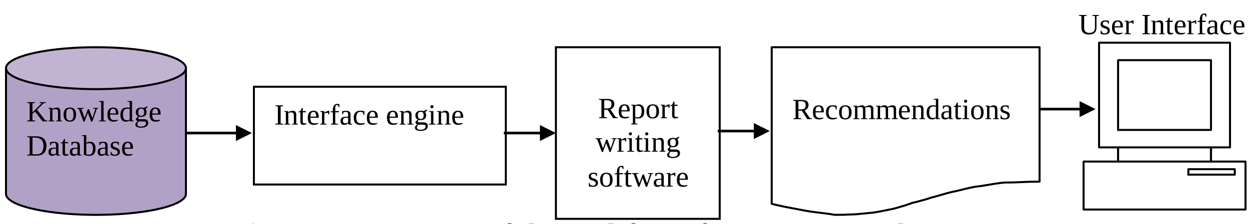

Figure 2. Structure of the tool for safety recommendations.

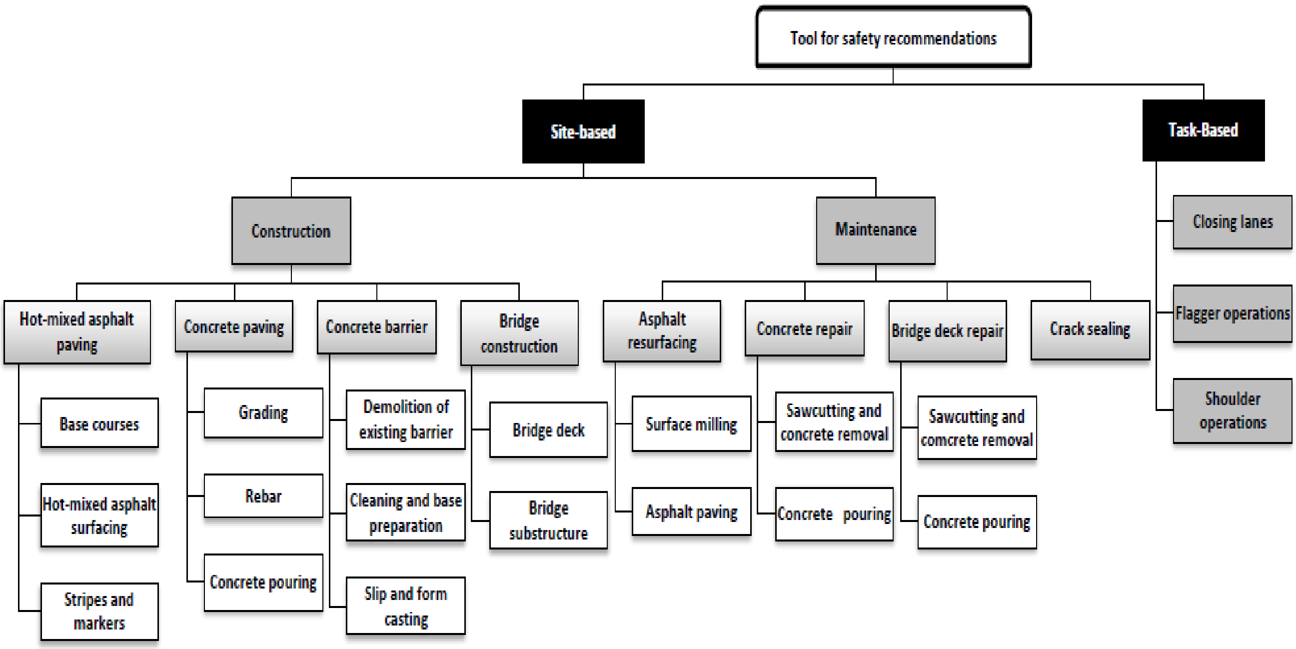

Figure 3. Categories and sub-categories of site-based and task-based recommendations.

The content of the database is easily editable so that the database can be adapted to the needs of the user and the applicable regulations. The recommendations tool consists of five main consecutive screens, which are described in Table 1. In each screen, the user enters specific inputs, which are used to refine the information to be used in the recommendations. In the *project information* screen, the user enters project information such as the name, contract number, and duration of the project, which identifies the project, and the safety recommendations. In the *project type* screen, the user enters input regarding the type of work site and activities performed. In the *project characteristics* screen, the user enters input regarding the characteristics (e.g., number of workers, length of the work zone, original speed limit, etc.) of the project for which safety recommendations are sought. Figure 4 is a screenshot of the "Project Characteristics" screen. The input here is used in the selection of the safety information available in the database to match the specified project type and characteristics. For instance, when a user defines the original speed limit of the highway in which the work zone is set up, the safety recommendations will be tailored based on the specified speed limit. The output of the safety recommendations tool is grouped within four main categories: (1) lighting, (2) traffic control, (3) personal protective equipment, and (4) general awareness. Within each category, and when applicable, recommendations are given in each one of the sub-categories listed in Table 2.

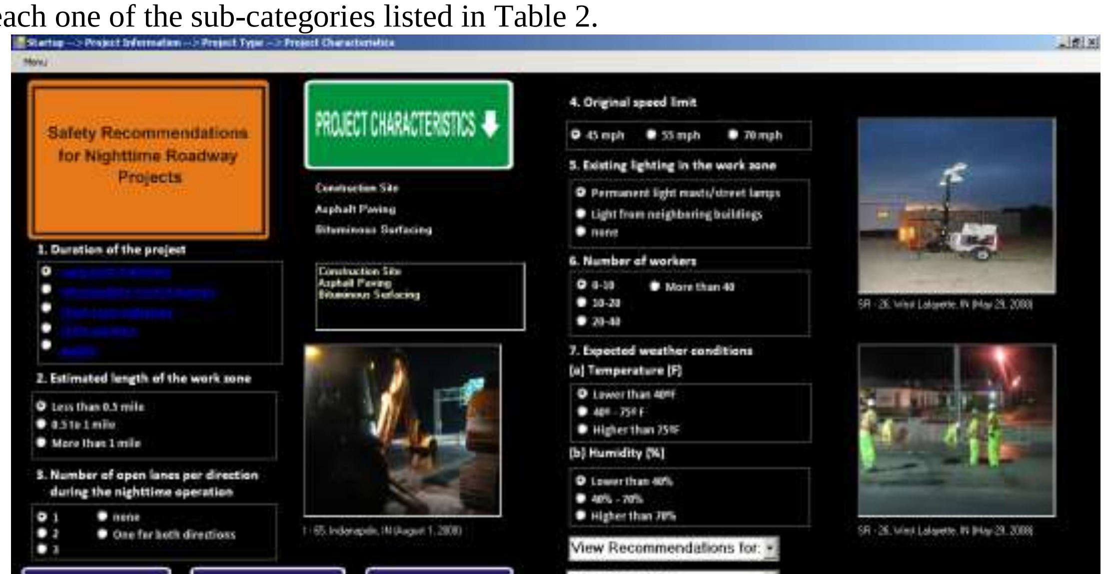

Figure 4. Graphic user interface of the project characteristics screen

Table 1. Description of the screens in the tool for safety recommendations

Screen Name	**User Input**	**Additional information**
Introductory screen	N/A	- Provides access to credits and references used in the output of the tool. - Refers to the grant received from NIOSH. - States the disclaimer for using the tool.
Project information	- Project name - Project location - Project duration (start and end dates) - Contract number	This information is used to record the project and the safety recommendations
Project type	Activity-related characteristics: - Type of recommendation (site-based, task-based) - Type of site - Activity to be performed - Sub-activity to be performed	The program, upon the user's request, provides a definition and a figure of each sub-activity
Project characteristics	Project- related characteristics: - Duration of the project (as defined by the 2009 MUTCD) - Estimated length of the work zone - Number of open lanes per direction - Original speed limit - Existing lighting in the work zone - Number of workers - Expected weather conditions: (a) temperature (b) humidity	The user has the option to view the recommendations in a new screen or to print out a report
Recommendations	N/A	In this screen the user is able to access the recommendations applicable to the set of characteristics

		without having to print out a report

Table 2. Recommendation categories in the tool for safety recommendations

Recommendation Category	**Sub-categories**
Lighting	▪ Minimum illuminance level ▪ General lighting ▪ Task lighting ▪ Lighting layout
Traffic Control	▪ Speed control ▪ Signing ▪ Channelizing devices ▪ Safety equipment
Personal Protective Equipment	▪ High visibility protection ▪ Head protection ▪ Hands and arm protection ▪ Hearing protection ▪ Eye and face protection ▪ Foot and leg protection ▪ Respiratory protection
Recommendations Regarding General Awareness	▪ Awareness and accidents

Evaluation of the tool

During nine on-site validation/evaluation meetings, nine groups of potential stakeholders (64 individuals total) evaluated the tool; see Table 3 for more details about the groups. After the nighttime safety recommendations tool was briefly demonstrated, evaluation questionnaires were distributed to each group. The individuals in each group had the opportunity to use the tool and obtain safety recommendations for a specified project before completing a questionnaire about the features and content of the tool and any recommendations the users had on improving the tool. Figure 5 shows the results of the evaluation of the tool for each of the evaluated categories. After each validation meeting, the recommendations received from the stakeholders were reviewed and used to improve the content, presentation screens, and output of the tool.

Table 3.Groups involved in validation of the Safety Recommendations tool

Group	**Number of Evaluators**	**Date**
Indiana Department of Transportation (INDOT),	1	04/09/2009
INDOT LaPorte Highway SubDistrict Office	2	04/17/2009
INDOT Work Zone Safety Division	6	05/05/2009
INDOT's Indianapolis Subdistrict Office Nighttime Crew	13	05/05/2009
INDOT Safety Directors	7	05/13/2009

Indiana Contractors Association (ICA), Indiana Department of Transportation (INDOT), Indiana Division of the Occupational Safety and Health Administration (IOSHA), and the Indiana State Police (ISP) Safety Joint Cooperative Committee	18	05/13/2009
La Porte Sub-District Office - Safety Review Meeting	12	09/10/2009
Faculty members from U.S. universities	5	02/09/2011

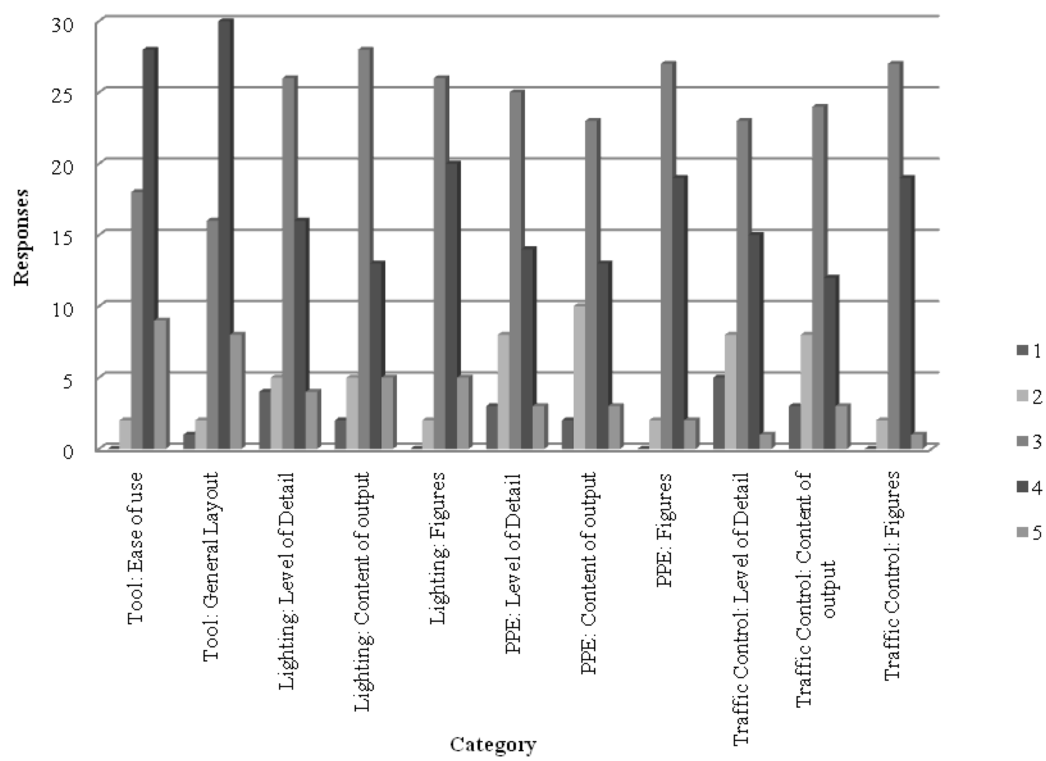

Figure 5. Results from the evaluations (1- Needs improvement, 2 - Needs minor changes, 3 – Good enough, 4- Very good, 5 – Excellent) (y- axis – Number of responses)

3. Safety Course Modules

According to Usmen (1994), the role of engineers is to seek opportunities to eliminate or minimize unsafe acts and conditions through their roles in design, management, and training. The objective of the course modules in construction safety is to provide training to future and current engineers about the importance of safety in project goals, devising safety strategies, and good and poor safety practices at the job site.

Structure and components

The course modules consist of three PowerPoint presentations: (1) Construction Safety: An Overview, (2) Construction Safety: Focus on Highway Construction, (3) Construction Safety: Focus on Nighttime Operations. The content of each module is summarized in Table 4.

Validation

In spring 2010, the course modules were presented to a total of 54 undergraduate students at Purdue University in West Lafayette, Indiana as part of the course "CE 497- Life Cycle Engineering and Management of Constructed Facilities." After the modules were presented, the students were asked to complete an evaluation survey. In addition, the course modules were evaluated by five faculty members from U.S. universities. Based on the recommendations of the faculty members and the students, additional photos and videos were included in the tool, and the text in some of the slides was enhanced.

Table 4.Summary of the content of the course modules

Course Module	**Sections**	**Content**
Construction Safety: An Overview	Role of safety	- Construction project metrics - Examples of impacts of safety violations - Occupational and fatal injuries statistics - Fatal falls
	Accidents in construction	- What is an accident - Causes of accidents - Examples of unsafe acts - Examples of unsafe conditions - Worker's poor attitudes and behavior - Other issues affecting safety
	Motivation for safety practices	- Statistics - Impacts of injuries and fatalities
	Metrics	- Safety metrics - Factors motivating safe job site practices
	Regulations	- Federal legislations and regulations - OSHA requirements - Application of the OSHA law - Application of state and federal OSHA provisions
	Strategies	- Working safely - OSHA training - Safety program
Construction Safety: Focus on Highway Construction	Violations in highway construction	- Examples of impacts of safety violations
	Statistics	- Statistics on injuries and fatalities in highway operations.
	Causes of accidents	- Hazards leading to serious or fatal occupational injuries in work zone - Typical behavioral causes of safety incidents in work zones - Typical accident events in work zones
	Legislation and regulations	- MUTCD - Worker visibility (23CFR634.1)
	Safety strategies	- National Highway Work Zone Safety Information Clearinghouse - Components of a temporary traffic control zone - Type of roadway operations considering duration - Examples of safety strategies
Construction Safety: Focus on Nighttime Operations	Introduction	- Nighttime operations statistics - Why nighttime operations - Advantages and issues - Noise control - Speed
	Lighting	- Lighting issues - Factors affecting illumination requirements - Lighting equipment alternatives - Recommended illuminance levels

	Traffic Control	- Factors considered when establishing temporary signing - Speed control methods - Work zone implementation
	Personal Protective Equipment	- Importance - Factors that determine the effectiveness of PPE - Additional information - ANSI-ISEA 107 2004 - Retroreflectivity (cd/lx*m²)
	Awareness and Training	- Role of the engineer - Unsafe practices

4. Nighttime Safety Web-based Training Tool

The objective of the web-based training tool for nighttime highway operations is to provide preliminary training to workers and engineers who are new to nighttime highway construction operations. The training tool is designed to be used by organizations, personnel, and workers who are involved in nighttime highway construction and maintenance operations to provide basic safety training. Similar to the tool for safety recommendations discussed in Section II, the intent of this training tool is not to replace any applicable or existing guideline or training material, but rather to complement them. The materials provided in the tool are based on general conditions typically present on jobsites, and are not specific to any particular job site.

Structure and components

The tool was developed using HTML language and consists of the three major components shown in Figure 6: network database, content database, and quiz database. The databases were developed using Microsoft Access tables and are stored on a Purdue University server (http://rebar.ecn.purdue.edu/nighttime/index.aspx). The function of the network database is to store the information about the trainees (e.g., trainee name, name of organization, username and password, and the information related to completion of quizzes. The first time a user accesses the tool, setting up a login is necessary in order to access to the tool (Figure 7). The login information is stored in the network database. The network database is a dynamic database which is updated as a trainee progresses through the quizzes related to the learning modules. The function of the content database is to store the learning modules. The learning modules are created in the form of web pages in HTML language. The function of the quiz database is to store the question banks. For each learning module, there is a quiz to be completed by the trainees. The questions presented in the quizzes are randomly chosen from question banks related to the learning modules. Therefore, when a trainee retakes a quiz, a different set of questions is presented.

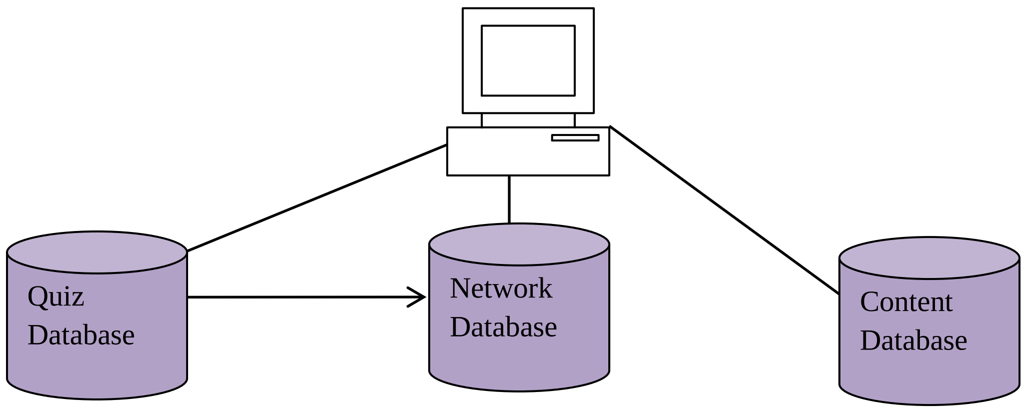

Figure 6. Structure of the Training Tool

Figure 7. Login set up for the first time users

Learning Modules

There are four main topics covered in the training tool: traffic control, lighting, personal protective equipment (PPE), and awareness. Each of these topics includes different learning modules. The list of learning modules is presented in Table 5. The *nighttime work zones* module discusses the parts and planning issues of nighttime work zones. Important considerations in planning the layout of nighttime work zones, internal traffic control plans, and external traffic control plans are discussed in this module.

The *channelizing devices* module discusses the purpose of channelizing devices. and their layout and spacing considerations are explained. The *work zone signs* module discusses the use of temporary signs for traffic control in work zones. The characteristics of different temporary signs, such as warning signs, regulatory signs, and information signs and their locations in nighttime work ones, are presented. The *speed control module* discusses the key features of speed control techniques typically used in nighttime work zones. The *lighting in* *nighttime work* module discusses the different aspects of lighting in nighttime work zones. The minimum illuminance levels for different construction operations are discussed, and lighting design considerations are explained. The *lighting equipment* module discusses the key features of temporary lighting equipment as well as lighting sources and different configurations of lighting systems. The *Personal protective equipment (PPE)* module discusses the different types and applications of protective equipment and addresses issues related to the selection of PPE for nighttime operations. The *Awareness* module discusses the main causes of accidents in nighttime work zones. The module explains the importance of awareness in nighttime work zones and provides examples of good practices and poor practices using photographs.

Table 5. Learning Modules

Topic	**Learning Module**
Traffic Control	Nighttime Work Zones
	Channelizing Devices
	Work Zone Signs
	Speed Control
Lighting	Lighting in Nighttime Work
	Lighting Equipment
PPE	PPE Types and Applications
Awareness	Awareness Issues

The content of the learning modules includes: 1) the findings of the research studies in the area of safety in nighttime construction operations, such as the findings related to safety management strategies, speed control, traffic control, PPE, and lighting considerations; and 2) information from relevant guidelines and specifications, such as the MUTCD, and information from the current nighttime safety literature (e.g., Bryden and Mace (2002), Burgess et al. (2007), Miller (2009) and Valentin (2010)) is also used. The references are also provided in order that a trainee can refer to them for more information. Figure 8 shows a screenshot of a learning module.

Figure 8. A screenshot of a learning module

Quizzes

There is a quiz associated with each learning module. The questions in each quiz are randomly chosen from the question bank related to the learning module. The questions are designed to ensure that trainees "learn" the materials presented in the modules. The passing grade for each quiz is 80%. If a trainee fails to complete the quiz satisfactorily, reviewing the learning module again and retaking the quiz are possible. To ensure the learning process, the questions in each quiz are randomly changed each time. The information related to the trainee's progress related to the completion of the quizzes is stored in the network module. Trainees can track their progress at the quiz progress page (Figure 9).

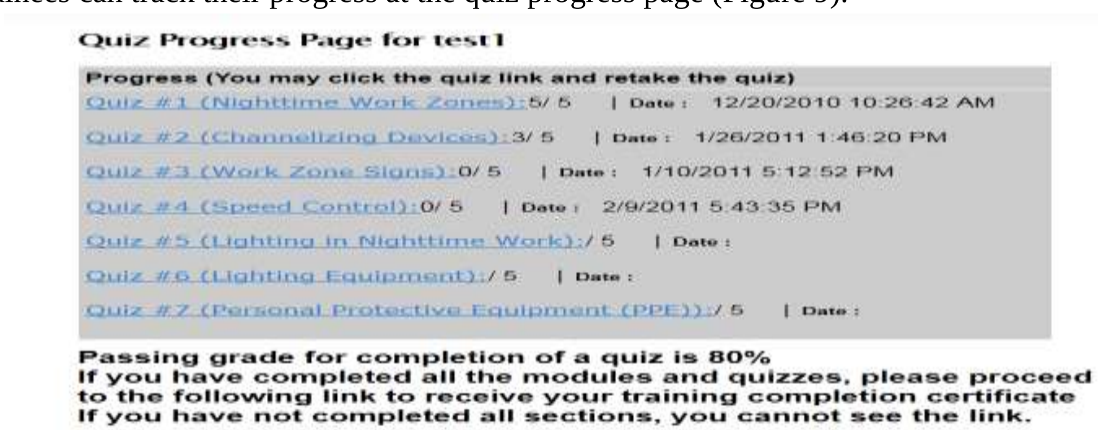

Figure 9. A screenshot of the trainee's quiz progress page

When all of the learning modules and related quizzes are completed successfully by a trainee, a completion certificate is presented to the trainee, and this certificate can be printed. Figure 10 shows the completion certificate.

NIGHTTIME CONSTRUCTION SAFETY TRAINING TOOL – COMPLETION REPORT

This is to certify that Mr. / Ms. test1 test1 has completed the Nighttime Construction Safety Training tool.
The tool provided web-based training regarding safety in nighttime construction operations*.
The summary of the trainee's completion of the training modules is presented in the following table:

Progress (You may click the quiz link and retake the quiz)			
Module	**Completion Date**	**Score obtained and Percentage**	**Completion Status**
Quiz #1 (Nighttime Work Zones):	12/20/2010 10:26:42 AM	5/ 5, 100%	COMPLETED
Quiz #2 (Channelizing Devices):	3/12/2011 11:33:16 AM	4/ 5, 80%	COMPLETED
Quiz #3 (Work Zone Signs):	3/12/2011 11:34:03 AM	5/ 5, 100%	COMPLETED
Quiz #4 (Speed Control):	3/12/2011 11:38:04 AM	4/ 5, 80%	COMPLETED
Quiz #5 (Lighting in Nighttime Work):	3/12/2011 11:39:20 AM	5/ 5, 100%	COMPLETED
Quiz #6 (Lighting Equipment):	3/12/2011 11:41:04 AM	5/ 5, 100%	COMPLETED
Quiz #7 (Personal Protective Equipment (PPE)):	3/12/2011 11:42:37 AM	4/ 5, 80%	COMPLETED

Figure 10. A screenshot of the training completion certificate

Validation of the Safety Training Tool

The initial version of the training tool was tested by four faculty members in construction engineering from different universities in the U.S. who have conducted extensive research related to the safety of construction operations. They evaluated the training tool in terms of the content of the learning modules and quizzes and the structure of the tool. Table 6 summarizes the faculty members' evaluations of the tool, where the number in each cell represents the number of faculty members who rated a specific characteristic of the tool.

Table 6.Summary of the evaluation of the Safety Training Tool

Web-based Nighttime Safety Training Tool					
Characteristics of the Tools	**Evaluation**				
	Needs Improvement		**Good**		**Excellent**
	1	**2**	**3**	**4**	**5**
Comprehensiveness of the Topics			2	2	
User Interface			2	2	
Graphics and figures		1	2	2	
User friendliness			3	1	
Organization of Modules			3	1	
Depth of Contents			3	1	
Structure of Quizzes			3	1	
Structure of the Tool			3	1	
Functionality			3	1	
	Not of Value		**Moderate Level of Value**		**Significant Value**
Value to Safety personnel in Industry			1	2	1
Overall Evaluation of Modules			1	2	1
Overall Evaluation of Quizzes			1	3	

5. Summary and Conclusions

Research-to-practice tools are needed to facilitate application and consolidation of the new knowledge created in research studies related to the safety of nighttime highway operations. Three research-to-practice tools related to the safety of nighttime highway operations were presented in this paper, and their objectives, components, structures, and functionalities were discussed in detail. These tools have the potential to facilitate diffusion of research findings related to the safety of nighttime operations into practice and enhance the knowledge consolidation in this area.

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Can Safe Design be a Source for Construction Innovation?

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Abstract:

Despite the advances of safe design regulation and research over the past twenty years, its effect on business value will ultimately determine the concept's adoption and its effect. This is particularly true in the United States where regulations like the United Kingdom or Australia are not likely at least in the short term. This paper is a theoretical paper which describes the creative opportunities that thinking about safe design can have across the life cycle of the built environment. We will provide examples of how safe design has enhanced creativity yielding both organizational and technological innovations resulting in safer more productive construction projects. We will explain how a well formulated and implemented safe design strategy facilitates these innovations.

Keywords: Safe design, innovation, strategy.

1. Background

Globally, most notably in the United Kingdom and Australia, safe design regulations have been in place for some time. In the United States, the National Institute for Occupational Safety and Health (NIOSH) national initiative on Prevention through Design, established in 2007, is at its midpoint. Despite the advances of safe design regulation and research over the past twenty years, its effect on business value will ultimately determine the concept's adoption and its effect. The design and construction community has choices as it relates to the safe design concept. They can resist safe design and ignore it. Secondly, they can react to safe design once it is regulated or otherwise imposed on them. This usually results in a checklist type mentality seeking to meet a regulatory requirement or, at best, a client's request. Thirdly, they can embrace and internalize safe design using it to their advantage as a new strategy. This is the focal point for our paper. A strategy is defined as the planned processes used by firms to improve core competencies and facilitate innovation (Burgelman et al. 2004). The essence of strategy is choosing to perform activities differently than rivals (Porter, 1996). Innovation refers to ideas, practices, or objects that are perceived as new by an individual or other unit of adoption (Kale and Arditi, 2010). The Council on Competiveness (2005) defines innovation as the “intersection of invention and insight, leading to the creation of social and economic value”. Innovations can be categorized as either technological or organizational: the former have a technical or physical character, and typically involve product or process innovation, while the latter are about advanced firm practices, and typically involve marketing or managerial innovation (Manley et al, 2009).

This paper is a theoretical paper which describes the creative opportunities that thinking about safe design can have across the life cycle of the built environment. We will provide an example of how safe design has enhanced creativity yielding both organizational and technological innovations resulting in safer more productive construction projects. We will explain how a well formulated and implemented safe design strategy and culture facilitates these innovations.

In 1991, Harvard business professor Michael Porter published his seminal essay which challenged the false dichotomy between environmental regulations and economic competitiveness (Porter, 1991). Porter and van der Linde (1996) published a frequently cited manuscript in *Harvard Business Review* on the way that environmental regulations could drive a firm’s competitiveness. They claimed that innovations can address environmental impacts while simultaneously improving the affected product itself and/or related processes. At that time, there was critical pushback by businesses maintaining that environmental regulation eroded their ability to create profit. It was ecology versus the economy. However, Porter and van der Linde argued that strict regulation can trigger innovations that ultimately lower the total costs of a product or improve its value. Using specific examples from the Dutch flower industry and global chemical companies, they reported that these innovations enhanced resource productivity making a company more competitive, not less. The safe design concept is in a parallel condition today as was the environmental movement when Porter and van der Linde published their ideas. While the safety community purports the value of safe design to construction site safety, its *effective* adoption will not be fully realized until the business case can be demonstrated.

2. How do design innovations occur?

According to Drucker (1985), most innovations, particularly the successful ones, are derived from a conscious purposeful search for innovative opportunities, only found in a few situations. Engineering design innovation happens deliberately more often than it does by inspiration; it is more often incremental than radical (Petre, 2004). Incremental innovation is a small change, based upon current knowledge and experience, whereas, a radical innovation is a breakthrough in science or technology that often changes the character and nature of an industry (Slaughter, 1998). Incremental innovations most often appear within the organization that has the knowledge base upon which to develop improvements (Marquis, 1988 as cited by Slaughter, 1998). We view safe design, as an overarching principle within design, as an incremental innovation.

Panuwatwanich et al. (2008) found that perceived organizational culture in a design firm can function as a gateway to the diffusion of innovation, by mediating the relationships between leadership and team climate, and innovation diffusion outcomes. In other words, without a culture for innovation, it is unlikely that creative ideas will be transformed into innovative products.

Petre (2004) describes fourteen strategies that expert designers use to ‘get out of the box’ of familiar thinking, to identify gaps in existing products, and to go beyond ‘satisficing’. They are:

1. Systematic knowledge acquisition (Patent searches; technical literature reviews; analysis of legislative requirements and regulatory standards; review of the competition)
2. Collection of ‘loose possibilities’ (Idea diaries)
3. Record keeping
4. Reflection on completed projects
5. Systematic re-use or re-application of recent innovations
6. Identification of barriers
7. Attention to conflicts (Between engineering and cost – maybe between engineering and safety?)
8. Brainstorming
9. Systematic exploration of possibilities: gap finding
10. Scenarios and consequences
11. Stripping down to fundamentals
12. Considering ‘essences’
13. Systematic variation in constraints
14. Playing with toys

A further characteristic of the exceptional companies is routine investigation beyond domain boundaries; engineers actively explore ideas and technologies outside their own areas of expertise (i.e., safety) (Petre, 2004). This exploration is sometimes problem-oriented but sometimes open-ended. Often they find ‘pointers’ by consultation and discussion with colleagues in other domains; clearly this is facilitated in a multi-disciplinary environment (Petre, 2004). Design as problem solving requires the ability to embrace many different kinds of thought and knowledge—art, science, and technology. Design solutions therefore tend to be holistic, and designers have been referred to as “knowledge brokers” (Rylander, 2009).

3. How can safe design be a source for innovation?

The hypothesis that safe design can be a source for innovation comes largely from John Culvenor’s previous work. Culvenor (2006) evaluated the hierarchy of controls as a problem solving tool and hypothesized the relationship between their implementation and creativity potential as shown in Figure 1.

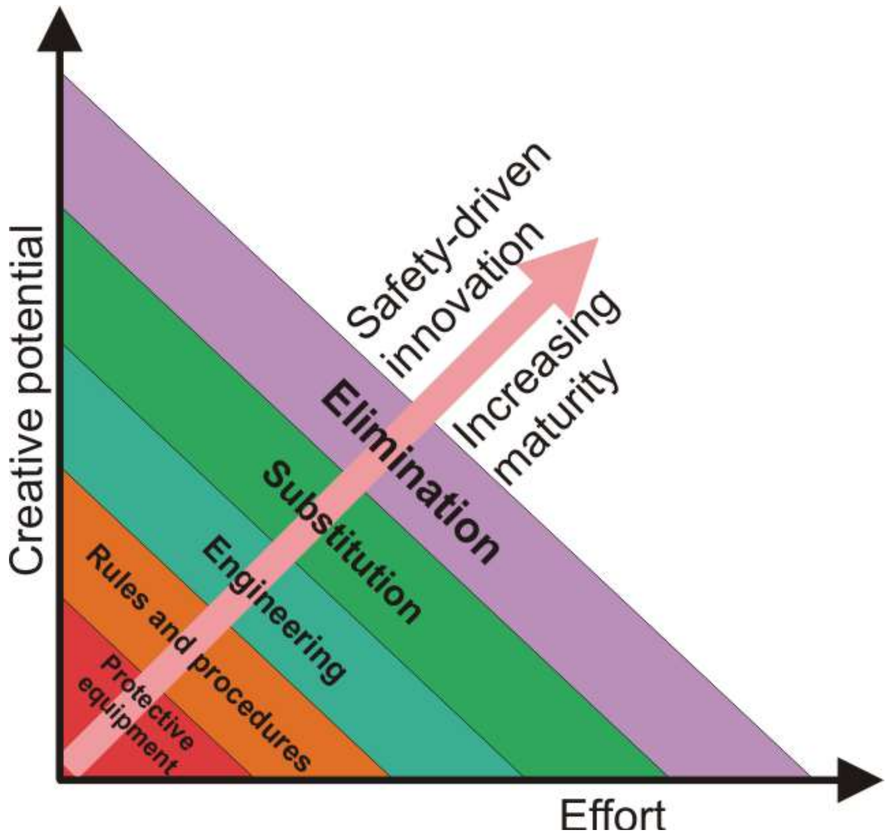

Figure 1: Relationship between hierarchy of control use and creative potential

Culvenor proposes that the high-order solutions (engineering, substitution, and elimination) present a great opportunity, but they are difficult and demand a high level of thinking. His figure hypothesizes that if the hierarchy is applied to thinking about OHS problem solving, they have the potential to drive creative thought and possibly arrive at not only a safer way, but a better way, of achieving a given outcome. He correctly warns that this thinking is very much a double-edged sword; on one hand helping to drive creativity, but on the other being too easily brushed aside as farfetched. Culvenor's earlier research highlights the notion that ideas like eliminating a piece of equipment or a process makes no sense and can even be insulting to those who are responsible for the design (Culvenor, 1997). He demonstrates the parallels between breaking creative thinking paradigms and OSH problem solving. Culvenor (2000) states that innovative thinking means searching for a new paradigm for an old problem. Safety will continue to be a burden, continue to be something to 'pay for', unless creative solutions are sought (Culvenor, 2000).

4. How Do We Design for Safety?

This is a fundamental question for our paper because the available tools to implement safe design is related to how well firms can be innovative. One approach can be a systematic approach utilizing existing guidance documents and design suggestions. For example, the Health and Safety Executive has a Red, Amber, and Green list of practical aides to designers on what to eliminate/avoid, and what to encourage (http://www.hse.gov.uk/construction/cdm/hse-rag.pdf). The Construction Industry Research and Information Association (CIRIA) in the United Kingdom publishes a guide with deign suggestions. The Construction Industry Institute in the United States produces software which includes a database of over 400 design suggestions. Behm (2005) developed additional suggestions based on a review of fatality cases. The idea behind these suggestions is that it specifies to a designer that ways to mitigate the design to reduce risk. The suggestions are largely engineering controls (i.e., design in anchor points) or communication of risk to contractors (i.e., that overhead power lines are in the area of work).

Another approach would be to brainstorm about safety and health risks during the design phase on a construction project. This is embodied by incorporating safety into design reviews. An example process would be the Construction Hazard Assessment Implication Review (CHAIR) process, which utilizes a pre-determined set of guidewords or prompts to assist brainstorming process with the goal of identifying and eliminating or minimizing risks in a design as soon as possible in the life of a project. By brainstorming about safe design, designers have the ability to think outside the box and generate new innovative solutions. In contrast by using a list of design suggestions or checklists, a designer might feel confined to those suggestions, which are largely engineering controls or risk communication. We're not saying these aren't good; these suggestions have been proven to reduce risk. What we're saying is that there is a greater opportunity for innovation with brainstorming and out of the box thinking compared to checklists which tend to constrain ideas.

If we are to consider safe design as a source for construction innovation, the distinction that must be drawn for the safety paradigm is between safety as a regulatory and compliance notion, and that of an innovation modality. The design process in its most successful form enlists curiosity, inquiry and ingenuity to reach beyond the expected to the possible. It therefore can be proposed that Safe Design is the use of the design process to reach beyond the expected (regulation – Hudson Calculative) to the possible (innovation - Hudson Generative). There is a differential condition between design for compliance and design for innovation. Design for compliance accepts the existing safety and knowledge state for a limited set of conditions and use (checklists); whilst safe design explores the future state. For Hudson's Safety Culture Maturity Model, see Figure 2.

Safe design is a generative environment with incremental innovation that exists in a state of continuous discomfort with the current state, whilst design for compliance depends on the assumption that the standard is inherently safe, and is the expression of the accumulated current knowledge state.

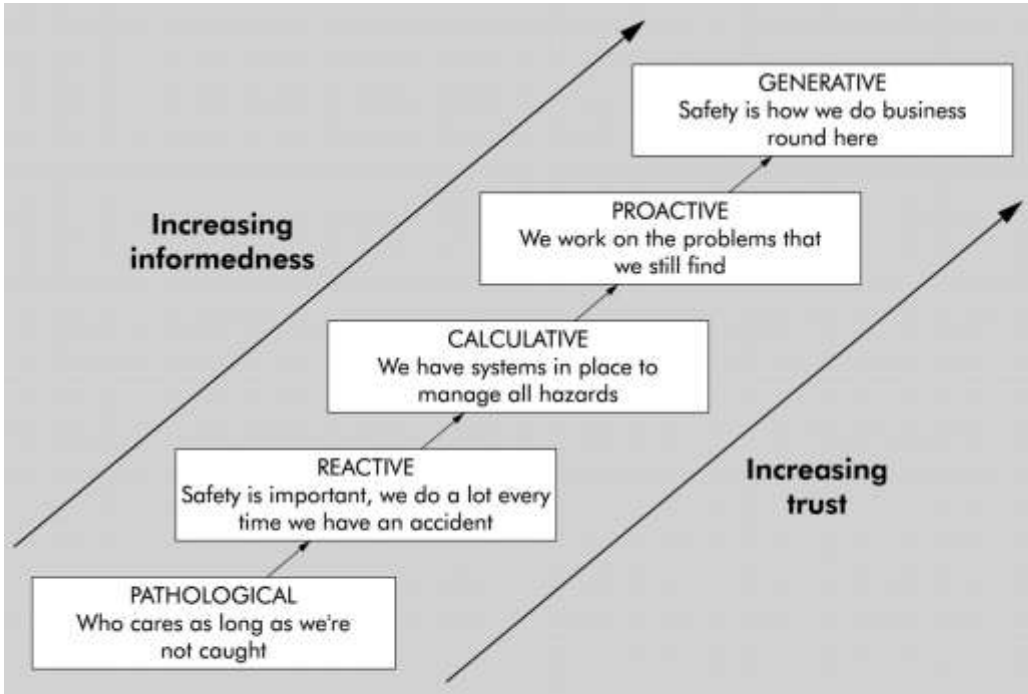

Figure 2: Safety Culture Maturity (Hudson, 2003)

Reason (1997) proposed three organizational conditions for safety: 1) Commitment, management commitment to a safety culture and practice; 2) Competence in the correct way to gather safety information on the right matters and to react to information correctly; and 3) Cognisance, where there is organizational mindfulness and a constant state of unease with the current state. To effectively engage Safe Design, these three organizational characteristics must be integral to the client, designers and constructors cultures. We stated earlier that the CHAIR process is better than checklists in eliciting innovation; however, any process is only as good as the organizational conditions that allow it to grow and be innovative.

The innovation that we are talking about was characterized by Edward de Bono (1977) as ‘lateral thinking’. If you look at a construction schedule it is anything but lateral. It implies that one thing will follow another thing until the work is complete. So you don’t occupy the building before you build it. However that is just what you need to do. You don’t maintain an air conditioner before you design the system. But that is what is needed. The key problem with construction rework, accidents, commissioning problems, etc is that the construction schedule proceeds faster than knowledge acquisition. If knowledge about a commissioning problem arises at commissioning then it is too late. The consequences are delays and expenses. This does not occur if the information is available at the right time. So the key is to drive information, knowledge and ideas up the schedule. Working out issues after they are done, after mistakes are made, cannot be a recipe for success. Developing an understanding of the full lifecycle of a construction job is just as vital as it was in quality management. For instance, consider the work of Deming (1982). Once you made a bad part in a factory it was obvious. This was knowledge. However it arrived too late. All that could be done at that time was to sort out the mistakes from the good parts. The key to quality was to understand how the whole system performs through analysis and importantly the involvement of all people who contribute. Much the same can be done in construction today.

5. Case Study Firm

Sinclair Knight Merz (SKM) is a leading projects firm, with global capability in strategic consulting, design and delivery operating in three regions: Asia Pacific, the Americas (Central and South) and EMEA (Europe, Middle East & Africa). SKM executive management believes that the impetus for safe design goes beyond the regulatory and moral reasons. According to their website "safety in design is one area where we can use safety to gain a market edge and differentiate ourselves from our competitors". See http://www.skmconsulting.com/.

We had the opportunity to conduct focus groups and interviews with SKM designers and safety professionals with the goal of gaining an understanding of how they view safe design within the organization and to explore the tools and methods they utilize. For example, one engineer described his involvement with a telescopic column canopy for petrol service stations. The idea was developed by thinking about construction worker safety and seeking to minimize work at height. By developing a hydraulic lifting process, the canopy could be constructed quicker and with less cost. He stated to us

> *"The results from this particular innovation have been very encouraging; the total man hours required to work at height on canopy installations has been reduced by 95 per cent, almost eliminating the need to have workers exposed to risks associated with such work. The telescopic column canopy has also reduced the critical path of the construction timeline."*

A video of the telescopic canopy and the feedback from the client, Shell, can be found at: http://www.skmconsulting.com/Knowledge-and-Insights/Achieve-Magazine/Issue4-2010/article1.aspx. Figure 3 and Table 1 illustrate and sum up the benefits to both safety and site productivity.

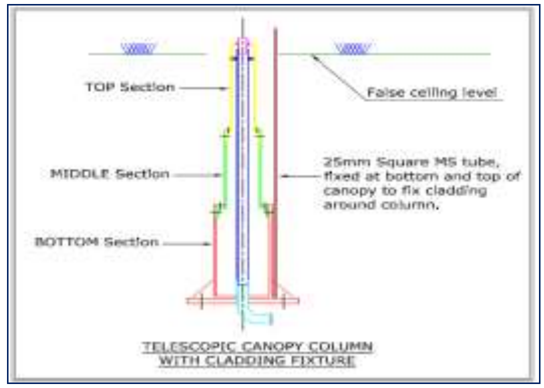

Figure 3: Pictures and description of telescopic gas station canopy

Table 1. Safety and productivity benefits of the telescopic canopy

Risk	Conventional Canopy used earlier	Telescopic Column Canopy
Working at Height Exposure Hour	3,250 Hrs	50 Hrs
Time frame to carry out activity	25 to 30 Days	6 to 8 Days

By focusing on worker safety and thinking outside the box, the design engineer was able to create a win for safety and a win for cost and schedule. Furthermore, by eliminating the hazard, we have instituted a passive control, where the worker does not have to act to institute the control. By analyzing the hierarchy of controls, we can easily find several solutions to the recognized hazard of construction worker working at height to build the canopy. Designers could communicate the fall hazard and specify in the bids documents or construction plans that fall protection is necessary. This would be a downstream measure that may not be feasible and would require the constructor to engineer fall protection solutions; we already showed that this is more difficult as the project schedule evolves. The designer could design in anchor points, horizontal lifeline, or other means of fall protection. These controls are active controls in that their success requires proper use by workers. Passive controls are preferred over active controls. By designing the telescoping canopy to be built at ground level and then jacked up, the designers have installed a passive control which is truly eliminating risks.

We classify the telescoping canopy as an innovation based on the definition of Kale and Arditi (2010), referring to ideas, practices, or objects that are perceived as new by an individual or other unit of adoption. Further it is a technological innovation as defined by Manley et al. (2009). However, the thinking about safe design in beyond compliance ways that seek to add value is also an organizational innovation since very few, if any, firms are thinking in this way. According to Porter (1996), strategic positioning means performing different activities from rivals or performing similar activities in different ways. This is why SKM views safe design as a market differentiation strategy.

Additionally, this example demonstrates the innovation and creativity that can develop when a designer focuses on something outside their original sphere of expertise or takes advantage of the lateral thinking opportunities offered by the safe design approach.

Lateral thinking characterises thinking outside the boundary. In connection with creative thinking, the use of the term lateral thinking arises from the work of de Bono (1971) who defined main features of lateral thinking as follows.

1. Recognition of dominant polarizing ideas.
2. The search for different ways of looking at things.
3. A relaxation of the rigid control of vertical thinking.
4. The use of chance.

Edward de Bono (1992) illustrated lateral thinking with the diagram below showing that lateral thinking is a jump from the obvious. While the side path looked small, once the jump is made the pathway appears as wide as the original path.

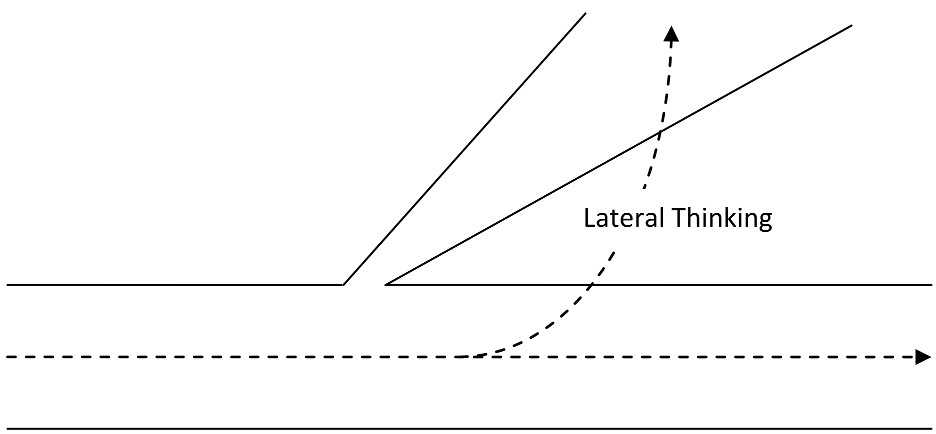

Figure 4. Lateral Thinking (de Bono, 1992)

The construction process is often presented as a linear sequence as below. There is pressure to get to the next stage. The whole job is “important”, but completing the current stage is “urgent”. Diversions from the path are unwelcome.

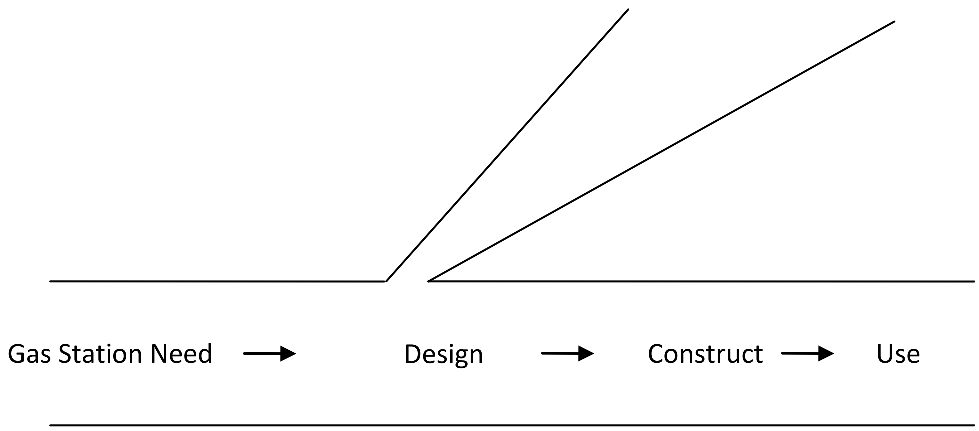

Figure 5. Traditional thinking about gas station, this way looks like the obvious way – expedient and normal.

New ideas can come from mistakes or lucky events. Alternatively we can drive them purposefully. The gas station example is a good illustration. The usual way of preparing the design would have been a faster. The next stage in the process would have been faster. However the overall effect would have been slower, more expensive and less safe. The lateral provocation was driven by safe design. The eventual benefit of the lateral provocation was better safety and a better schedule. The challenge is that while this is obvious afterwards, it is not obvious before. There must be a culture that encourages exploration of new possibilities. Occasionally these will be elegant and very useful. Very often efforts of this kind will lead to nothing and we will return to the normal path. However, without looking the result will be guaranteed to be nothing.

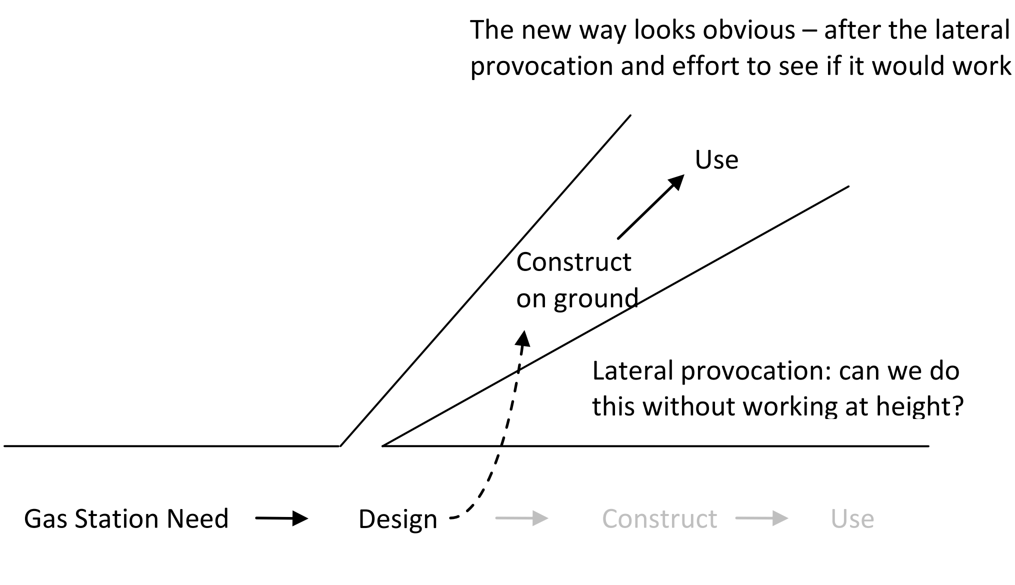

Figure 6: A design innovation brought about by thinking about safety

6. Conclusions and Future Research

How do designers react to safe design? Do they react with thoughts of ‘possibility’ or ‘pain’? Is their mindset that “I better do that or I’ll be in trouble”, or is it that “I can be great at this”. The safe design approach offers designers the freedom to think which is enabling because that’s what’s they’re good at doing. Organizations need to create the construct for them to go beyond regulation. In other words, design organizations need to be “adaptive”. Boris et al. (2009) suggest a new age of safety, called the ‘adaptive age’, where human (both designer and constructor) variability is an asset rather than a liability and learning from successful performances is as important as learning for failure. At SKM, designers are encouraged to utilize a cognitive framework to design for safety, and a large part is client driven. The goal within the culture is to enable designers to do innovative thinking rather than constrain them through rules and standards. The interesting aspect of safe design, both as a philosophy and as a regulated matter is that it is a ‘rule’ that encourages creativity. There are techniques to help like brainstorming and social networking among designers is also another common method. SKM makes an effort to be adaptive. They don’t pretend you can write everything down about safe design, but it’s about a mindset of the designer about what safety in design means – it’s not designing to the rules/specifications, but rather it’s thinking about the outcome and how it can be met. Fall from height is a general risk term that would appear in many (almost all) construction projects. Rules-based thinking would follow a checklist to either inform about the risk or design in active systems such as anchor points. Those ideas would probably be useful steps forward but they would not offer additional benefits that were delivered in the gas station example. Because each construction project is unique, an adaptive firm has an advantage in safe design. Each project is an opportunity for something new in a new discipline for the design team. That represents the “possibility”; the checklist mentality is the “pain”. Creativity in safe design is not about being random and doing whatever comes to mind, but rather using this mandate to prompt new ideas, and to use them if they are better. They won’t always be better, thus rigorous analytic thinking remains necessary. It is not known whether the design community sees safe design in this way. Do they see the possibility and innovation that it offers?

Sometimes meeting safe design regulations can force a “check the box” type of mentality. However, sometimes grappling with the constraints imposed by legal requirements leads to reformulation and innovation; sometimes it simply improves performance by focusing efforts on what is realistic within the rules (Petre, 2004). Viewing safe design as an opportunity rather than a pain is a positive first step in the maturity path to a generative environment. Win-win situations will not always occur. However, we suggest they are worth the look, and as Culvenor recognizes, the effort is higher but the creative potential is too. In response to Porter’s seminal essay and then U.S. Vice President Al Gore’s praising of the green economy, Walley and Whitehead (1994) argued the inspirational rally cry of Gore and Porter provided little specific guidance for managers. Further, they purport that win-win solutions are rare, are largely insignificant, and suggest that seeking win-wins should not be a firm’s environmental strategy. Seventeen years later, we wonder what Walley and Whitehead would think of the green movement today, in 2011.

To sum up our view, we parallel Porter and van der Linde again and substitute the phrase 'safe design' for 'environmental regulation'.

How an industry responds to safe design may, in fact, be a leading indicator of overall competitiveness. Only those companies that innovate successfully will win.

To answer the question posed in our title, we believe safe design can be a source for construction innovation in a culture of innovation exists within a generative safety culture. We further believe that safe design as a source for innovation is highly underutilized. Safe design can be an intersection of invention and insight, leading to the creation of social and economic value. This was demonstrated by the telescoping example, and this is not an isolated example from SKM. Admittedly, SKM still has a long way to go to develop their safe design culture. They are in a continual process of organizational learning and that is their culture.

Because this paper is a theory building paper, there are numerous potential future research endeavors. Some that we see include:

1. Survey SKM design professionals, or other design firms using who have experienced safe design innovation, on the methods they use to design for safety and quantify the value of their methods.
2. Evaluate the specific safe design strategies used by SKM, or other design firms using who have experienced safe design innovation, and measure their impact on eventual life cycle safety and on traditional business measures for a variety of projects.
3. Perform case studies on the impact of various safe design methods utilized by SKM, or other design firms using who have experienced safe design innovation. Measure the impact of innovations. Measure the financial and time costs and benefits of safe design.
4. Perform the above with a variety of firms for comparison.

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Factors that Contribute to Positive and Negative Health and Safety Cultures in Construction

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Abstract

Although there is no consensus on how to define the safety culture of an organisation, the concept is now recognised as an essential contributor to improved occupational safety performance in construction. Indeed, the subject of safety culture has attracted considerable attention in the literature in recent years. The health and safety culture in an organisation is determined by the social and psychological relationships in the workplace. Some view safety culture as a management issue but so fuzzy to the extent that it cannot be measured or reliably changed. The concepts of organisational culture and climate are discussed. The concept of health and safety culture is evaluated including the factors that influence it; its assessment and measurement methods. Results of interviews with site safety managers of construction companies that exhibit strong safety cultures are reported. The objective of this work was to determine what works for them. The results reveal that the factors that contribute to positive and negative safety cultures in construction can be grouped into six categories: organisation factors, individual factors, team factors, job design factors, management factors and supervisory factors. The overall aim of this research is to recognise and understand the complexity of health and safety culture on construction sites, to develop successful measurement methods and intervention tools to create a positive culture on a construction site.

Keywords: organisation culture, construction safety, safety culture, safety climate.

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Keywords: organisation culture, construction safety, safety culture, safety climate.

1. INTRODUCTION

It has been recognised that cultural change in organisations in the construction sector is essential to bring about a fundamental change in performance to deliver improved safety. It is for this reason that the concept of safety culture has attracted significant attention in safety science research over the last three decades. Safety culture may be considered as a sub-set of organisational culture. The concept of organisation culture is reviewed in this paper including an assessment of its key characteristics. This is followed by a discussion of the concept of safety culture although it should be made clear that there is at present no universal agreement on its definition. A review of research studies on safety climate and safety culture is provided. Results of interviews with site safety managers of construction companies that exhibit strong safety cultures are reported. The objective of this work was to determine what works for them. This study was motivated by the desire to answer a number of fundamental questions on safety culture in construction. These questions are: Can safety culture be measured? Can it be changed? Can it be controlled or managed? Is there empirical evidence linking safety culture and safety performance?

2. ORGANISATIONAL CULTURE

Organisational culture can be defined in a number of ways. For example, Schein (1992) defines organisational culture as a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration; that have worked well enough to be considered valid and therefore to be taught to new members as the correct way to perceive, think and feel in relation to these problems. Another definition of culture is a common set of ideas, values, attitudes, and norms that characterise a group of people. Culture is an aspect of all sides of a society and influences how we approach safety, technology, politics, economics, etc. It influences how we think and act in our everyday lives. Thus, culture is something that has an influence on most things and perhaps everything that we do (Haukelid, 2008).

Organisational culture can be placed alongside other organisational parameters such as organisation structure, the goals and corporate strategic plans, the competence and talents of staff, management style, and the systems and procedures. Culture is one of the organisation's variables that influence its performance. All these variables are however interactive and interdependent. Organisational culture has a number of important functions. It can specify values and goals that are important in an organisation. It can prescribe appropriate relationships between the employer and employees and vice-versa. It can indicate how behaviour is controlled in the organisation and the controls that are legitimate.

Organisational culture can be influenced and changed but perhaps over a period of time. Guldenmund (2007) argues that within organisations, there are three major forces that operate at the same time and are interrelated. They are: organisation structure, culture and processes. The organisation structure outlines the formal organisation and the mechanisms of communication, coordination and control. Organisation structures allocate formal power. However, alongside these formal structures are informal structures. Informal structures are equally important to understanding the culture of an organisation. The processes are the actual primary and supporting processes going on throughout the organisation. If we accept that safety culture is part of the organisational culture, then it is influenced by both structure and processes.

There is general consensus that there is a difference between the terms organisational culture and organisational climate although in some literature there is a tendency to treat them as synonymous. Cox and Cheyne (2000) take the view that culture in general and safety culture in particular, is often characterised as an enduring aspect of the organisation and thus not easily changed. On the other hand, organisational climate can be viewed as a manifestation of organisational culture. In other words, climate follows naturally from culture. Cox and Cheyne (2000) argue that climate is a temporal manifestation of culture, which is reflected in the shared perceptions of the organisation at a discrete point in time.

Guldenmund (2000) states that the term organisational culture refers to a global, integrating concept underlying most organisational events and processes, whereas the term organisational climate means the more overt manifestation of the culture within an organisation. Climate is commonly conceived as a distinct configuration with limited dimensionality surveyed through self-completion questionnaires and that it is up to a certain point, objective and semi-quantitative. On the other hand, organisational culture is often determined through a combination of methods including observations, focus groups, interviews, through mutual comparisons and so on. Measures of organisational culture are thus qualitative and difficult to quantify.

3. SAFETY CULTURE AND SAFETY CLIMATE

Safety culture can be considered as a particular aspect or subset of organisation culture. No review of safety culture would be complete without an evaluation of the relevant aspects of organisational culture. The definition of safety culture must therefore be consistent with the parent term organisational culture. Establishing a link between safety culture and safety of construction operations requires an understanding of the characteristics of safety culture. Such characteristics must be consistent with the definition and key attributes of organisational culture. No attempt will be made to distinguish between safety culture and safety climate in this paper. Many authors use the term safety climate and safety culture interchangeably, for example Wu, et at (2010), and Rollenhagen (2010). However, it should be noted that safety climate is now accepted as a surface expression of a safety culture.

Wu, et al (2010) using a stepwise regression model analysed the influence of higher level managers (employers), mid-level or operations managers and safety professionals on various factors that shape safety culture. They found that four safety leadership factors significantly affect safety culture. These are *safety caring* by employers, *safety informing* by operations managers, *safety co-ordination* and *safety regulation* by safety professionals. Of these four predictive factors, safety informing had the most significant effect on safety culture.

Safety caring refers to a paternalistic style or approach to safety management, achieving consensus in working practice, showing respect and trust for employees, showing care about employees’ needs and empathy with their problems. Safety informing includes three aspects: safety monitoring, safety dissemination, and safety representing. Safety monitoring means collecting relevant safety information through a monitoring system. It is vital that this information is then continuously circulated so that employees receive important updates. Safety committees improve safety culture by enabling communication between management, safety representatives, safety professionals and employees. Safety co-ordination refers to safety policy development, safety information management, and safety communication. Organisations with positive safety cultures are characterised by open channels of both formal and informal communication up and down the organisation structure. Safety regulation involves safety inspections, safety audits, and safety incentive systems. Their research implies that certain role behaviours demonstrated by senior managers, operating managers and safety professional can significantly shape or change safety culture (Wu, et al, 2010). However, the authors acknowledge that this change cannot be achieved at a stroke.

Although it has been commonly argued that many problems associated with risk and safety can be addressed from a human and organisational perspective, Rollenhagen (2010) cautions against focussing on safety culture and not rethinking design of technology in the pursuit of solutions to safety problems. He argues that the concept of safety culture, if misused, could lead to adoption of non-effective change strategies. He therefore advocates adopting a balanced safety management approach recognising that safety is a dynamic property that arises from interactions with components and sub-components of people, technology and various institutional arrangements.

One question in the safety culture debate is whether safety climate or culture in an organisation can be considered as an important indicator of safety performance in construction. This question was raised by Wamuziri (2007) who called for research to evaluate whether this is indeed valid from a scientific point of view with specific reference to the construction sector. At the same time, Guldenmund (2007) reviewed a considerable amount of previous research and concludes that there are a large number of factors (dimensions, scales, and facets) that make up the safety climate concept and that safety climate and safety performance are weakly correlated at best. This is in agreement with Clarke (2006) who concludes following a meta-analytic review that it is unlikely that a strong relationship exists between safety climate and measures of safety performance. Choudhry et al (2007) suggest that although development of a positive safety culture can be an effective tool for improving safety, measurement of safety performance remains problematic. Indicators such as accident rates or compensation costs are lagging indicators and measure system failure rather than its success. A multi-instrument approach involving leading or upstream proactive approaches such as hazard identification and observation of percent safe behaviour is suggested. Further research into that the measurement of safety performance is recommended for the benefit of industry.

Further questions can be posed from an organisational perspective are: Can safety culture be managed or controlled and changed? Can safety culture be measured? On the first question, Haukelid (2008) argues that it is possible to change a culture, but it takes a long time. However, because culture is something more fundamental and lasting, it is something that is difficult to manipulate or control. Cultural content is seldom if ever static. Finally, culture changes over time, no matter what managers or employees think or do. On the question of measurement of safety culture, Haukelid (2008) concludes that it is necessary to invoke more than one methodological angle (triangulation). The answer to measurement of safety culture is thick descriptions and the favoured method for this is ethnographic fieldwork. Fieldwork and participant observation are especially important to map out tact knowledge, basic assumptions and the deeper levels of any given culture. Questionnaires and interviews are seldom sufficient to reach this level of cultural expression. Despite this note of caution, there is recent research aimed at developing questionnaire-based measurement methods of safety culture and climate, for example, Hahn and Murphy (2008) and Díaz-Cabrera, et al (2007).

Several authors are in agreement with a multi-dimensional or triangulated approach to measurement of safety culture. For example, Grote and Künzler, (2000) opine that assessing safety culture requires undertaking long-term and in-depth studies of the social system using a range of qualitative methods like narrative interviews, participatory observation and analysis of company documents. However, they defend the use of questionnaires in addition arguing that their use helps to gain organisational members' views from different occupations, departments, and hierarchical levels on the factual characteristics of the company, and perceptions regarding operational safety, safety and design strategies in order to gain a deeper understanding of safety management and safety culture in a company. However, Guldenmund (2007) is sceptical about the use of questionnaires to measure safety climate and states that previous findings from safety climate research using questionnaires might very well represent general attitudes towards management and its perceived influence on working conditions rather than an evaluation of the conditions themselves and that it may not make much sense to correlate general notions about safety management with safety performance indicators in the form of output variables (behaviour or accidents). Research by Cooper and Phillips (2004) lends support to this view and suggests that the hypothesised paths from attitudes and beliefs (i.e. climate perceptions) to behaviour, to accidents and injuries are weak and not as clear cut as is often assumed. Safety climate perceptions do not necessarily match actual levels of safety performance. Therefore industry should focus it primary safety improvement efforts on changing unsafe situations and conditions as well as people's safety behaviour at all organisational levels rather than concentrating on improving people's attitudes, beliefs, and perceptions about safety. It is reductions in unsafe behaviours, unsafe conditions or situations that reduce the opportunity for accidents to occur not perceptions on how safety is operationalised. This is not to down play the importance of perceptions about safety climate for improving safety performance. On the contrary, Cooper and Phillips (2004) recommend that all organisations should regularly survey their prevailing safety climate to highlight areas where systems and physical changes are required within an organisation as well as safety-related behaviours.

O'Connor et al (2011) reviewed several studies that have examined safety climate in commercial and military aviation. They found that safety climate factors identified in the aviation safety climate questionnaires are consistent with the literature on safety climate in non-aviation high reliability organisations. Thus aviation safety climate tools had some construct validity (the extent to which the questionnaire measures what it is intended to measure). However, the majority of the studies made no attempt to establish the discriminate validity (the ability of the tool to differentiate between organisations or personnel with different levels of safety performance. They recommended that rather than constructing more aviation safety climate questionnaires, researchers should focus on establishing the construct and discriminate validity of existing measures by correlating safety climate with other metrics of safety performance.

A recent study by Törner and Pousette (2009) identified the following preconditions and components for high safety standards in construction. They are:

- Project characteristics and nature of the work which sets the limiting conditions to which safety management must adjust;
- Organisation and structures which includes: project planning, allocation of roles and responsibilities, procedures and resource allocation;
- Collective values, norms and behaviours which includes climate and culture, interaction and cooperation;
- Individual competence and attitudes which includes knowledge, ability, and experience characterised by personal engagement, taking personal responsibility and prioritising safety.

Thus achieving high safety standards in construction involves effective management of several interactive factors incorporating organisational, group, individual and technical aspects.

4. RESEARCH AIMS AND METHOD

After nearly three decades of intensive research on the subject, safety culture remains a fuzzy concept for which there is no unanimously accepted definition. Furthermore, there is very minimal agreement on its indicators. Nevertheless, Fernández-Muñiz et al, (2007) recommend research into organisational factors that encourage or hinder the creation of a safety culture and implementation of a safety management system. This will be invaluable to organisations in defining areas where they need to progress if they wish to improve their safety performance. Literature on the effectiveness of such organisationally based intervention measures to improve safety performance remains sparse. However, a recent study (Hale, et al 2010) reports that although such change is hard, interventions bringing about constructive dialogue between shop-floor and line management, providing motivation to line managers and strengthening the monitoring and learning loops in the safety management system appear to be successful. The amount of energy and creativity injected by top management and the safety coordinator (safety professional) appear also to be a distinguishing factor. Training and publicity are at best necessary but were found not be sufficient requirements for improvement.

The overall aim of this study is to evaluate the factors that contribute to positive and negative safety cultures in construction organisations. This was achieved by interviewing six senior safety/project managers from construction companies that exhibit strong safety cultures. Safety managers operating at a senior level in construction organisations were considered best placed to provide descriptions of the real world with respect to interpretation and meaning of safety culture. The objective of this work was to determine what works for them. Characteristics of the interviewees are as follows:

- **Interviewee one:** A project manager with over 10 years experience in construction project management in one of the world's largest construction companies with offices across Australia, the UK, Germany, India, South East Asia and the United Arab Emirates. The company is 100 per cent privately owned, with approximately 36,000 employees' worldwide and gross revenues in excess of US $11 billion a year. The project manager also oversees site safety throughout the group.
- **Interviewee two:** A site manager in a UK-based construction company with origin stretching back as far as 1874. The company has a large network of offices covering England, Scotland and Wales and projects in the education, retail, mixed use development, health, office, leisure and law order sectors.
- **Interviewee three:** The divisional project manager with 20 years experience in a UK leading construction company into building construction and refurbishment with offices spreading throughout the U.K.
- **Interviewee four:** A Health and Safety Manager of a civil and construction engineering company involved in high value projects such as house building, leisure management and retail. The Company has completed in excess of 60

projects for the retail sector, ranging from renovations to new-build superstores.

- **Interviewee five:** A director with over 10 years experience in design and construction project management and supervision in a construction company based in Scotland with expertise in design and construction of commercial and industrial facilities ranging in value from £50,000 to £5m. The company employs over 2000 people.
- **Interviewee six:** The head of health and safety, quality and environmental department in a multidisciplinary Scottish construction company providing services to the private, public, corporate, retail, leisure, health, education and industrial sectors.

5. ANALYSIS AND DISCUSSION OF RESULTS

Perception of the safety culture approach to improving safety performance

In recent years there has been a shift from technological and management system approaches for enhancing health and safety performance in organisations to understanding human attitudes, norms, beliefs and psychological factors that contribute to accidents and health and safety failures. Opinion was sought on the effectiveness of this new approach to enhancing safety performance in organisations.

All the interviewees agreed on the need to better understand the factors that influence employee safety behaviours and attitudes as most accidents or safety failures on construction sites have been attributed to unsafe behaviours employees' exhibit on site which sometimes is times is not explainable.

Interviewee two estimated that 80% of workplace accidents are as the result of unsafe acts, not unsafe conditions. He stressed that although safe procedures could be made available, some individuals are sometimes overconfident and daring to the extent that their actions result in accidents. '*If unsafe attitudes can be pre-empted and corrected it is likely that most accidents on site could have avoided'*.

Interviewee three noted that the effectiveness of a cultural approach to safety improvement can be achieved from shared norms and values about safety that permeates an organisation. He stressed that where a safety culture exists, thinking about safety and prioritizing safety permeates all the organisational levels such that there is a consensus on safety and how it should be managed from top management to blue collar levels. '*People at all levels are involved in safety and take responsibility for safety, such that there is a rich communication concerning safety issues'*.

Interviewee six concurred that successful development of a safety culture in organisations can help realize immediate and tangible results in reducing workplace accidents and their associated costs, including decreased productivity, employee morale and increased hiring and training costs.
Overall there was a general consensus on the need to better understand behavioural and attitudinal factor that affect construction safety.

Relationship between safety culture and safety performance

Many organisations use records of their health and safety performance as an indication of the effectiveness of their health and safety management and systems. Opinion was sought on whether lagging indicators of health and safety performance can be taken as good indicators of the health and safety culture within an organisation.

Interviewee two asserted that the link between safety culture and performance is a complex one, he indicated that the link has no simple and direct correlation, stressing that the culture contributes significantly to the performance, while performance may not truly indicate the existing culture. '*traditionally safety in most organisations is measured based on lost time injury for small organisation while larger organisation go as far as yearly health and safety audits to check laid down management procedures, so safety performance are usually based on outward records which are influenced by legislative requirements but safety cultures are in-built norms, attitudes and practises which are hardly assessed*'.

Meanwhile, interviewee three stated that safety performance cannot stand to indicate safety culture and went on to state that ' a *strong safety culture is critical to long-term safety performance, there are many challenges to ensuring a positive safety culture in all business operations at all locations, with additional challenges posed by acquisitions, mergers, and divestiture, long term safety performances will eventually result in strong safety cultures but where there seem to be incoherence between the two, a system failure will eventually expose cultural lapses over time '*.

Interview six stated that using performances to indicate cultures can be problematic; and stated that *'accidents can be relatively rare events, they may not be recorded accurately or routinely, and risk exposure may not be taken into account'*. Other measures, such as safety behaviour and minor injuries, have also been used, and more modern approaches tend to focus on current safety activities and systems to measure success as opposed to failure, perhaps in combination with the more traditional approach to measuring performance. This more predictive approach to safety culture measurement can also mean that organisations do not have to wait for a system failure before identifying and acting on problem areas.

Influence of Management Commitment and Employee Involvement

Writers on subject of safety culture assert that management commitment to safety and active employee involvement in health and safety through adequate resource allocation, putting safety before production, designation of safety roles to supervisors, middle managers, managers and top managers, timely response to safety action plans, holding consultations with employees on safety matters and decisions etc, are the key factors that contribute to a positive health and safety culture within in an organisation. Opinion was sought on this and interviews were asked to explain how this relates to their own organisations.

All subjects rated the importance of management commitment to health and safety very highly and added that it is the key to promoting positive health and safety cultures within their organisations. Interviewee one went to say that management commitment has the main influence on employees' safety commitment; he made known that he has noticed that employee behaviour towards safety is usually in line with those of their front line managers and supervisors. '*Although senior management might show good attitudes and behaviour to safety, but their efforts are sometimes subject to negative stereo-typing by middle managers and supervisors on the site, who we do hand over safety responsibilities toe*' this suggests that management actions have to be backed with trust among supervisors and managers to represent the top management efforts.

Interview two stated: '*Top management do want safety to be a key element within their company, but there are always barriers between senior managers and workers, these barriers are created by middle managers being resistant to change. Middle managers may hear safety rhetoric from senior management but are confronted daily with other, often stronger messages of cost cutting, downsizing and productivity levels, which makes it quite difficult for them to implement safety culture elements within the organisation*'. He stressed that for top management commitment to be driven down to front line workers there must be agreement between top management, middle managers and supervisors. Supervisors must be accountable and there should be an active involvement of middle managers.

Interviewee three referred to management commitment as the cornerstone for a strong safety culture. He stated that it is not enough to designate roles or to have procedures on how safety is to be managed but there must be a reflection in behaviour. This helps employees to perceive the safety culture better. He made known that his organisation have adopted senior management visibility at working and operational stages of projects. '*We make sure that senior managers spend adequate time alongside safety officers on safety issues with front line employees. As a project progresses, project managers spend at least one hour per day. First line managers spend 30% of their time and senior executive usually schedule at least an hour per week for concentrating on safety with employees'*. This approach obviously will help employees perceive safety better in the organisation helping them to frequently open up on safety issues.

Interview four stressed the link between management commitment and employee involvement and suggested: *'Listening to one's employees is a form of true management leadership and commitment. The role of management to provide a safe work place should not exist in a vacuum'*. He explained that there must be an active and a working trust between management and employees in order for the company to stay with a safe working system. '*Here supervisors and worker safety representatives are fully aware of their responsibility for safety. Supervisors and worker representatives react swiftly and act resolutely. The safety representative has a mandate to act. The supervisor follows up to ensure that safety measures have actually been implemented. The supervisor plays an important role in developing a good safety culture that permeates all levels. In organizing the site, there is a centrally placed person with generic responsibility for safety and to whom anyone can turn, since such a person can bridge the organizational divisions between different work teams*'.

Interviewee five and six expressed the view that a corporate safety culture of a construction company to be a precursor to job safety. Interviewee five stressed that the culture of safety is strongest when top managers are committed to safety as a value that is shared and internalized by everyone in the organization. He referred to an instance when the owner of a prominent design and build construction firm hired his college age Son to work as a labourer on a construction site for the summer. When the Son reported to work without a hard hat and wearing flip-flops instead of the required steel-toed boots, his father literally chewed him up out in front of a group of older workers and sent him home for the day. That safety lesson came from the very top, and it was never forgotten.

Interviewee six stressed that safety programmes should be initiated from the top management of an organization. '*The top management should formulate a policy indicating a commitment to safety*'. This step will lead other policy changes and procedures concerning safety. Without it, it is very difficult to achieve a successful safety programme. He further explained that management commitment was the most significant measure that helped to determine and influence safety performance on all their building sites.

Influence of Project type on Employee Behaviour

In construction, project sizes, types and the work environment e.g. bridge construction, road construction and other high risk jobs may influence personal safety behaviour and performance based on the perception of risk and the work environment. Opinion was sought from the interviewees on the extent to which these factors may help to ingrain and maintain safety attitudes n employees.

The factors here refer to the nature of the construction project related to: the physical structure being built (e.g., a building, a tunnel, or a road), the physical possibilities at the worksite for securing the work area, related to the physical situation of the structure, and the complexity of construction work as such. All these conditions create restrictions that "set the stage" on which the work is performed and thus define the limiting conditions according to which all parties involved must adjust their safety management.

Interviewee one was of the view that, the state and the nature of the work environment helps to some extent to alert employees at the jobsite on the risks that they may face "*Sometimes in our daily work it is all the machines that surround us, loaders or trucks or saws or reinforcement stations. A lot of tools all the time, which pose a risk making employees perceive some hazards and adjust their acts and behaviours towards safety*''

Other respondents said they have been involved in consistently similar job patterns but acknowledged that project sizes do affect the effective management of site safety. Interviewee four stated that: '*The specific conditions at the worksite, the characteristics of the project, and the preconditions for securing the work area specific to the structure under construction are the limiting conditions to which safety management must be adjusted by all parties involved*'. A construction project being executed in the midst of city traffic is associated with different restrictions for workplace layout than the construction of an industrial building in the country. In construction work, people inevitably move around in non-standardized patterns near any number of machines. Building and construction work also differ from much other industrial work in that it evolves constantly. The work site does not look the same from day to day, and different groups of professionals come and go from the project at different stages. Often several companies are involved, and the personnel representing each company may differ from one project to another.

When questioned if these conditions help employees maintain better attitudes towards safety, all respondents made known that bigger projects call for notifications to the enforcing agencies i.e. the Health and Safety Executive (HSE) and local authorities under the Law so they thus require that the management allocates more resources and time to managing of safety on site. Interviewee one, three, four agreed that such practise over time help enhance the safety culture within the organisation and across projects. Interviewee two, five and six were of the view that large projects do involve some sub-contracting and working with unknown staff and teams on site amidst a wider range of hazards, so that there is usually a need for a higher level of caution and understanding among operatives. They went on to say that there are usually manifestations of poor cultures of different teams and organisations which makes it a challenge for principal contractors to create high safety standards given these characteristics.

Influence of subcultures on change programmes

Organisations are characterised by work groups based on department and expertise. These groups do have their own styles of management and have different levels of concern for safety issues; in effect, they have their own safety subcultures. The subcultures do vary mainly by occupation, age, shift pattern, prior accident involvement and grade. Safety climate surveys do ignore the contribution subcultures make to workers' perception of safety. Can a safety culture change programme be designed for large organisations without taking into account the subcultures in place, how they interact and power relations between them? The interviewees were invited to respond to this question.

Four of the respondents agreed that it is important to take into account different subcultures within an organisation for a successful cultural change programme. Subcultures may develop when employees working in the same organisation experience different working conditions. It was stated that a lack of communication and risk sharing between subgroups might result in accidents. Shift patterns such as day and nights shifts should be characterised with good communications and hazard sharing that enables different work groups to share and understand the other group's risks. It was further stated that terms and conditions of agency and other contractor workers also bring about subcultures which must be taken into account in a safety culture change programme. For example, interviewee two made known that some agency staff or contract staff may not receive holiday or sick pay. '*They were employed to do the most dangerous and physical work. Their working experience resulted in them becoming distanced from the operating company and its safety culture, viewing safety as something that was subordinated for the demands of production; unsurprisingly they experienced more accidents than company employees*'. The presence of a subculture will result in the lack of a cohesive safety culture in an organisation. However, subcultures can be a positive influence on safety, by bringing different perspectives and a diversity of views to safety problems.

On the other hand, two of the respondents believe the recognition and existence of subcultures within large organisations do create some conflict between professional and technical staff and front line employee safety culture. In some cases such cultural differences do create differences between managers and workers and could potentially cause problems for communication and risk taking behaviour as well as other safety issues. Such a difference in job perception results in the technicians carrying out their tasks differently to how the company prescribes.

Influence of managerial training in safety on safety culture

Competence factors in organisations include: qualifications, knowledge and skills and taken into account in recruitment and selection, training and assessment of competence. While some construction companies require some level of employee competence in health and safety for appointment, some organisations pay little attention to such requirements. In some organisations, managers appear to receive little health and safety training. Interviewees were asked to evaluate whether establishing competence standards within the construction industry at all levels can help bring about a desired health and safety culture.

All the respondents agreed that competence standards in the construction industry are necessary for enhancing health and safety cultures across sites. The CSCS - Construction Skills Certification Scheme was highlighted to have been set up to help the construction industry to improve quality and reduce accidents. '*CSCS cards are increasingly demanded as proof of occupational competence by contractors, public and private clients and others. They cover hundreds of occupations so that whatever you do in construction there will be a card that is suitable for you, that is the standard we have set for employees coming to work on our site*'' Workers' adequate knowledge, skill and ability to undertake their work, especially their attitudes towards risks and dangers in their work, may minimize accidents. These competences can be enhanced through training and appropriate worker selection. Interviewee four noted that although his organisation requests some level of standard at recruitment in relation to both that task and safety, continuous training is usually provided in house to help employees to improve their knowledge of job safety and risk assessments.

Interviewee four made known that whilst front line employees and supervisors receive a great deal of training in health and safety issues due to legal requirements, managers did not. He noted that around sixty percent of company executives had received basic health and safety management training, while 20% have "very basic" training and others have never had any safety training at all. He stressed that to derive better management commitment; top managers in construction should improve the level of health and safety management training- '*they may not have strength to be firm on a safety issue if they don't have the experience or necessary training*'.

Influence of communication on safety culture

One of the identified causes of accidents is poor communication. Good communication is founded on shared beliefs of the importance of safety and mutual trust as well as confidence in effectiveness of preventive measures. Communication modes can range from formal to informal, written and unwritten to face-to-face discussions and other open approaches. While some organisations tend to rely heavily on formal processes and modes of communicating safety issues, some welcome all forms of communication. Interviewees were invited to provide perspectives on their experience of the impact of communication forms in influencing employee attitudes towards safety in their organisations.

Interviews one and three were of the view that open communication forms such as open confrontation on safety issues, employee being able to speak out and receive responses on safety matters aids quick dissemination of information on safety matters to authorities and encourages employees to speak out and not cover up issues that are not open to people in authority or management. '*health and safety professionals spend most times of the day communicating by emails, telephone, writing instructions and responding to technical and not so technical queries from employees and other colleagues. This approach is always required and should be backed up by informal talks and discussions on site by front line supervisors and managers in a manner that encourages front line employees to speak up on safety matters without waiting for their safety officers. In doing this we receive a lot of information on other risks that may not be channelled or identified through pre-planned risk assessments*'.

Interviewee four expressed the view that in a system of open and two way communications, management provides information to employees on hazards and risks associated with the organisation's operations to build understanding on how to work safely. '*Our supervisors and managers in turn listen and act on concerns of employees; in this case people contribute more efficiently in this environment that provides a framework for consultation and communication and creates conditions where individuals are encouraged and prepared to report hazards, near misses and incidents'.*

Interviewee six indicated that toolbox talks and health and safety tours are very important tools of communication that have been developed within his company and have consistently helped to identify relevant issues of safety. He stressed that team leaders and supervisors are encouraged to undertake toolbox talks at the beginning of shifts to remind employees on the need for safety and the hazards around; they bring up issues affecting their own health and safety on the job as well. In this manner management also communicates their commitment to health and safety to employees thus enhancing safe behaviours in employees. Findings of risk assessments are also required by the management of health and safety regulations to be made available to all employees by their employers as a way of communication.

Relationship between behaviour-based safety and safety culture

Some organisations have introduced behaviour-based safety (BBS) methods in a bid to reduce work-related incidents and accidents. Behavioural theory focuses on the main behaviours that lead to accidents rather than the accidents themselves, which are relatively infrequent and difficult to investigate objectively, or attitudes which are difficult to change. It is claimed that behavioural methods are proactive and focus on potential risky behaviour. BBS involves identifying, through observation; behaviours which are safe and those which involve risk of injury. However, behaviours have been distinguished from attitudes as people may sometimes behave contrary to their real attitudes based on some factors and certain reasons. Interviewees were asked to explain whether there be any link between behaviour-based safety (BBS) and safety cultures.

This question prompted discussions into the understanding of the differences between attitudes and behaviour. It was noted that cultures are firmly rooted in the norms and beliefs which people develop by virtue of the environment or childhood. Interviewee four stated that behavioural based safety is directed to study people's behaviour with respect to safety on their job. Attitudes are portrayed through behaviours and behaviours can be independent of attitudes when people are made to behave contrary to their attitudes, concluding that behaviour based safety can perhaps be a tool for assessing safety cultures within organisations through behaviour observation.

Likewise interviewees five and six were of the opinion that BBS programmes play a major role in promoting a positive health and safety culture. Interviewee five made known that behaviour safety interventions have been implemented across their building sites in the UK to correct employee unsafe behaviours when performing their duties on site. He found that a high level of management commitment played a vital role in implementing behavioural safety interventions. Interviewee six expressed the view that BBS can be used to discover reasons for the success or failure of safety culture programmes and requires continuous management support.

Behavioural based interventions appear to be a useful tool to improve safety behaviour within an organisation. Interviewee three believes BBS can put emphasis on safe behaviour on the worker rather than addressing the safety culture of the organisation. He cited an instance that if an employee is trained on safe behaviours, for example what to do if a machine gets stuck, if the safety culture of the company puts production pressures over safety that employee may still try to fix the machine themselves rather than following procedures and waiting for maintenance to fix it, adding that companies may find that BBS techniques are of more use in getting workers to adhere to health and safety procedures than bonus schemes.

Interviewee two made mention of the safety triad, which is a combination of three measurable components: work environment, person (employee) and behaviour, stressing that only when these three elements are combined can workplace accidents be eliminated. He said the behavioral part is often ignored and should always be implemented within organizations which show concern for safety and it's perhaps an indicator of positive safety cultures.

Influence of safety culture on subgroups

Employees tend to exhibit safe attitudes and behaviours based on experience, age and even nationalities as some people might have developed different safety attitudes by virtue of their national safety culture from where they come from. Interviewees were asked to assess the influence of subgroups such as; new workers, young/old workers, apprentices, female workers and immigrant workers on health and safety cultures in construction.

Strong health and safety cultures have a great influence on mostly new entrant workers with little experience. Interviewees stated that young and inexperienced workers are always placed under a supervisor that monitors effectively their work procedures to ensure their safety, although it is a requirement across sites that all operatives must have a Construction Skills Certification Scheme (CSCS) certificate that ensures their competence and safety on the job.

Interview four expressed that whatever the new site employee's background they are required to have the CSCS certification and are further put through in-house health and safety training, inductions and demonstrations before they are put on the job. He however stressed that young and apprentice workers do a have a gap in quickly adjusting to the safety culture, they are usually put under careful monitoring by their supervisors to see they have obtained a high level of competence before being allowed to carry out high risk jobs.

Interview six noted where a strong health and safety culture exists, it is usually an influencing factor for subgroup categories as actions of other workers will tell and make them adjust but where a poor culture exists it may further influence subgroups negatively as well. Thus it is the culture in existence that matters to how well subgroups are influenced.

Other factors that influence safety culture

Apart from factors mentioned above, there are other factors that may contribute to positive safety cultures in organisations. The interviewees were asked to highlight other measures that have been developed by their organisations to contribute to a strong health and safety culture and to suggest some other measures that could be adopted.

Here, respondents made reference to a range of initiatives which centred on caring for the employees, encouraging accident and near miss reporting so that lessons are learnt for the future. Also mentioned were use of written standard operating procedures for machinery and equipment. These procedures are usually drafted to ensure safe operation of machinery and must be adhered to by employees.

Interviewee one mentioned that a no blame policy has been adopted within his organisation, '*when near misses or minor accidents occur we ensure that no one is put on the spot for them, it is necessary that this is done so that employees can always speak and report such incidents for investigation and future improvements*'. He also mentioned that open confrontation on safety issues has been allowed such that lower employees can openly confront and correct each other and even their supervisors on unsafe acts.

Interviewee four stated that employees have been encouraged to quit and stop work processes when they feel unsafe or have not got necessary safety protection to the extent that they feel safety is uppermost than the job and wouldn't be blamed for such. Also mentioned is supervisors and managers setting good examples by always having their Personal Protective Equipment (PPE) and frequently welcoming and discussing safety issues with their employees, noting that when such enthusiasm is seen among them, employees are usually obliged to follow suit on such actions, bringing about a culture of safety first.

Also mentioned by respondent three is the issue of supervisors ensuring that the right thing is done at the right time such that there is no conflict between duties and processes. This has been said to help oversee site processes better and safely. Managers are also required to perform routine safety inspections often and intelligently, this is backed by the need to ensure that they have higher health and safety training to be able to identify and correct hazards on site. Continuous learning was also identified as a way of enhancing health and safety cultures, '*our employees are given safety training periodically and as new hazards arise from technology and projects, this has helped to maintain safe working systems across our sites and projects'*.

6. CONCLUSIONS

Although there is no consensus on how to define organisational safety culture, the concept is now recognised as an essential contributor to improved occupational safety performance in construction. Indeed, the subject of safety culture has attracted considerable attention in the literature in recent years. The health and safety culture in an organisation is determined by interaction of the social and psychological relationships in the workplace. Other factors that influence safety culture in an organisation include its structure and work processes.

The safety culture in an organisation is part of the organisation culture. Indeed we can talk of other cultures such as a production culture, an innovating culture, etc. The safety culture in an organisation can change. The literature reviewed suggests that this takes place slowly and over a considerable period of time. The safety culture in an organisation can be assessed through qualitative methods such as ethnographic field surveys, focus groups, interviews and participant observation. Questionnaire-based methods are however useful in gauging the safety climate in an organisation. Safety climate is now accepted as a surface expression of a safety culture.

There is no empirical evidence suggesting a link between safety climate and safety performance. If there is any link, it is at best very weak. There is also no universal agreement on the on the factors that make up the safety climate concept. Furthermore, measurement of safety performance remains a challenge. Use of lagging indicators such as accident rates and compensation costs is a measure of system failure, not safety performance. Leading indicators such as: risk exposure, unsafe behaviours, etc must also be taken into account.

Factors that influence positive safety cultures in construction have been evaluated by interviewing six safety mangers in large construction organisation that are known to exhibit strong safety cultures. The factors that have been identified to positively influence safety culture are these:

- Top management commitment to safety and leadership
- Employee involvement including middle level managers and supervisors
- The type, size and location of project thus dictating the inherent risks

- Senior management training in safety
- Formal and informal communications on safety matters founded on trust
- Use of programmes such as behaviour based safety

- Initial close supervision of at risk groups such young and inexperienced workers.
- Insisting on industry recognised qualifications such as CSCS cards in recruitment and selection decisions.
- Encouraging open reporting of accidents and near misses
- Periodic training to identify hazards arising from new technology, construction plant and projects

In summary, the factors that contribute to positive and negative safety cultures in construction can be grouped into six categories: organisation factors, individual factors, team factors, project related factors, management factors and supervisory factors. This work is part of an ongoing research project with the overall aim of recognising and understanding the complexity of health and safety culture on construction sites, and to develop successful measurement methods and intervention tools to create positive cultures on a construction sites.

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Health and Safety Communication at Olympic Park – Emerging Findings

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Health and Safety Communication at Olympic Park – Emerging Findings

Abstract:

Safety performance in construction continues to generate much interest. Despite continuing efforts to reduce deaths, injuries and ill health, the UK construction industry has high rates of fatal and major injuries. Linkages between safety programs and the actual state of safety have been studied extensively, but typically focus on programs run by single organizations. The London 2012 Olympic and Paralympic Games construction project offers a unique opportunity to investigate the impact of safety initiatives and communication across a range of organizations working side by side. Numerous techniques have been employed to elucidate this, including: interviews, focus groups, analysis of paperwork, and observations of safety meetings. This has revealed a client and project management system which aims to facilitate communication and safe practice. Collaborative communication was found; contractors learn from each other and knowledge is transferred both within Olympic Park and to other projects managed by the same contractors. Numerous sources and channels of communication have been identified, some of which appear novel, and it has been possible to track safety messages through various layers of management. The impact on workers is complex, but there is evidence that workers are changing their safety behavior, although the transfer of this behavior to different contexts has yet to be tested. Lessons learnt and good practice are also being transferred across contractor organizations and to other organizations.

Keywords: Communication, Health and Safety, Construction

1. Introduction

This paper outlines research investigating health and safety communication during the building of the London 2012 Olympic and Paralympic Games. The research was funded by the UK Institute of Occupational Safety and Health (IOSH) and access for data collection was facilitated by the Olympic Delivery Authority (ODA) Learning Legacy Team. This research seeks to gain insights into health and safety communication good practice, aiming to provide the construction industry with recommendations to enable them to communicate more effectively with their workforce when engaged with large, multi contractor projects.

Safety performance within the construction industry generates much interest, because despite efforts directed at reducing the number of deaths, injuries and ill health, construction has one of the highest rates of fatal and major injuries (Hide et al, 2003). This continues to be the case and in the UK, where in 2009/10 there were 42 fatalities in construction (HSE, 2011). Detailed information can be found relating to the types of accidents which are prevalent within this industry but their underlying causes are less understood. Hide et al (2003) indicates that accidents arise from failures in the interaction of variables associated with the work team, workplace, equipment and materials. Furthermore, the actions, behavior, capabilities and communication of the work team are influenced by their attitudes, motivations, knowledge, skills, and supervision. Dainty et al (2006) also highlight the influence of communication on the behavior of the workforce. The complexity of the construction environment makes communication within projects challenging. In this dangerous environment, if this is not overcome it can have negative consequences for health and safety (Dainty et al, 2006).

Abudayyeh et al (2006) suggest that successful safety initiatives rely on the participation of both managers and workers in establishing a feedback system that drives continuous improvement. Aksorn and Hadikusumo (2008) agree that management support is the most influential factor for safety program implementation in their study of success factors influencing safety initiative performance. Abudayyeh et al's (2006) own findings go on to suggest that management commitment and leadership can be demonstrated by managers who have appropriate knowledge and skills, who involve and empower their workers, who have good communication skills and who devote time to monitoring performance.

Linkages between safety programs and the actual state of safety have been studied extensively, but in most cases this has involved the investigation of programs run by single organizations. The London 2012 Games construction program offers the opportunity to investigate communication systems in a uniquely complex environment, across a range of organizations working side by side, allowing comparisons to be made and good practice to be determined.

Communication Human Information Processing Model

There are many models which describe the communication process; however in this research the Communication-Human Information Processing (C-HIP) model of communication outlined by Conzola and Wogalter (2001) is most applicable. This model has been designed to address the communication of health and safety information. It goes beyond the understanding of information, recognizing the importance of attitudes/beliefs, motivation and ultimately the impact of communication on safety behavior. Safety communication must pass through a number of stages to successfully impact on behavior. The stages are: Source, Channel, Attention, Comprehension, Attitudes/Beliefs, Motivation and Behavior. If information is blocked, at any stage, this can have negative consequences for safety behavior. Therefore, to evaluate if health and safety information is being successfully communicated it is important to examine the communication process in its entirety.

The London 2012 Games Construction Project

The London 2012 Games construction program consists of Olympic Park (OP), Europe's largest construction project, the Athletes Village, Europe's largest new housing project and several other sites at different locations (Bust, 2011). To understand the communication process at OP it is helpful to know how the Park is organized and structured. The Client is the ODA; they are the public body responsible for developing and building the infrastructure and venues for the Games. The ODA have engaged a delivery partner, CLM, a consortium made up of three organizations – CH2M Hill, Laing O'Rourke and Mace (London 2012, 2011). CLM help ODA to project manage the delivery of the Olympics' venues and infrastructure (London 2012, 2006). The various infrastructure projects and venues are then managed by a Principal Contractor (or Tier 1 contractor). The only exceptions to this are various temporary venues (e.g. Basketball) which have CLM as the Principal Contractor. Within each site there are various subcontractor Tiers. ODA and CLM communicate directly with Tier 1s, who then communicate these messages to the subcontractors within their site. The workers are typically employed by subcontractors, and the majority of daily safety messages will come directly from the subcontractor, however Tier 1s may also communicate directly with the workforce. Communication is not unidirectional and systems are in place to allow communication in various directions.

Aims

The aim of this paper is to discuss our emerging finding, specifically:

1. The processes by which main hazards and safety messages are communicated to workers on OP;
2. The extent to which OP Health and Safety initiatives impact on individual workers on site, in terms of awareness, attitudes and behaviors;
3. The extent to which contractors on the OP learn from each others' implementation of initiatives; and
4. The extent to which good practice from OP is transferred to other sites managed by OP contractors.

2. Method

Research Design

The research was conducted in two main stages, "Time 1" and "Time 2", with interviews and focus groups conducted at each. Concurrently, additional data was collected (direct observation of meetings and document review). Between Time 1 and 2 preliminary analyses was undertaken. Inventories for Time 2 data collection were amended to focus on emergent themes and issues, and determine the successful transfer of safety messages. At Time 2, interviews and focus groups were also conducted at comparison non-Olympic sites.

Data Collection Techniques

A number of techniques were used to collect data relating to the communication of health and safety information. This section provides an overview of the various data collection methods used.

Observation of Meetings and Document Analysis to Establish Key Health and Safety Messages for Tracking. Various meetings were attended including: Safety, Health and Environment Leadership Team (SHELT), the Health, Safety and Environment Forum (referred to as the "Forum"); and meetings with contractors and their supply chain. The Forum was the primary focus of observations. It occurs monthly, with attendees including: the CLM assurance team; senior personnel from ODA and CLM; and senior site managers and health and safety managers from contractors. The meetings cover: health and safety campaigns; emergent health and safety issues; lessons learnt; and good practice. Supply chain meetings were attended with one contractor. This enabled direct observation of safety message transfer.

Various documents have been obtained, including: minutes from the Forum; information from the ODA Site Communications team about the health and safety campaigns they had run; information from the document management system; and project Health and Safety Plans.

From the meeting observations and document analysis it was possible to determine the main Pro-active campaigns (developed in advance of a likely risk or hazard emerging) and Reactive safety messages (developed in response to accidents or near misses). Once a preliminary list had been established it was checked with the CLM assurance team (who monitor health and safety data and run the Forum meetings) and the ODA Lead (a gatekeeper role – providing information and advice to the research team) to ensure its accuracy. This final list was used in the Time 2 interviews and focus groups to determine if information about these health and safety campaigns had successfully transferred to site and the workforce.

ODA and CLM interviews. Interviews were conducted with pertinent members of the ODA and CLM teams to obtain an understanding and overview of the OP structure, organization and development. The semi-structured interviews were based on broad topic areas including: general health and safety; initiatives and interventions; communication flow; knowledge transfer; and impact on the workforce's awareness, attitudes and behavior.

All interviews and focus groups were recorded digitally, transcribed and typically lasted about an hour.

Site Interviews. Semi-structured interviews were conducted at seven OP sites. At each site, personnel from various levels of seniority were interviewed, from the Project Director to supervisory personnel. The Time 1 interviews were conducted in November / December 2010 and the Time 2 interviews were conducted from March to May 2011. Time 1 interview inventories were designed based on the aforementioned C-HIP model of communication (Conzola and Wogalter, 2001). Using this model to formulate questions allows the entire communication process to be assessed as well as the impact on workers' behavior.

Inventories were augmented to take account of developing themes and check the successful communication of key messages which had been identified at Time 1. The Time 2 interview inventories probed a number of areas in more depth, including: leadership; supervision; behavioral safety training; planning and organizing; creating an environment; worker engagement; changes in worker behavior, attitudes and awareness; and knowledge transfer. Sections were also included to specifically check that the key ODA / CLM safety campaigns and messages had successfully transferred.

Focus Groups. Focus Groups with workers were conducted at each site at Time 1 and 2. Participants varied in terms of trade, experience in the construction industry, time at OP, and the vast majority were male. Semi-structured inventories were used and, akin to the interviews, the questions changed between Time 1 and 2, with Time 1 interviews based around the C-HIP model and Time 2 inventories probing specific themes and message transfer.

Comparison Interviews and Focus Groups. Interviews and focus groups were conducted at six sites elsewhere in the UK within two contractor organizations. Interviews were conducted with senior site managers, health and safety managers and supervisory staff. Focus groups were conducted with operatives. The inventories were similar to those used at Time 1 on OP, but focused more on learning and knowledge transfer.

Interview and Focus Group Analysis.

Thematic analysis was conducted on the interview and focus group data.
To date, a preliminary analysis of this qualitative data has taken place identifying emergent themes. These emerging themes are outlined in the next section.

3. Results

This section outlines the main research findings corresponding to each research aim. The first two aims are discussed together by outlining findings in relation to the stages of the C-HIP model and facilitating factors which aid health and safety communication at OP.

Research aims 1 and 2 – Communication Process and Impacts on Safety Behavior

It has been possible to determine the communication process and track messages through all the stages of the C-HIP model, from source to behavior. It is apparent that there are various facilitating factors at OP, which aid the communication of health and safety information, these are also discussed in this section.

Source. The main sources of health and safety communication are ODA / CLM and contractors. Subcontractors also provide information, especially large organizations. Communication flows in all directions: (1) communication messages are initiated from ODA / CLM and are transferred through sites to the workforce; (2) communication messages from the contractor or subcontractor (either internally on the site or from outside the Park) are transmitted to the workforce; (3) numerous forms of engagement are used to capture the views of the workforce and pass this information on to contractors; (4) information is transferred between contractors and individuals via formal and informal communication systems; (5) information is also passed from contractors to ODA / CLM in various forms.

Channel. Due to limited space, only the most pertinent channels are discussed. The most effective forms for the workforce were frequently said to be verbal face-to-face talks and conversations e.g. daily briefings, toolbox talks. Some forms of face-to-face verbal communication are not well received e.g. site inductions. Effective verbal communication is to the point, relevant and involves interaction. Switching between different media, humor and real world examples is also helpful. Pictorial information is useful especially for people who do not have English as their first language. For workers, other forms of communication seemed to have a supporting role, reinforcing health and safety messages e.g. posters. Behavioral safety programs were being implemented with varying success and with mixed reactions from workers. Various communication channels between ODA / CLM and contractors were discussed. The Forum was mentioned frequently, enabling the dissemination of key information and allowing contractors to learn from each other. Site visits, between contractors were useful as contractors learnt from each other and adopted practices they observed.

Comprehension / Understanding. Health and safety messages were perceived as easy to understand. Workers did not always understand why certain rules were in place, indicating that some aspects of health and safety should be flexible and required more "common sense". Understanding why rules are implemented is important, as workers indicated that if they appreciate this they are more likely to comply. It was also apparent that workers had received information about the key proactive and reactive safety campaigns.

Attitude and Beliefs. Attitudes and beliefs displayed by ODA / CLM, contractors and subcontractors were typically positive to health and safety. More inconsistency was found in the workforce. Although they showed frustration in some instances, all valued the importance of health and safety, and working in a safe environment. Workers' reactions depended on implementation style. There was a dichotomy in beliefs about management motivations, with some workers believing that management truly "cared" about their wellbeing and others claiming that it was a means of management protecting themselves. Sites with effective worker engagement seemed to engender positive responses from their workforce. On these sites management were said to listen to the workforce and act on their concerns.

Motivation. Safety behavior was determined by a number of interacting variables and varies between individuals. However, some generalizations can be made. Workers' motivation for behaving safely stems from a desire not to injure themselves or colleagues, and concerns about the impact of an injury on their family. For some workers, often those who had worked on large projects for a long time, it seemed to be an unconscious habit, indicating that they knew what was expected and conformed. For others, motivation to behave safely stemmed out of a fear of being observed disobeying the rules and the potential consequences of this.

Behavior. Workers indicated that they were complying with rules and behaving safely, including wearing the correct PPE. There was evidence that key proactive and reactive campaigns had impacted on worker behavior e.g. they asked for sunscreen following a campaign about summer working. Some workers indicated that they expected that as projects come to an end they will be put under pressure to take risks. They indicated that it had not happened yet, but they believed that it would. This is a reflection of the industry rather than OP and demonstrates a mental model of what typically happens within the construction industry.

Tracking Messages. Interviewees, including subcontractors, and focus group attendees were familiar with the key campaigns and safety issues. This showed that health and safety messages were being successfully transferred from ODA / CLM, to Contractors and through their supply chain to their workforce.

Client and Project Management Systems which Facilitate Communication and Safe Practice. Various factors have been highlighted which aid the communication process. Leadership from ODA / CLM has been highlighted as important and influential. They are perceived as truly prioritizing health and safety and do not "pay it lip service". Visible leadership is also important on sites with management frequently making themselves accessible to the workforce. A positive environment for safety has been encouraged; worker engagement and behavioral safety programs are particularly pertinent. On sites where they have been effectively implemented, the culture is open; workers, feel able to stop work and raise issues, receive feedback, and believe that management care for their wellbeing. Reward systems have been implemented, both for contractors and for personnel within contractors, to positively reinforce the safety message and encourage safe behavior. Planning ahead, and having the time and resources to do so, has been highlighted as important. This enables forward planning of the health and safety messages communicated to the workforce. Obtaining and developing a competent workforce has been highlighted in a number of guises. Generally, it is perceived that personnel, ranging from ODA senior management to the workforce, have a high level of competence. This is aided by training programs and systems for checking competence. The competence of supervisors was addressed through specific training focusing on communication skills. Continuous health and safety improvements are made by reviewing health and safety in an ongoing process, disseminating lessons learnt and developing standards of common practice.

Research aim three – Sharing good practice between OP contractors

Good practice is transmitted in a variety of ways. In Forum meetings, presentations and discussions take place covering, accidents and near misses. Through cross site visits contractors are able to observe health and safety practices taking place on other sites and adapt them for their use. However, due to the wide adoption of some initiatives it is not always possible to determine where they originated. "Common Standards" outlining appropriate safety practices at OP are produced in a collaborative manner and contractors agree to adhere to them. Informal networks operate extensively across OP. Subcontractors are learning from Tier 1 contractors. Some indicate that they are taking many of the policies, procedures and practices they have observed back into their own organizations.

Post completion, outside of the Games culture, knowledge sharing between contractors could be inhibited. A good safety record and practices which support this are currently used as a marketing tool and a source of competitive advantage.

Research aim four – Transferring good practice outside of OP

Many interviewees said it was difficult for people based at OP to know what good practice had been implemented elsewhere. However, through the comparison interviews and focus groups it has been possible to determine good practice transfer. Although this data is more limited in scope, coming from two organizations, it is possible to see good practice transfer. Personnel transferring to different projects are taking their knowledge with them and implementing good practice.

4. Discussion and Conclusions

The process of communication at OP has been revealed as an efficient system of formal and informal communication. Communication is not unidirectional and contractors communicate frequently with each other and the workforce is engaged, encouraging them to highlight health and safety issues. This has been facilitated by ODA / CLM who have pushed workforce engagement and the development of informal networks across OP. Attitudes to health and safety were generally positive, but with more mixed views amongst the workforce. The workforces' motivation for working safety varied on different sites, depending mainly on the engagement and discipline process. Typically, workers were behaving safely. Good practice is shared between contractors at OP. Monitoring and communication systems developed by ODA / CLM enable contractors to learn from each other's incidents and communication initiatives. Knowledge transfer beyond OP is more difficult to track, but comparison site data demonstrates that initiatives and practices developed at OP are being transferred. As people leave OP they take their tacit knowledge with them, implementing what they have learnt on new sites.

This research concurs with literature which has discussed the influence of communication on safety behavior. Specifically, organized systems of communication (Dainty, 2006), management support (Aksorn and Hadikusumo, 2008) and competent management who engage their workforce (Abudayyeh et al, 2006) are pivotal. The C-HIP model has utility, providing a means of systematically checking each stage of the communication process, and evaluating successful transfer of information and influence on behavior.

Recommendations for improving practice can be aimed at different levels of the construction industry. Large, multi contractor projects could directly adopt some of the communication systems used at OP, the use of a delivery partner (or overseeing management layer) to co-ordinate and facilitate communication is useful; specifically, Forums, cross-site visits, the intranet systems and assurance systems could easily be adopted by other projects. Contractors in general can facilitate effective communication by: having visible leadership (ideally, including the client); fostering an open, positive safety culture; positively reinforcing safe behavior through reward systems; allowing sufficient time to plan ahead; developing a competent workforce; and putting reviewing and learning systems in place to allow continuous improvement. For all organizations good practice in terms of dealing with the workforce can be implemented. Where possible, safety information should be given verbally, with the support of other media. Ideally, talks should be brief, practical, relevant to individuals' jobs, interactive and include humor. The workforce is more likely to get involved with the health and safety process if they are engaged and feel that management care for their wellbeing. It is also important that when workers raise issues that they receive feedback on what is done. To achieve compliance, it is essential that workers understand why rules are in place. Managing unsafe behavior is a sensitive issue and it is better to talk to the worker directly when observed. Workers resent it if they are reported without being spoken to. Where this occurs it can cause problems, appearing to lead to us / them cultures and less engagement.

Overall, OP demonstrates an efficient system of health and safety communication. Effective practice has been identified which the construction industry can apply to facilitate the communication of health and safety messages. These emerging findings will be developed further in the remainder of the research project.

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Fall Prevention Training and its Impact on Trainees

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Abstract

Death and injury from falls are a long-standing and continuing problem in construction, responsible for at least a third of the construction deaths in the U.S. from 2004-2007. Nevada has exceeded the national percentage each of those years. While loss of balance is the proximate cause of most falls (Hsiao, Simeonov 2001), multiple biomechanical, psycho-physiological, and environmental factors interact to increase or decrease risk of loss of balance. While "both physical and visual training can improve postural stability by enhancing the mechanisms of balance control" (Hsiao, Simeonov 2001), conventional fall protection training is more narrowly focused on recognizing fall hazards and using fall protection systems. Although 29 CFR 1926.503 sets forth Occupational Safety and Health Administration (OSHA)'s requirements that construction employers train employees exposed to fall hazards and document such training, the incidence of deaths and injuries from falls are an indicator that such training is either not provided or effective. The specific aim of this study is to 1) design, deliver, and evaluate an effective fall prevention training program for Southern Nevada construction workers, a large proportion of whom are Hispanic; 2) produce English and Spanish curricular materials, including the training approach, for dissemination; and 3) measure the impact of training on workers' self-reported job site behavior. Through these aims, we will reduce risk of occupational injury or death from falls. In focus groups, Southern Nevada Hispanic construction workers expressed a desire for practical, simulation-based learning, with role playing specific situations. Many foreign-born Hispanic laborers are unfamiliar with formal lecture-based classes and have learned their trades through hands-on apprenticeships or tutoring by mentors. Therefore, practical, role playing methods were used in a course funded by an OSHA Susan Harwood Training Grant. This paper will discuss the materials and methods used in the training, report the assessment of participants' knowledge about the use of fall safety equipment, and summarize the

feedback of the participants. This paper also will provide the initial findings of the follow up survey conducted with the participants to measure the immediate impact of training on self-reported job site behavior.

Keywords: Falls, OSHA, Personal Fall Arrest Systems, Construction, Hispanic Workers

1. Introduction

Construction work is considered to be one of the most dangerous jobs, compared to other industries. Whether building homes, dams, bridges, or skyscrapers, most construction workers have to work on heights that can lead to a fatal fall. Death and injury from falls are a long-standing and continuing problem in construction, responsible for at least a third of the construction deaths in the U.S. from 2005 – 2007 (Table 1). Nevada has exceeded the national percentage each of those years.

Table 1. Construction fatalities due to falls in Nevada and U.S.

Year	Fatal Falls (% of Total) Nevada	Fatal Falls (%) U.S.
2007	8 (38%)	447 (37%)
2006	7 (39%)	433 (35%)
2005	6 (46%)	394 (33%)
2004	9 (60%)	445 (36%)

Sources: Nevada Division of Industrial Relations and United States (U.S.) Department of Labor, Bureau of Labor Statistics (2005 – 2009)

The Occupational Safety and Health Administration (OSHA) divides falls into whether they were from a higher level to a lower level or on the same level; the former is a more frequent cause of death and injury. Table 2 shows the number of fatal injuries, fatal falls, and falls to lower levels that occurred from 2005 to 2009. In injury cases, ladder-related falls often result in long work absences and sometimes permanent disability (Smith et al. 2006). Although in most of the serious fall-related injuries, workers suffered fractures to the spine, vertebra, shoulder, hip, arm, hand, and legs, in 9 out of 10 fatal injuries, workers died due to a fracture of the skull or to brain injury (Hsiao, Simeonov 2001).

Table 2. Fatal falls and falls to lower levels in the U.S.

Year	Total Fatal Injuries	Fatal Falls	Fatal Falls to Lower Level
2009	4340	617	518
2008	5214	700	593
2007	5488	847	746
2006	5703	827	738
2005	5734	770	664

Source: U.S. Department of Labor, Bureau of Labor Statistics, Census of Fatal Occupational Injuries

OSHA data show that the majority of fatal falls occurred while working on roofs, ladders, scaffolding, staging, and steel structures. In the past five years, falling from roofs and ladders constituted the greatest number of fatalities related to falls (Table 3). Clearly, these statistics imply the necessity of fall prevention training.

Table 3. Fatality percentage by type of works.

Year	Fatal Fall to lower level	Roof	Ladders	Scaffolds and stagings	Girders or steel structure	Total	Percentage
2009	518	109	122	53	15	299	57.72
2008	593	123	119	68	30	340	57.34
2007	746	161	132	88	42	423	56.70
2006	738	185	132	91	33	441	59.76
2005	664	129	160	82	25	396	59.64

Sources: Nevada Division of Industrial Relations and U.S. Department of Labor, Bureau of Labor Statistics (2005 – 2009)

2. Target Population

Today, the ethnic composition of United States has changed because of the large wave of immigration in the last two decades (Brunette 2005). According to the U.S. Census Bureau, as of July 1, 2009, there are 48.8 million Hispanics living in the nation, making them the country's largest ethnic minority. Another study by the National Institute for Safety and Health (NIOSH) revealed that in the last decade, the number of Hispanic workers doubled among all U.S. industries and more than tripled in construction, as shown in Figure 1(CPWR Data Center 2009).

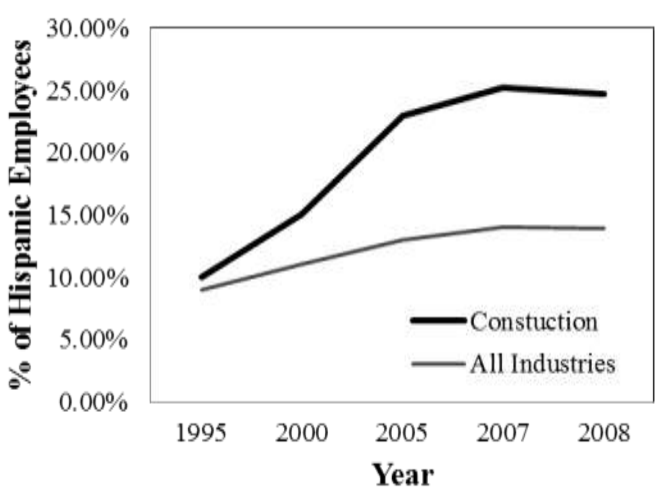

Figure 1. Hispanic employees as a percentage of Construction workforce versus All Industries.
Source: U.S. Department of Labor, Bureau of Labor Statistics, Census of Fatal Occupational Injuries

Hispanic workers are subjected to more severe and hazardous working conditions and have a higher injury and illness rate than non-Hispanic whites (Baker et al. 1999). In 2006, the U.S. Department of Labor reported that fatal work injuries involving Hispanic workers reached the highest on record. Fatalities for foreign-born Hispanic workers increased from 12% in 1996 to 18% in 2006. Until 2006, the rate of fatal injuries for Hispanic construction workers was about 41% higher than white, non-Hispanic construction workers. However, the fatality rates for these two groups were same in 2007 and 2008. A study done by Dong et al. (2010) found that between 2003 and 2008, 40% of work-related deaths among Hispanic construction workers are caused by falls; 80% of these workers were foreign-born.

Geographically, Hispanic workers are found to be more concentrated in the southwestern U.S.; in 2007, 40% of the construction workers in Nevada were Hispanic (CPWR Data Center 2009). Besides the high concentration, the percentage of Hispanic workers death in relation to total construction workers death in Nevada is higher than that of whole country from 2006 to 2009 (Table 4). The data showed that the percentage of Hispanic death in Nevada is rising compared to that of whole country. Southern Nevada experienced a residential and commercial building boom from 2005 to late 2007; when the current recession began, construction stalled in Nevada, as in the rest of the country. In the U.S., construction employment has fallen by 1.3 million since the start of the recession (Bureau of Labor Statistics 2011). Among those who lost jobs, Hispanic construction workers have been affected disproportionately (Kochhar 2008). Some construction unions have reported a drop in membership due to job losses, reducing the funds available to them to provide safety training to their members. However, these employment challenges also represent an opportunity to attract underemployed workers to participate in fall prevention training classes in preparation for the next increase in construction job demand. Although available to all construction workers in Southern Nevada, this training focuses on Hispanic construction workers as an at-risk population.

Table 4. Percentage of Hispanic workers death in relation to total deaths in Nevada and in the U.S.

Year	% of Total Nevada	% of Total U.S.
2009	25.0%	15.4%
2008	31.7%	15.4%
2007	16.9%	16.6%
2006	24.5%	17.0%

3. Curriculum Development

The federal Occupational Safety and Health Act of 1970 and associated regulations mandate that employers provide education and training regarding job site safety to their covered employees. The training requirement stipulated by the Occupational Safety and Health Administration (OSHA) covers such factors as who is to be trained, when initial training is to be completed, frequency of training, content of the training program, and access to information and training materials. Although these requirements seem specific, rather they are quite ambiguous. For example, the conceptual approach to training and the organizational structure for training and instruction are not clear (Vojtecky, Schmitz 1986). The basic objective of the training is self protection against site hazards. Thus, the theory is that better trained workers are more aware and cautious, therefore less susceptible to hazards and accidents. For Hispanic workers, safety education and training are essential to reduce fatalities in the construction workplace. However, training for Hispanic workers requires resources that are linguistically and culturally appropriate; for example, the translation of existing English resources into Spanish requires rigorous care (National Research Council 2003). Baker et al. (1999) documents the difficulties of this process, since much of the language used in OSHA safety standards is specific to English and has no readily comparable counterparts in the Spanish language. Few Spanish language documents are of good quality, but rather are mere translations of available English material and are often inaccurate (Brunette 2005).

A study conducted by Thompson and Siddiqi (2007) found that construction employers need to understand Hispanic cultural issues comprehensively and to use that knowledge to their advantage to significantly reduce injuries to Hispanic workers. Creating awareness about the workers' importance to their families has also worked well to create safety awareness. In addition, this research found that Hispanic workers often have a tendency to ignore bringing up safety issues to a supervisor; therefore, they needed to be educated on the importance of initiating discussions of safety concerns with supervisors. Providing extensive safety training in their own language was important because most of the skilled workers in Spanish-speaking countries get jobs in their homelands; most of the people who come to U.S. seeking jobs are unskilled. This research emphasized the importance of developing Spanish language training materials and providing hands-on training.

For this fall prevention training, the curriculum topics were selected by considering the most recent data available from OSHA regarding fatalities at construction sites. From OSHA safety data of 2009, iron workers had the most deaths occurring in the construction industry. The number of deaths per 100,000 full-time workers for iron workers and roofers were about 10 and 8 times higher, respectively than the construction industry average. Figure 2 shows the number of deaths per 100,000 full-time workers for various types of workers involved in the construction industry. The data also show that the majority of these workers died from falling from heights. Therefore, these factors were considered during the selection of the topics to be included in curriculum.

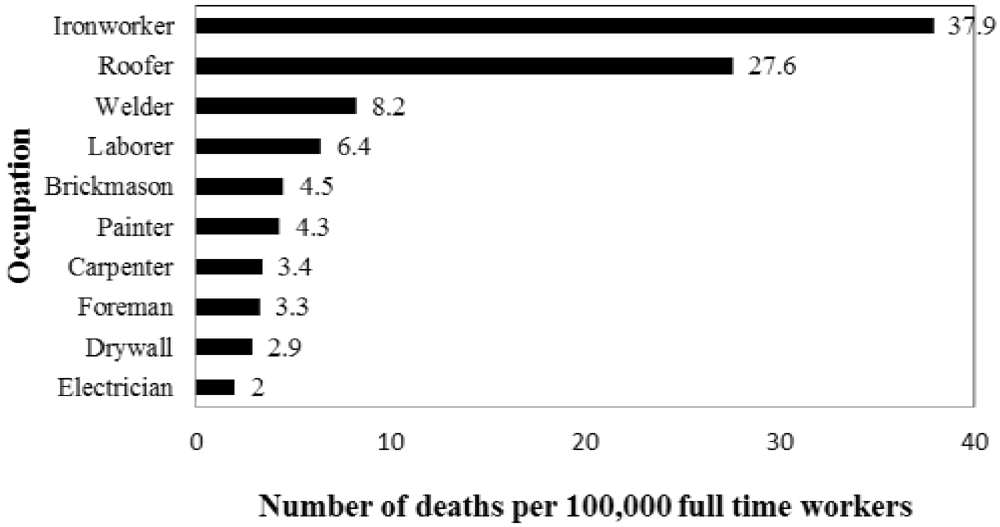

Figure 2. Fatality rate of various construction occupations.

The training topics exclusively covered in the fall prevention class provided under this Susan Harwood Training Grant are listed below:

- Assertiveness Training
- Fall Protection Requirements
- Fall Protection Hierarchy
- Safe Work Practices
- Falling Object Hazards
- Warning Line Systems
- Safety Monitoring Systems
- Safety Nets
- Controlled Access Zones
- Guardrails
- Personal Fall Arrest Systems
- Harness Safety Checks
- Ladders Safety and Setup
- Scaffold Safety and Setup
- Connectors & Lanyards
- Anchor Points
- Equipment Inspections
- Rescue Plan
- Recognition of Environments with High Risk of Falls

A key element of this training program was to provide assertiveness training to enhance communication skills while working in construction sites. Trainees needed to have confidence that, if they recognized a poor safety situation, they have the right and ability to demand correction or safety equipment prior to proceeding.

All the training and educational materials were developed in English and then translated into Spanish. Figure 3 shows the flow chart depicting the curriculum development process. The English curricular materials were prepared by a faculty member of Construction Management Program at the University of Nevada, Las Vegas (UNLV) who has extensive experience in construction safety and by a nursing faculty member with expertise in occupational safety and health, who has conducted research with Hispanic construction workers. While preparing the training materials, such existing sources as eLCOSH and OSHA documents were used; in addition, original materials were created where necessary. The prepared English materials were translated into Spanish by a bilingual undergraduate student (a senior) at UNLV's Construction Management program. This student used English-to-Spanish OSHA dictionaries as well as other sources including:

- The Wiley Dictionary of Civil Engineering and Construction: English-Spanish/Spanish-English;
- Construction Spanish (en inglés y español);
- Constructionary, Second Edition: English-Spanish/Spanish/English by the International Code Council; and
- The R.S. Means English/Spanish Dictionary for Construction.

In accordance with Brunette's recommendations (Brunette 2005), the written materials were developed to a fifth grade literacy standard and contained many pictures. The training materials were sent to trainers at the Laborers International Union of North America (LIUNA) Local 872 and industry safety experts in Las Vegas for review and then sent to OSHA for final review. After the final feedback from OSHA, the training materials were printed on paper and in DVD format. These copies and DVDs were provided to the trainees so that they could refresh their knowledge periodically at the conclusion of the class. In addition, wallet cards with eight fundamental steps to avoid fall at job sites were provided to the workers so that they could have them at their job sites.

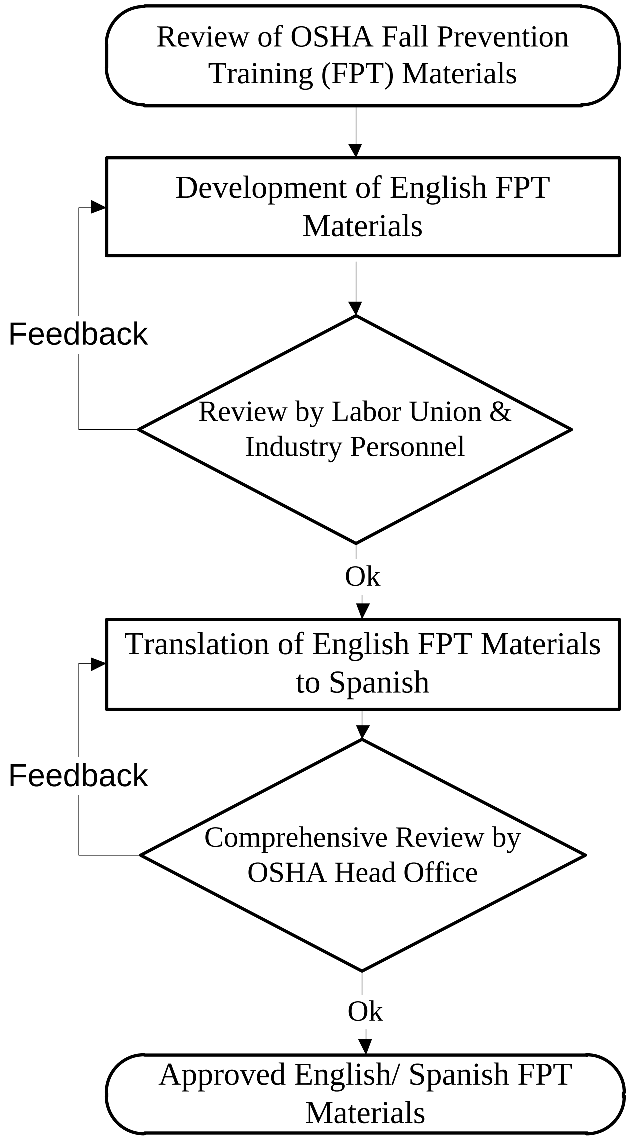

Figure 3. Flow Chart of Curriculum Development.

4. Training Approach

Safety training has been effective as primary prevention for construction injuries (Dong et al. 2004). However, because training minority worker populations is difficult due to literacy, language, and other socio-cultural and legal barriers, traditional lecture-based safety training approaches are often ineffective. The training program described here uses an innovative approach to providing fall prevention training using lecture-based as well as hands-on experience. During focus groups, Southern Nevada Hispanic construction workers expressed a desire for practical learning with role playing of specific situations (Menzel and Gutierrez 2010). Many foreign-born Hispanic laborers are unfamiliar with formal lecture-based classes and have learned their trades through hands-on apprenticeships or tutoring by mentors; therefore, this training used role playing, as well as hands-on experience as its primary teaching strategies. Construction safety training using hands-on experience has been found to be effective in improving knowledge. (Wojcik et al. 2003).The Hispanic community with which we partnered were members of the local LIUNA; laborers are the entry level job in the construction trades for most foreign-born construction worker. Laborers are the first workers on any construction project and the last to leave. In Southern Nevada, a wide range of OSHA-regulated construction companies employ laborers, from small residential subcontractors to large multinational firms. In the 2009 biennium, the Nevada legislature passed a law that requires all construction workers to have OSHA 10-hour training. OHSA 10-hour training is very general in nature; there is a recognized need for more detailed training in specific hazard areas as they apply to specific trades. Additional fall prevention training for construction workers is an example of specific additional in-depth training that is appropriate for this trade, given that laborers had double the death rate from falls (7.5 per 100,000 full-time workers) between 2003 –2005, compared to all construction trades (3.8 per 100,000) (Dong 2007).

Figure 4 shows the process used to train construction workers regarding fall prevention, as well as the impact study of the training under the Susan Harwood Training Grant. After development and the pilot testing of this course curriculum, separate training classes were conducted in English or in Spanish, based on the needs of attendees. Training was provided by instructors certified in OSHA 10- and 30-hour training. The bilingual student worker provided concurrent translation of the instructors' words, while the trainees followed the content in Spanish-language written materials. The eight-hour training class was divided into two four-hour sessions and was offered on either weeknights or weekends.

The training session included less theoretical instruction and more use of audiovisual materials, demonstrations and return demonstrations, and simulations of fall prevention methods. Approximately three fourths of the training involved classroom instruction and one fourth involved actual hands-on training. The classroom instruction was made interactive by showing recent, actual site photos of violations of safety rules; the trainees were asked to identify each violation and were encouraged to share their own site experiences. Hands-on training involved the use of the Personal Fall Arrest System (PFAS) and the fall prevention options including guard rails, safety nets, scaffoldings, and ladders. The participants' competency in using PFAS was also assessed during the hands-on training. In addition, they were asked to identify hazards involving defective ladders and scaffolds. At the end of class instruction, the trainees evaluated the class and made suggestions for its improvement. The study was approved by the UNLV Institutional Review Board. Those who consented to participate in a follow up impact study filled out a research contact information form. Eight weeks after each class ended, telephone interview were done with the trainees who provided consent for the impact study. The questionnaire was used to assess whether the trainees were able to recall and describe specific fall prevention skills, whether they had been exposed to fall hazards in the previous month, and, if so, what specific fall prevention behaviors they used, if any.

We also asked whether they fell at work in the past month or not and how many possible fall hazards they have avoided.

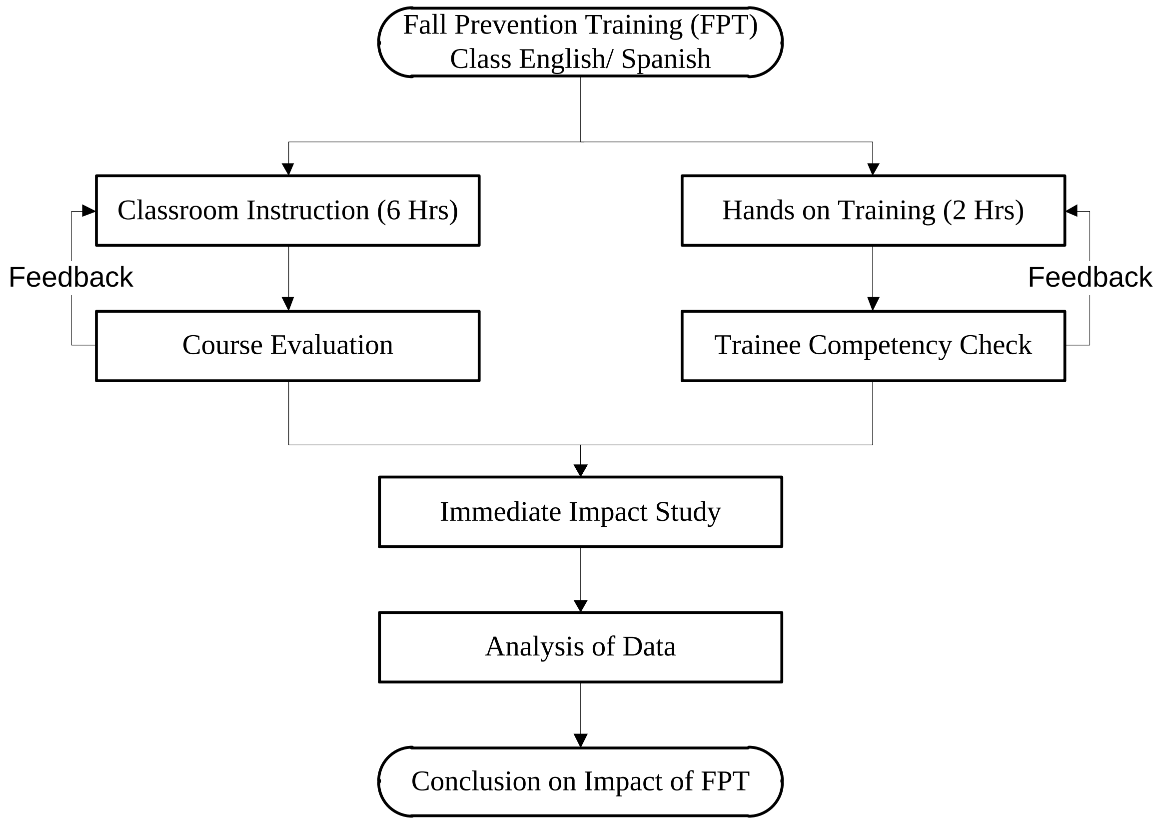

Figure 4. Training and Impact Study Process.

5. Results

The goal of this program was to train about 760 construction workers in Southern Nevada. During the time of this paper was written, about 100 trainees already were trained. Half of the trainees were English speaking, and half of them were Spanish speaking. The data analysis related to the course evaluations, trainee competency assessment, and immediate impact study of these trainees is described as follows.

Class Evaluation

All the trainees were asked to fill out class evaluation forms. The evaluation form was comprised of five questions regarding the course content and the instructors' abilities. It also had a Comments section to provide suggestions for improving the class. The respondents were instructed to provide a grade, using five point scales with 5 as 'excellent' and 1 as 'poor.'

The analysis of the evaluation forms showed that the class was effective in all categories mentioned in the evaluation forms. Table 5 shows the analysis of class evaluation data.

All five questions asked in the form had high ratings. The trainees agreed that the class helped to improve their skill in identifying fall hazards and to prevent accidents from falling. The trainees also said that the instructors were prepared to teach and responded their questions properly. The data also showed that both the English and Spanish classes were equally successful.

Table 5. Results of Class Evaluation Forms.

S. No.	Evaluation Criteria	Average Ratings		
		Spanish N = 50	English N= 50	Total N= 100
1	Increase your knowledge about dangers of falls on the job	4.8	4.7	4.75
2	Improve your knowledge of how to identify and prevent falls on the job	4.8	4.7	4.75
3	Improve your skills in preventing falls on the job	4.8	4.8	4.8
4	Instructors answered your questions properly	4.8	4.8	4.8
5	Instructors were well prepared	4.8	4.8	4.8

According to the comments, most of the trainees appreciated the effort of providing the training, and many thought that the training met their expectations. The majority of trainees hoped that the paper handouts and DVDs provided would be helpful in the near future. The participants were satisfied with the subjects covered in the class and also with the videos shown. Even though the course offered hands-on training, some of the trainees requested a site visit. There was mixed reaction about the duration of the class: some said that it was a long class, while others said that the class time should be increased to cover the topics in more detail.

Trainee Competency

Before the start of the hands-on training, the trainee competency forms from all the trainees were evaluated. Competency of the workers in using PFAS, guard rails, and ladders was assessed and graded as competent or incompetent. Figure 5 shows the result of the workers' competency assessments. The results show that about 75% of the trainees knew how to set up a ladder, install guard rails, and check PFAS and guard rail safety. About 60% of trainees knew how to use the PFAS and check for ladder safety. These percentages show that some of the trainees did not know safety systems for fall prevention. When the data were divided into English and Spanish trainees, it showed that the majority of English trainees knew how to set up ladders and check for PFAS safety, whereas the majority of Spanish workers knew how to install and check guard rails.

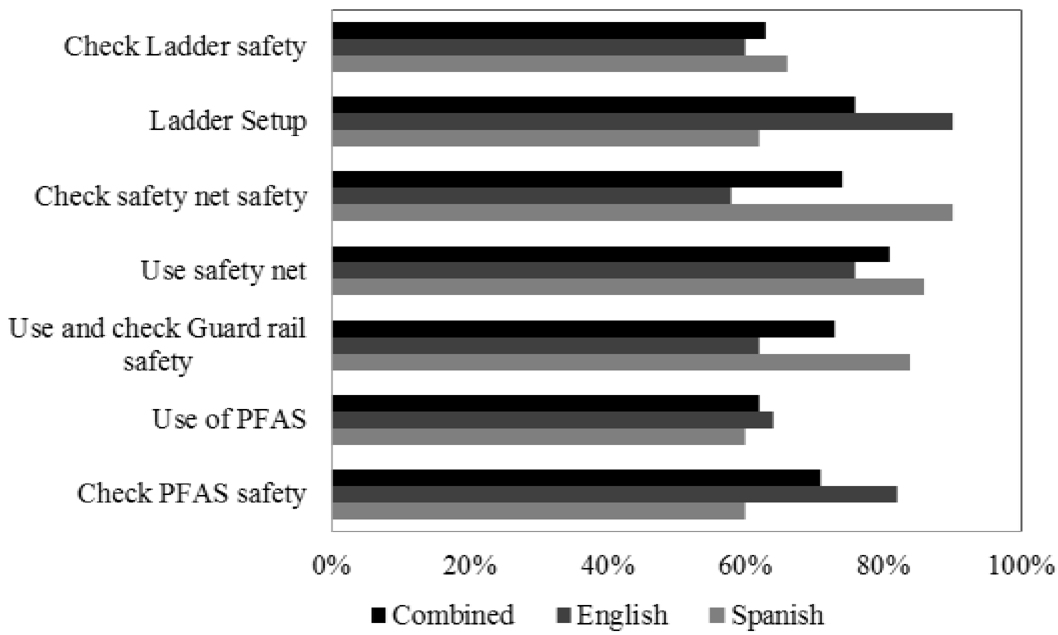

Figure 5. Results of Competency Assessment

Follow up interview

Follow up interviews were made eight weeks after completing the training. Telephone calls were made to 28 English-speaking and 23 Spanish-speaking trainees who completed this training to ask about the impact of the training in their day-to-day work behavior. The data from the follow up interview questionnaire conducted by telephone were analyzed, and is presented in Figure 6. The data showed that the most important topics covered in the training were portable ladder safety and the PFAS. The least important topic was about the safety nets. In the construction industry, safety nets are rarely used, so the trainees viewed this topic as least important. For the Spanish-speaking trainees, the most important topic was PFAS, whereas for English- speaking trainees, it was the portable ladder. Although there was a mixed result about the relevancy of these topics to their work, the majority of the trainees expressed that PFAS and portable ladders were more useful for their work. This indicates that a significant number of trainees had jobs that required a sound knowledge about the proper usage of PFAS and ladders.

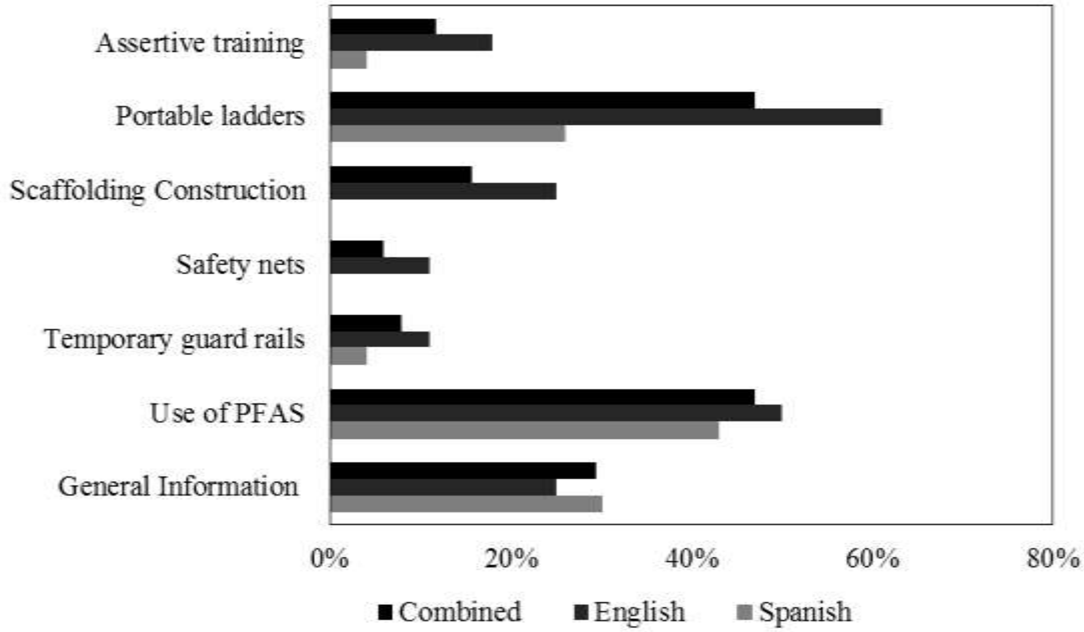

Figure 6. Usefulness of Fall Prevention Training Topics.

The data from the follow up interviews showed that the majority of trainees improved their fall prevention knowledge and made changes to their fall prevention behavior (Figure 7). About 80% of the trainees were involved in jobs that require fall prevention knowledge and skills. This indicated that after this training, most of the trainees were working in the construction jobs where they were exposed to fall hazards.

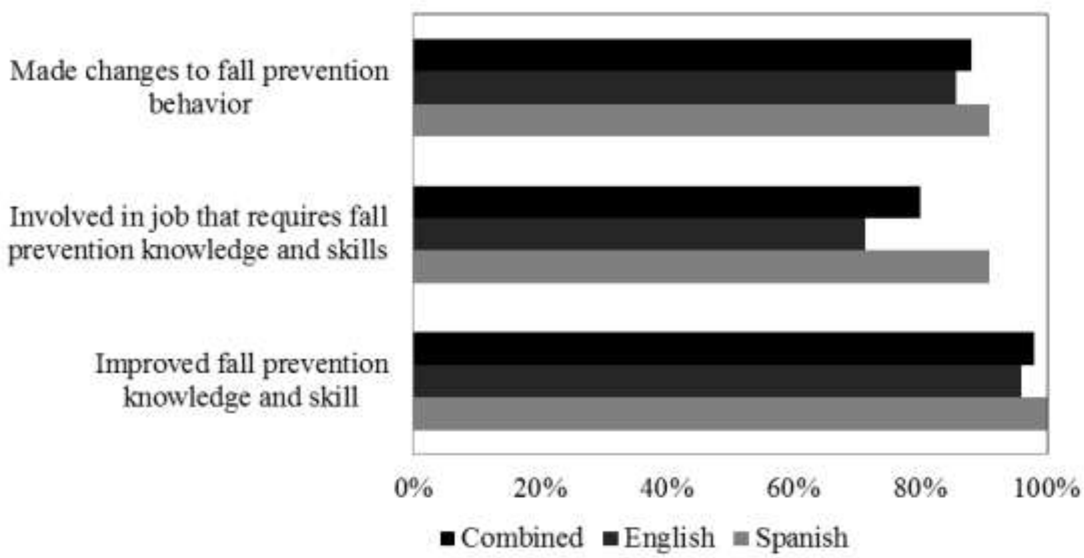

Figure 7. Impact of Fall Prevention Training.

6. Conclusions

The goal of this fall prevention training program was to improve trainee awareness of fall hazards at construction sites and to acquire the knowledge and skills needed to use safety equipment systems to prevent falls. The training curriculum was refined with the feedback of OSHA personnel, the local labor union, and construction industry professionals. Trainees judged the topics included in the training as very important. Similarly, analysis of the class evaluation form showed that the class was taught in an excellent manner and that the experienced instructors paid appropriate attention to the details of fall prevention methods. The majority of the participants found this training to be valuable. The data from follow up interviews also showed that the majority of the participants improved their fall prevention knowledge and skill. They indicated that as a result of this training, they changed their behavior to avoid falls at job sites. From the above analysis, the training program achieved its goals.

7. Acknowledgement

The authors want to acknowledge OSHA for providing the Susan Harwood Training Grant to develop and conduct this training. We also would like to thank all the construction industry personnel, labor union, and OSHA officials who gave constructive feedback during the curriculum development. Finally, we appreciate the participation of construction workers of Southern Nevada in this training.

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A Method for Measuring Safety Communication in Project Networks

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Abstract

Effective safety communication among all parties in a construction project is essential for optimal safety performance. Construction safety communication should include the following: (1) open discussion regarding safety issues among all individuals from different levels; (2) encouraging safe behavior by providing verbal feedback; and (3) implementing a lesson-learned program for safety. Previous studies have found that open communication and frequent interaction between employees and supervisors differentiates construction companies that have low accident rates from companies that have high rates. Through interviews with construction crew members on active construction projects, this research study identifies, analyzes, and quantifies patterns of safety communication. Social Network Analysis (SNA) was utilized to obtain measures of safety communication such as centrality, density, closeness, and betweenness within project teams. In addition, sociograms were used to visualize the safety communication patterns within effective safety networks. Preliminary results indicate that high performing crews had networks with high density and well distributed centrality among crew members. Conversely, low performing crews had high level of centrality for specific members and low level network density. The SNA strategy employed in this study can be used by practicing professionals to analyze and measure safety communication within their project teams.

Keywords: Safety communication, Communication patterns, Social network, Network density, Network centralization.

1. Introduction

Though workers in the construction industry account for 8% of the US workforce; statistics show that the occupations within the construction industry account for 21.7% of work-related fatalities (U.S Census Bureau 2006). In fact, there were 1178 fatal work injuries in the US construction industry in 2007 (Bureau of Labor Statistics, 2008) and between 2001 and 2003, over a million construction injuries were recorded by OSHA (National Safety Council 2001; 2002; 2003).

In 2005 alone, Hispanic workers accounted for 84% of construction workers in the US. Of these workers, 42% reported that they don't speak English even at a proficient level (CPWR 2007). Traditionally, Hispanic workers have been at a disproportionately high risk for workplace injuries, illnesses, and fatalities. Specifically, in 2005, Hispanic workers had a fatality rate of 12.4 per 100,000 workers while the fatality rate for non-Hispanic workers was 10.5 (CPWR, 2007). Unfortunately, the fatality rate for Hispanic workers has continually increased from 108 in 1992 to 321 in 2005. One potential cause of these alarming injury rates are communication barriers that exist among the many cultures represented on construction worksites.

Construction sites often involve multiple teams and multiple cultures that work together in the same workspace. Communication among these teams and individuals is critical when attempting to effectively implement a safety program. Effective safety communication should include the following:

- Clear communication and open discussion regarding safety issues to all individuals from different levels within one or more organizations;
- Encouraging safe behavior by providing feedback; and
- Implementing a lessons-learned program for safety.

The objective of this paper is to present a study that aims to (1) quantify the level of safety communication within small and medium-sized construction crews, (2) model the communication patterns and trends within these crews; and (3) critically analyze success factors and potential barriers with regard to safety communication on construction worksites. This study introduces social network analysis as a potential method to analyze this safety communication using metrics such as centrality, density, closeness, and betweenness. Particular attention was paid to modeling multicultural work crews where not all members of the crew speak the same native language.

2. Literature Review

Safety communication

It has been recognized that open communication and frequent interaction between employees and supervisors, or among employees themselves are significant characteristics that distinguish organizations with low accident rates from those with high rates (Zohar, 1980; Smith et al., 1978). For example, Smith et al. (1978) claimed that immediate feedback to employees with good safety performance and correcting unsafe behaviors enhance safety performance. Others showed that the most effective supervisors discuss safety issues with construction workers from different trades, and provide feedback about safety behavior and performance to those workers (Mattila et al. 1994; Niskanen, 1994; and Simard and Marchand, 1994). Additionally, communication has been listed as one of the top ten management practices that have a direct positive impact on safety (Bentley and Haslam, 2001; Hofmann and Morgeson; 1999; Sawacha et al. 1999).

Other studies have discussed safety communication within the context of the overall safety program. Havold (2005), for example, defined safety orientation as, “the cultural and contextual factors creating the attitudes and behavior that influence occupational health and safety.” Havold (2005) and Loosemore and Andonakis (2007) found that organizations that had a positive safety orientation are able to promote behavior that prevents accidents. Effective safety communication was found as a critical component of a ‘safety orientation’ because it helps organizations to overcome the challenge of language and educational barriers. Similarly, Van Dyck et al. (2005); Parker et al. (2001); and Cigularov et al. (2010) found that strong communication about safety issues was a critical component of error management.

Safety communication is expected to become even more challenging in coming years. A recent Bureau of Labor Statistics report found the number of foreign-born and non-native English speaking construction workers is increasing at an exponential rate (BLS 2008). Consequently, construction organizations have found that training and orientation for a multi-lingual construction workforce is significantly more difficult, which has increased the proportion of OSHA citations that are linked to training and orientation (OSHA 2008). Such trends make measuring and monitoring safety communication increasingly important (Emmitt and Gorse 2003). One emerging method of measuring communication among project participants is Social Network Analysis (SNA), which has potential application to specifically measuring and modeling safety communication.

Social Network Analysis

Social Network Analysis (SNA) was first developed by Jacob Moreno in 1934 to study the social interactions of groups. Moreno (1960) defined SNA as, “A quantitative analytic tool used to study the exchange of resources among different groups.” It’s also defined by

Haythornthwaite (1996) as “An approach and set of techniques used to study the exchange of resources among actors.” The main benefit of SNA is to identify patterns of social relations among many actors (Wasserman and Faust, 1994). In addition, SNA analyzes the structure of these patterns and identifies their effects on individual behavior (Scott, 1991). SNA is being used as research method within the social and behavioral sciences to model the relationships among different actors within one or more organizations. That relationship can be information exchange, trust, or task assignment. In addition, SNA is a helpful technique for researchers to visualize the interactions among actors to determine the central actor in one organization.

Social network data consists of actors, relationships or links among actors, and attributes or characteristics of each actor. In order to analyze a social network it’s essential to plot a diagram of how the data components relate. The social network data can be visualized by sociograms, which illustrate the connections among participants of interest (Wasserman and Faust, 1994). Sociograms model nodes representing actors (e.g., crew members) and the links between actors represents the relationship of interest (e.g., communication about injury prevention). In this paper, sociograms are also used as a tool to investigate the structure of personal relationships with other actors. Accurate and meaningful network visualization depends on the underlying mathematical analysis and methods implemented to gather input data. Once valid and reliable input data are obtaine and appropriate and accurate mathematical models are designed, SNA can produce the following metrics:

Network density. Density is a measurement that indicates ratio of the actual links or relationships available between the network actors to the maximum possible number links that the network could have (Borgatti and Everett, 2006). The higher is the density value, the more likely that actors are connected to each other. Network density is measured using Equation 1.

$$\Delta = \frac{L}{g(g-1)} \qquad \textbf{Equation 1}$$

Where Δ is the network density, (L) is the number of existing connections in the network, and g is the total number of actors;

Centrality. Centrality measures the total number of direct relationships that any actor in the network has with other actors in the network (Freeman, 1977). The network centralization can be also obtained based on the degree of centrality of each actor in the network. The network centralization mirrors how the relationships are distributed through the network. A high centralized network means a smaller percentage of actors have a higher percentage of relationship with other actors in the network. On the other hand, a low centralized network means that most of the actors in the network have equally distributed number of relationships. Equation 2 is used to compute the standardized degree of centrality use and Equation 3 computes the network in-degree and out-degree centralization. In-degree centrality quantifies the density of a particular individuals' receipt of information from the other actors in the network and the out-degree centrality quantifies the information provided by one actor to the rest of the network.

$$C_D\text{ (actor x)} = \frac{(c_D\text{ (actor x)})}{(g-1)} \qquad \textbf{Equation 2}$$

Where c_D (actor x) is the total number of relationship that the actor x has (in or out), and (g-1) is the maximum possible number of relationship that actor x can have, where g is the total number of network actors.

$$Network\ Centralization = \frac{\sum_{i=1}^{g}[C_D(n*) - C_D(n_i)]}{[(g-2)(g-1)]} \qquad \textbf{Equation 3}$$

Where $C_D(n*)$ is the largest observed value of $C_D(n_i)$ (Wasserman and Faust, 1994)

Closeness. Closeness measures how 'close' an actor is to all other actors and is measured as the proportion of all actors that are reachable by a certain actor in one, two, or three connections (Freeman, 1977). An example of an actor in a construction organization who would have a high value for closeness centrality would be a foreman for a crew because this individual should typically communicate with the other actors in the crew's network directly, rather than through other individuals. The president of most companies would have a low degree of closeness because they communicate indirectly with most employees through mid-management.

Betweenness. Betweenness measures the amount of information that must go through a specific actor who lies between two different actors in the network. In another words, this metric indicates the total number of occurrences when a specific actor is required to connect two disparate actors in a network (Freeman, 1977).

These metrics are the most important tools that are available to SNA researchers and they represent the heart of the hypothetical constructs when modeling communication patterns. In this research study, the authors use SNA as a tool to study the safety communication patterns among actors in small construction crews that are working on active building construction projects. Specifically, this research study aims to determine if the metrics obtained and patterns observed can be used to predict strong safety communication and, consequently, strong safety performance.

3. Methods

Social Network Studies

The research team started with designing a questionnaire, as shown in Appendix A in both English and Spanish. The survey consisted of two identical parts. The first, relates to providing safety information to others in the crew and the second part concerns about receiving safety information from others in the crew. The questionnaire included

- General information of participants such as name, position, and company name;
- The frequency with which a particular participant provides or receives safety information from each other member of the crew (i.e., once a month, bi-weekly, weekly, once a day, and more than once a day); and
- Most commonly used communication modes such as formal communication, training, toolbox talk, written communication, and informal discussion.

The research team contacted representatives from 11 active building construction projects in the Denver Metropolitan area of the US. Due to funding constraints, projects outside of this geographic region were not targeted for this research effort. Before surveys were administered, the team discussed the objectives of the study and the research protocol with the safety manager or project superintendent. Once this introduction was complete, the survey provided as Appendix 1, was administered to a small crew on the project. To avoid bias, the research team insisted on administering the surveys directly to the worker rather than allowing the surveys to be distributed and described by the project leadership. This direct communication with the workers also allowed the research team to provide detailed directions and answer questions. It was of utmost importance that ***everyone*** on the crew participated in the study. If even one individual declined to participate or was not present, the results were not analyzed.

Initially, the research team aimed to collect data from 11 small construction crews with approximately 8 to 12 participants. It was also required that the crews have been working on a project that is at least 50 percent complete to ensure that the crew had been assembled for a significant period of time. Table 1 shows the salient demographics of the participating crews. Because this effort was largely exploratory (i.e., the first known application of SNA to safety in construction), the research team conducted the interviews in an iterative process as new information was received and challenges were recognized. Fortunately, the project participants agreed to provide data during follow-up interviews. This iterative process was important for preserving internal validity.

Once the data had been obtained from the crew members it was coded and sorted using MS Excel so that it was compatible with the most standard SNA modeling software: UCINET. This software system computes the aforementioned SNA metrics, which are nearly impossible to calculate by hand or through MS Excel functions once project networks exceed 4 members. When coding the frequency of safety communication, the following scheme was used: 1= once a month; 2= bi-weekly; 3= weekly; 4= once a day; and 5= more than once a day. The data were coded into a total of twelve matrices, with six representing the data for the receipt of safety information and six for the distribution of safety information.

Table 1. Salient crew demographics

Crew no	Trade	Number of workers
1	Plumbing	8
2	Roofing	8
3	Concrete work	9
4	Electrical work	9
5	Dry wall	10
6	Electrical work	8
7	Concrete work	8
8	Mechanical work	8
9	Electrical work	11
10	Steel work	8
11	Mechanical work	18

Once all data were coded and entered into UCINET, the software system produced the aforementioned metrics and sociograms. UCINET allows the user to plot several sociograms for each crew. For example, the data can be filtered to report only the network of receipt of information, the network for formal or informal communication, and the network for each frequency level.

4. Results and Analysis

Based on the initial results and the sociograms of the eleven crews, the research team selected two crews (i.e., 3 and 10) to highlight in this analysis. Due to space constraints, the analyses for the other crews will not be provided in this paper. The teams found very interesting trends for these two crews. Table 2 shows the SNA measures for these two crews. These measures are for the entire network, which includes both receiving and providing information and all frequency levels.

Table 2. Basic SNA measurements summary for the three crews

	Crew 3		**Crew 10**	
	Receiving	Providing	Receiving	Providing
Density	0.819	0.792	0.321	0.286
Network centralization (out-degree)	20.31%	23.44%	28.58%	32.66%
Network centralization (in-degree)	20.31%	23.44%	28.57%	32.65%
Network betweenness	14.17%	0.18%	17.69%	4.08%
Number of relationships	59	57	18	16

The following is a brief discussion of several of the interesting aspects of the SNA results for the three crews highlighted. An initial hypothesis for this study is that crews with a higher density of safety communication would have stronger safety performance because high density corresponds to a network with a high amount of overall communication among all participants. Thus, centrality is the key aspect of the analysis below.

Crew 3

For crew 3, the density was measured to be approximately 82% indicating that 82% of possible connections in the network had been made. In comparison to the other crews in this study, this value is very high. In a follow-up interview with the superintendent, it was revealed that this crew had strong safety performance and overall productivity and had been working together for multiple projects. The superintendent noted that this continuity was largely responsible for the high level of density and the overall performance of the crew. The sociogram for crew 3 is provided as Figure 1.

The result shows that actors C and H are the most influential actors in the network because all other actors receive safety information from these two. Once can see the centrality of these two individuals by observing Figure 1. Another important trend that may be observed is that actors A, B, D, F, H, and I all receive safety information from all other actors in the network. Consequently, the in and out degree centrality in the network is equal (20.31%). This value is limited by the fact that not all actors provide safety information to each other and because the influence is evenly distributed throughout the network. From a knowledge sharing perspective this is good because there are few highly influential actors who serve as ‘gatekeepers’ of safety information. Instead, in this network, safety knowledge is more openly shared without the need to follow predefined communication channels controlled by few individuals as was observed in other networks. Another interesting trend in this network is that the overall betweenness index is relatively low at 14.17%. This makes sense when views Figure 1 because most of relationships can be made in this network without aid of any intermediary. Only actors C and H have a greater amount of influence than the others.

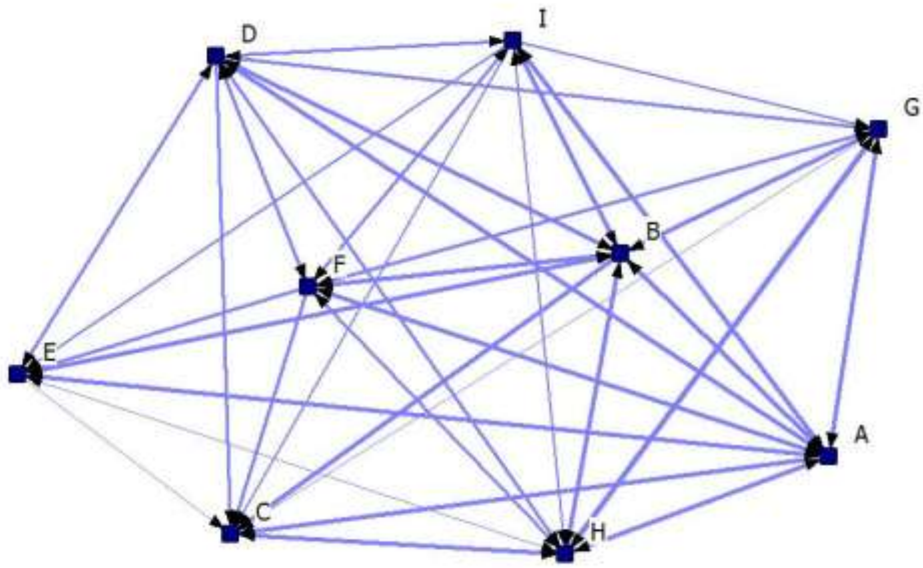

Figure 1. Sociogram for receipt of information for crew 3

In addition to asking participants to note who they provide safety information to and how often, participants were also asked to note who they received information from in an effort to internally validate the results. Ideally, the network for providing information and all resulting metrics and sociograms should be identical. However, the research team hypothesized that is may be possible that an individual thinks they provide safety information to another individual but that the individual who supposedly receives this information does not recognize the receipt of such information. Vice versa could also be true. The sociogram for receiving safety information is provided as Figure 2. When one compares Figures 1 and 2, it becomes obvious that some connections from Figure 2 are missing in Figure 1. In fact, the density of the network for providing safety information is 79% while the density of receiving information is 82%. This indicates that, for this particular crew, some actors actually recognized the receipt of safety information from other actors who did not realize that they were providing such information.

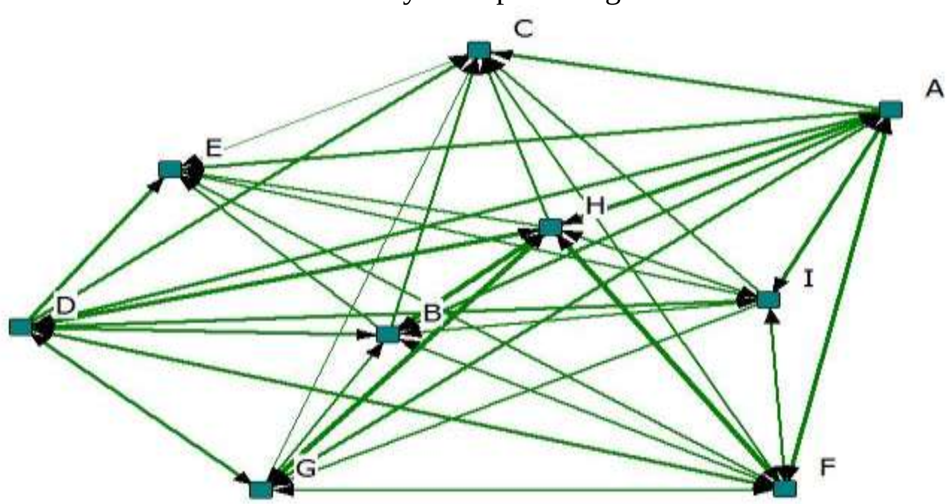

Figure 2. Sociogram of providing safety information for crew 3

Crew 10

The density of crew 10 was significantly lower than crew 3 at 32% indicating that only 32% of the possible connections were made. The sociogram for this network is provided as Figure 3. For brevity, only the network modeling the receipt of safety information is provided for this crew. As one can see, Actor C has the greatest in-degree of centrality and, consequently, is the most influential actor in the network. In fact, two actors (A and H) rely on Actor C to receive any information from the others in the network. This is problematic because (1) information can be lost through the connection as Actor C obtains information from other actors and distributes it to Actors A and H (similar to the childhood game 'telephone') and (2) the loss of Actor C completely disconnects Actors A and H from the rest of the network and ad hoc connections would have to be established to keep these actors informed.

A deeper analysis revealed that Actors A and H were English-only-speaking workers, Actor C is bilingual, and the rest of the actors were Spanish-only-speaking workers. This network provides strong empirical evidence that language barriers strongly influence the communication patterns in the network. The sociogram also clearly shows Actor C, the bilingual worker, as the cultural barrier spanner (CBS) who serves a critical role in keeping the multi-cultural network connected. This individual influences the overall success of the network far more than any other actor.

When one focuses on the 5 Hispanic, Spanish-only-speaking workers, it becomes clear that this part of the network is quite dense and has a low degree of centralization, indicating an even flow of safety information without a critical gatekeeper. Such a network dynamic encourages open safety communication.

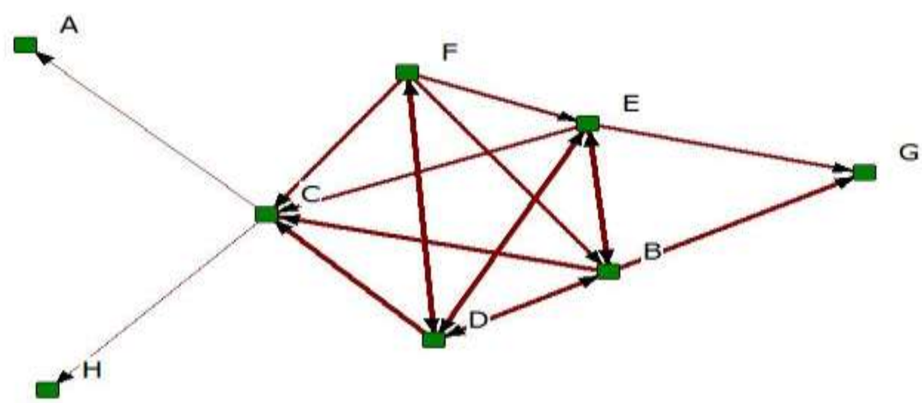

Figure 3. Sociogram for crew 10

5. Conclusions

The purpose of this research study was to explore the viability of using social network analysis to measure and model safety communication patterns within small construction crews. Though SNA has been used to model general communication within construction companies, no previous researchers have explored using SNA to measure safety communication specifically. The analyses provided in this paper represent the most interesting findings that surfaced from modeling 11 crews in the Colorado region. This exercise revealed strong support for using the technique to identify central actors who control the distribution of safety information (centrality), to quantify the degree to which the network shares information (density), and to identify potential cultural barrier spanners (Di Marco and Taylor, 2010) who should be considered as vital actors who should be provided support and recognition for the role that they play.

Based on the authors experiences during the research process and the trends observed, the research team strongly believes that future research must be conducted in the area of modeling safety communication. Though the survey used to collect data is quite simple and easy to understand, it is essential for future researchers to make the study sample comfortable with the research process and to obtain honest and accurate responses. It is suggested that future researchers continue collecting data on this topic, refine the data collection process to ensure internal and external validity, and to collect a sample large enough to statistically analyze the correlation between centrality, density, betweenness, and closeness measures with lagging indicators of safety performance.

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Appendix A

Your Name:______________________________________
Your Position: ________________________________ Company ________________________________

University of Colorado Boulder

With whom on your crew do you PROVIDE safety information to, how often do you communicate, and through which means?

Name of individuals who you PROVIDE safety information to		Frequency of communication (check boxes)					Most common mode(s) of communication (check all boxes that apply)					
First Name	Last Name	once a month	bi-weekly	weekly	once a day	more than once a day	Formal communicaiton (mgt role)	Written communication	Training	Informal discussions	Toolbox talk	Other (please specify)
John	Doe			x				x	x			

***If you need additional pages, please let the researcher know

Your Name:______________________________________
Your Position: ________________________________ Company ________________________________

University of Colorado Boulder

With whom on your crew do you RECEIVE safety information from, how often do you communicate, and through which means?

Name of individuals who you RECEIVE safety information from		Frequency of communication (check boxes)					Most common mode(s) of communication (check all boxes that apply)					
First Name	Last Name	once a month	bi-weekly	weekly	once a day	more than once a day	Formal communicaiton (mgt role)	Written communication	Training	Informal discussions	Toolbox talk	Other (please specify)
John	Doe			x				x	x			

***If you need additional pages, please let the researcher know

Exploitation of BIM based information displays for construction site safety communication

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Exploitation of BIM Based Information Displays for Construction Site Safety Communication

Abstract:

This paper discusses the potential of disseminating up to date and visualized safety related information to construction workers/site staff of building construction sites. The paper is based on an on-going research project called BIM Safety. This research effort was commenced in April 2009 and will continue until June 2011. As a part of the research, a pilot study was carried out where LCD information displays were placed at construction site premises and were used for presenting weekly updated information relating to safety issues. The presentations took also advantage of 3D- and 4D-model views of the building under construction. Feedback over the content of the display presentations was gathered with a questionnaire from the site staff. This paper presents the findings of the pilot study and the enquiry, such as identified benefits, and discusses the possibilities as well as targets for further development.

More information about the research project http://www.vtt.fi/sites/bimsafety/

Keywords: Building information modeling, safety communication, site planning, construction planning, visualization

1. Introduction

The research covered in this paper falls into the category of safety awareness creation. Generally the safety awareness creation can mean different kind of areas of actions including i) Continuous reviews of working conditions and relating potential hazards, ii) Analysis and anticipation of unsafe conditions, iii) Communication and collaboration between different professions and workers, and iv) Sensing and warning technologies. These can be as direct means of safety awareness creation whereas some additional indirect means exists as well that do also contribute to this arena. Education, training, safety regulations, safety planning procedures and safety by design can be understood as such indirect means which all have linkages to safety awareness creation.

In our research the safety awareness creation is addressed by exploring potential advanced communication solutions, this is the use of ICT enabled information display screens. Information display screens are common in industrial and commercial settings, where they are used to disseminate current, easily accessible information to the staff and visitors. Rapid advances in display technology over the past decade, in particular, have driven costs downward and thus even largest size flat displays have realized commoditization of these solutions. They are used very widely for different purposes varying from professional needs to individuals’ entertainment.

Digital technologies including building information modeling (BIM) are widely used in the design and construction that provides a natural starting point for the next step that is to take advantage of these technologies also for safety communication. Research suggests that ICT applications can help avoid accidents by collating design and planning data in formats that can be visualized and further explored. BIM technologies are generally seen as means to facilitate communication in relation to safety aspects (Eastman et al, 2008; Suermann & Issa, 2007; Heesom & Mahdjoubi, 2002; Khanzode & Staub-French, 2006). On the other hand some researchers suggest that the ICT applications can also have unintended and negative impacts (Huber, 1990). Overreliance is an example of a situation when individuals ability to observe is biased due to the received messages. This can raise the overall safety risk level in an unwanted manner. The described scenario reveals the high priority and importance of careful information content design for the purpose of safety communication.

A research experiment was designed for gaining an improved understanding of using this media as means for site safety communication. Particularly, rather than embracing general construction site safety information the research addressed the dissemination of safety notifications and guidance that were task specific according to the actual work progress on site. Also, the use of BIM as a way to communicate safety information visually was experimented. The objective of this paper is to present the gained results from an experiment where information display screens were used on building construction site for safety communication.

2. Approaches towards advanced safety communication

Safety communication is an integral part of an organizations safety effort. It provides support to the continuous, every day work on safety promotion and management. It helps to create and maintain prerequisites to safety and health at work, and contributes to promoting the organizations safety culture and atmosphere.

The basic aim of safety communication is to help personnel to make informed decisions regarding safety and adopt an attitude that can improve their health and safety. Communication can act as a means to disseminate company safety norms and beliefs. It can facilitate understanding of safety systems, risks, production pressures and organizational policies on safety. When utilized in an optimal manner it can act as a lubricant between organizations, people and tasks. (Real & Cooper 2009). Examples of important factors in safety communication are i) openness of communication, ii) two way communication and iii) easy access to information. According to Kines et. al. safety communication should be an integrated part of the entire construction process, from planning to construction and operation. (Kines et. al. 2010)

Openness in communication, which means open access to everyone, is a key factor in creating a positive safety climate. Openness in communication helps the personnel feel that they have the organization's support and their thoughts and opinions are valued (DeJoy et. al. 2004). Openness is also important since the events that lead to accidents and injuries are mostly non-routine and unpredictable (Zohar 2002). This is especially true in changing environments such as construction sites. Furthermore, open communication in working conditions also enables two way communication, in which the employees can e.g. raise their concerns on safety issues and suggest solutions to identified problems. This can also facilitate injury and accident reporting, which then provides basis to learn from past accidents.

Easy access to information means that safety information is effortlessly available to everyone. In example target groups, location, form, time and use of messages and media should be taken into account when planning safety communication. Using a multi-channel approach is seen as an effective communication way to reach the personnel in organizations and to improve information availability. This means that more than one communication medium is used in delivering safety messages. It ascertains that everyone has seen, read or heard the message, reinforces messages and increases exposure to information (Real 2008). When designed and planned well, safety information can be provided without detail overload. Safety messages should be kept simple and easy to understand, but also make additional information easily available for those individuals, who want to seek more information. (Real 2008.)

Visual communication

Visual communication is considered to be one of the oldest ways to communicate, the first versions of writing were, after all, pictures. People rely on vision to be the most reliable of their senses and so consider things they see to be true. (Hietala 1993.) Because of this, visual communication is a very high-impact way of communicating. Visualizations can be used to clarify and extend verbal communication. Visual materials such as plans, sketches, photos, videos and slide shows are used every day in most companies. The visual acts to support the message in a similar way as body language, expressions, intonation and volume does in direct oral communication (Yazdani & Barker 2000).

Still, the relationship between seeing and understanding is problematic. How one understands a thing one sees depends on social background and experience. The practices around visual materials may lead the focus of attention away from the relevant and also make the message more difficult to understand by complicating or concealing information from the viewer. (Weick, 2005.) On the other hand, visualizations can have ample benefits in making information understandable and crossing borders created by i.e. different native languages. Good visual design supports the message by presenting the essential (Brusila, 2000).

Building information modelling and communication

Physical and virtual models are part of the current design, construction and management practices. People usually have a need to visualize the building or environment or simulate different functions. Building Information Modelling (BIM) can be used to visualize the project and methods of construction. Building information model is a three-dimensional description of a building, the surroundings and e.g. temporary site equipment. Beside 3D geometry it may include many kinds of product and construction information, such as identification and property information of building components, as well as construction schedule of the building assemblies. These BIM-models can be used to support communication, for example to help discussions on the construction process between professionals and to disseminate information to project stakeholders. It can also help to make the process more understandable to people with no background in construction.

From the viewpoint of safety, BIM technology can result in improved occupational safety by connecting the safety issues more closely to the construction planning, providing more illustrative site layout and safety plans, providing methods for managing and visualizing up-to date plans and site status information, as well as by supporting safety communication in various situations, such as informing site staff about coming safety arrangements or warning about risks (Sulankivi et al. 2010).

Today, most experience in using BIM for safety purposes is related to BIM based site layout plans, but there is some experience for example of BIM based falling prevention planning also. A three-dimensional site layout model can be used to produce various illustrative views of the site plan, from the desired viewpoints and perspectives. Challenging points or solutions can also be highlighted from the plan. Some modelling software include tools also for producing animations from the same BIM-model. Animations can provide a general understanding of the site quickly, and can be used for example as virtual sightseeing when introducing the project to site staff, or when presenting site arrangements to the client. Visualization opportunities regarding site arrangements and risk zones includes for example visualization of temporary site area or space reservations, visualization of site walkways and visualization of risk zones related to cranes (Sulankivi et al. 2009).

3. Pilot for advanced safety communication at construction site

As a part of the BIM Safety research project, a pilot study was carried out where LCD information displays were placed at construction site premises and used for presenting weekly updated information relating to the safety issues. The target was to test the usability of LCD information display screens together with novel material, to promote safety communication at construction sites.

The pilot study took place on an office building construction site. The pilot project was fully designed using 3D building modeling technologies. The resultant models were used in site meetings for planning construction activities and additionally the models were used as discussion facilitators in meetings participated by main contractors and sub-contractors. In this case, the site managerial personnel was experienced in working with 3D views and relating tools, and was eager to take 3D model usage to the next level in order for improved site-communication. Since creating videos with the BIM tool in use on this project was not possible, a slide presentation with views from the model was utilized. The presentations were up-to-date and visualized taking advantage of 3D and 4D model views of the building under construction.

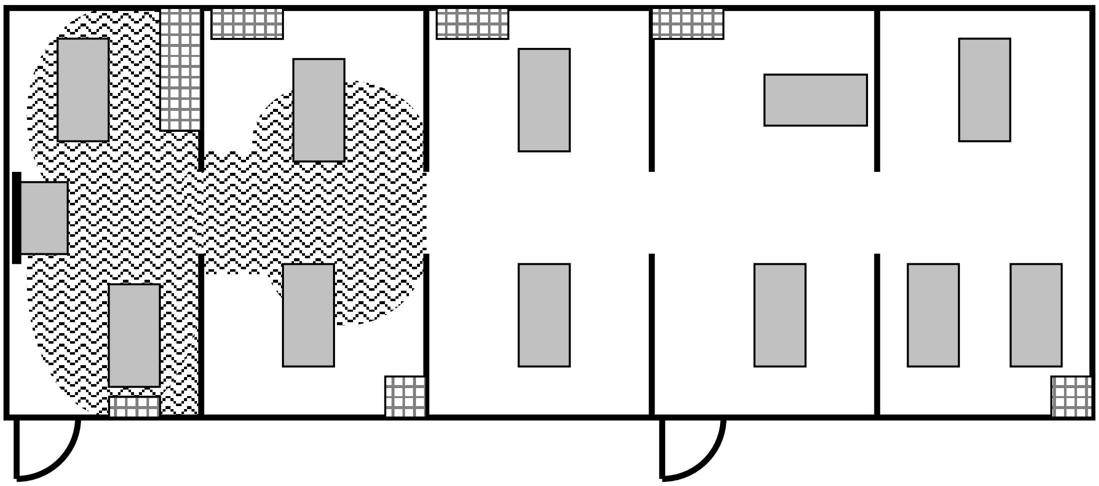
Two LCD displays were acquired for the pilot. The main contractor's IT department installed the displays and a computer with basic Microsoft Office package to the site according to instructions. The displays were placed at construction site premises, one in the site office hall and the other one in the staff break room, so that as many as possible of the site personnel would have access to the screens (picture 1).

Picture 1: The LCD information display unit placed at the construction site staff break room.

The staff break room is built of five units that are connected via doorways. Personnel can use two doors to the room. The doors are in units one and four. The information display screen was in unit one, up on the end wall, next to a door and in the middle of the information boards (picture 2). The watching area of the display is restricted because of the distance from the display and the walls between units.

The site personnel have daily two coffee breaks, both lasting 12 minutes and a lunch break of 30 minutes. Viewing the information display during the whole length of a break is possible only if a person is in a specific area that is highlighted in picture 2. People who were not actually present in this viewing area could only see the information display in the case of using the front door of that unit. Part of the personnel would have had no visual contact with the display in the case of using merely the other front door and staying outside the specified viewing area.

The display in the staff break room was the main display for site personnel, since they usually were not stopping to watch the other display in the hall while visiting the offices of site management.



Picture 2. Simple drawing of the staff break room of the site. The information display unit is placed on the left. The space includes 12 tables. There is one main kitchen in the unit one and several microwave ovens and refrigerators, marked with grids. The watching area is marked with wave.

Presentation

The presentation shown on the display screens consisted of in average 25 slides. The actual slide show lasted less than ten minutes and it was run as a continuous loop throughout the day. The research team designed the content of first presentation in co-operation with the contractor's safety personnel and site staff, and it was updated weekly with new information. Contents of the slides were gathered from the company's general site safety instructions and from site-specific plans and models. A member of the site staff used weekly one hour to gather the needed material and update the slides.

The presented slide shows provided information related to the following topics

- current affairs and events
- schedules and more detailed weekly plans
- positive safety notes
- safety observations
- accident or near-miss reports
- safety issues that need improvement
- particularly dangerous places on the site presented with help of 3D site plan
- 3D site plan
- TR Safety observation results
  (weekly safety level using TR Safety observation method, where TR is an acronym and stands for the Finnish words "building construction")
- 4D-model views presenting the weekly plans

Picture 3: 3D site plan that is captured from the 4D model of the pilot building construction project. This is an example of part of slide show that run on the information displays.

The pilot trials lasted 4 weeks, after which the site staff have continued updating the presentation and showing it independently.

The idea of this pilot was to experience the use of 3D and 4D model viewing as a part of broader site safety communication. Intention was also to improve site safety communication by providing support to other communication channels. Improving knowledge of site staff about the on-going operations and shortly coming events on the construction site was seen as an important way to increase site safety. The idea was to bring safety issues closer to the site staff by conveying them as a part of standard working environment.

Method

The pilot construction site employed 50 people at that time. Feedback over the display screens and presentations was gathered with a questionnaire which was distributed to all of the site's personnel by a member of the site managerial staff. It consisted of 12 questions divided into three categories: i) watching habits, ii) display placement, iii) perceived necessity and content of the info screens. Both dichotomous and multiple choice variable questions were used and complemented with open questions. The questionnaire was responded anonymously, and 36 employees returned the questionnaire, resulting in a 72 % response rate. 20 of the respondents were the main contractor's employees and 16 were subcontractors' employees.

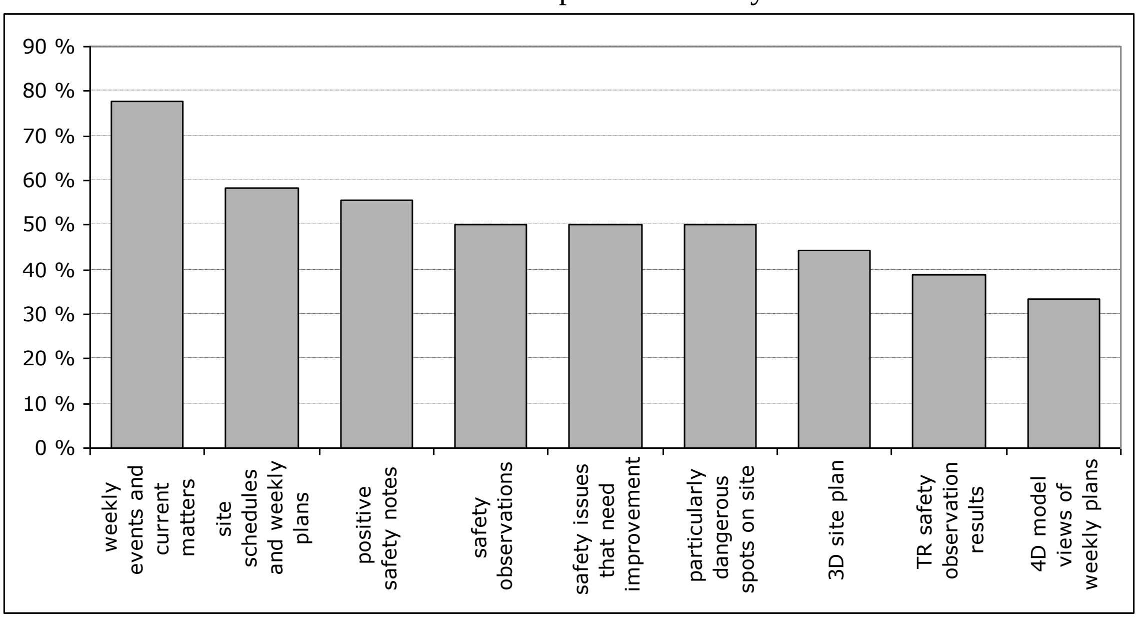
4. Results

The results propose that the display screens are mostly viewed on a weekly basis (37%), which means that viewers watch the entire slide show once in short portions during the week. Watching time is mainly short; more than half of the respondents watch the information display half a minute at a time. 20 per cent of respondents did not watch the display at all.

The information display screens and their contents as used in the study were seen as useful for site operations and their safety. Respondents have received information about current site events (83%), safety issues (82%) and timetables (77%). Weekly updating is considered sufficient, only 9 per cent of respondents replied that updates were not often enough.

All contents of the display screen presentations were considered somewhat useful at a minimum (table 1). Over 50 per cent of respondents considered weekly events, current matters, site timetables, weekly plans and positive safety notes to be important. The least important were weekly 4D target plans, TR Safety observation results (weekly observed safety level at the site) and 3D site plan.

Table 1: The usefulness of presented safety information.



The information display was generally considered as a good source of knowledge on site affairs. For example, the site staff reported that they had gotten useful information particularly concerning dangerous spots on site and also the shown material have improved their overall understanding what is happening on site. Weekly timetable and accident reports were mentioned as good examples of useful information. Only three of the respondents from the total 36 had had no benefits of the display screens.

Considering development possibilities, clearer information about different site manager's responsibilities and the location of first-aid supplies on site were requested. Also, many of the respondents thought that the changing of the slides was too quick.

Administrative prerequisites

During the testing resource requirements of the maintenance were discussed. Although the time usage is not a significant factor, some basic IT knowledge is required to update the presentation. On the test site, an IT-capable project secretary took care of the weekly updating of the display materials. She was engaged and sought to further develop the weekly content. However, not necessarily each site has a person that has required capabilities. This may lead to a need for an off-site support for up-dating the weekly presentations.

Also, the content of the presentation was discussed. The more site-specific the content is, the more valuable the site personnel consider the displays. However, if off-site updating of presentation is required, the information gathering and transfer becomes more cumbersome and more generic company-specific information may reduce the value of the site experiences.

5. Conclusions

The usage of information display screens on construction sites has promising possibilities. Such displays provide support to other means of communication and disseminate messages to a wider audience. The target audience of construction site communication is wide – examples of those are permanent site staff, subcontractors, cooperation partners, and authorities. Information displays can provide equal information packages to all those involved. Keeping safety issues visible at all times can help to build and reinforce the openness for site safety communication.

Benefits

Site staff, subcontractors and cooperation partners are on a construction site for various times and durations. The benefit of the screens in such conditions is providing current, updated information that is available regardless of date or time of the day. This information acts to increase safety by making the people on site more aware of what is going on there. Also, as can be seen from the survey results, one does not have to have a lot of time to get information from the screen, which makes a functional medium for job sites with only limited time to disseminate and assimilate information. It can be used to reinforce safety regulations and values of the site.

The display screens also contribute clearly towards openness in communication by providing equal information to everyone being present. This and the nature of visual communication as crossing language and other communication boundaries make it a very democratic medium that has great potential.

As the use of BIM is rapidly increasing in the whole supply chain, it has great potential to develop into an easy-to-use method for supporting the supply chain and spreading up to date information about construction activities on site and related safety hazards. This is why it is important to develop and trial new ways for planning and communicating safety related issues to all stakeholders in an easily understandable virtual 3D environment.

Further development

Based on the pilot study, chances for further developments were also identified. Firstly, placement of the information display screen in the staff break room was such that it was not seen from all over the room. This possibly explains the 20 per cent of respondents who did not watch the display at all. Solutions to this problem could be i.e. providing a second screen or making the current screen movable so that it could be in a different place in different times of the day or week, or placing display screens in places where people are waiting or queuing and so have free time to pay attention to them. Another solution would be to design the staff premises with communication in mind, creating places for effortless receiving and exchanging of information and open spaces where the displays are seen by a larger number of people at a time.

Secondly, the possibilities of using 4D and 3D visualizations are also somewhat limited at the moment. Currently there are only limited possibilities to create moving videos of models without special software. Using still visualizations from 3D and 4D models is not as impressive and eye-catching as moving picture would be. There are also some issues with the understandability of the colors used in the visualizations that are based on structural BIM-models. Different colors have their structural meanings in the model, but may not be understandable to a viewer who is not accustomed to it. Converting model colors from their structural meaning to more realistic ones should be made possible and easy to use in the future, so that more photorealistic images can be created and the pictures are more interesting and easier to understand.

Thirdly, a passive medium such as the information display screen has a risk of becoming background noise over time. People become uninterested if the information is not catching enough and also if changes in the content are not clear enough. The manner of representation should be changed from time to time to keep up interest and viewer's opinions of what information is needed should be heard and taken into account.

For the information displays to stay in use, the content should be easy to create and update. Existing, site specific information, such as timetables, current safety information and BIM visualizations or videos should be easily adapted to use on displays. Participation from i.e. contractors' communication department and safety specialists would also be beneficial, as they could support the site specific information with more general content that could be used in all of the company's work sites.

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EFFECTIVE COLLECTION AND SHARING OF REWORK INFORMATION IN CONSTRUTION PROCESS USING SMART MOBILE

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Abstract

Rework during the building construction process has begun to affect both schedule and cost overruns. There is, however, a lack of research on collection and management about rework information and it still has not examined the fundamental causes and suggested solutions. Also, Safety management is similar with Quality management in construction site from inspecting nonconformity parts to ordering rework and making report repeatedly. In this way, safety and quality management in construction site has a possibility of improving efficiency. Meanwhile, smart mobile, up-to-date technology, is lightweight, portable and easy to input data, so it is used to various industries. This paper proposes a web-based rework information management system to collect, share, and manage efficiently the rework information by grafting functions of smart mobile. It is recommended that the proposed system would improve a collection process of rework information as well as a quality of project performance by sharing and using rework information.

Keywords: Rework, construction, quality, safety, smart mobile, web-based rework information management system

1. INTRODUCTION

Uncertainty is inherent in construction, and because construction failures occur due to complex reasons, feedback of construction failure information created in the construction management process is most important to prevent failures (Love, 2008). Although specialists in the construction industry recognize the importance of construction failure information, sharing of construction failures has not been accomplished due to negative perspective that disadvantages in personnel performance assessment and decreases of the company's image may occur (Park, 2009). Rework, which is one of the major reasons of failure in the construction industry, has been recognized as one of important management items affecting unexpected costs and delays. In the case of construction rework generated in the construction stage, it is understood that the average of 15% of the construction schedule is delayed (Love, 2002a) and an average of 5% of total construction cost is increased (CII, 2001). Also, even though knowledge sharing is important to prevent the rework, because, due to characteristics of the construction industry, team unity is dismantled when one project is finished, their knowledge is hard to be converted to the competitive power of the company (Lee, 2005). Besides, there are many cases that the processing of rework was done administratively at the construction site, then the generated information was been reused, similar reworks tend to be generated repetitively. the construction industry has the one-time feature of an outside production method, cannot manage all the information generated during the project and have a standardized process. Also, most inspection works are executed at the site while all information required for the decision making is saved in the office, so it is hard to use the current information. Moreover, because the construction industry has longer project periods than other industries and the participants vary and change frequently, the necessity of information management is huge. In addition, it is most important to achieve high quality in a safe way in the construction industry (Loushin, 2006). It is clear that the condition to inspect and manage is similar with quality and safety and it can prevent accidents by performing the scheduled task exactly as planned (Hinze & Wilson, 2000; Ketola et al., 2002). In this way, TQM(Total Quality Management) considers that safety is one of the factor in construction management (Husin, 2008). Actually, safety and quality management in construction site are quite similar in the meaning of proceeding according to PDCA (Plan, Do, Check, Act). However, Safety management is weighted towards Do compared to quality management, so safety management needs to consider all of the procedure of PDCA (Kim, 2008). Also, the process from inspecting nonconformity parts to ordering rework and saving the rework information on paper document is similar, but inefficient. Meanwhile, with the rapid development of recent IT, distribution rate of smart mobile has been increased, and many companies derive the efficiency of work using the smart mobile. Construction industry also tries to apply the smart mobile in the work. Specially, construction site where various construction materials and processes are mixed uses the smart mobile as a tool for human resource, process management, quality and safety management. This can reduce the time required in the documentation and management for existing work processes and increase the work efficiency. Most of all, necessary information can be searched immediately at the site by using the smart mobile, and this means that efficiency of construction management can be increased with fast and accurate decision making. This study is to develop the rework information related to safety and quality management and sharing system using the smart mobile to solve the problems related to the rework information. To do this, existing rework process is understood, and by using the smart mobile technology, process the rework information can easily be saved. Based on this, knowledge-sharing system that inside and outside company sharing of rework information is available will be suggested. To verify the application of the suggested system in this study, a survey on the efficiency of rework management systems using the smart phone was conducted the survey targeted working-level persons, and was an investigation on the recognition of the possibility of a knowledge sharing system

2. LITERATURE REVIEW

Rework Research in Construction

Construction rework is defined variously in the researches related to the construction management. Ashford(1992) defines it that process satisfying the requirements with repetitions of completion and modification, and CIDA(1995), Love(1999) defines it that task executing nonconformity situations suitable for the requirement. CII(2001) defines the construction rework from the work, which executes the completed work again in the site and to the work, which removes the previously installed ones. Generally, construction rework means that work which should be repeated to accomplish the target quality.

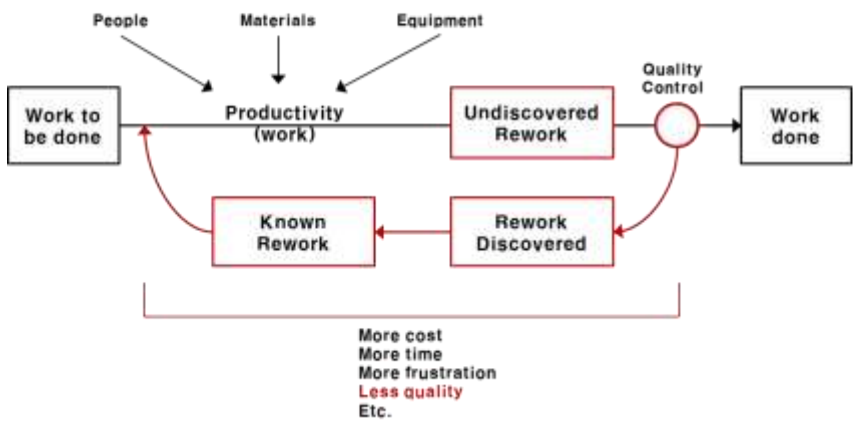

Figure 1: The Quality Control Rework Cycle (AEW Services, 2001)

Figure1 means the rework should be executed by discovering the necessary parts for the rework underlying during already completed work through the quality management in the construction process. Because work previously executed is repeated while rework is discovered and executed, additional cost and item is also required. Also, in the construction site, numbers of workers execute the construction work by using various materials and equipment, management is getting complex, and due to lack of the communication between participants, it is easy to generate the rework.

To solve this problem, various researches on the rework have been performed.
Love (199) tried to prevent the rework by investigating the reasons of rework in the actual construction project. Hwang, Bon Gang (2009a, b) argues the necessity of rework to maximize the construction cost performance by analyzing the construction rework from the construction project. Love (2004) argues that from the result of rework reason analysis, there is lack of communication in the design team including ordering body and suggested the new ordering system focused on communications. In addition, Zhang(2009) figured out the rework information in the construction industry to suggest the task modification and integrated management system to prevent the rework.

If previous researches were compared, they finds out the reason for construction rework and emphasizes the necessity of rework management by calculating the additional cost generated due to the rework, and suggests the management system for this. However, suggested communication-focused ordering system, task modification and integrated management system only expresses the theoretical suggestion, and researches on investigation and improvement about rework process and saving of rework information are not sufficient. Also, by looking for the reasons through analysis of saved rework information, it emphasizes the importance of rework information, but researches on suggesting the basic solution through rework information sharing is insufficient.

Thus, this study suggests the sharing system using the web and improving the rework process in the construction site by using the smart mobile. For using this system to search the defect of safety and quality then save it all, it can improve the efficiency of construction site management.

Smart Mobile in Construction Industry

Smart mobile can do long-distance work process and is portable, and opinion sharing among relating people is easy. In addition, when saving data, real-time data saving is possible, and since work can be done even in offline situation, it can solve the problems caused by differences between site and office works, and it can promote the productivity increases. These advantages are also used in the construction industry.

Irizarry(2009) suggests the adjacent construction equipment rental place searching application and application, which can be used in the safety education, and relating education data can be searched in real times if education data related to the safety management is required in the site.

Domestic A construction company interlocks the Project Management Information System(PMIS) established and used in the company to the smart mobile, so basic which can use the smart mobile not only in the task, such as mail, board and approval, but also in construction, labor and material management in the site has been operated. Specially, work order for the work, which can be the problem during site inspection, is registered with the smart mobile to use them in the management task under offline (Lee, 2011). However, in real tasks, if smart mobile and PMIS is used in a same time, it can be recognized as the overload of overlapped work of information input.

I-phone based “Site Clean Up” is the site environment management application, and construction manager can take a picture of place where environment management is required, even he/she does not meet the subcontractor, to order the countermeasure. Also, subcontractor can take a picture of modified environment right after executing the order and send it to the construction manager for the confirmation. Like this, if smart mobile is used in the construction site, information exchange can be done faster so that efficient of management work can be increased.

Smart mobile can search the information in the outside of site, and advantage which decision for the work is that moves to the office after site inspection in the rework process. And, process finding relating information can be done in a same time with the site inspection, and picture took with the smart mobile is sent to web automatically, so transmission process of picture information took by camera to the computer can be omitted.

3. DEVELOPMENT OF REWORK MANAGEMENT SYSTEM

Overview of Rework Management System

Document used when quality and safety management in the construction site consists of various items, such as work procedure, drawing, check list, manual, etc., and these document are saved in computerized document format. However, because a manager uses printed paper when inspecting the site, it is hard to find the required information in a short time so they should move to the office to find out the required document (Cho, 2007). In addition, to record the inspected content, they should move to the office again, and if there is much data to be recorded after the inspection, and it is hard to memorize the all contents without looking at the site when he moves to the office. Specifically, in case of rework, there is a lot of information to be obtained depending on required quality and safety standard. The field situation should be recorded accurately, as there are many inefficient parts of work if a computer is only used.

Thus, this study applies the smart mobile to the rework process to search the quality information in real times at the site, so fast decision making is possible. Information can then be saved without any overlap between the site and the office.

Also, by analyzing the rework information saved through the web and comparing it to the daily quality and safety management plan of other current projects. This comparison to the quality and safety management plan of other projects is done so that rework can be prevented. Through a web-based system, the availability of rework information which is insufficient can be improved and sharing utilization can be increased. Beside, saved rework information can be linked with PMIS using site management in each company, thus site information can be managed more efficiently.

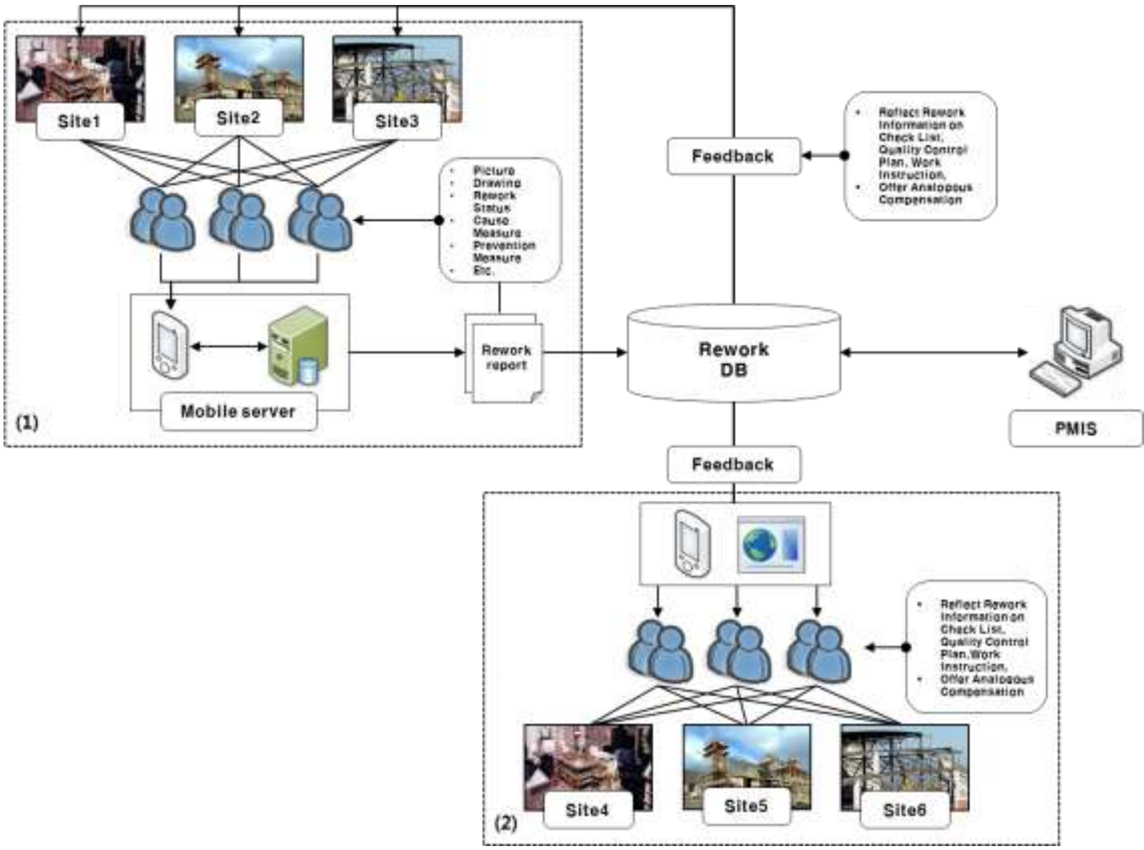

Figure 2: Conceptual model of Construction Rework Information System

Rework information management system suggested in this study consists of two parts as shown in figure 2.

(1) Support internal task process: saves the rework information generated in various projects executed by one company by using the smart mobile and write them to rework report, and by saving them in web server, Rework Database will be created.

(2) Sharing internal information: saved rework database searches similar data depending on parts, processes, and materials and can be used as field and quality management data on other projects.

Meanwhile, task process of construction rework information, which is complex when a rework information management system is used, can save time, which in and out of the field and office by using the smart mobile. Also, by using the web, saving and sharing of information is possible. Thus wider knowledge management is possible.

The web system in this study can use the internal task process supporting and internal information sharing which saves the rework information. However, outer sharing of rework information may be hard because of negative awareness about publication of failure information and because rework is recognized as a failure. It is assumed that an efficient connection plan with a quality and safety management system, is being used in the existing construction, overall management system.

Development of Rework Process Using Smart Mobile

(1) Overview of Rework Process in construction

This section compares the procedure of the rework information management system using smart mobile to existing task procedures. The existing task procedure was researched and generalized through a literature review related to the rework task procedure and Site Personnel interviews as shown in figure 3.

The nonconformity report is the report prepared to find the nonconformity parts of quality or safety shown at the construction site and correct it. The rework action plan is recorded together with it, and both should receive the final approval of site manager.

The rework result report indicates the rework to improve the nonconformity situation, decide and record the action taken, and contains the entire company's information from the discovery of rework to the result confirmation

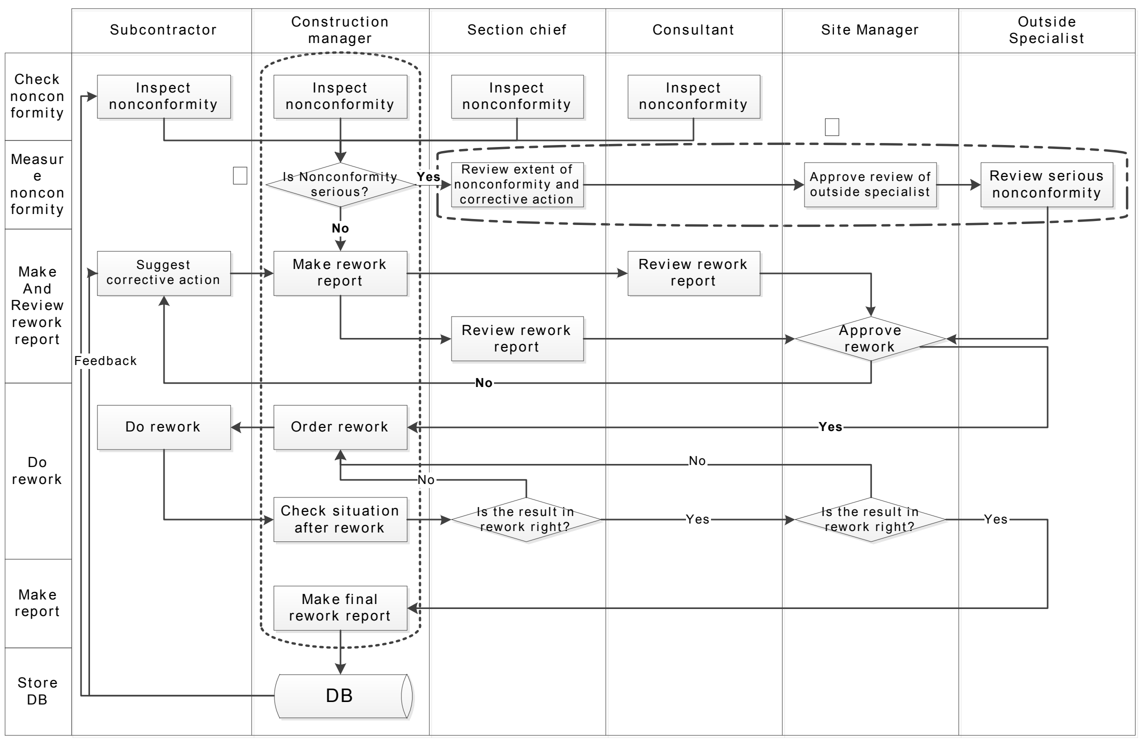

Figure 3: Flow Diagram of Rework Process in construction field

At the site, construction manager executes quality and safety management continuously and finds out the nonconformity situation, where rework is required. The construction manager, subcontractor, chief and consultant discover the nonconformity situation and inform it to the construction manager. The construction manager decides the level of nonconformity, and if he decides that it is serious, he requests the review of the outside specialist through an internal meeting to find the solution. After the review of outside specialist is finished, rework is ordered and executed through the rework approval of the site manager. If then nonconformity is minor, a rework report can be prepared with the construction manager's judgment. The subcontractor who executes the nonconformity parts should suggest the rework plan to solve the nonconformity when preparing the rework report. The rework report prepared by the construction manager is submitted to the chief and consultant for the review process. After the reviewing, the site manager approves the rework, if the rework is not approved, efficient measures should be suggested again. The suggested measure is indicated in the rework report again and the review and approval process will be repeated. When the rework approval of site manager is completed, the construction manager requests the subcontractor who constructed the nonconformity part the rework to confirm that the rework is completed. The chief informs the site manager of the rework result if the action taken is not satisfactory. If correction does not satisfy quality and safety standards or additional work is required, he requests the construction manager to do the rework again. Rework content taken and verified by the site manager is included in the rework result report by the construction manager and saved as rework DB.

Case of No. ① is the minor nonconformity case generated frequently at the site, and is work which can be solved without any special meeting. Thus, if smart mobile is applied to the No. 1 process, it is possible to increase the improvement of the rework task.

Case of No. ② is the serious nonconformity case, so it does not occur frequently, but because the nonconformity information is delivered to the outside, security of the information is important. Because a meeting should be held the time required for the work process is long, and the work procedure is complex. Thus there are many people who participate in the decision-making process. Due to this reason, it was decided that the rework task was hard to improve by applying the smart mobile.

(2) Existing Rework Information Management Process using Computer

If the No. ① task is considered the task that can be improved by using the smart mobile, it can be divided into discover of rework task, decision, record, execution, and preparation of report; and tasks executed at the site and office, it can be shown Figure 4.

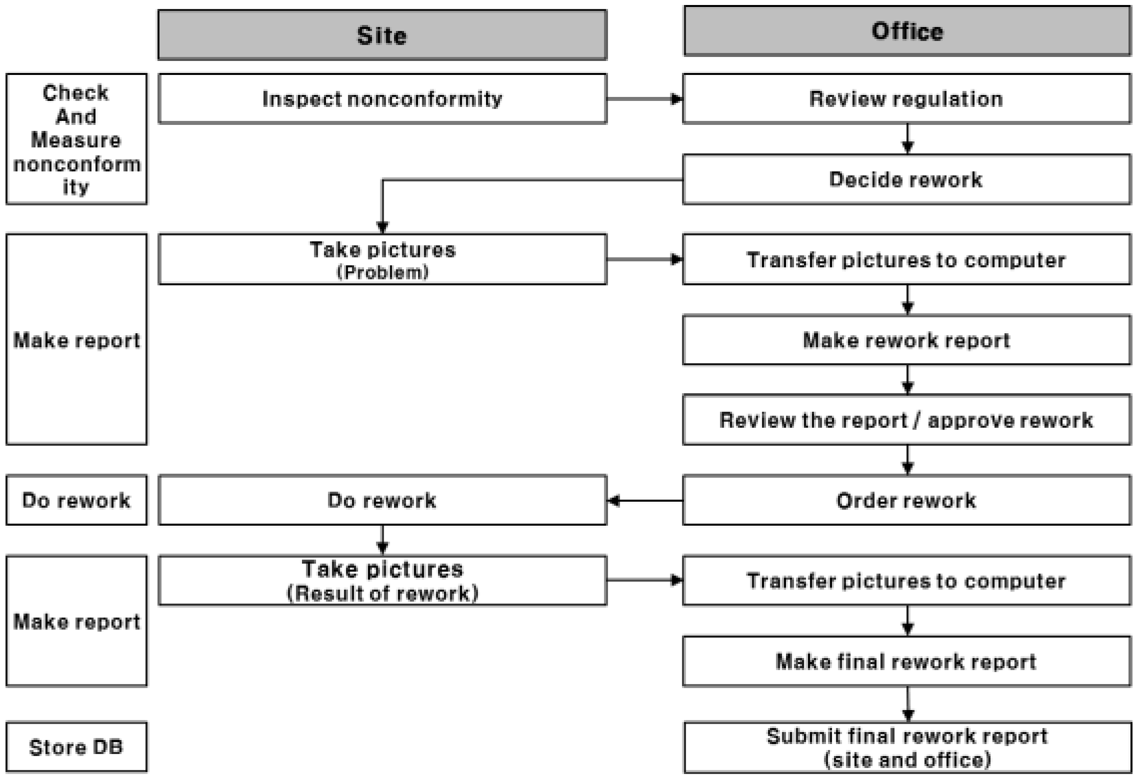

Figure 4: Flow Diagram of As-Is Rework Process in construction field

If defect items are discovered during inspection that do not meet the quality and safety standards and relevant regulations such as drawings, specifications and regulations, the field manager decides whether rework is necessary. If he decides that rework is required, he moves to the field, takes pictures of site with a digital camera and records the circumstances. After he defines the site conditions, he returns to the field office and transfers the picture data in the digital camera and searches the drawings, specifications, work procedures and quality and safety standards related to the part where rework is required. He then writes the 1^{st} nonconformity report. When the 1^{st} nonconformity report is finished, rework is ordered by approval of the construction site manager. If rework is ordered for subcontractor, the quality standard related to the rework report should be provided so that subcontractor can accurately understand the work contents. After the subcontractor's rework is completed, the field manager checks whether it achieves the target quality and meets the safety standard through site investigation and review and whether or not it should be reworked. The field manager should return to the office after checking the rework results, and inputs the rework information into the 1^{st} nonconformity report.

As described in above, there are too many waste of times while he comes and goes between the field and office, making the process of rework information inefficient. Also, there are many cases that the nonconformity report may be completed after writing the paper.

(3) Improved Rework Management Process using Smart Mobile

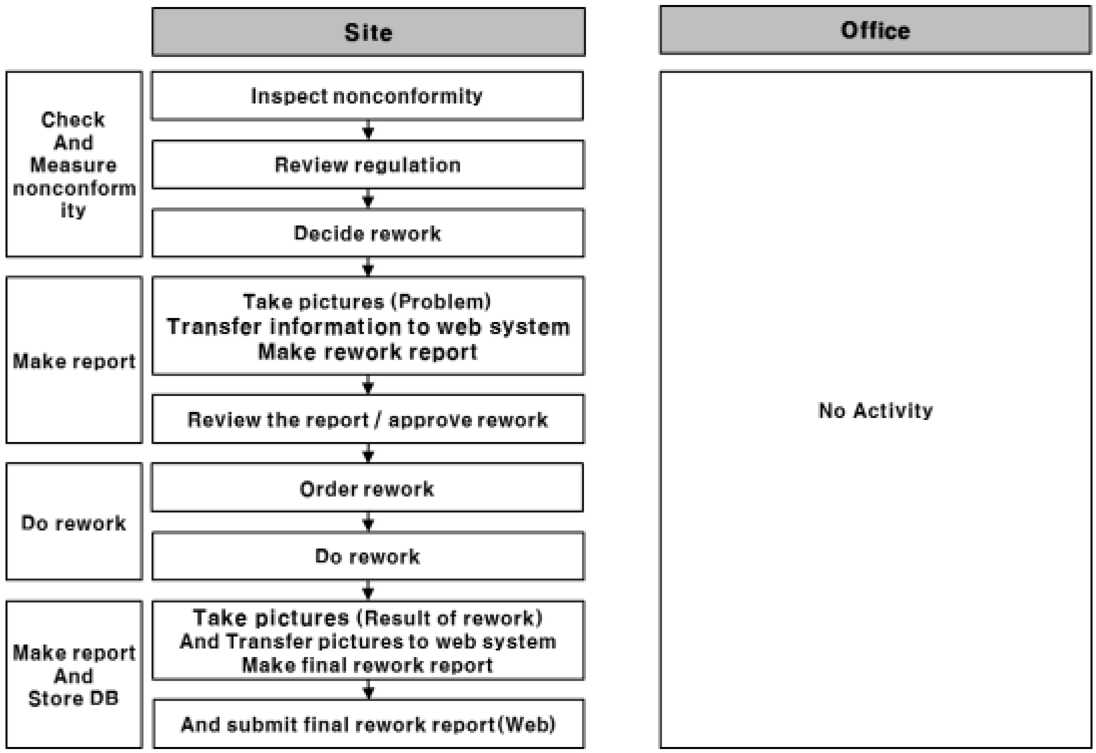

Figure 5: Flow Diagram of To-Be Rework Process in construction field

If smart mobile application is used, field manager can search the drawing, specification, law, construction plan and work order in real times, so he can find out nonconformity items and decide the necessity of rework. In addition, while field inspection is executed, by using the camera equipped in the smart mobile, field picture can be taken and saved while sending them to the rework information management system established previously. Input all the information related to the rework, prepare the measurement report and by using the mail sending function of smart mobile, send it automatically. Then after approval of the site manager is received, rework is ordered and executed. After the rework is completed, take pictures of the action taken and send them to the system to prepare the results report. The system in this study saves the final nonconformity report in the web-based system. Stored rework information can provide feedback to the similar rework information through parts, process, material, and keyword searches. The improved rework process, when smart mobile is applied to the rework information management, task done in the office will be reduced and handled immediately at the site. This means that field management can be done efficiently by overcoming the gaps of task due to distances between field and office. Meanwhile, to use the smart mobile in the field tasks requires interface configuration and execution processes.

4. DEVELOPMENT DETAILED SYSTEM

Smart Mobile Interface for Data Input and Process

① Initial Screen

② Input personal information

③ NCR input and search window select

④ Taking field pictures and input drawing, specification, law and procedure

⑤ Input general information

⑥ Nonconformity information input

⑦ Action confirmation input

⑧ NCR Search

This application is developed using ios. It creates the screen that can save report and search the rework information generated during the construction stage. When looking at the interface flow of rework information for a management application; first, execute the application, and insert the employer ID and password to login, then select screen which can insert the Rework information from the site and search for similar Rework information. When the rework, which you want to search, is inserted, the picture, drawing, specification, law, and procedure can be inputted with a simple touch of screen. Then other information input is completed, general information such as nonconformity Number., date, writer, location that happen construction rework and the type, method, and material are inputted, then nonconformity information of contents, reason, action taken and prevention plan can be inserted. Finally, after the rework information is inputted, evaluation on rework executed can be inserted. When rework information is searched, element, method, material and keywords are inserted, choose to derive the similar cases. In case of architecture work, construction methods can be divided into temporary work, earth work, bracing work, foundation work, reinforce concrete construction, steel construction, water-proof construction, masonry work, tile work, carpenter's work, curtain wall construction, stone construction, roof work, fitting, glass work, plastering work, metal work, painting work and other work, by using the touch method, then inserting and searching the construction-type.

Web Process

Rework information inserted by using the smart mobile is saved in the server as an electric document through the web-based system. The construction manager can search the rework information and compare it to the quality management plan by using the computer and smart mobile at the construction site. Thus, activation of feedback of rework information saved through this is possible. To do this, content configuration of the web interface is important as follows. In the case of searching for rework information that is already saved for other construction site, the generalization process, which removes the unnecessary information such as nonconformity report number, date, and writer, will be executed. It will be divided into general information, rework information and other references. The general information includes element, method, and material and the nonconformity information. It shows about all of conditions related to the rework and prevention plan as text. In addition the front and the rear situation pictures of rework corrective action taken will be displayed on the screen with text. In the other reference, an additional window will pop up when clicking, then specification, construction plan, work order, and building law can be downloaded. Web interface should be easy for all inserters and users. This emphasizes the importance of rework information to minimize the negative awareness that the release of rework information damages company reputation. To do this, generalization of information should be required and before establishing the system, various opinions should be accepted through expert consultation.

5. QUESTIONNAIRE SURVEY

(1) **Summary of Survey**
A survey of the Site Personnel was conducted to determine the quality and safety management and rework information management system that is established and used in the construction company. A total of 50 surveys were distributed and 50 copies were collected. Survey items consists of personal data, rework information management system in the company, real condition, field task application status of smart mobile in the field task, web-based sharing system status, and capability of suggested system.

(2) **Efficient of Rework Task using Smart Mobile**
From the survey results, some large construction companies have already established an information and management system, so the rework task has been also processed and inputted electronically. This is a formal task, and in the case of small and medium-sized

enterprises, most do not have an information management system due to economic issues. There are many reasons why feedback of rework information is not done, for example, the rework report is stored in paper and disposed when project is completed. In addition, they feel it is inconvenient to save the rework information and writing the report.

From the results of this study, diagramming the rework task smart mobile process was done. Smart mobile is used it can reduce the differences between field and office tasks. Also, there is the opinion that even if the system is not established, the application of smart mobile is useful because drawings can be checked in the field using CAD applications or PDF and Hangul documents can be saved so that they can be checked at the site.

As above, if smart mobile is used, not only management efficiency improves but also applications in various tasks can improve.

(3) **Analysis of Awareness on Rework Sharing System**
Everybody agrees the necessity of sharing and the importance of rework information. Negative awareness results were found because it was thought that rework is a site failure and company information leakage is a failure of the company negatively effecting personal performance evaluation. However, it shows that if rework information is generalized within the scope which does not influence the negative effect on the company's image, 70% of the respondents may share the rework information with others. There are many opinions when sharing rework information internally. Evasion of the responsibility for rework should be avoided, and modification of restrictions on the occurrence rework is required.

Based on the survey results, establishing the system requires consideration of social awareness. To do this, regulations for rework information should be submitted for public orders. Also, for internal and external sharing of rework information, generalization of information should be performed first, and the cost of establishing the system should be minimized. In addition, the difficulty of smart mobile application and web-based information management system should be lower to increase their efficiency.

6. CONCLUSION

Because rework in the construction industry increases the cost and delays the schedule, and the re-occurrence rate is high, management of rework is required. Although people working in the construction industry are aware of the importance of rework information, there is no effort to share rework information because of the negative connotations of rework. Because information which task processes of rework information cannot be verified through surveys, the task of coming and going between field and office has been done inefficiently. The places where rework information management systems are established are limited to certain major companies.

By using the smart mobile suggested in this study, necessary information can be searched rapidly, and rework information can be saved, so efficient tasks can be achieved by improving the construction rework process. Also, through web-based rework information system, sharing of rework information is possible. Thus, negative awareness of rework in the construction industry can be changed and information difference between major company and small and medium-sized company can be reduced. Regardless of the size of a company, rework rate in the field can be reduced by sharing rework information.

Rework information saved and shared through a rework information management system can be used as construction class material in the university, and it can be reused as the educational data for new employees and subcontractor's employees. In addition, reflecting on the quality and safety management procedure at the site is the place where rework occurs can be easily managed in advance.

However, a rework information management system as suggested in this study is only a prototype, and to implement this concept, technical items for establishing the system should be considered. Also, a rework information system prototype which is the final output of this study was not applied at an actual sites, but only in the research survey. Finally, since it uses the existing integrated construction information classification system, if this classification system is used for the core information by analyzing various rework cases, it is expected that the search for and use of rework information can be easy.

Acknowledgements

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Barriers to the Adoption of Prevention through Design (PtD) Controls among Masonry Workers

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Barriers to the Adoption of Prevention through Design (PtD) Controls among Masonry Workers

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Abstract

Dust from masonry operations affects not only the workers involved in direct exposure-causing tasks, but also those performing ancillary activities. Dust generated by these operations contains quartz, which has been classified as ‘group-I human carcinogen’ by the International Agency for Research on Cancer. To reduce dust generation during masonry activities, various Prevention through Design (PtD) control options are available. However there is lack of systematic adoption of the control options among the workers. The objective of this study was to identify the barriers to the adoption of PtD controls among the masonry workers. Survey research methods were employed for this study and member companies of the Mason Contractors Association of America were selected as the sample. Content analysis of the survey data identified decline in productivity due to the use of PtD controls as the major barrier. Other emergent themes include unsuitable work conditions and lack of trust in technology.

Keywords: Prevention through Design (PtD), masonry, dust, silica.

1. Introduction

Crystalline silica is a ubiquitous mineral and a basic component of soil, sand, granite, and many other minerals. Occupational exposure to silica occurs in a large number of industries, such as construction, mining, quarries and granite production and many others. An estimate of nearly two million workers in the United States are exposed to respirable crystalline silica in their occupational environment (OSHA, 2002). Occupational exposure to silica has been considered as a possible risk factor for several diseases: silicosis, lung cancer, pulmonary tuberculosis, and chronic obstructive pulmonary disease (WHO, 2000). Some autoimmune diseases may also be associated with occupational crystalline silica exposure; such as, rheumatoid arthritis and scleroderma (McCormic et al., 2010).

Silica exposure continues to be an important hazard in the construction industry and, therefore, remains a concern for the health and safety of construction workers. The construction industry has the highest rate of silica-related occupational fatality among all industrial sectors (Linch, 2002). Followed by sandblasting, other construction activities that result in severe silica exposure include jack hammering, rock/well drilling, concrete mixing, concrete drilling, and brick and concrete block cutting and sawing (OSHA, 2009). The dust generated by concrete and masonry operations contains respirable silica. This dust affects not only the workers involved in direct exposure-causing tasks, but also those performing ancillary activities. An examination of data provided by the Occupational Safety and Health Administration (OSHA) suggested that occupational categories such as masonry, stonework, tile setting, and plastering (Standard Industrial Classification (SIC) code group 174) are potentially more over-exposed to respirable silica than any other SIC code group (Linch et al., 1998). One author suggests that current "silica exposures are grossly unacceptable" and interventions are necessary to reduce worker exposures (Rappaport et al., 2003).

Review of existing literature reveals that interventions, in the form of Prevention through Design (PtD) control options, are available for the reduction of dust generation during masonry activities. Some of the effective control techniques include use of tool-mounted local-exhaust ventilation (LEV), area ventilation, wet methods, and sweeping compound for clean-up activities. However, for the PtD controls to be effective, they must to be used regularly and become a part of normal work process. It requires ongoing management support and worker acceptance to be effective. In reality, the use of PtD controls in the masonry industry is very sporadic and lacks systematic adoption. Since the decision to adopt/purchase PtD control technologies is made at management levels of the organizations, the objective of this study was to identify the owners' perception on the barriers to the adoption of PtD controls.

2. Intervention Methods

In a generic way, intervention can be defined as an attempt to change how things are done, in order to make an improvement (Robson et al., 2001). Interventions can be designed to prevent hazards at any of the three locations: (i) at the source; (ii) in the path between the source and the receiver, and (iii) at the receiver as shown in Figure 1.

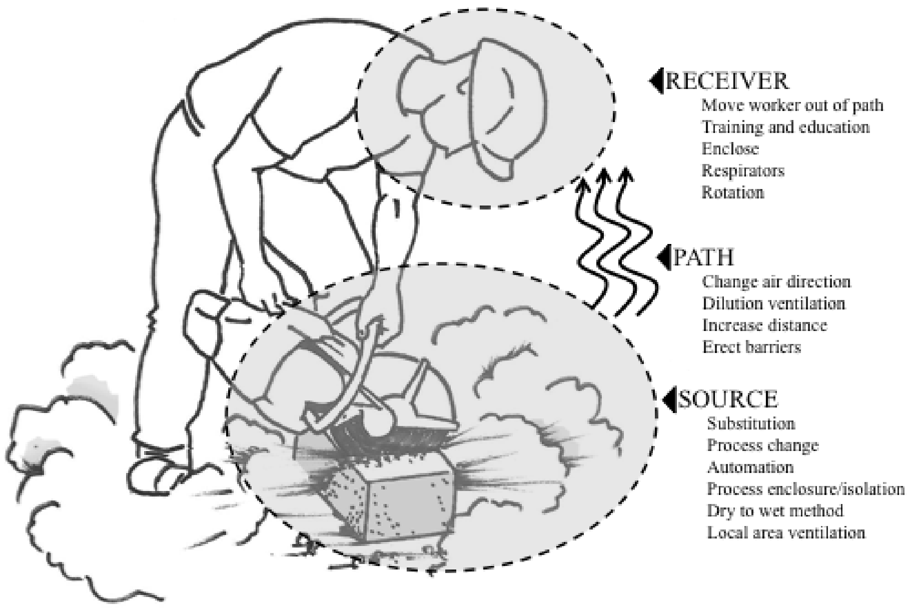

Figure 1: Interventions to prevent hazard exposures

Intervention practice uses a hierarchy of controls to prevent hazard at the source, substituting with less hazardous materials or processes as the ideal approach. However replacing concrete or brick as building materials is not feasible at this time. With the rise in the price of steel, buildings are being constructed with even more concrete. The aggregate, particularly granite, used in concrete is the primary source of respirable crystalline silica exposure during concrete cutting and finishing operations.

Changing the process will require more focused improvements in design and construction planning that may reduce some of the concrete cutting (after it is poured in place). Such improvements would require a specific commitment to planning, scheduling, and integration by all the parties involved in the construction project (Hecker and Gambatese, 2003). In most situations, the level of planning required to achieve the desired integration remains unrealized in the construction industry. The use of personal protective equipment (intervention at the receiver) is considered the least desirable approach to controlling construction health hazards. However respiratory protection is the primary, though still relatively underused, dust exposure reduction method currently used in construction. Studies have indicated that respiratory protection equipment is often not available or not used properly and that it may not provide sufficient protection from respirable crystalline silica for many tasks (Tjoe-Nij et al., 2003, Flanagan et al., 2006).

Several PtD control options are available for the reduction of dust generation during concrete and masonry activities. The Occupational Safety and Health Administration (OSHA) has recommended the use of PtD controls based on their performance in controlled environments (OSHA, 2009). General categories include: local-exhaust tool-mounted ventilation, area ventilation, wet methods, and sweeping compound for clean-up activities. Cutting, grinding, and sawing tools can be equipped with local-exhaust ventilation (LEV), which has been found to be very effective (Akbar-Khanzadeh and

Brilhart, 2001). Wetting of the substrates before or during abrasive operations has also been found to be effective (Akbar-Khanzadeh et al., 2007). Area ventilation, if properly designed, can offer some worker protection, although not as effectively as local-exhaust ventilation. Sweeping compound is composed of dyed sawdust, sand, and mineral oil and if spread over the floor before sweeping helps to keep down the dust. However, for any intervention to be effective it not only has to be effective but also must be accepted as part of daily work process.

The adoption of the PtD controls is dependent on the perception of the firm owners to a large extent. Some studies have examined the barriers and incentives for the implementation of interventions to improve occupational health in construction; but they are few in number. Other studies conducted by Akbar-Khanzadeh et al. (2007), Flynn and Susi (2003), Hess et al. (2004), Meeker et al. (2007), Neitzel and Seixas (2005), Rempel et al. (2010), Young-Corbett and Nussbaum (2009) have focused on the efficacy of the intervention rather than the implementation process.

3. Objective

Adoption of increased number of PtD controls can reduce risks to the workers from dust exposure. But there are certain factors, which act as barriers to the adoption of these controls. Hence, identification of the barriers to the adoption of PtD controls is necessary to increase the systematic adoption. Further, the recognition and significance of these barriers can vary among the firm owners. The objective of this study was to evaluate the firm owner perceptions of risks associated with masonry dust and potential barriers to the use of PtD controls.

4. Methods

A survey research method was adopted for this study. The overall research process of the study involved the following steps: (1) selecting sample masonry firms; (2) developing the survey instrument; (3) performing cognitive interviews for instrument validation; (4) administering the survey and collecting data; and (5) analyzing the collected data.

Sample selection

To evaluate PtD control use in the masonry trade sector, the members of the Mason Contractors Association of America (MCAA) were identified as the sample population of interest. MCAA is the foremost national trade association representing masonry contractors and suppliers in national legislative and political affairs, codes and standards composition, workforce development, education, market promotion, and general industry advocacy. The association's membership of over 1000 firms accounts for $2 billion in masonry sales annually. For the purpose of this study, the member firms of MCAA who are headquartered in Virginia (n=15) were selected as the sample.

Survey instrument development

The individual survey questionnaires were composed of two types of questions: (i) close-ended questions with ordered choices and (ii) open-ended questions. The questionnaires were divided into two parts: (i) close-ended questions addressing key demographic information of interest: type of project(s) the firms deliver, contractual roles of the firms, annual revenue of the firms, and number of employees; and (ii) open-ended questions regarding perceptions of the respondents regarding: health impact of masonry dust and about use of tool-mounted local-exhaust ventilation, area ventilation, wet methods, and sweeping compound. Respondents answering "rarely" or "never" on these items were subsequently asked "why not?" Survey respondents were also asked to list any additional methods for controlling dust employed by their firms and to share any additional information about their experience with dust and dust control.

The survey instrument development process is summarized in Figure 2 and described below.

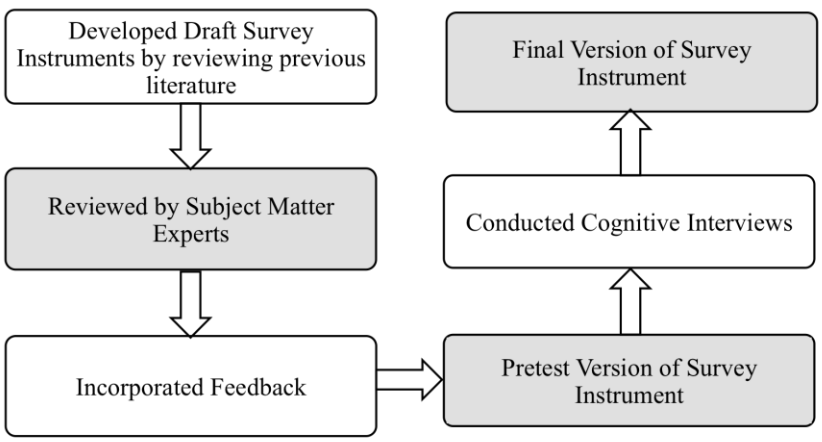

Figure 2: Survey instrument development process

The authors identified the survey items based on the study's key constructs of interest. Once the first drafts of the survey instruments were developed, a research measurement expert and two subject matter experts in construction reviewed those in order to ascertain the content validity of the items in terms of relevance, representativeness and technical quality. Feedback from the subject matter experts was incorporated into the second draft, the pretest version of the survey instruments.

Instrument validation

The pretest versions of the instruments were next evaluated for substantive and structural validity through cognitive interview procedures. Cognitive interviewing techniques, based on works of Willis et al. (1999) using a concurrent, scripted probing method were employed. Two experts from the construction industry were included for the cognitive interviews. Information obtained from the cognitive interview sessions were incorporated into final version of the survey instruments. Several typographical errors were corrected and several words in the questions were revised to increase clarity.

Data collection

Each of the 15 mason contractors headquartered in Virginia was contacted until reached, or to a maximum of three attempts. These attempts were made at different times of day and on different days of the week. Out of the sample size of 15, the owners of five organizations agreed to participate in the study, representing a response rate of 33.33%. After agreeing to participate, authors provided them background information about this study and appraised them about the requirements for data collection. The survey was conducted over phone following a standard protocol during April 2011. Interviews began with a brief summary of project objectives, a review of informed consent information, and an assurance that firm identity would never be linked to responses and that only aggregate data would be published.

Data analysis

Content analysis was utilized for analyzing the data from the open-ended questions. The authors examined the transcriptions to see what categories emerged and how those categories were related. Subsequently, these categories became the themes of the study. Data analysis began with the coding of each individual interview transcript. Authors reviewed the interview transcripts to identify key terms or phrases that summarized participant responses. After the second iteration, a table of exhaustive and mutually exclusive codes was created. These codes were then assigned to responses.

5. Findings

Based on the responses of the closed ended questions, all the respondent firms had been involved with the following types of projects: residential, office, educational and retail as subcontractors. The firms reported their annual revenue in the range of one to five million USD and they had employees in the range of 101 to 200.

Perception of risk

The respondents identified mainly two types of potential risks with dust exposure: (i) impact on workers' health, and (ii) customer satisfaction. However the comments pertaining to the health did not indicate their perceived risk towards workers' health due to exposure to dust. While two respondents identified crystalline silica present in the dust as hazardous to workers health, their overall perception could be captured in the following comment: "you cannot work in construction and remain dirt free…dust is a part of our job". All the respondents had been working in the construction industry in excess of 10 years (ranged from 10 – 30 years) and had considered the dust generated by the operations as part of it. Their workers were suggested to wear respirators, but not made mandatory. None of their workers had ever experienced lost day away from work due to dust exposure; neither firms had any worker's compensation claim due to dust exposure ever.

Perceived risk to customer satisfaction due to dust was evident from the responses. While most of the time working outside it was not possible to keep the dust under control, customer always complain about dust. But they made conscious efforts to keep the dust within control, as they wanted "repeat business" with the clients.

Use of PtD control technologies

Among the PtD control technologies, wet method was most commonly used by the respondents followed by use of sweeping compound (interior work), and tool-mounted local-exhaust ventilation. None of the respondents had used area ventilation in any of their projects so far. Respiratory protection was also identified as the most commonly used method of controlling worker exposure to dust. However, the use of respiratory protection is not mandatory and had been left on workers' discretion.

Analysis of the open-ended comments revealed key barriers to the adoption of PtD control technologies that can be categorized under three emergent themes: (i) decline in productivity; (ii) unsuitable work conditions; and (iii) lack of trust in technology. Respondents expressed concerns over usability of tool-mounted LEV (for tuck-pointing and grinding) and that it would take longer for the workers to learn the use of the technology. In addition, productivity issues identified were that the workers currently had a level of proficiency with the traditional tools and that the more complicated LEV tools would hamper their desired productivity. Also noted were problems associated with the size of the LEV and how that limit maneuverability in tight spaces. While majority of the tools used by the respondents were battery or gas operated, additional attachments for the LEV would constrain and limit worker movement. Also, the need to empty dust collection containers and lines was perceived as a hindrance to productivity. Several respondents mentioned a common work condition factor: PtD control technologies require power sources and this was not always available in locations close enough to the work. Moreover, as most of the works were outside there was minimal use of sweeping compound to control the dust.

Comments pertaining to wet methods identified it as the most commonly used control technology. Though no productivity issues were identified with this control technology, respondents pointed out the need for rinsing the equipment frequently. None of the respondents had used local area ventilation and were unfamiliar with the technology. Another common theme that emerged from the analysis was the pervasive lack of trust on the PtD control technologies. Most comments pertained to the belief that these control technologies did not provide dust control, dust was still generated and workers were covered with dust.

6. Discussion

Responses to the open-ended questions confirmed the understanding of the masonry firm owners that masonry dust contains crystalline silica. Several comments indicated the perceived understanding of the health risks to the workers due to the dust exposure, and some reflected the desire to reduce the dust and need for improved control technologies. However there was a strong undercurrent of an implicit acceptance of the risk of dust exposure as being inherent to construction activities, and to some extent unavoidable. Interestingly, respondents perceived a serious threat to customer satisfaction due to dust especially in educational and office projects. This indicated that masonry firm owners were not focused on the objective risk to workers.

Content analysis of the responses revealed that some firm owners misunderstood the difference between ambient dust control and dust control to protect workers from exposure. While ambient dust could be controlled by sprinkling water, that could not control dust generation from the activities within worker breathing zone. Respirators could reduce the threat to dust exposure but its use was not consistent. The prevailing theme was that the owners considered it the responsibility of the worker to wear the respiratory protection. There was a clear lack of perceived role on the part of the owners in establishing policies and protocols to improve the adoption of PtD control technologies by the workers.

Limitations and future direction

There were several limitations to the present study. The work presented in this paper describes the pilot data collection stage of ongoing work; therefore, the sample size was small. Ongoing phases of the project involve the use of a validated instrument with both quantitative and qualitative items. The second limitation of the study was the selection of sample firms that had membership with larger trade organizations. As a trend, firms that opt to join trade organizations tend to be larger in size (Young-Corbett, 2007). Thus the present study only included the perception of the larger firms and lacked the input of the relatively smaller sized firm owners. Future study will include firms of varying sizes in the sample. Finally, the assumption that decision to adopt/purchase PtD control technologies is made at management levels of the organizations was supported, in a majority of the cases. However, the perception of the workers also plays an equally important role in adoption of the PtD control technologies. Further research will be necessary to examine the perception of the workers along with that of the firm owners.

7. Conclusion

Perception of risk is a critical antecedent of mitigating risk. Thus for the adoption of any intervention for mitigating risks, it is important to examine the decision makers' perception of risk – there is an association between risk perception and adoption of interventions. One of the objectives of this study was to evaluate the masonry firm owners' perception of risk from masonry dust exposure. While there is a common understanding that masonry dust contains crystalline silica that has detrimental effects on the workers, still the workers accept it as inherent and unavoidable part of the operations. The second objective of this study was to identify the key barriers to the adoption of PtD control technologies in the masonry trade. Inputs of particular importance are in the form of the three emergent themes of barriers such as decline in productivity, unsuitable work conditions and lack of trust in technology. These themes will provide inputs into the improvement of existing control technologies as well as in the design of effective controls technologies in the future to protect masonry workers from dust.

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Health and Safety Organization in Micro and Small Construction Companies

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Health and Safety Organization in Micro and Small Construction Companies

Abstract

Despite the beneficial effects of the adoption of safety management systems are known, in Italy, their application is not common for companies in the construction sector. The majority of construction companies are unstructured companies whose working nucleus consists of a few people. The adoption of a quality management system, according to the standard ISO 9001, is instead common for those enterprises which participate in public tenders.

Recently, the Italian Law has introduced two new features for companies through the Legislative Decree (D.Lgs.) 81/08: (i) the chance to define and adopt a "models of organization and management" and (ii) the opportunity discharges from the administrative liability deriving from the adoption of an appropriate "model of organization and management", in case of "manslaughter, bodily harm or serious committed in breach of safety regulations and the protection of hygiene and health at work" (D.Lgs. 231/01).

At the Building Environment Science & Technology department (B.E.S.T.) of *Politecnico di Milano*, a research project has been recently instituted in order to study a way to allow construction firms, even micro and small-sized, to benefit from mentioned advantages. This paper deals with a simplified "model of organization and management" based on a progressive number of requirements, which is in a developing phase.

The introduction of "models of organization and management" also for micro and small enterprises can drive to the renewal of the policies related to health and safety in the Italian construction sector.

Keywords

Health and safety management system, model of organization and management, construction sector.

1. Introduction

A "management system" is a set of related or interacting items which manage coordinated actions for driving and keeping under constant control an organization. It also has the task of establishing explicit policies, objectives and strategies to achieve them.

The adoption of management systems can offer several benefits to a firm. In particular, concerning the health and safety at work, Bottani et al. (2009) demonstrated that the adoption of health and safety management systems involves both a better performance - in terms of (i) definition of the targets in the field of health and safety and their communication to employees, (ii) updating data on risk and the risk analysis, (iii) identifying risks and defining corrective actions and (iv) training of workers -, and a significant reduction in the number of accidents.

2. Italian legislative framework

Even in Italy, the regulatory approach to health and safety in the workplace has evolved from a so called "command-control" system, to an "evaluative-contextualized" system. In particular, in the building construction sector, when an evaluative aspect is considered very important, the Law provides that its evaluation and the evaluation of any action resulting from it are carried by more than one subject.

According to this approach, Trani (2011) proposed the "dual control" theory, whereby the public administration, who organizes a public tender, has also to develop an "aware" design of safety in order to eliminate or reduce the risk sources related to the execution phase. In this way, the construction companies are faced with a project developed by the client, who can assess also their ability to manage the construction site with maximum safety.

The D.Lgs. 81/08 distinguishes the firms that participate in a public tenders, in two categories: general contractors which obtains the contract and executrix firms which actually carry out the work (of course, the general contractor could be an executrix firm as well). The general contractors are usually enterprises of medium and large dimensions, structured and adopting management systems. Instead, the executrix firms are typically micro and small enterprises not structured and non adopting management systems (Bottani et al., 2009).

the D.Lgs. 81/08 requests that each firm involved in a public or private building construction activity has to provide the client the necessary documentation for "technical and professional competence" (TPC) and the client is required to verify the validity of the documentation submitted. With the expression TPC we mean the evaluation of documents providing objective evidence of technical and professional qualifications of the firm.

Recently, the D.Lgs. 81/08 introduced two innovations for companies and enterprises: (i) the chance to define and adopt a "models of organization and management" (it is not a mandatory request) and (ii) the opportunity to have protection on administrative liability deriving from the adoption of an appropriate "model of organization and management". These responsibilities include "manslaughter and bodily harm or serious committed in breach of safety regulations and the protection of hygiene and health at work" (D.Lgs. 231/01).

The Italian legislation is acting a restrictive policy against these types of accidents. Heavy sanctions are used to inhibit unsafe behaviors, such as administrative and penal sanctions and the suspension of the firm.

The suspension of the firm may be acted in case of non-regular use of staff and in case of the reiteration of violations in health and safety in the workplace. In particular, the violations that implies the suspension of a company are:

1. lack of the risk assessment document;
2. lack of the personal protective equipment against falls from above (*e.g.* safety belt);
3. lack of collective protective equipment against the void (*e.g.* parapet);
4. non-application of the reinforcement of support;
5. work near power lines in the absence of organizational and procedural measures to protect workers from the deriving risks;
6. presence of bare conductors in tension in the absence of organizational and procedural measures to protect workers from deriving risks;
7. lack of protection against direct and indirect contacts (*e.g.* grounding devices, circuit breakers, breakers),
8. lack of the notify before starting work that may involve the risk of exposure to asbestos;
9. plan of emergency and evacuation;
10. lack of education and training;
11. non-establishment of services for prevention and protection and the appointment of its manager;
12. Lack of the operational safety plan (POS).

D.Lgs. 231/01 provides financial penalties in every case of violation to laws about health and safety at work. The amount of the fine depends on two criteria: (i) determination of shares in a number between 100 and 1 000, (ii) allocation for each share of a value between € 258 and € 1 549.

In the event of a penalty the court shall determine the number of shares and the respective value taking into account: (i) the gravity of the act, (ii) the degree of responsibility of company, (iii) the work done to eliminate or mitigate the consequences of the fact and to prevent the commission of further accidents.

The amount of the fee shall be based on economic conditions of the company in order to ensure the effectiveness of the penalty. A possible consequence for the enterprise is that it could be forced to close down.

Finally, according to the D.Lgs. 81/08, a "models of organization and management" satisfies the requirements on health and safety, if it is constructed in accordance with OHSAS 18001 or with the UNI-INAIL guidelines (2003).

3. Statistical framework

According to the latest data published by Confcommercio (2009), dating back to 2006, in Italy, the percentage of construction enterprises is the 13,7% over the total. Their disaggregation by number of employees per enterprise is shown in figure 1. The micro and small construction companies represents therefore almost the totality of the companies in the construction sector, however they consist of unstructured or family nuclei composed by few working units. At the same time, the highest number of accidents (INAIL, 2009) is recorded in the construction sector (figure 2).

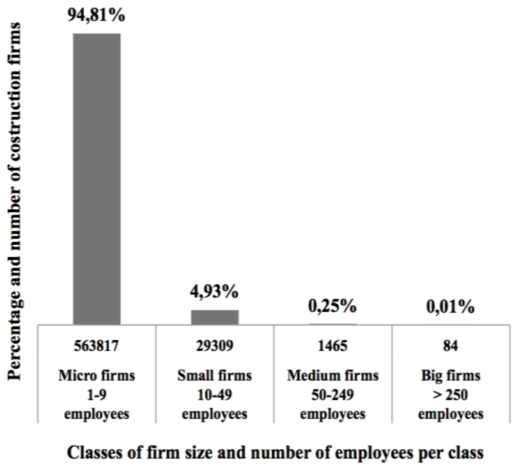


Figure 1: Percentage and total number of construction firms per firm size.

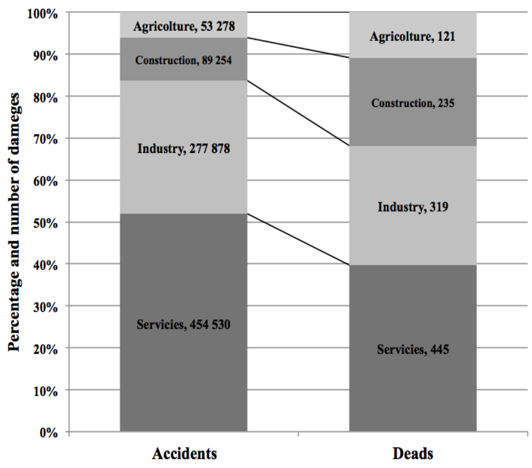


Figure 2: Percentage and total number of accidents and dead people per economic sector.

Despite the beneficial effects resulting from the adoption of safety management systems are known, in Italy, their application is not common. Up to now, 22 624 companies are accredited to the ISO 9001 and only 312 companies to the OHSAS 18001 (ACCREDIA, 2011).

Currently, the micro-sized construction firms are not able to cope appropriately with a review of TPC, which is simply to provide some technical and administrative documents. The documentation for the TPC also includes documents relating to health and safety at work, such as the risk analysis, statements regarding the training of personnel, etc. Ambition to apply the models of management and organization, as they are currently conceived, at a micro-small enterprise appears utopian.

In order to allow also the micro and small companies to benefit of the advantages deriving from the adoption of management systems (possibly fully integrated), a simplified model of organization and management is in a developing phase.

However, Salomone (2008) has found that implementing a safety management system is generally compatible with the economic and human resources of large companies, on the contrary, it is not considered sustainable by micro and small firms, mainly because of: (i) organizational difficulties, (ii) lack of information, (iii) high costs and (iv) the lack of dedicated human resources.

For this purpose, a research project has recently been established. Its goal is to design a framework called "progressive model of organization and management", which provides for the implementation of simplified models of organization and management, each of them designed in relation to (i) company size, (ii) the available human resources, (iii) operational needs and trying to streamline document production borne by the employer. Its voluntary adoption enhances the company in relation to its competitors and demonstrates its proactive approach respect to health and safety in the workplace.

4. Management model

General contractors are usually medium and big sized companies that can adopt existing management systems as they are proposed, for example, by ISO 9001, OHSAS 18001 and ISO 14001 without strong barriers and directly benefitting from their advantages (Bottani et al., 2009); however the executrix firms are often micro or small sized and the progressive model of organization and management is designed on their peculiarities. One of the most important features of a micro and small sized firm is its management structure. Typical management structures and key actors of a building firm are presented below.

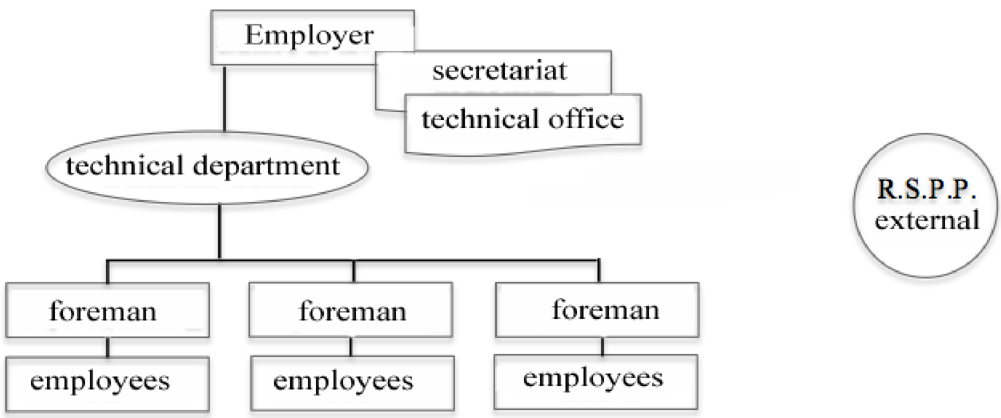
Key actors of typical micro and small enterprises

The D.Lgs. 81/2008 defines the following key actors:

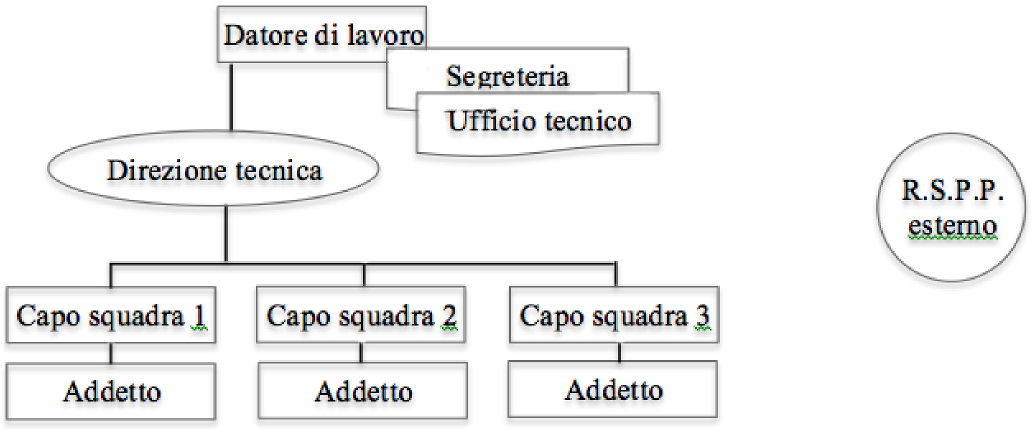
1. employer - the titular subject of the employment relationship with the worker;
2. manager - person who by reason of professional skills and powers of the hierarchy implements employer's directives, organizing and supervising work activity;
3. responsible - a person who by reason of professional competence and within the limits of hierarchical authority oversees the work and provides direct orders, monitors the proper execution by workers and exercising functional power of initiative;
4. responsible for prevention and protection in terms of health and safety, or RSPP - person with specific skills and professional qualifications including a degree in technical and vocational training courses with mandatory five-year update, being part of the prevention and protection in terms of health and safety in the workplace; this figure can be covered by a worker of the same company or by an outside professional;
5. Employee - person who, regardless of the type of work contract, works for a public or private employer.

Organizational structures of typical enterprises

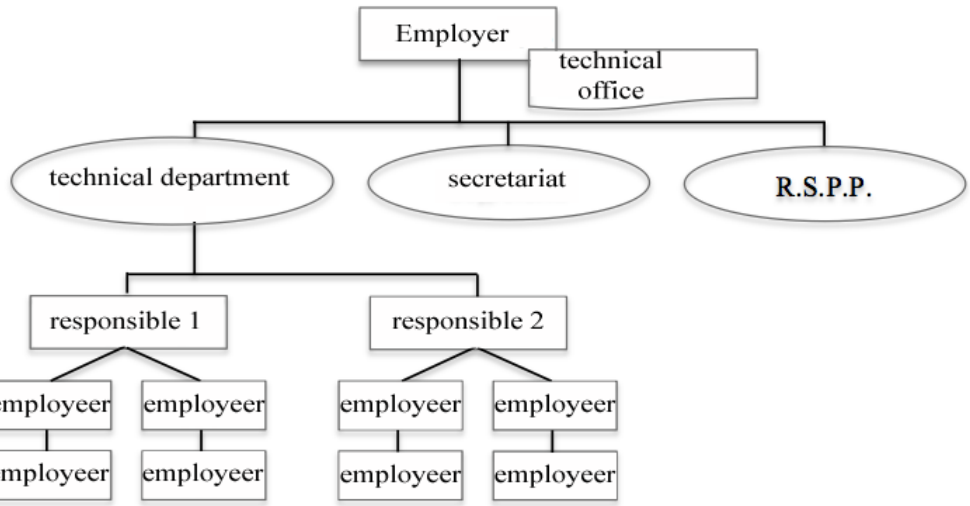
(i) Model of a micro enterprise constituted by 3 working units:



(ii) Model of a micro enterprise constituted by 8 working units:



(iii) Model of a small enterprise constituted by 14 working units:



The presented models are derived by existing firms on which the applicability of simplified models of organization and management will be tested during a following phase of the project.

5. Progressive model of organization and management

The progressive framework is intended to gradually implement security management within a company driving to create awareness and a culture of health and safety in workers (employer, managers, responsibles and employees).
Thus, a management system is effective when it is approved of and encouraged by all the workers within a company, who must contribute to ensure the safety of themselves and others and it can achieve its goal if it has a dynamic nature and it evolves consequently the input it receives (INAIL, 2003).
The prerogative of a progressive models is to propose sets of requirements which, if met by the company, can allow (i) to become competitive – Set 1 –, (ii) to achieve a stable position and to develop itself thanks to conquered technical merits – Set 2 – and (iii) be able to overcome serious, very serious or fatal injuries – Set 3 –.

Set 1: Reaching a competitive status

In Italy, the "technical and professional competence" was introduced and precisely defined by the D.Lgs. 81/2008. It involves the production by the company of some documents: (i) inscription to the chamber of commerce, (ii) the risk assessment document, (iii) a document which proves that it regularly paid contributions (called with the acronym DURC). A company with a "technical and professional competence" is also more competitive in terms of safety.
However, in order to remain competitive, it is not enough for a company having acquired a high TPC, but the TPC has to be constantly updated (*e.g.* adopting a policy of continuous training of employees) or the documentation must be submitted an ongoing review process, to stay current and thus available (*e.g.* avoiding the expiration of the DURC).
For this purpose, it is necessary to create procedures tailored on the company, which do not go to weigh down its operation, but make it more effective. Models of management and organization are volunteers. This point is important, since it does not require the employer to comply with regulatory requirement, but as previously mentioned, allows for a competitive company ahead of its time with a proactive approach.

Set 2: Achieving a stable position and developing it thanks to conquered technical merits

Following the consolidation of methodologies for updating of administrative documentation, a constant updating of skills of workers, which will over time become increasingly specialized, must be achieved.
Testa (2009) states that performing tasks safely is in the interest of both the enterprise and the worker, since work in a risky benefits no one. However, sometimes, the use of safety devices is perceived by stakeholders in the construction process as an impediment that involves the slowing down of work flow. There is no doubt that this impression does not justify the risk to which employees are exposed.
Thus, having good ability to work in a generic sense is not enough, what is important is to carry out work activities in safe mode, because this is the only mode of professional work. Then, the aim is the creation of virtuous reference models that conceive safety as an essential part of professionalism.
Of course, the virtuous behavior does not exempt the company from the production of more specific documentation. Limited to the field of safety, the Set 2 requires the drafting of the Operational Safety Plan (POS) that will meet all the requirements demanded of D.Lgs. 81/2008, such as:

1. company name, address and telephone number of the registered office and the construction site;
2. list and description of the construction activities carried out by the executrix firm and by the self-employed;
3. the names of the responsibles for first-aid, for fire-fighting, for evacuation, for emergency management and workers' representative and their certificates of qualification to perform the job to which they are assigned;
4. name of the doctor in charge,
5. name of the head of prevention and protection (RSPP),
6. name of the technical manager or of the foreman,

7. the number and qualifications of employees of the executrix firm and of the self-employed people working in the yard on behalf of the the executrix firm;
8. the specific tasks, regarding safety and security, carried out on site by each figure,
9. description of the construction activities,
10. list of scaffolds and provisional works of major importance
11. list of dangerous substances and preparations used with their technical specifications,
12. the outcome of the report about noise evaluation;
13. identification of additional preventative and protective measures,
14. Documentation on information and training of employees on site.

Set 3: Overcoming serious, very serious or fatal injuries

The application of this last set of requirements assumes that the company has fully integrated the previous health and safety requirements into its own procedures
But what if the company that works in a virtuous way faces a serious accident at work (serious, very serious or mortal injury or accident) arising out negligence or a wrong behavior of an individual worker?

As mentioned in a previous paragraph, nowadays, Italian Law adopts a strict policy in the field of health and safety at workplace (*e.g.* Corte di Assise of Torino, 2011). However, the D.Lgs 231/01 gives an important opportunity to the employer which consists in having protection on administrative liability deriving from the adoption of an appropriate "model of organization and management".

Then, the Set 3 consists in the integration of the requirements proposed by the D.Lgs. 231/01, we have not reported yet, with the coordination of the relationship management of yard with other contractors or sub-contractors. For coordination of the relationship management of yard with other contractors or sub-contractors we mean: coordination meetings of health and safety, report of inspection, coordinated use of facilities of other firms, testing and maintenance of these facilities and the coordinated management of emergencies.

To clarify the application of the progressive model of organization and management, the combination between the three schemes of firms and the three sets of requirements mentioned, is reported:

1. the micro firm model consisting of 3 units shall apply the requirements of Set 1;
2. the micro firm model consisting of 8 units shall apply both the Set 1 and 2;
3. The small firm model consisting of 14 units shall apply all the three Sets proposed.

Every company, on which the progressive model will be tested, can skip to the next set only after proving the successful integration of the requirements of the starting set in its procedures.

6. Organization model

An organizational model is a set of related or interacting items which organize a group of people and resources, with defined responsibilities, authority and interrelationships. The model of organization resulting from the D.Lgs. 231/01 has a structure that is based on the Diming cycle: planning, implementation, monitoring, evaluation/action (do, plan, act, check), making it overlapping to a safety management system according to OHSAS 18001 or UNI-INAIL. Therefore, they can be integrated fairly easily.

7. Integration between a management system and a model of organization

In Italy, in 2008 for the first time, D.Lgs. 81/08 introduced the model of organization and management. This model will be the special part of the model D.Lgs. 231/01 shown in the following chart:

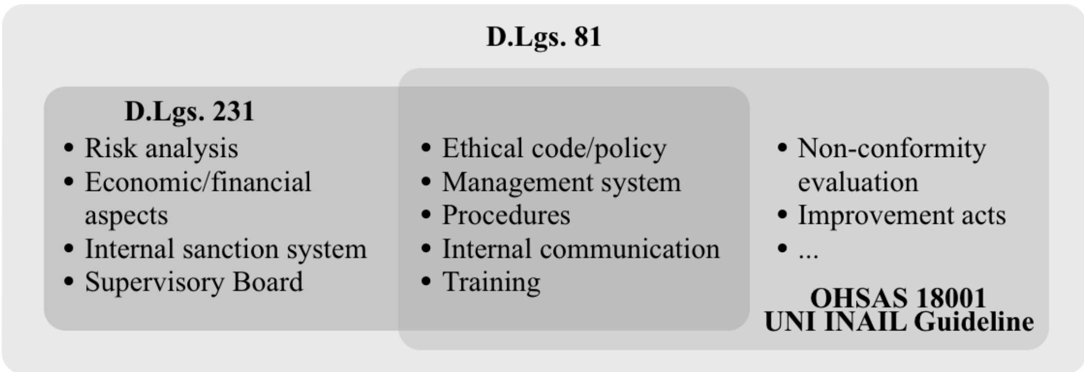


Figure 3: The overlap between a safety management system (OHSAS 18001:2007 and UNI–INAIL Guideline) and a model of organization (D.Lgs. 231/01).

A safety management system at work (SMS) is a system aimed at achieving the health and safety goals and it has to be designed to minimize the ratio between costs and benefits.

The adoption of a SMS is not mandatory, but permits to reduce the costs of "non-safety": (i) indirect costs, because it reduces the probability of occurrence of accidents and the deriving costs, (ii) direct costs, because the firm adopting a SMS can request a reduction of the fee.

This reduction, combined with the *bonus-malus* mechanism could result in a total discount of 35% - 40% of its insurance premium, calculated according to different parameters (INAIL, 2003).

8. Conclusions

While in Europe and in the rest of the world, up to now, several case studies of fully integrated management systems have been documented, their implementation in Italy is still far to be a common practice. Only the ISO 9001 certification is perceived as a necessity in particular for those firms which participate to public tenders. Moreover, despite the high number of accidents per year, there are few firms which have applied for and obtained the accreditation OHSAS 18001.

Then, always in Italy, the micro and small construction companies represents therefore almost the totality of the companies in the construction sector. However, despite the beneficial effects of the adoption of safety management systems are known, the implementation of a safety management system is not considered sustainable by micro and small firms, mainly because of (i) organizational difficulties, (ii) lack of information, (iii) high costs and (iv) the lack of dedicated human resources.

In addition, the D.Lgs. 81/08 introduces two innovations for companies and enterprises: (i) the chance to define and adopt a "models of organization and management" and (ii) the opportunity to have protection on administrative liability deriving from the adoption of an appropriate "model of organization and management". This model allows satisfying the requirements on health and safety, if it is constructed according to OHSAS 18001 or to the UNI-INAIL guideline.

Starting from these items, we proposes a so called “progressive model of organization a management”, which provides for the implementation of three simplified models, each of them designed in relation to (i) company size, (ii) available human resources, (iii) the operational needs and trying to streamline document production borne by the employer.

The proposed progressive model of organization a management will be tested on existing construction firms to evaluate the applicability and the effectiveness of the proposed model.

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Managing Health and Safety Sustainability in Building Construction through Infrastructure Provision

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Abstract

The physical construction process is characteristically constituted as a major challenge within the context of health and safety. It exposes site workers to a range of health and safety hazards. Associated injuries and even loss of lives have been recorded in various research publications. Losses from site-worker accidents range from physical, to economic and social amongst others and they have direct bearings on all stakeholders in construction projects. The welfare of employees on construction sites should therefore be of paramount consideration to any construction company. Proactive safety measures have been identified and typically recommended in various similar studies, but little attention has been given to the studies that hinge on reactive measures. This research thus aims at eliciting information on the various degrees of the willingness to make provision for purposeful on-site health services and facilities as emergency responses and reactive measures on construction sites. Using a managerial survey instrument, information was obtained from various construction managers in Lagos, Nigeria, on a spectrum of health facilities on site. Results revealed a wide divergence of opinions on reactive health and safety measures. The feedback from the study will aid policy formulation and review for the construction industry, as well as protect the ultimate welfare of construction workers.

Key words: Construction managers, developing country, lagging indicators, leading indicators, site safety, health services.

1. Introduction

The risk of accidents on construction sites is inevitable as the nature of the physical construction process typically constitutes and presents safety challenges. According to Laryea and Mensah (2010), construction is widely regarded as an accident prone industry due to several factors such as; the physical environment, the nature of construction work operations, construction methods, construction materials, use of heavy equipments, and physical properties of the construction project itself. The impending losses from site accidents or mishaps may include injuries, loss of life, financial and time resources, professional reputation, and loss of goodwill amongst other factors (Adenuga, Soyingbe and Ayayi, 2007). Safety on construction sites should therefore be of paramount importance to any construction company that wants to continue to operate. Although dramatic improvements have taken place in recent decades, the safety record in the construction industry continues to be one of the poorest (Huang & Hinze, 2006; Farooqui, Arif & Rafeeqi, 2008). As a central part of the regulatory framework, many developed countries have incorporated safety indicators in responding to the increased requirement generated by one of the most hazardous sectors of the economy.

Traditionally, measures of safety are ‘after-the-occurrence’ actions when injuries would have already taken place. Farooqui et al (2008) state that these measures are labeled ‘reactive’, ‘trailing’, ‘downstream’, or more technically ‘lagging’ indicators because they rely on retrospective data. These measures are post-accident in nature and consider injury, ill health and other relevant factors pointing to the incident. More contemporarily, there has been a departure from these safety measures towards ‘leading indicators’- which are more pro-active in nature. Many authors report that proactive, or pre-accident measures are better suited to producing better safety performance on sites (Smith et al,1991; Staley et al 1996, Kuju-Ahmad, 2000). Some other reports (undated) even suggest that organizations need to combine proactive and reactive techniques into an integrated system for investigating, monitoring and responding to changing situations. However, the formal adoption of any of these general measures of safety should fit into the localized context of any construction industry. In Nigeria, there is little data on the issue to suggest best practices. Generally, proactive measures deal with data and require essential feedback on performance before injuries or incidents occur. Reviews should be constantly carried out in order to recommend the most ideal indicators of safety performance. Anderson (1992) states that proactive safety performance requires the provision of plant & equipment (hardware) and systems & procedures (software) which are 'fit for the purpose' of reducing risks, and people who are competent, through knowledge, skills and attitudes, to operate the plant and equipment and to implement the systems and procedures. However, most developing economies are financially constrained, and these requirements may represent additional fiscal loads far beyond the budgetary estimates of the project itself. Further, reactive practices happen to be indicative of many sectors in developing countries. Adewunmi, Famuyiwa and Harrison (2009) explain that the ‘reactive syndrome’ is a common phenomenon in third world countries. This is traceable to many factors that emanate primarily from extremely limited resources. In this light, the lagging approach for construction safety may have potentials which have been generally ignored recently. It implies lesser resource allocation in construction health and safety planning. Nevertheless, the inevitability of health and safety risks in the construction process makes it widely agreeable for construction personnel to adopt the use of *fundamental* health and safety precautions during construction.

This study aims to elicit information on the various degrees of the willingness of construction managers to make provision for purposeful on-site health services, as reactive measures for the safety and health performance on construction sites in Lagos, Nigeria. In fulfilling this aim, the following objectives were sought.

1. To identify the health and safety risks associated with construction sites in the study area.
2. To determine the levels of safety measures at construction sites in Lagos
3. To assess the level of 'leading indicators'
4. To assess the influence of risk on site workers wages.
5. To ascertain the willingness of construction managers to make provision for preliminary on-site health facilities.
6. To recommend a health and safety system best suited to fit the welfare and economic needs of various stakeholders within the study area.

2 Literature

Safety Management and Construction Sites

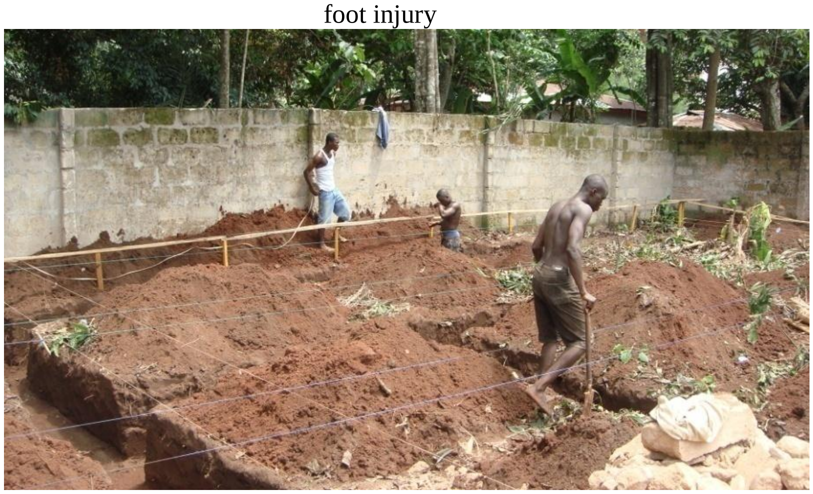
Many accidental occurrences and fatalities stem from on-site construction activities. Throughout the world, the construction industry is disproportionately more dangerous when compared to other industries (Rosenfeld, Rosenfeld, Sacks and Baum, 2006; Mohamed and Chinda 2010). For example, the construction industry in Nigeria looses 5-7% of her workforce annually to avoidable construction accidents. The industry has been placed in a fatality league after coal and petroleum products industries. Adenuga et al (2007) discovered in their study that employers largely ignore worker safety and welfare on construction sites in Lagos. It was reported that workers were never put through a safety training programme nor did they have any prior training in construction safety management. Managers also ran their company without any safety management structure. Ironically, a large percentage of managers felt that workers on their site knew the proper safety procedures for their job. According to the International Labour Office (1999) a dangerous act can be performed hundreds of times before it results in an injury, therefore managers' efforts must be directed at eliminating these potential dangers. Safety management involves the functions of planning, identifying problem areas, coordinating, controlling and directing the safety activities at the work site, all aimed at the prevention of accidents and ill health. Effective safety management has three main objectives; to make the environment safe; to make the job safe, to make workers safety conscious. Its importance cannot be over emphasized in the building construction workplace.

Risks in Construction

Risk taking forms one of the biggest problems in the industry in terms of health and safety on sites (Rawlinson and Farrell, 2009). Construction risk is essentially the possibility of incurring an injury on site. According to Kuju-Ahmad (2002) an accident may not necessarily imply an injury. Olatunji, Aje and Odugboye (2007) identified construction site risks of site workers in Lagos. In their study, it was established that only 25% of the contracting firms surveyed provided ‘fair’ standards of safety. Respiratory equipments for protection against dust or gases were rarely used while protection against corrosive and irritating substances were not available. Safety goggles for protection against chemical splashes were also very uncommon. It was concluded that health and safety procedures do not exist, especially in the areas of protective materials, user training, maintenance, and supervision. The same study further revealed no evidence of medical surveillance to monitor the health status of site workers, as the practice is usually employed in order to detect early signs and symptoms of illnesses in workers, so that timely intervention may be made. See also (Ayodele and Ayoola, 2005).

Figure 1: Worker at roof top of ongoing construction in Lagos not equipped with any safety or personal protective equipment. No scaffold support in place either

Plate 2: Site workers during preliminary construction at a site in Lagos working barefoot. Highly subject to foot injury



Safety approaches (Leading and Lagging Indicators in Construction)

Safety is everyone's responsibility and it is a moral and legal obligation of employers to provide a safe working place and of employees to work safely. Proactive safety provides feedback on safety performance within an organization *before* an incident occurs. It involves measuring compliance with the performance standards that have been set and achievement of the specific objectives. The primary purpose of proactive monitoring is to measure success and to reinforce positive achievements in order to nurture a positive safety culture. According to the UK Health and Safety Executive (HSE) policy advisory group (2010) proactive measures entail acting before things go wrong, carrying out regular inspection to ensure standards are being implemented and objectives are being met. It ensures that inspections and reports are of adequate quality, common problems and weaknesses are identified; training needs are met; deficiencies previously reported are rectified; resource implications are recognized and that risk assessments remain valid. Reactive monitoring on the other hand (lagging indicators) entail investigating injuries causes of illness and property damage and identifying why performance was substandard. What makes a technique Proactive or Reactive is the purpose to which it is put. That is: either to investigate dangerous situations, with a view to putting them right before an accident occurs; or to investigate accidents that have already occurred with a view to determining their causes and preventing a recurrence. Reactive measures include accident investigations, inspections and job safety analyses. These measures utilize factual data about the victim such as age, gender, occupation, description of circumstances surrounding the incident, activities which were directly and immediately involved in the accident such as time and conditions, details of events, including the direct causes of any injury like ill health, other losses suffered from the incident and any underlying causes, for example failures in management control, details of the outcomes, i.e. nature of injury, damage to property/other losses, details of remedial actions, both immediate and long term. They also rely on the efficiency of reporting. Though, Kuju-Ahmad (2000) claims that historically, there has always been a low level of reporting of accidents by employers. They are however very useful in that they are: relatively easy to collect; easily understood; arguably the most valid indicators of OHS performance; easy to use in benchmarking or comparative analyses; and useful in the identification of trends (Lingard and Wakefield, 2010). Nevertheless, it has been argued that this approach is easier to deal with, as opposed to proactive safety measures which require time and resources (that may not always be readily available). However, in spite of the fact that this technique is now largely ignored, it may prove essentially useful in locations where there has been extremely poor existence of *any* construction site safety and health management methods. As such, it has been evaluated for this study in view of financial constraints which potentially can weigh down the adoption of the more widely accepted approach in an economically constrained region. This indicator would thus serve as a ‘beginners’ guide for improvements in the general outlook and attitude that governs construction site safety in Lagos.

3 Research Area and Procedure

The Building Construction sector in Nigeria is expanding strongly with a growth of 10% per year. This sector is supported by multiple real estate projects which vary in size. This study concentrates on the population of accredited members of the Council of Registered Builders of Nigeria who practice in Lagos. This list was derived from the current professional directory of the council. In deriving a representative sample, one out of every two names from the list was picked making provisions for poor response rates. Fortunately, response rate for this study was 75% (150) which is fair enough for a population of 414. Lagos state was picked as study area due to the relative preponderance of building construction firms. A structured questionnaire was then administered, where variables were derived from the Construction Safety and Health Regulations of the ILO (1999 and 2005) and literature survey. Data was analyzed with the aid of SPSS software (Statistical Package for Social Sciences). The research procedure consisted of the following steps:

- Investigation of previous literature to obtain past and recent dialogues for knowledge essential for survey development
- Survey administration for eliciting relevant data.
- Data analysis i.e. assessment and evaluation in order develop conclusions and recommendations

4 Findings and Discussion

Results from the survey revealed the respondents background and socio-demographic characteristics. The sample population comprised construction managers, executive directors, project managers, planning and resources managers of building construction firms in Lagos. 98% of respondents are male. A large number (78%) hold at least a tertiary institution degree. Most of the organizations (42%) surveyed had been in construction operations for more than 10yrs and also had worked with their organizations for over five yrs.

Table 1: Frequency of site accidents/emergency occurrences in Lagos

Frequency	Percentage	
Very Frequently	7	4.7
Frequently	12	8.0
Occasionally	77	51.3
Rarely	51	34.0
Never	3	2.0
Total	150	100.0

Source: Field survey 2011

Table 1 above shows that (51.3%) accidents occur ‘occasionally’ at sites. About (34%) of the respondents also agreed that accidents rarely occurred on their sites while (8%), (4.7%) and (2%) of the respondents agreed that site accidents occurred ‘frequently’, ‘very frequently’ and ‘never’ respectively. This suggests that site accidents/emergency occur mostly ‘occasionally’ on construction sites in Lagos.

Table 2: Common site incidents/risks recorded by construction firms in Lagos

	Frequency	**Percentage**
Roof falls	15	10.0
Falls in excavation trenches	12	7.9
Falling objects	33	22.0
Worker being run over by operating equipment	16	10.7
Electrical accident on construction sites	18	12
Fires and explosions on construction site	3	2
Defective power tools	8	5.8
Injuries from tools/equipments usage	35	23.1
Structure collapse	10	6.9
Total	150	100

Source: Field survey 2011.

In fulfilling the first objective of this study, table 2 above shows that the most common type of incidents recorded on construction sites in Lagos are injuries from the handling and use of tools/equipments with a 23.1% frequency. 'Falling objects' then came in next with a frequency of 22%. The least significant cause of accidents was 'fires and explosions' with a frequency of 2%

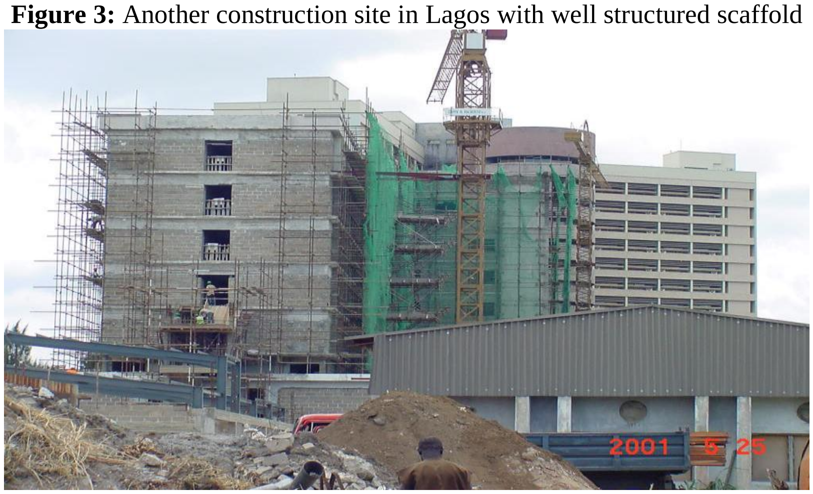
Table 3: Level of provision of site safety precautions in Lagos State

	Mean item score	**Rank**
Fall protection/scaffold rail support	4.67	1
Standard safety footwear e.g safety boots	4.65	2
Safety helmets	4.61	3
Quality of tools used e.g ladders	4.43	4
Eye protection/sight protectors/visors	4.34	5
Planned site design/layout	3.23	6
Drug/alcohol control test	3.19	7
Periodic training programmes	3.16	8
Hand touch/lamps	3.15	9
Fire extinguishers	3.12	10
Work areas safe and tidy	3.09	11
Electrical cords and equipment properly grounded	3.03	12
Waist safety belts for ladders	3.00	13
Welfare facilities e.g sanitary and changing room	2.58	14
Vehicular inspection	2.57	15
Respiratory protection	2.21	16
Ear defenders	2.11	17
Provision of Protective clothing	2.07	18
Alarm for summoning help	2.00	19
Excavation trenches sloped or shored	1.76	20
First aid / medical surveillance facilities	1.73	21
Ambulance/transport facilities	1.65	22

Notes: Coding and scale used for rating are represented as follows: AD = Adequately provided (5); FA = Fairly provided (4) IN = Inadequate (3), PO= Poor (2) NP= Not Provided (1)
Source: Field survey 2011

The questions asked on the availability of site safety precautions in the table above were derived from literature survey and were based on a 5 point Likert scale as denoted beneath the table. Rankings of the level of provision of site safety precautions in Lagos State were carried out using the mean item score method. Fall protection/scaffold rail support came in first position with a mean score of 4.67, Standard safety footwear e.g safety boots ranked in second position with a mean score of 4.65, the level of provision of first aid equipments was found to be low with a mean item score of 1.73. Ambulance and transport facilities ranked least on the scale with a mean item score of 1.65.

Figure 3: Another construction site in Lagos with well structured scaffold



The table below shows the variances explained with the Principal component analysis. Each component represents the factors described in table 3 above. These findings though were not in accordance with that of Olatunji, Aje and Odugboye (2007) and may therefore suggest an improvement in the provision of safety facilities on construction sites in Lagos recently.

Table 4: Total Variances Explained

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.923	53.845	53.845	8.808	36.698	36.698
2	3.517	14.654	68.500	6.612	27.548	64.246
3	2.425	10.106	78.605	3.446	14.359	78.605
4	.890	6.209	84.814			
5	.773	3.221	88.036			
6	.642	2.673	90.709			
7	.528	2.198	92.907			
8	.338	1.406	94.314			
9	.289	1.205	95.518			
10	.230	.956	96.475			
11	.196	.816	97.291			
12	.134	.560	97.851			
13	.115	.480	98.330			
14	.091	.379	98.709			
15	.084	.350	99.059			
16	.057	.236	99.295			
17	.048	.202	99.497			
18	.036	.151	99.648			
19	.032	.135	99.783			
20	.022	.090	99.873			
21	.016	.068	99.941			
22	.009	.038	99.978			
23	.005	.022	100.000			
24	2.78E-016	1.16E-015	100.000			

Extraction Method: Principal Component Analysis.

Table 5: Proactive measures to ensure health and safety on sites in Lagos

Indicators	Mean	Rank
Recognizing financial arrangements to prevent accidents from occurring	4.81	1
Making financial arrangements to prevent accidents from occurring	4.79	2
Identification of common possible problems by periodic inspection	4.21	3
Rectification of imminent risks	3.93	4
Training of workers against accidents	3.71	5
Maintenance of high quality of the reports of accidents	2.31	6
Provision of equipments to reduce risks	1.98	7

Notes: Coding and scale used for rating are represented as follows: VAD = Very Adequately Done (5); AD = Adequately done (4) NS = Not sure (3), ID= Inadequately done (2) VID= Very Inadequately Done (1)
Source: Field survey 2011.

Proactive measures are recognized by construction managers in Lagos but not necessarily implemented. The table above shows that managers recognize financial arrangements and 'risky areas' in construction (mean item score of 4.81 and 3.93) and also do make financial arrangements, however they do not adequately provide equipments to reduce risks (1.99 mean item score). There is thus a gap between making financial arrangements to prevent accidents from occurring and providing equipments to this end. This gap therefore needs to be further studied and implies that leading indicators for safety and health in construction are not currently sustainable in Lagos.

Table 6: Willingness to accept higher wages for increase risk

	Frequency	Percentage
Yes	23	71.3
No	7	28.7
Total	30	100.0

Source: Field Survey, 2011

In a simple survey of construction workers at thirty sites, workers admitted that they would accept higher risk in view of higher wages. The table above shows the details of this.

Table 7: Willingness and attitude to make provision for preliminary on- site medical/ emergency facilities

Criteria	Mean	Rank
I am completely willing to make provision for preliminary on-site Medical facilities	4.73	1
It depends on fee negotiation outcomes with client	4.52	1
If workers are prepared to accept lesser wages	4.13	2
The company just lacks the funds	4.02	3
I have not ever thought about it	3.97	4
I would love to make such provisions but it eludes my mind	3.91	5
I would make provision only if I am compelled to (e.g by a Regulatory body)	2.67	7
I would like to but it would erode profit from project	2.59	8
Site workers are adults and can take care of themselves	1.93	9
I cannot be bothered	1.37	10
It is not important	1.33	11
I don't have the time to think about it	1.11	12
Other reasons	1.01	13

Notes: Coding and scale used for rating are represented as follows: AC = Absolutely Correct, 5; C = Correct,4; MB =Maybe , 3; IC= Incorrect, 2; AI= Absolutely Incorrect,1.

Source: Field survey 2011.

When queried on their willingness to make provision for preliminary medical facilities such as first aid tools, readily available ambulances, medical surveillance etc as reactive measures, (as they include details of remedial actions in their process) the table above reveals the responses and views of construction site managers in Lagos. The essential idea here is to protect the site worker from any form of loss in terms of health and safety and consider the welfare of the worker in any instance. In the question above, respondents were given the choice to tick more than one indication about their attitudes to providing these facilities. There was a wide variance in the results. Variable 1-

‘completely willing to make provision for preliminary on-site medical facilities’ was highly positively skewed with a mean item score of 4.73. From the observation of direct responses in the questionnaires and results above, it can be deduced that some of the respondents who are ‘completely willing’ to make provisions were not ready to go through the procedure e.g. the aspect of making financial commitments. However, most of the other reasons behind the willingness to provide for medical facilities hinged on financial considerations as in variables, 2,3,4 and 6 in the table. Some mangers even confessed that they ‘couldn’t be bothered’ yielding a mean item score of 1.37.

5. Recommendations and Conclusions

From the foregoing, it has been observed that the levels of safety precautions on construction sites in Lagos have considerably improved recently. Benchmarking against previous studies, there have been significant improvements, on the state of facilities on sites. See Olatunji, Aje and Odugboye (2007). Though, the current state can be better. This study also revealed the gap between making financial arrangements to prevent accidents from occurring and providing equipments. Finance thus still remains a major challenge in the developing economy as is reflected even in this study on construction safety and this revelation is recommended as an area of further research. Government intervention therefore largely remains a veritable tool for sustainable development in this regard as well as providing a regulatory mechanism for site safety compliance- A significant percentage of responses tilted towards ‘needing’ regulatory propaganda for effectiveness. According to Idoro (2011) construction site and the activities therein in Nigeria excluded from the coverage of any Act in the country. Williams (undated) suggests that there is clearly a need for the law to deal with problems arising from the concern for the health, safety and welfare of citizens in general and those who work in factories or are engaged in industrial activities in particular. There is a necessity that such provisions are adapted in the light of current scientific knowledge, international practice and international norms. As such, a national policy and legal framework for enacting and regulating site safety is urgently required. Training should be conducted at all levels, including managers, supervisors and workers. Subcontractors and their workers may also need to be trained in site safety procedures, because teams of specialist workers may mutually affect each others’ safety. Safety should not be an option, rather a precept.

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Influences of Health and Safety Impacts on Construction Waste Management Initiatives in Developing Countries: Thailand Case Study

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Abstract

Economic growth in several developing countries has rapidly increased in the past decade. This results in an extensive urbanization, which leads to construction of new infrastructures, renovations of existing buildings, and demolition of old structures. Such activities generate high volume of wastes that cause adverse impacts on health and safety of construction workers, people in surrounding communities, and the general public. While the sustainable construction concept has globally expanded, management of construction-related waste in many developing countries has been found insufficient and inadequate. This study therefore aims to investigate factors that affect the level of efforts exerted for managing construction wastes in Thailand as a case study. Field studies and questionnaire surveys were carried out in 34 construction projects across the country with a total of 384 respondents. The obtained data was analyzed by using the Structural Equation Modeling (SEM) method. Health and safety concerns were found to have significant influences on construction stakeholders' effort on construction waste management. Findings emphasize that, while current waste management initiatives mainly focus on material development and managerial process improvement, the health and safety issues should be primarily promoted and strategically integrated to C&D waste management initiatives for attaining sustainable construction in developing countries.

Keywords: Construction waste, developing countries, health and safety, sustainable construction, Thailand

1. Introduction

Construction industry has a significant role in economic growth and development of the country. Unfortunately, the construction sector has been found to be a major generator of waste and pollution as construction and demolition activities result in high volume of wastes and significantly pollute the environment (Shen et al., 2004). While the booming economy in several developing countries has lead to rapid and extensive urbanization to meet higher demand of built facilities and infrastructures, related activities such as construction, renovations and demolitions of buildings have caused many social and environmental problems. In developing countries such as Thailand, Construction and demolition (C&D) waste management practices rather insufficient and inappropriate (PCD, 2007). On-site, construction workers' health and safety (H&S) are adversely affected due to unavailable and/or improper practices for handling C&D wastes. Off-site, C&D waste are still illegally dumped to public areas, causing environmental and social problems to local communities.

As willingness of construction stakeholders influences changes of their behavior and attitudes towards waste management initiatives (Teo and Loosemore, 2001), this study reports the research conducted to investigate factors that have influences on the effort of people in construction projects in handling C&D wastes. It is expected that understanding on the influencing factors, including H&S issues, and their interrelationships shall provide useful insights for establishing effective C&D waste management strategies for developing countries in the near future.

2. Background studies

Sustainable construction and C&D waste management

Sustainable development primarily concerns a balanced achievement of economic, social and environmental goals (WHO, 2005). As such, environment protection, pollution reduction, natural resources conservation, and safeguarding the quality of life of all people are main objectives of sustainable development. Accordingly, sustainable construction addresses the ecological, social, and economic issues of a building (Kilbert, 2005) aiming to create a healthy built environment while balancing the economic, social, and environmental benefits. While the environmental sustainability aspect emphasizes the ability to maintain the qualities valued in the physical environment and the economic sustainability concerns the necessity to attain the economic growth, the social sustainability ensures a better quality of life for the people. These people can be direct stakeholders (such as construction workers and other project participants) or indirect stakeholders (such as local people living or working near construction sites and building users) of the construction industry.

Health and Safety (H&S) in construction

When considering the social impacts in construction industry, the H&S issue is largely associated with C&D waste management because construction workers and general people are subject to risks caused by insufficient management of construction waste (Klang et al., 2003). Those who have physical contact with waste materials and construction pollution suffer eye and skin infection more frequently than others. As such, handling of C&D wastes that are hazardous materials need to be concerned and included in a health and safety plan in construction projects (Cole, 2000). This is particularly important because the poorer people in developing countries may have inadequate access to healthcare services. In these countries, including Thailand, despite experiencing increased economic growth and booming construction industry, problems related to C&D wastes have not been adequately recognized and studies on C&D waste management are still at beginning stage (PCD, 2007).

Efforts on Construction and Demolition Waste Management (C&D WM)

Effective C&D WM is an important component of sustainable construction, as it reduces the amount of waste directed to landfills, enhances the resource recovery for future construction work so that the C&D WM plan should then be enacted and tailored to every step from the management to the operational levels (Tam et al., 2006a) so that efforts to reduce, reuse, and recycle (3Rs) construction wastes can save money, reduce liability, keep job sites cleaner and safer, conserve valuable landfill space, and enhance the resource recovery for future construction. However, there are still major challenges in increasing such efforts such as people's awareness (Tam et al., 2006b), attitudes and perceptions (Teo and Loosemore, 2001 and Kulatunga et al., 2006) towards C&D WM initiatives that can have influences on their behaviours (Lingard et al., 2000) and decision making regarding waste handling. The factors that drive construction stakeholders' efforts on C&D WM should therefore be investigated for future improvement and achievement of practical and effective C&D WM.

3. Objectives and Methodology

There are limited research on C&D waste management in Thailand. As such, main objective of this study is to examine the factors of sustainability issues that have influences on the level of efforts exerted by the construction stakeholders in Thailand to manage C&D wastes in construction projects which cause direct or indirect impacts. It is expected that findings would to be useful for Thailand's C&D waste management improvement framework in the future. An analytical framework was established based on five constructs of sustainability aspects, C&D WM efforts, and the achievement of sustainable construction. The Structural Equation Modeling (SEM) method was used for data analysis in this study. General SEM involves two interrelated procedural components; a measurement component and a structural component (Byrne, 2001). The measurement component specifies how latent variables (or constructs) are measured in terms of observed variables. The structural component expresses relationship among the latent variables. Observed variables provided data that can be directly measured such as numeric responses to a rating scale item on a questionnaire. A conceptual model was then developed, as shown in Figure 1. The structural model was developed by linking all measurement models together, as presented in Figure 2. To obtain primary data for a quantitative analysis, field studies and questionnaire surveys were carried out in 34 construction projects across the country with a total of 384 respondents.

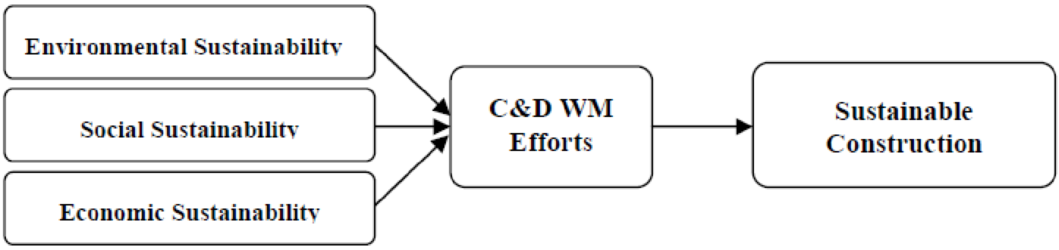

Figure 1: Conceptual model for examination of C&D WM efforts

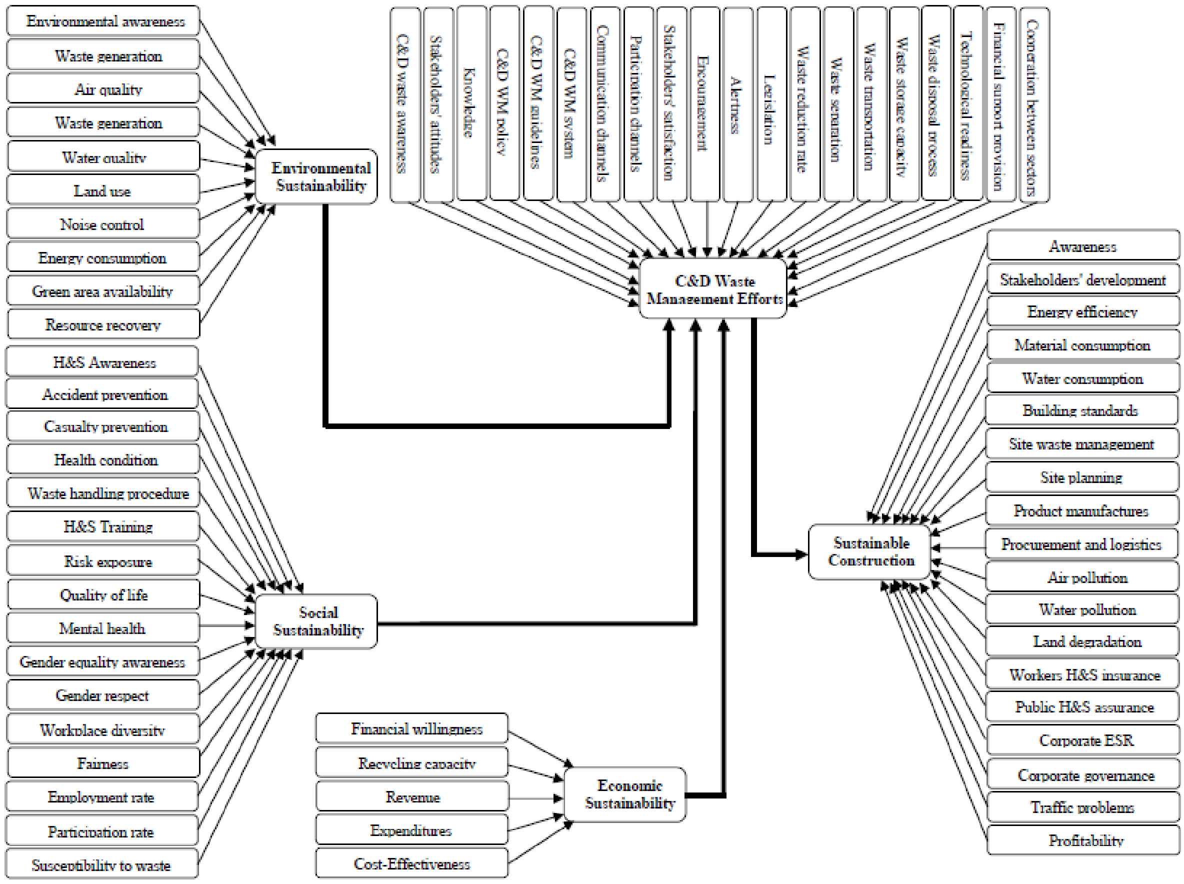

Figure 2: Initial Structural Model

4. Results

In the SEM part, the research measurement model was tested by confirmatory factor analysis (CFA) while the structural model was assessed according to the goodness of fit indices. The CFA identified major concerns of sustainability aspects. Firstly, it was found that the environmental sustainability was comprised of two major factors; Environmental impact and Resource consumption. Secondly, the social sustainability was comprised of two major factors; Health and safety, and Gender equality. Thirdly, the economic sustainability construct was comprised of only one major factor: the Economic incentives. Fourthly, the C&D WM was comprised of four major factors; recognition, management, policy and plan enforcement, and effectiveness of the policy and plan. Finally, the sustainable construction construct was comprised of two major factors; resource utilization and impact prevention and correction measures.

Further refinements of the structural model were carried out, using the AMOS program version 16.0, until the best fitted final SEM model was achieved. Model revisions include deletion and relocation of variables; rearrange of direction of influences; exclusion of insignificant paths; and addition of covariance; which were recommended by modification indices. In the final model, the influences of variables resource consumption construct were found to be not significant in the model's path analysis. Hence, their paths are not illustrated in the simplified final structural model. The structural model's fit indices are shown in Table 1. It has been found that the final model has a very good fit (IFI, TLI, and CFI indices are all greater than 0.90; RMSEA<0.05; and CMIN/DF<2.0).

Model	Goodness of Fit Measures					
	CMIN	CMIN/DF	RMSEA	IFI	TLI	CFI
Starter Model	4272.822	2.234	0.057	0.831	0.821	0.830
Revised 1	4118.631	2.153	0.055	0.842	0.832	0.841
Revised 2	3991.453	2.091	0.053	0.851	0.841	0.850
Revised 3	3826.822	2.062	0.053	0.858	0.849	0.857
Revised 4	3647.662	2.031	0.052	0.865	0.857	0.864
Revised 5	3460.110	1.927	0.049	0.879	0.872	0.878
Final Model	**2740.815**	**1.771**	**0.045**	**0.907**	**0.900**	**0.906**

Table 1: Results of Goodness of Fit Measures

Figure 3 presents remaining variables of each major factors showing their standardized path coefficients indicating direction of their influences among the examined research constructs. Considering the final best-fitted model, major factors influencing on the C&D waste management efforts and achievement of sustainable construction are main focuses. As such, Figure 4 shows the simplified final model with path coefficients, which briefly indicate all significant influences of sustainability factors on the waste management effort and sustainable construction.

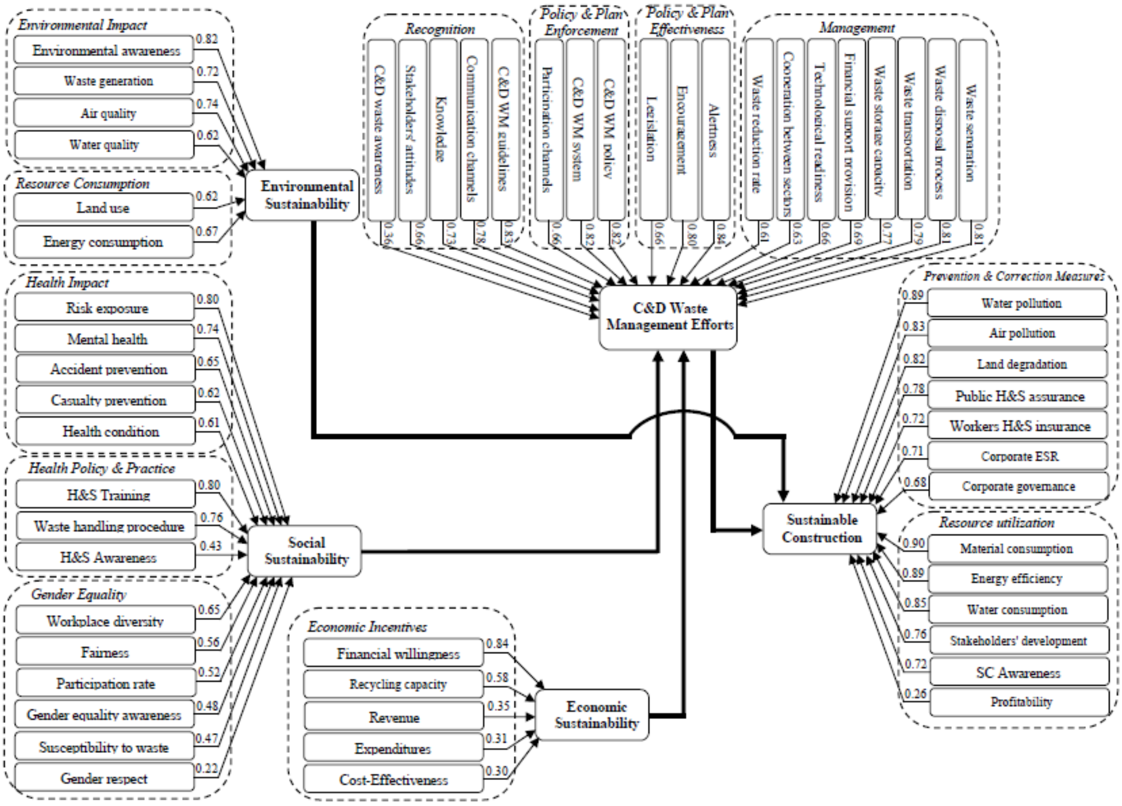

Figure 3: Final Measurement and Structural Models

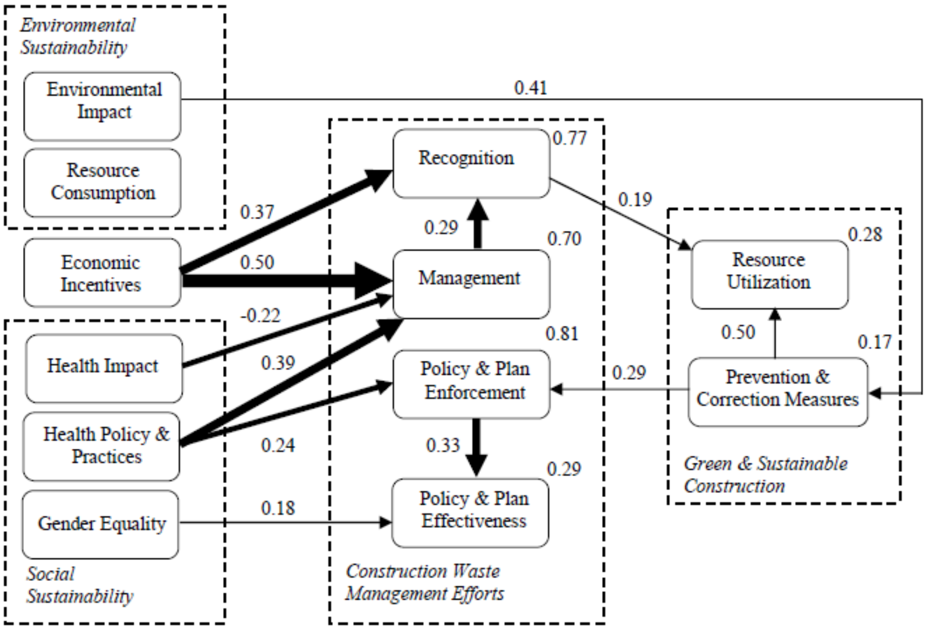

Figure 4: Simplified Final Structural Model

In the final model, all path coefficients are statistically significant at 0.001 level of confidence. The numbers located at top corners of major factors of latent constructs are the squared multiple correlations (R^2) values indicating how well the model fits the data. It can be seen that the obtained final model can be used to explain the effects of the economic and H&S issues quite well e.g. between 70 to 80 percent (R^2 ranges from 0.70 to 0.81).

As the final model shows only the statistically significant influences of factors, it was found that path coefficient of factors in the environmental sustainability constructs to the constructs of construction waste management efforts are not statistically significant and, hence, have no significant influences on the C&D WM efforts. Comparatively, the major factors (or sub-constructs) of the economic and social sustainability were found to have a statistically significant direct influence on C&D WM efforts. Thickness of lines representing influencing paths in Figure 4 clearly indicate level of such influences. Besides the importance of economic issues, it is found that the H&S issues such as the availability of H&S training, C&D waste handling procedures, and awareness of H&S issues have significant influences on the level of effort exerted to manage C&D wastes. The most influential factors in characterizing the health impact is the 'risk exposure' to C&D waste and the 'mental health impact'. This SEM results support the surveyed responses which indicate that health and safety issues are very important concerns for construction stakeholders, particularly for construction workers who are directly exposed to construction waste.

5. Discussions

Health and Safety (H&S) impacts were regarded as top priorities for Thai construction stakeholders. The issues of stakeholders' health and safety must not be overlooked. In this study, health impact was found to have significant negative influence on the management, meaning that the higher rate of stakeholders' suffering health problems reflects the lower level of managerial support to encourage the C&D WM efforts. Meanwhile, strong positive influences of H&S policies and plans reflects that there are needs of such initiatives in order to drive the management effort. To support the C&D WM efforts and to effectively implement policy and planning for C&D WM, enforcement of C&D WM policy and plan must be seriously emphasized. Altogether, the clearly established policies and practices concerning stakeholders' health and safety are also strong supports to C&D WM effort and effectiveness.

An implication of the findings of the study is that any strategy developed to improve C&D WM and to achieve sustainable construction should not only focus on raising construction stakeholders' recognition on C&D WM through promotion of economic incentives and environmental impacts, but should also focus on identifying, minimizing, and eliminating potentially adverse impacts on stakeholders' health and safety which have influence on the management process facilitating the efforts on C&D waste management. Use of waste handling and control system appropriately designed and specifically tailored to the stakeholders' health and safety is one way of minimizing potential obstacles of encouraging the effort for managing C&D waste.

6. Conclusion

In an attempt to increase stakeholders' awareness and improve management of C&D waste problems in Thailand, this study was carried out aiming to explore current situation in Thailand's construction projects from various regions. Primary data was collected through field studies and questionnaire surveys and then analyzed by means of the Structural Equation Modeling method which helps to identify major factors and variables that have significant influences on the level of efforts exerted to manage C&D wastes. It was found that the C&D WM effort is significantly influenced by the economic incentives as well as the issues of health and safety. To increase the C&D WM effort, stakeholders' recognition should be raised by effective management process while the C&D WM policy and planning would be effectively accomplished if only they were seriously enforced. This study concludes that it is essential to proactively promote the significance of construction and demolition waste management in developing countries in order to make construction stakeholders become more recognized, encouraged, and committed to responsively exert their effort on waste management initiatives in order to effectively practice and achieve sustainable construction. It is also recommended that protection of stakeholders' health and safety must be first priority to be considered particularly by those who have decision-making power in relevant governmental, private, and people sectors.

7. Acknowledgement

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Dynamics of Accident Prevention: A Focus on the Disabling Injury Frequency Rate

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Abstract

The management of occupational health and safety (OHS) including safety culture interventions is comprised of complex problems that are often hard to scope and define. Due to the dynamic nature and complexity of OHS management, the concept of system dynamics is used to analyze accident prevention. In this paper, a system dynamics group modeling building (GMB) approach is used to create a causal loop diagram of the underlying factors influencing the OHS performance of a major drilling and mining contractor in Australia. While the organization has invested considerable resources into OHS their disabling injury frequency rate (DIFR) has not been decreasing. With this in mind, rich individualistic knowledge about the dynamics influencing the DIFR was acquired from experienced employees with operations, health and safety and training background using a GMB workshop. Findings derived from the workshop were used to develop a series of causal loop diagrams that includes a wide range of dynamics that can assist in better understanding the causal influences OHS performance. The causal loop diagram provides a tool for organizations to hypothesize the dynamics influencing effectiveness of OHS management, particularly the impact on DIFR. In addition the paper demonstrates that the SD GMB approach has significant potential in understanding and improving OHS management.

Keywords: Occupational Health and Safety, Safety Culture, System Dynamics

Dynamics of Accident Prevention: A Focus on the Disabling Injury Frequency Rate

1. Introduction

Significant improvements in occupational health and safety (OHS) have been made within the construction and engineering industry over the last decade. Emphasis has traditionally focused upon the victims of accidents as being their cause (e.g. Heinrich, 1959), but there has been a subtle shift in direction by organizations in recognizing the importance and role of their culture, management systems and processes in contributing to accidents (Flin et al., 2000; Zohar 2000; Mearns et al., 2003; Fernandez-Muniz et al., 2007; Robson et al., 2007; Fernandez-Muniz et al., 2009). Despite the advancement of OHS management, major accidents still arise. For example, in April 2010 the BP/Transocean Deepwater Horizon catastrophe occurred (Chemical Safety Board, 2010). Lessons from the accident at the BP Texas oil refinery explosion in 2005 should have been learned (Baker et al, 2007). Evidently, they have not, and there is still much to be learned in terms of OHS management. The difficulties in managing OHS not only arise due to major accidents, but confront most managers on a daily basis. There is a growing realization that OHS management has become a more complex and challenging task particularly in the minerals and petroleum sectors due to increasing demands from India and China (Goh et al., 2010a,b). The complexity that arises with OHS management may result in problems being difficult to define, analyze and resolve, and may in even be compounded as managers attempt to solve them. Such problems are messy and are classified as being ‘wicked’ (Rittel and Webber, 1973; Peter Wagner & Associates, 2010).

To add to such complexity, the impacts of actions to deal with OHS problems are frequently delayed. As a result, managers may not be able to observe their effects. Such characteristics of OHS management render *system dynamics* a suitable analysis tool for representing and better understanding OHS issues (Sterman, 2000; Goh et al., 2010a,b). In contrast to the linear paradigm of cause and effect, where dependent and independent variables are clearly defined, system dynamics emphasizes the importance of feedback by expressing problems systemically (Morecroft, 2007). This paper utilizes the deep individualistic knowledge of employees from a leading Australian Drill, Blast and Exploration organization to examine how the underlying dynamics influence safety performance and culture. The paper demonstrates how system dynamics can be used as an effective medium to comprehend the messiness of causal factors impacting the safety performance culture. Such understanding is needed to determine the appropriate OHS management practices to implement, especially in relation to reducing the *disabling injury frequency rate* (DIFR).

2. OHS Management and Safety Culture

Most organizations have been relying on the implementation of an OHS management system (OHSMS), which has risk assessment at the core of its process, to improve their safety performance. Risk assessment is essentially a systematic process that requires a workplace to actively identify hazards, analyse and evaluate the risk of the hazards and implement controls to eliminate or reduce the risk of hazards [International Labor Organization (ILO), 2001; Standards Australia and Standards New Zealand, 2001]. Despite widespread adoption of OHSMS by organizations, its effectiveness has been debatable. Fernandez-Muniz et al. (2009), among others for example, have posited that OHSMS is beneficial to an organization's overall performance. In stark contrast, Robson et al. (2007) have estimated the failure rate of OHSMS to be at least as high as the failure rate of quality management systems, which have between 67% to 93% (Gardner, 2000). In a similar vein, Quinlan and Mayhew (2000) and Gunningham and Sinclair (2009) have expressed doubts about the effectiveness of OHSMS. With Gunningham and Sinclair (2009) specifically revealing that effective OHSMS is dependent on informal variables such as trust and commitment, which are critical components of a positive safety culture.

After the Chernobyl accident (INSAG, 1986) the term 'safety culture' was introduced as a lexicon to the normative safety management literature (Cullen, 1990; Hopkins, 2000; Baker et al, 2007). Such an emphasis is not surprising as culture is defined as "the way things are done around here" (Schein, 1992:p.8). It is usually 'the ways things are done' or patterns of safety-related behaviour that triggers accidents. Safety culture has been frequently studied using employee surveys (Zohar, 2000; Yule et al., 2003; Rao, 2007; Lu and Tsai, 2008). In these questionnaire surveys the derived metric is usually defined as safety climate, which is a cumulative perception of the way OHS is being managed at the workplace. Safety climate research has determined that the mean corrected correlation between safety climate and injury rate was −0.38 and −0.42 between safety climate and the United States OSHA medical record (Zohar, 2010). Even though there is a significant relationship between safety climate and OHS performance, the strength of the relationship remains questionable. Safety climate research has tended to view the different components of safety climate in a hierarchical and linear manner. For example, the model developed by Fogarty and Shaw (2010) points to management attitude as the most fundamental factor influencing the occurrence of safety violations. Such causal inference does not reflect the multitude of inter-related factors that can influence management attitude. As a result, this may over-simplify the difficulties of improving OHS performance.

Due to the limitations of human cognitive ability, there is a tendency for managers to adopt a 'silo mentality' when making decisions in complex systems (Sterman, 2000; Senge, 2006; Forrester, 2007; Meadows, 2008). A silo approach encourages managers to look at 'parts' of the system that they are overseeing and design actions to address problems that they see in their defined area of responsibility. These solutions are usually ineffective in the long-run and may generate counter-intuitive behaviours in the overall system (Checkland and Scholes 1999; Senge, 2006). Thus, this paper seeks to demonstrate how system dynamics can facilitate a systemic perspective on the causal influences of OHS performance and culture.

3. System Dynamics

Causal loop diagramming, an inherent feature of system dynamics, is a qualitative technique used to construct models of real world issues (Burchill and Fine, 1997; Sterman, 2000; Senge, 2006; Goh et al., 2010a,b). A causal loop diagram seeks to highlight the feedback and complex interactions between variables, where causes and effects are often indiscernible. It can be used to model the influences of inputs on outputs and vice-versa (Sterman, 2000). A positive link (arrow with a '+') indicates that 'if the cause increases, the effect increases above what it would otherwise have been, and if the cause decreases, the effect decreases below what it would otherwise have been'. A negative link (arrow with a '-') indicates that 'if the cause increases, the effect decreases below what it would otherwise have been, and if the cause decreases, the effect increases above what it would otherwise have been'. In addition, a set of two parallel lines on an arrow indicates that there is a significant time lag between the cause and effect. A reinforcing loop occurs when an increase (or decrease) in a variable will lead to a tendency for the variable to be increased (or decreased) due to feedback through other variables in the loop. On the other hand, in a balancing loop, when a variable increases (decreases), there will be a tendency for the same variable to decrease (increase) due to feedback through other variables in the loop. Influence diagrams are simplification of causal loop diagrams, where the plus or minus signs are removed. The simplification enables research participants to represent their mental model more rapidly (Newell et al., 2007; Li, 2010). The influence diagrams can be converted to causal loop diagrams subsequently.

Group Model Building (GMB)

Group model building is often used in system dynamics when elicitation of knowledge from a group of experts is required to tackle 'messy' problems (Vennix et al. 1990; Andersen and Richardson, 1997; Vennix 1999). A system dynamics group model building workshop is similar to other facilitated workshops where a facilitator guides a group of participants through a series of activities to develop a deliverable (such as a model) or a decision (Papamichail et al., 2007; Franco and Montibeller, 2010). In the context of this paper, the deliverable is a causal loop and influence diagram, which demonstrates the key causal influences of safety performance and culture. Some group model building workshops aim to develop system dynamics simulation models (Andersen and Richardson, 1997), but others seek to develop only qualitative models (Checkland and Scholes, 1999). One of the key determinants of whether a qualitative approach is suitable is the availability of quantitative data and the purpose of the study (Coyle, 1999). If the workshop is exploratory, a qualitative model is typically adequate, especially when quantitative data is not readily accessible. Both quantitative and qualitative system dynamics models contain a network of relationships of a range of variables and are useful for managers to develop dynamic hypotheses of causes of problems.

4. Research Approach

The participating organization is a diversified mining and services organization providing services in mining, drill and blast, exploration, procurement and logistics, manufacturing, and telecommunications with operations in Australia, United Kingdom and Africa. The organization is publicly listed on the Australian Stock Exchange (ASX) and has more than 3,000 employees worldwide. An exploratory approach using system dynamics group model building method was adopted to gain an understanding of the complex nature of OHS management and culture in the organization. Due to the exploratory nature of the research, the methods were less structured so as to enable the researchers to discover varying causal influences that participants perceived to occur in practice (Miles and Huberman, 1984; Silverman, 2010).

The study aims to demonstrate how system dynamics group model building process can be implemented to develop content rich diagrams to facilitate understanding of the system, which is a critical step in solving wicked problems associated with safety performance and culture. As in most qualitative research, the research process is generally iterative and highly dependent on the judgement of the researchers (Yin, 2009; Silverman, 2010).

Pre-Workshop Discussions

The study was initiated after a series of discussions between one of the researchers and two managers from the organization: one of the managers is the Health, Safety and Environment (HSE) General Manager and the other is a HSE manager for one of the business units. The two managers are an essentially gatekeeper that "select appropriate people within the organization with whom to work before the workshop and works with the modeling team to plan those pre-workshop meetings, schedules them, and participates in them" (Andersen and Richardson, 1997). Even though the organization is using the research as an opportunity to evaluate the feasibility of implementing a system dynamics approach in the organization, to ensure that the study is meaningful, the researcher sought to identify actual OHS problems that the organization was facing. It was revealed that despite having hazard identification processes in place, the organization was still not able to prevent injuries. The manager hypothesized that safety culture components such as beliefs played a role in generating this problem.

Workshop Participants

As the topic was focused on OHS, three of the participants were HSE managers (including the two gatekeepers) with 15, 20 and 22 years of experience. The gatekeepers also invited an operations manager (20 years of experience) and an area manager (15 years of experience) to provide the viewpoints of operational departments. Due to the importance of training and competency to the topic of interest, a training advisor with five years of experience in drilling was also involved in the workshop.

Workshop Schedule and Activities

The workshop started with a brief introduction by the researchers and the purpose of the study. Since the workshop participants knew each other prior to the workshop, no *ice-breaker* was conducted. Instead the participants were asked to indicate their purpose for participating in the study on *post-its* (small pieces of sticky paper). This task is designed to understand the motivation of each of the participants and to calibrate and moderate the expectations accordingly. At the same time, the task gets the participants to start participating in the workshop immediately and become more receptive, and that is why writing on post-its as a lead up to later tasks. The participants were also asked to determine a set of ground rules to ensure that the workshop can be conducted effectively with minimal interruptions (Hogan, 2003).

One of the gatekeepers was then asked to present basic statistics of the OHS performance of the organization. The variations of the DIFR (the core variable of interest) across time, serves as a reference mode for the participants to define and discuss the problem statement (Sterman, 2000). Once the problem statement was defined, participants were asked to keep a copy of the statement with them so that they can refer to it throughout the workshop.

The participants were then asked to work in pairs to *brainstorm* the possible causal factors influencing the DIFR and its effects. The identified variables were recorded on post-its and placed on a wall (see Figure 1) to allow participants to cluster similar variables together and propose suitable over-arching sectors of the system. Subsequently, the facilitators provided more information on how to draw influence diagrams and participants gathered into pairs to develop them on large sheets of 'butcher' paper. Each of the pairs was then asked to present their influence diagrams (see Figure 2) in a plenary discussion. The other participants and the facilitator were given opportunity to comment on the influence diagrams.

Figure 1. Use of *post-its* to identify core variables and enable clustering

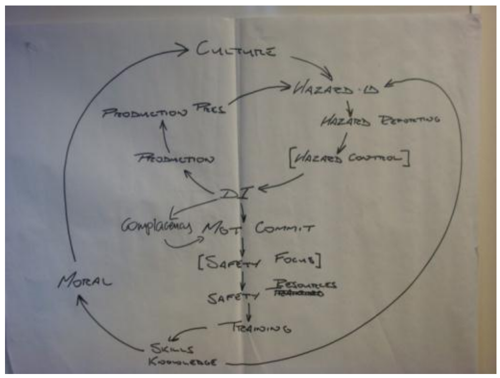


Figure 2. An example of an influence diagram drawn by participants

The facilitators developed the causal loop diagrams using *Vensim* (Ventana Systems Inc., 2010). Feedback was then provided to the group about the diagrams and the insights gained summarized. The participants were invited to comment on the findings to ensure that the computerized diagrams reflected their perceptions. The participants were also asked to identify important variables that were missing. The missing variables were then distributed for integration into the existing diagrams.

Post-Workshop Modelling and Validation

After the workshop the researchers (who also acted as facilitators) integrated the diagrams that were drawn by the workshop participants. The integration process aimed to capture all the dynamics that were identified during the workshop. As in ethnographic research (Silverman, 2010), the researchers reflected on the influence diagrams drawn by the participants and their field notes and observations of the intensive one-day workshop. The intention was not to get bogged down in too much of the detail identified by the participants, but to have a strategic review of their work. The aim was to ensure that key concepts were represented in a generic diagram. In fact, the causal loop diagram was kept as simple as possible and overlapping causal loops were removed. The causal loop diagram was then presented to the gatekeepers, who were given the opportunity to examine and critique its representation. The diagram was then amended accordingly to address its validity.

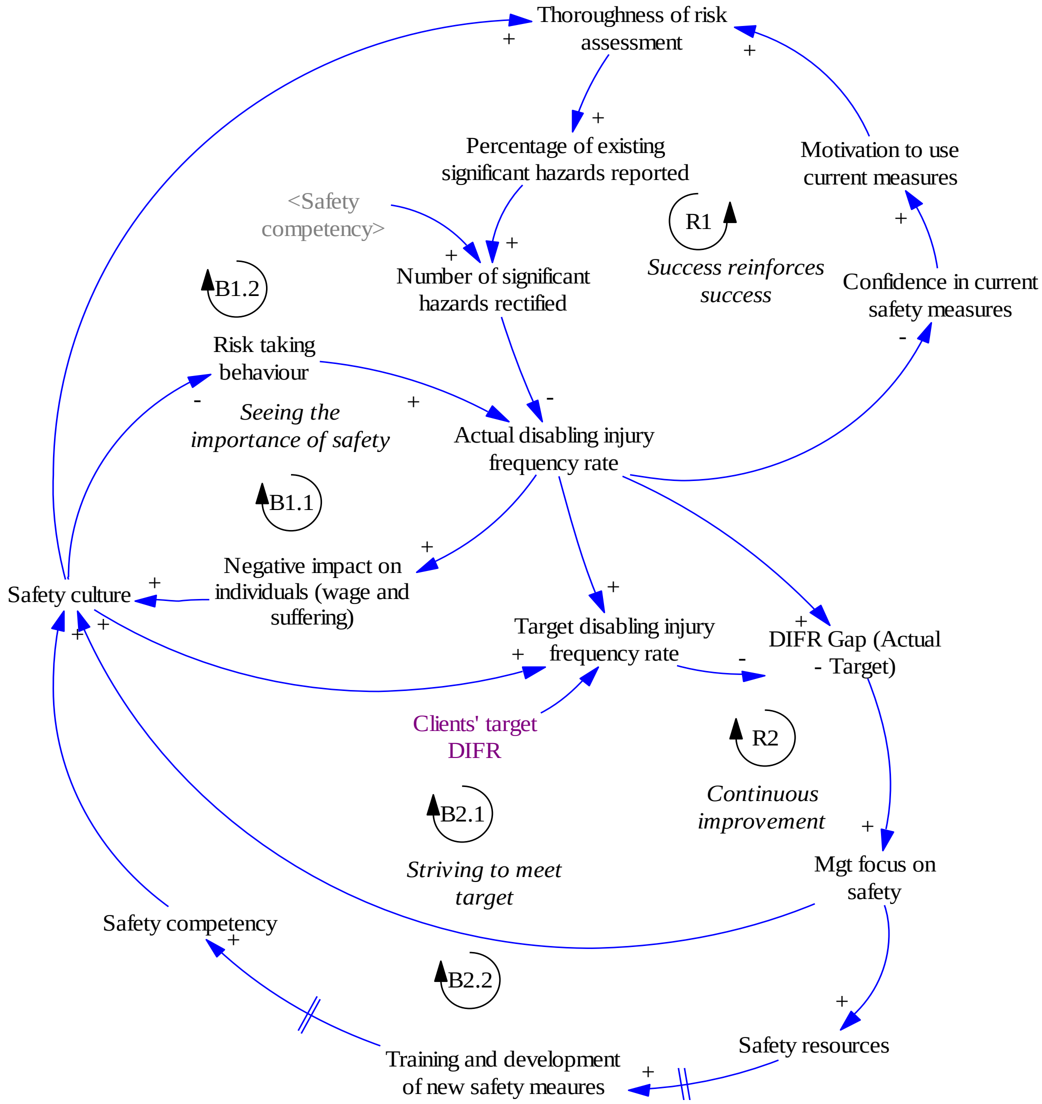
5. Causal Loop Diagram of Causal Influences of OHS Performance

During the workshop, the participants identified that their organization faced difficulties in improving its OHS performance despite significant investment over the years. The problem statement used in the workshop was defined as below:

> "Even though resources for improvement are increasing, the disabling injury frequency rate (DIFR) has not been decreasing."

Error! Reference source not found. denotes a section of the causal loop diagram that describes how the organization is actively seeking to improve the DIFR. As in most companies in Australia, risk assessment is the main process to prevent injuries (see loop R1 in **Error! Reference source not found.**). Loop R1 ('success reinforces success') in **Error! Reference source not found.** is a potentially powerful driver of growth, where effort in risk assessment reduces DIFR. When employees see reductions in DIFR, they are encouraged to do more thorough risk assessment. However, in view of the fact that the DIFR was not decreasing, the strength of this loop was not expected to be strong. Loops B1.1 and B1.2 ('seeing the importance of safety') are 'natural' balancing loops that do not require significant effort from the workplace. When the DIFR increases, the negative impact on individuals' wages and the suffering experienced will become observable in the workplace. This will encourage the workers to be more serious about OHS, improving the safety culture and reducing the chance of risk taking behavior and thoroughness of risk assessment. With a reduction in risk taking behavior or an increase in thoroughness of risk assessment the actual DIFR improves. However, loops B1.1 and B1.2 will probably be dominant only when the DIFR is significantly higher than industry average.

Loops B2.1 and B2.2 ('striving to meet target') were the key levers that the organization has been using to manage OHS performance. When the gap between actual and target DIFR (or other OHS indicators) is large, i.e. actual DIFR is significantly higher than target DIFR, then there is a proclivity for management (abbreviated as 'Mgt' in the diagrams) to increase their focus on OHS issues and allocate more safety resources to (loop B2.2). In the case of the participating organization, the target DIFR was set at the Group level, while not clearly determined at the individual business levels. Therefore, the lack of clarity on the target OHS performance can cause the business managers to determine their own implicit targets and these targets may be higher (higher DIFR represents poorer performance) than the desired level of OHS performance. Safety culture can also be improved when the management is more focused on OHS (loop B2.1). Loop B2.2 is perceived to be slow acting due to the time taken to train employees and develop new safety measures. The development of actual competency also takes time, causing the impact of any safety resources invested to be significantly delayed.



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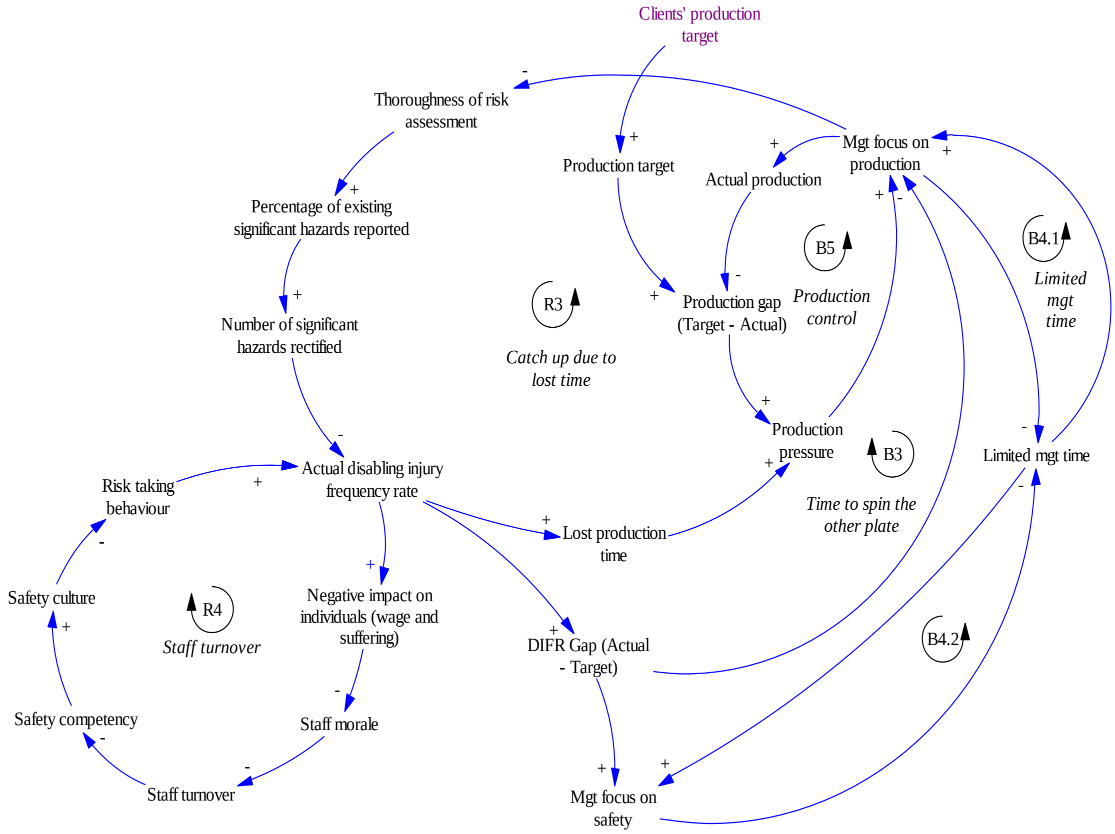
The loop R2 ('continuous improvement') reflects the way that targets are set. When the actual DIFR improves, management tends to set more demanding targets based on past performance. Thus, when actual performance improves, the target will become more demanding, maintaining the gap between actual and target performance. The loop goes through the variables 'management focus on safety', 'safety culture', and 'risk taking behavior'. Different variants of the loop can also be defined by linking the variables differently, e.g. 'safety culture' to 'thoroughness of risk assessment', but the dynamics created is very similar.

Resistance to Improvement Efforts

Error! Reference source not found. illustrates the causal influences that may negate the impact of the efforts to improve OHS performance.



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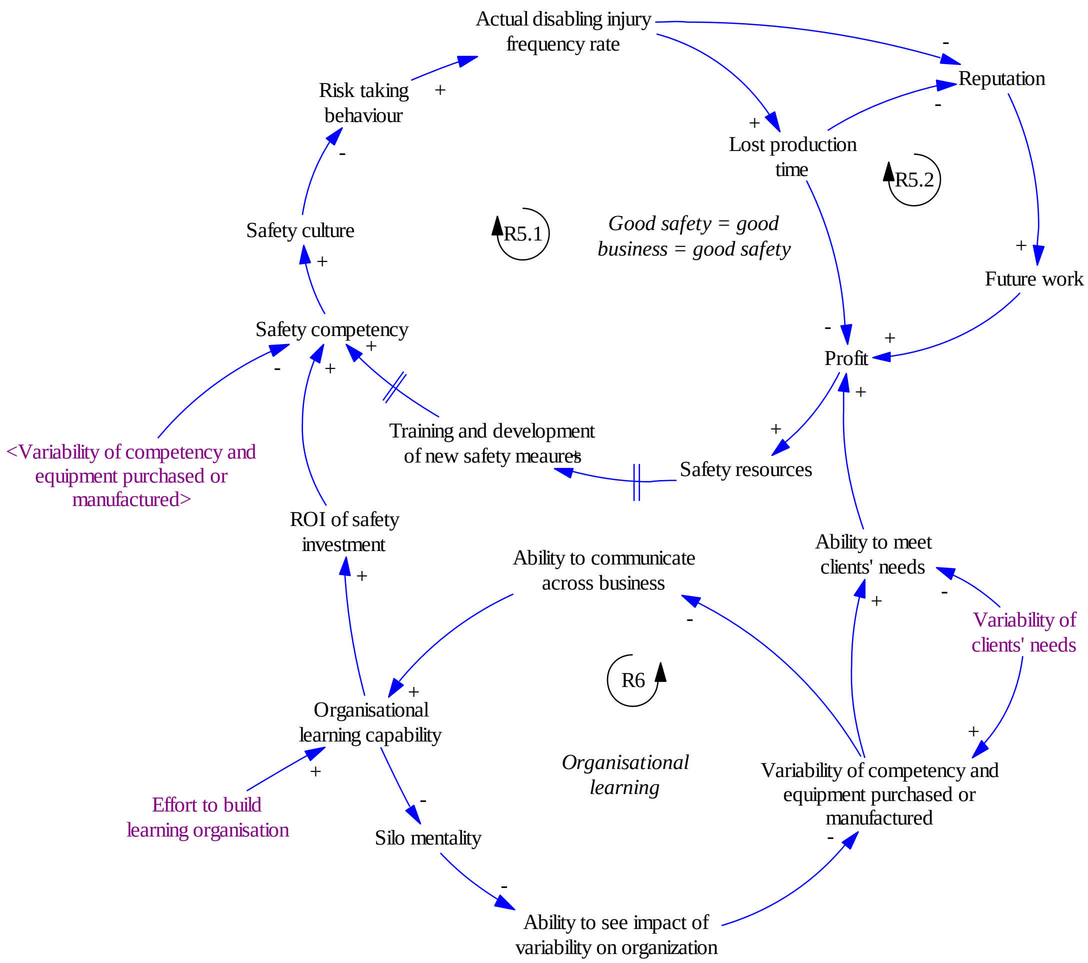
Loops B3 ('time to spin the other plate'), B4.1 and B4.2 ('limited management time') and B5 ('production control') represent the tension between production and safety. In Loop B3, a decrease in the actual DIFR may cause the DIFR gap to decrease, allowing the managers to spend more time on other important issues such as production and maintenance. Decreasing the focus on issues such as risk assessments may cause actual DIFR to rise. In Loop B5, production pressure due to the production targets set by clients will cause managers to focus on production more, thus reducing the effort in risk assessment. Loops B4.1 and B4.2 indicate that management time and effort is a scarce resource and any increase in management focus on production or safety may cause the focus on the other aspect to be decreased. It is this effort that shows where the increased safety resources can assist the management in focusing on the HSE requirements and therefore reducing the DIFR.

Loop R3 ('Catch up due to lost time') is a vicious cycle, where the business may try to catch up with lost production time due to client pressures. Down time that is caused from a number of reasons such as injuries that can potentially sacrifice the time spent on risk assessment. The lack of thoroughness in risk assessment may then lead to further an increase in actual DIFR. In Loop R4 ('staff turnover'), when the actual DIFR increases, staff will experience the negative impacts of injuries and morale is affected. This may result in loss of experienced staff and decreasing employee safety competency. When employee safety competency decreases, safety culture can be affected and risk awareness and understanding is decreased. This may lead to a further increase in the DIFR.

External Influences

All organizations are influenced by external variables. In the context of the participating organization, client demands are significant. Besides the clients' target DIFR and production target, their needs and variability can have a significance impact on the organization's safety management. When the organization tries to meet the needs of a wide range of clients in different business units within the organization, the organization accumulates a wide range of competencies and equipment purchased or manufactured. Even though such variability increases the organization's ability to meet clients' needs, it decreases the ability to standardize and manage due to specialization and segregation of activities. This increases the requirement for organization learning (see Loop R6, 'organizational learning') and may cause a silo mentality among managers of different business units, particularly those with similar equipment or processes.

When the silo mentality occurs, managers tend to concentrate on their business and not see the impact of their decisions on the organization as a whole which reduces the variability of competency and equipment through standardization across the organization. The lack of organizational learning will tend to decrease the return of investment (ROI) in safety resources as each dollar spent on improvement will tend to have localized improvement, and will not have organization-wide benefits. The drive to win future contracts is also beneficial. Loops 5.1 and 5.2 of **Error! Reference source not found.** ('good safety = good business = good safety') are reinforcing loops that can generate improvement in OHS performance. When the organization has lower DIFR, it has less production time lost (loop R5.1) and profit increases, allowing more safety resources to be expended to further reduce DIFR. Similarly, when DIFR and lost production time are low, the organization's reputation improves (loop R5.2), which may help the organization in winning more contracts, increasing its profit and safety resources. Nonetheless, loops R5.1 and R5.2 may be delayed due to the time taken for training and development of new safety measures.



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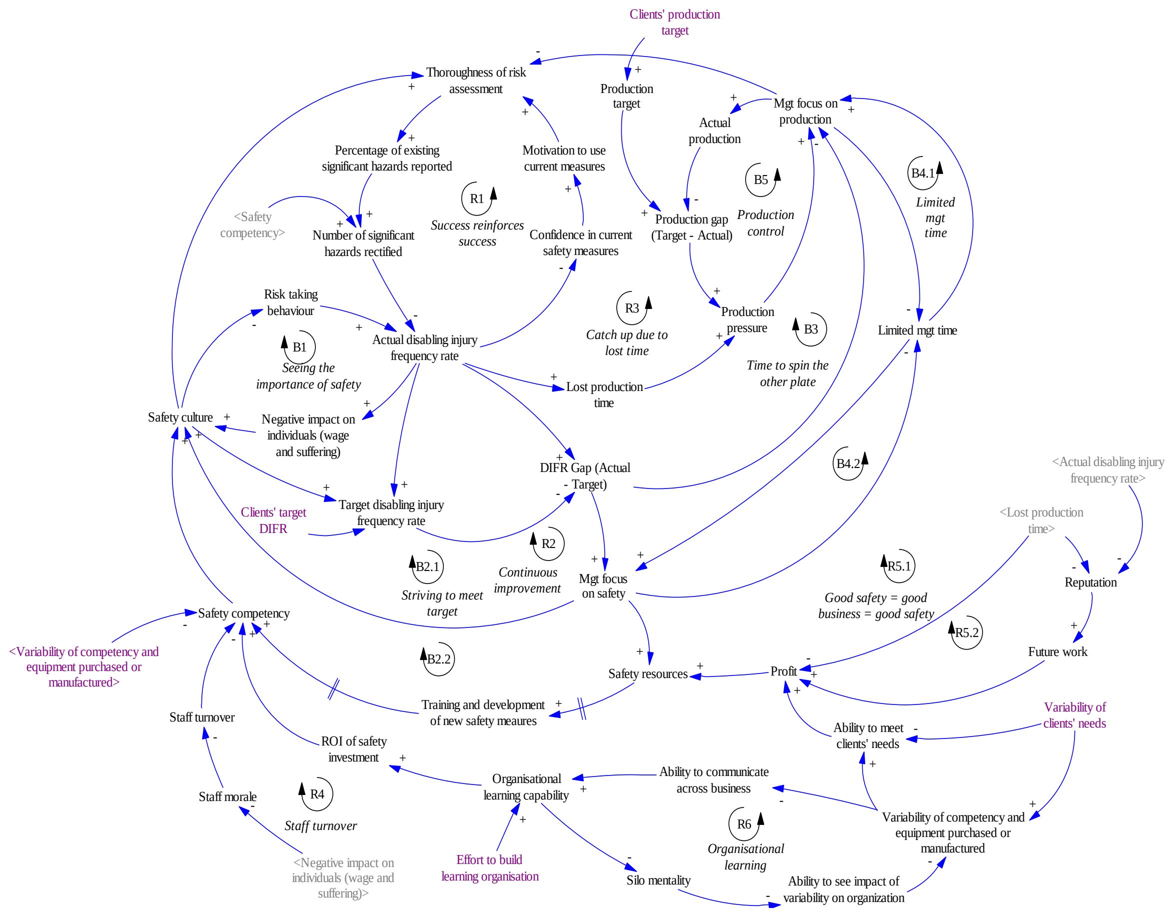
The integrated diagram (**Error! Reference source not found.**) combines all the aforementioned diagrams and allows decision-makers to assess how different variables interact with each other as well as evaluate their relative strength of different causal loops.

The HSE General Manager of the participating organization intends to use the diagram to discuss possible strategies with senior management. Even though the integrated causal loop diagram is complex, the diagram is disaggregated into three figures to assist understanding to prevent information overloading of the intended audience (**Error! Reference source not found.** to **Error! Reference source not found.**). As stated by Coyle (1999), qualitative system dynamics describes a system and the description "is, in itself, a useful thing to do which might lead to better understanding of the problem in question". This insight is in congruence with the experience of the participating organization.



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6. Conclusions

OHS performance, as measured by disabling injury frequency rate, has been examined using a group model building workshop with an Australia-based drilling and mining contractor. The workshop aimed to determine the underlying causal influences of OHS performance, with safety culture as one of the key variables of interest. The facilitated workshop enabled the participating organization to develop a causal loop diagram capturing a wide range of variables that are inter-related. The organization has begun using the causal loop diagram to hypothesize about the effects of different dynamics so as to develop suitable strategies to improve its OHS performance. Even though the causal loop diagram is organization-specific, its relevance to other organizations seeking to improve OHS is pertinent. Unlike typical linear multi-causation models, the causal loop diagram provides a more dynamic and holistic view of OHS management issues. Despite the growing interest in applying system dynamics methods in OHS issues, this paper is novel in its use of system dynamics group model building approach in analyzing OHS management issues. The research approach was described in significant detail to enable other researchers to study 'wicked' OHS problems using the system dynamics group model building approach. It is believed that the group model building approach has significant potential in OHS problem diagnosis and development of solutions. To enable scenario analyses of different OHS strategies, future research will convert the causal loop diagram into a quantitative stock and flow simulation model. The model can enable sensitivity analyses of different parameters to determine critical and key leverage points and facilitate selection of effective OHS strategies.

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A Case Study of Safety Performance Variations among a General Contractor's Regional Branches

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A Case Study of Safety Performance Variations among a General Contractor's Regional Branches

Abstract:

In construction, contractors' safety performance could differ from each other due to various reasons (e.g., the importance of safety at workplace, the adoption of different safety and health programs, the use of union or non-union workers, etc.). However, it has not been widely recognized that differences in safety performance also exist in the same contractor's regional offices. So far, the impact of regional differences on contractors' safety performance has not been well understood. In a case study of a general contractor's (GC's) newly launched safety management program, variations in safety performance of the same GC's regional branches were noticed. This paper analyzes incidence rates (IRs), safety violation rates (SVRs), and workplace safety climate from the GC's six major regional branches in four states. This research finds apparent regional differences in IR and SVR although the workers' shared perception of how the safety program is implemented (i.e., program-related safety climate) is consistent company-wide. This research also finds that regional IRs, SVRs, and safety climate scores have no correlational relationship. Therefore, integrating all these three factors into a safety management program and its effectiveness measurement is necessary and will lead to a more holistic approach to improving jobsite safety performance.

Keywords: safety performance, regional difference, incidence rate, behavioral violation, safety culture, safety climate

1. Introduction

In the construction industry, contractors' safety performance in terms of incident rates and/or experience modification rates (EMR) could differ from each other to a large degree. Potential causes include, but are not limited to, the importance of safety at workplaces, the adoptions of different safety and health procedures, the uses of union or non-union workers, different percentage of immigration workers in workforce, age differences, etc. (Dedobbeleer et al., 1990; Anderson et al., 2000; Gillen et al., 2002; Siu et al., 2003; Oh and Sol, 2008; Chen and Jin, 2011). However, it has not been widely recognized that differences in safety performance also exist in the same contractor's regional offices although the same safety program and procedures are in place. So far, the impact of regional differences on contractors' safety performance has not been well understood. The underlying reasons for such regional differences are unclear.

In a case study to evaluate the overall effectiveness of a general contractor's (GC's) newly launched safety management program—"Safety4Site," Chen and Jin (2011) found that the 19-month incidence rates (IRs) of the same GC's regional branches varied to a large degree. This inconsistency hurts the contractor's overall safety performance. This motivated researchers to explore underlying reasons for these safety performance variations. This research, at the current stage, focuses on two major factors, namely safety behavioral violation and safety culture/climate that may be related to IRs. These two factors are also considered unconventional safety performance measurements by this study. This leads to a holistic approach to assessing safety performance.

This paper first analyzes data for IRs, safety violation rates (SVRs), and workplace safety climate from the GC's six major regional branches in four states to investigate how much differences exist among these data. Then the paper focuses on presenting a correlation analysis on regional IRs, SVRs, and safety culture/climate. The research findings are expected to offer useful insights to help the contractor enhance the implementation of the safety program and achieve consistent and improved safety records company-wide.

2. Literature Review

Regional Differences

There have been previous work that confirmed the existence of regional differences in IR, best construction practices, and other factors that affect filed safety performance. According to International Association of Oil and gas Producers (OGP), regional differences were evident in the lost time injury frequency (LTIF) performance among their Asia/Australasia, Africa, South America, and Europe regions (OGP, 2005). Data from U.S. Bureau of Labor Statistics (BLS) shows that in the building construction sector, the 2009 IR from each state varied to a large degree. For example, some northern states, such as Iowa and Delaware, had their state IRs higher than 6.5, while some southern states, such as Alabama and Georgia, had their IRs below 3.0. For another four states where the aforementioned GC's regional offices are located, three of them have available IR data from BLS. These data (4.3, 3.8, and 2.2) were also very different (BLS, 2011).

Many factors could play a role in causing regional differences in safety performance. These factors include demographic variation, safety behavior, best construction practices, labor/safety management practices, jobsite climate, etc. For example, previous results showed the impact of racial and ethnic diversities in construction workforce on the safety performance of contractors from different regions. This is because of the higher fatal and non-fatal injury rates among Hispanic construction workers (Anderson et al., 2000; Brunette, 2004). Also, studies have verified that regional differences exist in adopting best construction practices (e.g., ergonomic best practices in masonry construction) or labor/safety management practices (e.g., drug tests, controlling labor turnover, etc.) that have an effect on contractors' safety performance (Hinze and Gambatese, 2003; Hess et al., 2010). In addition, industry practitioners gradually realize the existence of regional needs in developing and implementing safety and health programs and are increasingly aware that safety performance improvements should be aligned with regional and company culture and conditions (Cooper and Phillips, 2004; Choudhry et al., 2007).

Safety Performance Measurements

Traditionally, a contractor's safety performance is measured only through reactive factors including incident rates (e.g., lost time incidence rate, severity rate, and recordable incident rate), experience modification ratings (EMRs), and other quantitative safety performance measures (Jaselskis et al., 1996). In recent years, researchers started to point out that the outcome data (such as accidents) are not a good measure of safety performance because they are insensitive and ignore risk exposure (Glendon and McKenna, 1995). For example, a jobsite with zero accident and yet having a large number of unsafe acts or near misses cannot be considered safe at all. By contrast, proactive approaches that pay special attention to accident prevention were suggested as more accurate methods for measuring safety performance. These approaches include behavior sampling, hazard identification, and safety culture/climate (Stricoff, 2000; Cooper and Phillips, 2004; Choudhry et al., 2007).

Unlike more straight forward accident/incident-based measurements, measuring proactive indicators (such as safety behavior, safety culture/climate, etc.) is difficult, cost- or time-prohibitive, and subjective. Both qualitative and quantitative methods need to be used according to previous studies (Edkins, 1998; Griffin and Neal, 2000; Glendon and Litherland, 2001; Cooper and Philips, 2004; Wu et al., 2007, 2009; Choudhry et al., 2009; Jiang et al., 2010). Safety culture is a top-down organizational attribute approach while safety climate is about workers' perception of the value of safety in the work environment (Neal et al., 2000; Mohamed, 2003). Survey instrument remains the most widely used method in determining organizational culture and workplace climate.

Overview of "Safety4Site"

The "Safety4Site" program was designed and implemented by the aforementioned GC to reduce injuries and workers' exposures in OSHA (Occupational Safety and Health Administration) Focus 4 Hazards, namely falls, electrocution, stuck-by, and caught-in or between (OSHA, n.d.). This program focuses on increasing the safety awareness and accountability of the GC's employees, its subcontractors (Subs), and material suppliers, while achieving positive changes in safety attitude and behavior. The program consists of three basic elements: 1) eye protection, 2) daily "huddle" meetings, and 3) accountability for accidents, incidents, and near misses. Twenty non-negotiable unsafe behaviors related to Focus 4 Hazards were identified in the program development stage and violations were observed and reported during its implementation at the GC's jobsites. Based on the observed violations, certain penalties were applied to involved workers. After two-month probation/warning period, the program was in full effect at the end of May 2008 and has been ongoing since then.

3. Research Methods

The primary objective of this research is to investigate differences in workers' safety performance among the GC's six regional branches and perform hypothesis tests to determine whether these regions' safety violation rates, safety culture/climate, and incidence rates are correlated. A positive answer could imply that safety violations, organizational safety culture, and/or workplace safety climate have an influence on incidence rates. Improvement on these factors can help contractors reduce accidents on jobsites and maintain consistent safety performance company-wide. To achieve this goal, the following research methods were employed.

In the data collection stage, the GC's monthly revenues, numbers of accidents, and numbers of safety violations reported for each region were retrieved. Regional IRs were calculated and compared to determine if the GC had achieved consistent safety performance among construction sites across different states. Another unconventional safety performance measurement—behavioral violation—was also studied for the regional difference. To avoid the influence of fluctuating revenues on the monthly number of safety behavior violations, safety violation rates (SVR) were calculated and used for comparison.

A key part of this study was to compare each region's safety culture/climate on jobsites. Survey questionnaires for craft workers, site management personnel, and top executives of the GC were developed. Except for some general background questions, most of the questions fall into five categories, namely *awareness*, *accountability*, *buy-in/acceptance*, *culture/climate*, and *cost/schedule impact*. To ensure wide participation in the survey, the research adopted both face-to-face and online web surveys. The former was used for field workers and site management personnel, while the latter was used to collect feedback from top executives and site management personnel who either missed the face-to-face survey on jobsites or were not currently assigned to an on-going project. Craft questionnaire was translated to Spanish for Spanish workers. Due to space limitation, this paper focuses on presenting survey results from craft workers, which reflect safety climate (i.e., shared perception among workers of the value of safety in their work environment) on the jobsites. The questionnaire for craft workers consisted of 28 questions in various formats, including multiple-choice, Likert scale, and open questions.

From November 2010 to January 2011, the face-to-face surveys for craft workers were conducted at 31 construction sites across four states, where the GC's regional branches are located. Table 1 shows the number of surveyed workers in each region.

Table 1: Number of questionnaires collected from different regions

Region	1	2	3	4	5	6	Total
Number of surveyed workers	33	65	29	53	82	88	350

In the data analysis stage, 15 out of the 28 questions were selected to generate overall safety climate scores. These selected questions were later on divided into two categories, namely **program-related safety climate** (including subcategories of awareness, accountability, and buy-in/acceptance), and **general safety climate**. Scores for all of these categories and subcategories were computed.

After regional IRs, SVRs, overall safety climate scores, and its subcategory scores were obtained, comparison study was performed to determine the deviations and relative variations for these safety performance measurements across six regions. These regions' rankings in IRs, SVRs, and safety climate scores were also checked to see if the rankings were consistent. Finally, the relationships among these safety performance measurements were studied to determine whether they are correlated.

4. Results and Discussions

Regional Difference in Safety Performance

One focus of the "Safety4Site" case study was to compare workers' safety performance among the GC's six regional branches. Regional IRs were first compared to determine the consistency of the contractor's safety performance after the implementation of "Safety4Site." Safety violation rates and workplace safety climate scores, two unconventional measurements for safety performance, were also calculated and compared to determine regional variances. The results are presented below.

Incidence Rates among Six Regions. The incidence rates (GC-and-Subs combined) were computed as:

$$\textit{Incidence rate} = \textit{total recordable accidents} \times 200{,}000 / \textit{employee hours worked}. \quad (1)$$

Recordable accidents are those with non-fatal injuries that require more than First Aid treatment. Employee hours worked were computed based on the assumptions that labor costs account for 40% of the total revenue and workers' hourly rate (including wages and benefits) is $40 on average. Figure 1 shows the overall IRs over the 19-month study period (from 05/2008 to 09/2009) for each region as well as the overall six-regions-combined. Yearly IRs (2008 and 2009) falling into the study period are also shown.

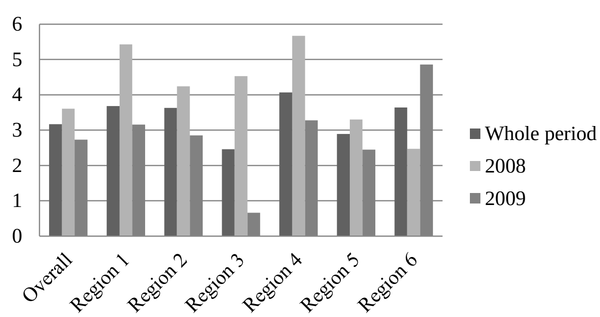

Figure 1: Incidence rates among different regions.

As shown in Figure 1, regional IRs and their yearly values varied to some degree. Region 4 had the highest IR (4.07), 65.45% higher than that of Region 3 (IR=2.46), which was the lowest. Trend of yearly change was also not consistent among different regions. Most regions had lower IRs in 2009 compared to 2008. Region 3 had the largest reduction of 85.43%. Region 6 is the only region that had an increased IR in 2009 by 96.76%. Although this was partially due to the fact that Region 6 had the lowest yearly IR in 2008, this sharp increase in IR as well as being the highest yearly IR in 2009 is unusual and needs further study.

Safety Violation Rates (SVR). The total number of unsafe behaviors observed for each region was generated by summing monthly violation numbers reported by the GC. The U.S. Bureau of Labor Statistics (BLS) showed that the decreases in fatal injury in 2008 and 2009 were partially caused by declines in employment or hours worked. This was especially true in the construction industry (BLS, 2010). Previous research has also confirmed a positive linear relationship between the GC's monthly revenue and violation numbers over the 19-month studied period (Chen and Jin, 2011). To exclude the potential impact of revenue (hours worked) on the violation number of each region, safety violation rate (SVR) was introduced into this study to measure the behavior-based performance, which can be computed as:

$$SVR = \text{number of safety violations} \times 200{,}000 \,/\, \text{employee hours worked.} \qquad (2)$$

Similar to IR, SVR denotes the number of violations per 100 workers on an annual basis. Figure 2 illustrates SVRs for six regions. The entire study period for SVR is the same as that for IR (from 05/2008 to 09/2009).

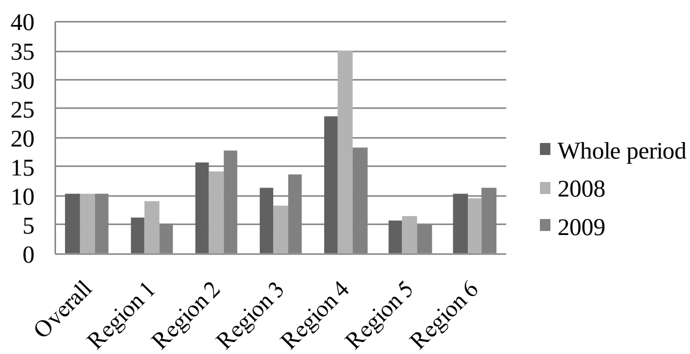

Figure 2: SVRs among different regions.

Similar to IR, SVRs were also inconsistent among different regions during the studied period. Region 5 had the lowest SVRs in the whole study period and yearly data. The whole period SVR from Region 4 was 321.59% higher than that from Region 5. The overall SVRs for the six-regions-combined did not vary much among the whole study period and yearly values. Three regions had lower SVRs in 2009, and the other three had higher SVRs instead. Region 4 had the highest change in yearly SVRs from 2008 to 2009, a decrease by 42.15%. The inconsistencies in regional IRs and SVRs led to a variation study presented later in this paper.

Safety Climate Scores. The overall workplace safety climate score, denoted by Y, was computed by the following linear expression:

$$Y = a + \sum_{i=1}^{15} b_i X_i \ , \qquad (3)$$

Where X_i represents the score obtained for the i th selected multiple-choice question, a represents an initial score, and b_i denotes the weight for the i th multiple-choice score. In this study, a is set to zero and $b_i = 1$, for $i = 1,\ldots,15$. Each X_i is upper bounded by one. Hence, the maximum value of Y is 15. More specifically, suppose that there are n choices for the i th question, then X_i is computed as follows:

$$X_i = \sum_{j=1}^{n} p_j q_j \ , \qquad (4)$$

where p_j denotes the percentage of the people who selected the j th option and q_j denotes the score earned for selecting the j th option. For example, suppose that there are two options for the first question, and the scores for these two options are 1 and 0, respectively. If 90% of the people selected that they are aware of Safety4Site (represented by score 1), and 10% chose the unaware option (represented by score 0), then the score X_1 is computed as $0.9 \times 1 + 0.1 \times 0 = 0.9$.

Regional Variance Analysis. Table 2 lists all the regional IRs, SVRs, climate scores in various categories, and their associated overall values, deviations, and relative variations.

Table 2: Safety measurement data among regions

Region	IR	SVR	Awareness	Accountability	Buy-in/ Acceptance	Program-related climate*	General climate	Overall climate
1	3.68	6.13	2.41	1.46	4.11	7.98	2.17	10.14
2	3.63	15.83	2.50	1.61	4.30	8.40	1.96	10.36
3	2.46	11.25	2.46	1.37	4.33	8.16	1.91	10.07
4	4.07	23.82	2.57	1.34	4.39	8.30	2.08	10.38
5	2.89	5.65	2.48	1.43	4.50	8.41	2.13	10.54
6	3.64	10.44	2.57	1.45	5.03	9.05	2.24	11.30
Overall	3.17	10.36	2.46	1.45	4.57	8.47	2.11	10.64
Deviation	0.59	6.48	0.07	0.09	0.31	0.35	0.12	0.44
Relative Variation	18.6%	62.55%	2.98%	5.99%	6.84%	4.07%	5.65%	4.13%

* The program-related climate is the sum of awareness, accountability, and buy-in/acceptance.

The overall value for each performance measurement was calculated using Eqs.(1), (2), and (3), respectively, based on the entire sample of six regions. Note that the overall value of each performance category is in general not equal to the arithmetic average of the corresponding scores of six regions. For convenience, the term "deviation" is slightly abused as follows. Let x denote a performance metric, i.e.,
$x \in \{\text{IR, SVR, Awareness, Accountability, Acceptance, General Climate, Overall Climate}\}$.
Also, let $\tilde{x}$ represent the corresponding overall value. Then, the deviation in this work is:

$$\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \tilde{x})^2} \ , \qquad (5)$$

Note that Eq.(5) is similar to the standard deviation computation. The difference is that $\tilde{x}$ in all the cases is no longer the arithmetic mean of regional data, but the overall value.

“Relative variation” in Table 2 is defined as

$$Relative\ variation = deviation\ /\ overall. \tag{6}$$

It can be seen from Table 2 that SVR has the largest relative variation (52%), showing an apparent regional difference in workers’ safety behavior. The relative variation of overall safety climate is 4.13% and other safety climate subcategories all have relatively small variations, implying that the perception from workers on the implementation of the “Safety4Site” program is consistent in all regions. There is no consistent ranking for each region in terms of its safety performance in IR, SVR, and climate. For example, Region 3 ranks the best in IR, the third in SVR, but the worst in the overall safety climate.

Correlation Analysis of Safety Performance Measurements

The inconsistency in ranking of regional offices’ safety performance motivated researchers to study the correlation coefficient among major safety performance measurements including IR, SVR, overall climate and its subcategories for the six regions. Pearson correlation (denoted by *r*) and its related *p* value were used to test the existence of linear relationships (see Table 3).

Table 3: Pearson correlation among safety performance measurements (N=6)

		IR	**SVR**	**Awareness**	**Account-ability**	**Buy-in/ Acceptance**	**Program-related climate**	**General climate**	**Overall climate**
IR	*r*	1	0.53	0.46	0.191	0.06	0.18	0.45	0.27
	p	0	0.28	0.358	0.717	0.91	0.733	0.38	0.60
SVR	*r*		1	0.64	-0.18	-0.03	0.04	-0.33	-0.07
	p		0	0.17	0.73	0.95	0.95	0.52	0.90
Awareness	*r*			1	-0.20	0.72	0.74	0.26	0.69
	p			0	0.71	0.11	0.09	0.62	0.13
Account-ability	*r*				1	-0.08	0.16	-0.09	0.11
	p				0	0.88	0.77	0.867	0.84
Buy-in/ Acceptance	*r*					1	0.97	0.53	0.95
	p					0	**0.002**	0.28	**0.003**
Program-related climate	*r*						1	0.48	0.97
	p						0	0.34	**0.001**
General climate	*r*							1	0.68
	p							0	0.14
Overall climate	*r*								1
	p								0

Data in Table 3 show that there is no linear relationship among IR, SVR, and workplace safety climate (including its subcategories). However, there are strong linear relationships among safety climate categories: Both the program-related climate and overall climate are strongly related to buy-in/acceptance of the safety program. The program-related climate also has a strong linear relationship with the overall climate.

Due to the lack of correlation among IR, SVR, and safety climate, a holistic safety management approach integrating all these three factors/measurements would be necessary for improving jobsite safety performance. They also need to be considered in evaluating the effectiveness of such a safety management program.

Limitations

It is challenging to quantify workplace safety climate in this study. In safety climate score calculation, each of the 15 selected questions was assumed to be equally important. To be more accurate, in the future research, a weighting system for these questions will be developed by surveying contractors' management personnel who will rank the importance of each question using a pre-defined Likert-type scale (e.g., 1-5 from the least important to the most important). Then, the relative weights of the questions can be computed.

5. Conclusions and Future Research

This case study presented information about regional differences in safety performance for a GC after the launch of a new safety program—"Safety4Site." The study included a traditional IR measurement and non-traditional measurements including SVR and workplace safety climate in the analysis. Differences in regional IRs (relative variation = 15.06%) and SVRs (relative variation = 52%) were apparent while the difference in workplace safety climate was minor (relative variation = 4.13%). This implies that the shared perception from workers on the implementation of the "Safety4Site" program is consistent in all regions, an indicator that the implementation of the program is also relatively consistent among regions.

Traditionally, the safety performance is measured by IRs, EMRs and other reactive factors. Safety behavior and safety culture/climate are considered external factors that affect workers' safety performance to some degree. To explore a more comprehensive way to assess contractors' safety performance, this research included SVR and safety culture/climate score as proactive measurements for safety performance. Therefore, a correlational relationship analysis was performed for the six regions to determine whether these three measurements are correlated. The results indicated that these three measurements are independent of each other. As a result, integrating these three factors into a safety management program and its effectiveness measurement is necessary, which will lead to a more holistic approach to improving jobsite safety performance.

This case study will be furthered in the following directions:

- Survey data from top executives and site management personnel will be analyzed to measure the organizational safety culture for the GC. This will complete the holistic approach adopted by this research.
- The current study has not thoroughly explored the factors that could cause regional differences in safety performance. Regional best practices, the effectiveness of

OSHA's supervision, workers' ethnicity and age range, percentage of self-performed and subcontracted work, and other factors could also play a role. Future research will study these potential factors.

- Factors that are significant to the buy-in/acceptance to the program and to the general safety climate on the jobsites will be identified, which could become the focal areas for the GC to further improve the program implementation and jobsite safety performance.

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The Development of an Innovative Tool Kit to Support Construction Field Inspections

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The Development of an Innovative Tool Kit to Support Construction Field Inspections

Abstract:

Occupational safety is imperative in construction and contractors' internal field inspections are common interventions that help enforce job safety on site. The field inspection process, however, suffers from inefficiency and ineffectiveness. Also, rarely are inspection results analyzed one-step further to reveal the unsafe patterns, possibly due to limited resources and the lack of well documented inspection results. This paper presents an innovative field inspection tool kit with the purpose to streamline the field inspection process as well as its resulting data records. The tool kit is essentially an automated field inspection form which will be ultimately deployed onto an iPad platform for robust uses. A paper prototype of the tool kit was designed, developed, tested, and improved progressively with the participation of construction management students and safety professionals in three stages. These stages are pilot test, group test, and field interview. In each stage, a participant would use the tool kit to record given violation scenarios and then provide feedback about the tool kit. Upon the completion of the paper prototype, a software prototype of the tool kit was implemented and evaluated using steps similar to the three stage approach. Evaluation results indicated the usefulness and practicality of the tool kit as well as advanced features to be incorporated in the future. The overall tool kit development process truly benefits from the involvement of targeted audience and makes the end product both safety and user centric.

Keywords: safety audit, field inspection, usability study, innovative technology

1. Introduction

One common intervention that helps enforce construction safety is field inspection. During field inspection, a safety professional typically takes notes for safety issues observed during a job talk, communicates with workers on site to express the concerns, and then upon return to his or her office recaps the inspection results in a report. Often times inspection results are further discussed in regular meetings to prevent similar issues from recurring, target specific areas for training, and raise the safety awareness among employees. As such, inspecting jobsite safety in the field is critical by all means.

Given its importance, however, field inspection is often accompanied by inefficiency (e.g. information needed on site not available immediately or multiple recording of the same inspection results on notebooks and spreadsheets) and ineffectiveness (e.g. typos, arbitrary descriptions for the safety issues, or inconsistent naming for the same trade). Current practices also do not take advantage of the time and resources that safety professionals have already consumed during field inspections. Therefore, rarely are inspection results analyzed one-step further to reveal the unsafe patterns on site, possibly due to limited resources and the lack of well documented inspection results. Most safety measures are after-the-facts in nature (Smith et al. 1991) and it is not uncommon to learn mistakes from incident or accident investigation (Chua and Goh, 2004; Goh and Chua, 2009). But why do we have to wait until an injury or even fatality happens if field inspection data could be potentially leveraged to highlight areas that need proactive precautions? The challenge is therefore bi-fold, i.e. supporting the practices of field inspections so that safety records could be managed more efficiently and effectively, and facilitating the documentation of inspection results so that data records could be streamlined for analysis, learning, and prediction.

Although information technologies (IT) are great tools in almost every field, they have not been fully investigated for construction safety applications to address the above challenge. While other functions (e.g. interface coordination) of construction management are becoming the test beds and beneficiaries of advanced information technologies, it is not uncommon to see contractors still resort to Excel or Word as their main tools for managing field inspection results even though integrated project management solutions usually have a placeholder for safety records. One possible reason for this is that prevailing IT solutions in construction are mostly designed for cost and time controls with minimum support to safety. Some have also reported that user satisfaction for information systems that assist “safety patrol” still remains low (Jung et al. 2008).

Based on the above observation, the authors developed a tool kit to support the day-to-day practices of field inspection and to facilitate the documentation of inspection results for data analysis. Construction practitioners were consulted to help make the tool kit truly safety and user centric. The paper introduces the tool kit and discusses its design, development, prototyping, and evaluation, particularly with regards to the field requirements. The first iPad employment of the tool kit will be launched in fall 2011 for show case and be field tested in spring 2012 for data collection.

2. Tool Kit Design and Development

To reflect upon the desired functions of the tool kit, observations of actual job walks and reviews of the resulting field inspection data records were made to provide a preliminary understanding of the inspection process. This understanding together with the topological structure of OSHA’s safety regulations for construction were applied to design a drafted template for safety professionals to record field inspection results on site. Figure 1 illustrates the drafted template, which is essentially a form that intends to serves as a framework for organizing and recording all possible types and scenarios of safety violations.

The drafted template then went through three stages (i.e. pilot test, group test, and field interview) of testing and improvement, with the participation of safety professionals and construction management students. This facilitated a constant check upon the practical requirements and allowed potential users to contribute to the designed process of application. Specifically, the drafted template was presented and tested in the form of a paper prototype in all three stages before its design was finalized for software prototyping. The major benefit of paper prototyping is that, it allows researchers to development multiple solutions in a relatively shorter time and with lower cost (Charles et al. 2005).

☐ Scaffold	☐ Tool Safety
☐ Fall Hazards	☐ Powder Actuated Tool
☐ Guard Rail	☐ Power Tool
☐ Fall Protection	☐ Machine Guard
☐ Other, please specify:	☐ Saw Guard
	☐ Other, please specify:
☐ Trenching	
☐ Electrical	☐ Policy
☐ Cord	☐ Smoking
☐ Other, please specify:	☐ Headphones
	☐ Other, please specify:
☐ Ladder Safety	☐ House Keeping
☐ PPE (Personal Protective Equipment)	☐ Equipment Operation
☐ Face Shield	☐ Crane
☐ Safety Glasses	☐ Scissor Lift
☐ Hard Hat	☐ Forklifts
☐ Gloves	☐ Vehicles
☐ Other, please specify:	☐ Other, please specify:
☐ Hazardous Chemicals	☐ Work and Public
☐ Fuel Gas	☐ Other, please specify:
☐ Other, please specify:	

Figure 1: Initially Drafted Field Inspection Form

Twenty violation scenarios were compiled and divided into two sets, basic and advanced, to test the drafted field inspection form. The basic set contains ten violation scenarios and was used in the pilot and group tests where participants were construction management students from the University of Washington. The advanced set has the complete twenty violation scenarios and was used in the field interview with safety professionals from the greater Seattle area. Violation scenarios in the basic set are more straight forward and easier to spot. Violation scenarios in the advanced set are generally more ambiguous or involve more than one major hazard. An example image from the advanced set is illustrated in Image 1.

Image 1: Violation Scenario from the Advanced Set for Testing the Paper Prototype

A post-test questionnaire was also designed to help evaluate the paper prototype. Specifically, the draft questionnaire was used in the pilot test for feedback and improvement and the updated questionnaire was used in the group test and field interview. The questionnaire assesses four design perspectives of the field inspection form, including the form's ease of use (i.e. is the form easy to understand and work with?), coverage (i.e. does it cover most of the on-site violations?), effectiveness (i.e. does the form help describe the observed violations?), and other potential benefits (i.e. does the form serve as an inspection checklist?)

Finally, a set of post-test interview questions was developed particularly for the field interview. The questions were intended to solicit open feedback from participating safety experts in terms of (1) the current safety inspection practices, the forms used for such practices, and existing analytical applications of the inspection data records, (2) applicability of the classification and terminologies used in the form, and (3) needed system revision and improvement.

Pilot Test

The main purpose of the pilot test is to check the flow and practicality of the overall testing procedure before the paper prototype was evaluated with a larger group of audience. Two University of Washington construction management graduate students who have had some safety-related experiences participated in the test. Of the two participating graduate students, one has ten and the other has three years of construction related experience. The participants used the paper prototype to record the basic set of violation scenarios, and their interactions with the paper prototype were observed to assess the practicality of the paper prototype. Some usability problems (i.e. violation pictures were not clear) were identified and addressed as a result of this process. The "trenching" category was also extended to "trenching/excavation" to widen its scope and accommodate a larger range of violations that involve earthwork. The participants also filled out the drafted post-test questionnaire so that question design issues could be captured earlier before the questionnaire was used in the group test and field interview. The pilot test lasted about thirty minutes with each participant.

Group Test

The group test was carried out in the undergraduate construction safety class CM333 at the University of Washington. The main purpose of the group test is to verify if the organization of the violation categories is logical so that most participating students would assign the same violation to a particular category. The test also helps assess students' hazard recognition capabilities. Since not all students have had construction experience prior to the test, those who recorded a given violation scenario under incorrect category for five or more times were considered outliers and their responses were removed from the test results.

Inspection results recorded by the students implied that the form organization is logical. Feedback from the students further indicated that the form covered most of the commonly-seen safety violations and its design was easy to understand and work with. When students used the paper prototype to record given violations, all of them described and observed the violations more promptly. Students also implied that they were able to scan through the form to make sure that they were not missing anything. After the group test, three main changes were made to rectify or clarify the used terminologies: "Face Shield" was replaced by "Respirator" under the PPE category, "Fencing" and "Other" were added to the "Work and Public category", and the "Policy" category was renamed to "Company Policy". The entire group test lasted about thirty minutes.

Field Interview

The purpose of the field interview is to ultimately define the requirements of the tool kit by verifying the drafted-and-then-revised field inspection form and by enhancing the form through expert feedback. Five companies, including one safety consulting firm and four general contractors from the greater Seattle area participated in the field interview. All participants, including one superintendent and five safety directors, from the five companies have been in safety related positions with years of experience. Each field interview lasted about seventy minutes.

During the field interview, additional categories (and sub categories) were identified by the participating experts. Therefore, two new categories, "Fire Protection" and "Required Documents", and their fellow sub categories were added to the form. New sub categories were added under "Scaffold", "House Keeping", "Trenching/Excavation", and "Ladder Safety". Some category and sub category names were also revised (e.g. "Work and Public" to "Worker and Public Safety"). Expert feedback further indicated that some violation categories are strongly related to each other (e.g. if the violation is "Electrical" related, it has a high chance of also being a "Tool Safety" violation) and these relationships, if built into the field inspection tool kit, could help potential users audit field safety more rigorously. Some commented on the usability of the form and suggested that the violation categories be number coded for easy references. Figure 2 illustrates the re-revised field inspection form after the field interviews were completed.

- ☐ 01 Scaffold
  - ☐ 0101 Egress
  - ☐ 0102 Fall Hazards
  - ☐ 0103 Structural Integrity and Connections
  - ☐ 0104 Other, please specify:
- ☐ 02 Fall Hazards
  - ☐ 0201Guard Rail / Midrails and Toe Boards
  - ☐ 0202 Fall Protection
  - ☐ 0203 Other, please specify:
- ☐ 03 House Keeping
  - ☐ 0301 Trip Hazards
  - ☐ 0302 Waste and Trash
  - ☐ 0303 Other, please specify:
- ☐ 04 Trenching / Excavation
  - ☐ 0401 Egress
  - ☐ 0402 Fall Hazards
  - ☐ 0403 Other, please specify:
- ☐ 05 Ladder Safety
  - ☐ 0501 Fall Hazards
  - ☐ 0502 Secured
  - ☐ 0503 Three Feet Extension
  - ☐ 0504 Other, please specify:
- ☐ 06 PPE (Personal Protective Equipment)
  - ☐ 0601 Respirator
  - ☐ 0602 Safety Glasses
  - ☐ 0603 Hard Hat
  - ☐ 0604 Gloves
  - ☐ 0605 Other, please specify:
- ☐ 07 Fire Protection
  - ☐ 0701 Fire extinguishers
  - ☐ 0702 Combustible material storage
  - ☐ 0703 Flammable material storage
  - ☐ 0704 Hot work
  - ☐ 0705 Other, please specify:
- ☐ 08 Electrical
  - ☐ 0801 Cord
  - ☐ 0802 Other, please specify:
- ☐ 09 Tool Safety
  - ☐ 0901 Powder Actuated Tool
  - ☐ 0902 Power Tool
  - ☐ 0903 Machine Guard
  - ☐ 0904 Saw Guard
  - ☐ 0905 Other, please specify:
- ☐ 10 Hazardous Chemicals
  - ☐ 1001Fuel Gas
  - ☐ 1002 Other, please specify:
- ☐ 11 Equipment Operation
  - ☐ 1101 Crane and Rigging
  - ☐ 1102 Scissor Lift
  - ☐ 1103 Forklifts
  - ☐ 1104 Vehicles
  - ☐ 1105 Other, please specify:
- ☐ 12 Worker and Public Safety
  - ☐ 1201 Fencing
  - ☐ 1202 Heat Related Illness
  - ☐ 1203 Other, please specify:
- ☐ 13 Company Policy
  - ☐ 1301 Smoking
  - ☐ 1302 Headphones
  - ☐ 1303 Other, please specify:
- ☐ 14 Required Documents
  - ☐ 1401 Emergency Plan / Site Specific
  - ☐ 1402 Training
  - ☐ 1403 Certification Card for Specific Operation
  - ☐ 1404 Other, please specify:
- ☐ 15 Other, please specify:

Figure 2: Field Inspection Form Revised After Field Interview

3. Tool Kit Prototyping and Evaluation

Software Prototyping

The finalized paper prototype targeted at the "effectiveness" issue and was further developed into a software prototype to address the "efficiency" (e.g. double data entry of the field inspection records) issue. It is envisioned that the software prototype will be employed as an iPad application so that a safety professional can walk job sites with an iPad and record the observed safety issues directly on site. While previously discussed tests and interviews were conducted by the Department of Construction Management at the University of Washington, this part of the software programming and system implementation was conducted by the Computer Aided Engineering (CAE) Lab at the National Taiwan University. Figure 3 shows the user interface of the tool kit.

In Figure 3, the left-hand side window (Frame A) is used to record the violator information. Since project and trade information can be preloaded, a safety professional can easily select appropriate options for logging the violator information.

The right-hand side window (Frame B) is used to record and show the violation detail. Each type of violation can be recorded by marking appropriate checkboxes. The checkbox was arranged in a way that it represents different and classified types of violation. A safety professional can select applicable checkboxes to easily describe the observed violation.

The lower bottom window (Frame C) is used to manage and display the violation statistics. The left side of the window shows the percentage distribution of each recorded violation type for a specific project. The right side of the window shows the frequency of each recorded violation type. The chart statistics change immediately when violation information is updated and so a safety professional can get immediate feedback from the system.

The lowest bottom window (Frame D) is used to manage the task completion. The system users can exit, save, clean and add field inspection records for the same or different job to fit their requirements. When they add an audit record for the same job, the user interface will clear up all the displayed data but keep the Job Name, Job Number, Data and Time. This particular design is expected to help safety professional's time during data entry.

In the current version of the tool kit, users need to transform the output txt file into an Excel file to manage the information in a spreadsheet style. The researchers will enhance the data output modules (e.g. XML file) in the future to reduce the current user burden.

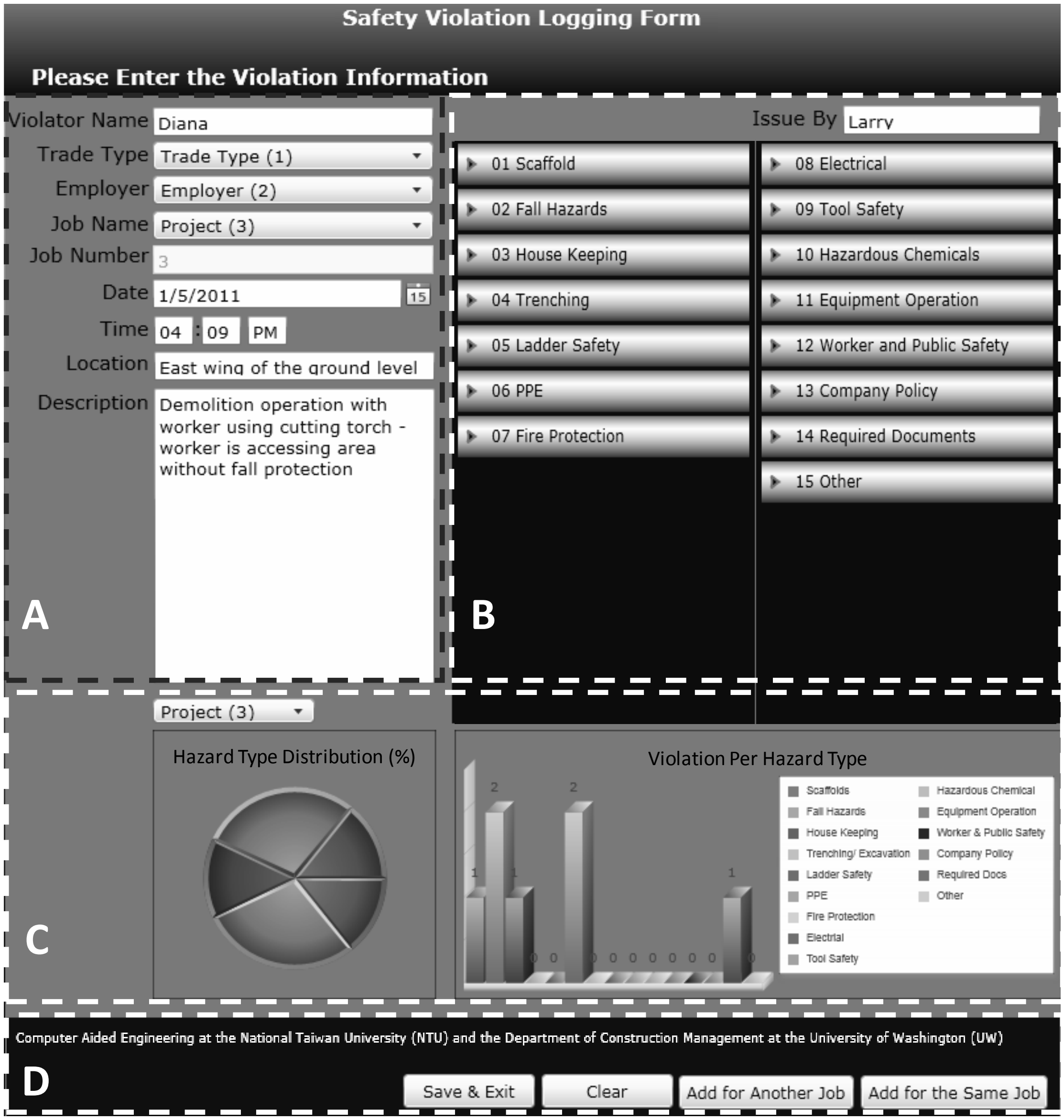

Figure 3: User Interface of the Field Inspection Tool Kit

Based on the observations and feedback obtained from the field interview during paper prototype development, two interactive functions were designed. The first function is the enrichment function, which leverages upon the relationships between different categories. With the enrichment function, when a user selects “08 Electrical”, “09 Tool Safety” will be highlighted automatically to remind the user that he or she needs to further verify if the violation is also tool related. The second function is the extraction function, which calculates the safety performance indicators. After a user completes the form, he or she can move the mouse to the violation statistics chart and see the hazard type distribution (in percentages) and the number of violations per hazard type across a project. This helps users obtain a quick glance of the site safety performance in real-time.

Evaluation

After its completion, the software prototype of the tool kit was evaluated to see if it satisfies the practical needs of field inspections and at the same time facilitates the documentation of field inspection results for data analysis. To evaluate the system, the same companies who participated in the field interviews were invited. In the end, one superintendent, three safety directors, and one project manager were available to help out with the evaluation. All participating experts have more than ten years of construction safety experience.

A new set of violation scenarios and questionnaire were used in the evaluation process. An expert would look at each scenario, identify the violation, and record the violation using the tool kit. After all scenarios were reviewed, the expert then filled out the questionnaire. During each evaluation session, each expert was accompanied by two researchers who helped administer the evaluation procedure, assist the expert with the tool kit system, record system operational mistakes, and collect feedback from the expert. Image 2 below illustrates how an evaluation session was set up with a participating expert.

Image 2: Expert Evaluation of the Tool Kit

In overall, the experts yielded positive evaluation of the tool kit. They agreed that the tool kit system is easy to understand and work with and that the system can help them with the recording and logging of on-site safety violations. They also gave additional comments to improve the tool kit's organizational structure and usability. For example, it was suggested that the sub category "Job Hazard Analysis" should be added to each category of violation and that multiple "Other" options should be made possible and available under each sub category. Usability-wise, empty fill-in space was desired under each sub category and that a searching function if put in place to identify the names of the violator and his or her trade could shorten the violation recording time on site.

4. Conclusion and Future Work

This paper introduces a form-based tool kit which is intended to support the daily safety field inspection activities, address their associated inefficiency and ineffectiveness, and facilitate the documentation of inspection results. The paper prototype of the tool kit went through three stages of testing and improvement, including the pilot test, group test, and field interview. This approach has the advantage of incorporating inputs from potential tool kit users throughout the tool development process and truly benefits from the comments and feedback provided by the participating students and safety experts. A software prototype was further implemented based on the paper prototype to automate recording of the inspection results, following steps similar to that used in the three stage approach. Evaluation results indicated that the software tool kit is useful and practical to the participating safety experts, although it still has room for refinement and improvement.

The presented field inspection tool kit is currently undergoing another round of usability testing and interface improvement from the software engineering's perspective (e.g. location and mechanism of the "Save" button). In the fall of 2011, the tool kit system will be transplanted onto the iPad platform for show case and also to incorporate new, advanced functions on the expert's wish list (e.g. built-in camera function for photo shooting). In the spring of 2012, the platform will be tested on actual job sites to collect data pertaining to the tool use as well as the inspection records. Foreseeable applications of the tool kit, besides field inspections, include instant performance indicator for management and administration and the potential creation of sharable surveillance resources for analysis and trend prediction.

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Designing a Sustainable Built Environment: A Hazards Analysis and Critical Control Points (HACCP) Approach

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Abstract:

Facility stakeholders increasingly employ a number of commercial off-the-shelf (COTS) technologies to improve sustainability in capital projects. However, many aspects of component and systems-level performance such as public health risk, life cycle technological and economic performance, and design usability/acceptability are still poorly understood. This has led to unanticipated consequences that affect performance, long-term sustainability, and subsequent diffusion of these systems. In particular, complex hybrids of COTS components present new challenges and opportunities for facility stakeholders, as performance cannot be understood using traditional analysis methods and conventional disparate disciplines cannot effectively deliver integrated systems. This research adapted the methodology of Hazards Analysis and Critical Control Points (HACCP) to design of sustainable built environment systems. The adapted HACCP approach was deployed in a proof-of-concept workshop in Atlanta, GA to demonstrate the feasibility of the approach during the design process for a proposed residential facility. Results suggest that HACCP provides a systematic framework for identifying potential problems and developing interventions to prevent their occurrence, thus using a "prevention through design" approach to increase facility sustainability and reduce threats to health and safety of facility stakeholders.

Keywords
Sustainability, hazards analysis, prevention through design

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Abstract

Facility stakeholders increasingly employ a number of commercial off-the-shelf (COTS) technologies to improve sustainability in capital projects. However, many aspects of component and systems-level performance such as public health risk, life cycle technological and economic performance, and design usability/acceptability are still poorly understood. This has led to unanticipated consequences that affect performance, long-term sustainability, and subsequent diffusion of these systems. In particular, complex hybrids of COTS components present new challenges and opportunities for facility stakeholders, as performance cannot be understood using traditional analysis methods and conventional disparate disciplines cannot effectively deliver integrated systems. This research adapted the methodology of Hazards Analysis and Critical Control Points (HACCP) to design of sustainable built environment systems. The adapted HACCP approach was deployed in a proof-of-concept workshop in Atlanta, GA to demonstrate the feasibility of the approach during the design process for a proposed residential facility. Results suggest that HACCP provides a systematic framework for identifying potential problems and developing interventions to prevent their occurrence, thus using a "prevention through design" approach to increase facility sustainability and reduce threats to health and safety of facility stakeholders.

1. Introduction and Background

With increasing interest in sustainable construction technologies and methods, the number of green facilities being constructed in the U.S. is growing at a significant pace. These facilities offer a number of benefits to their occupants, including a healthier indoor environment, increased resource efficiency and reduced operating costs, and overall lower impact on the natural environment. However, as green building becomes more mainstream, a number of unanticipated consequences have emerged as problems due to new combinations of technologies that interact in unforeseen ways. These consequences pose potentially significant health and economic impacts for facility stakeholders over various phases of the facility's life cycle. In the domain of water-related systems within buildings, examples of such unanticipated negative system interactions include:

- Accelerated corrosion and blockages of copper waste piping connected to waterless urinals due to concentration of salts in effluent (e.g., Gueverra 2010; Shapiro 2010)
- Increased incidence in opportunistic pathogens when tank-type hot water heaters are set at a lower temperature to save energy (e.g., Bagh et al. 2004; Mathys et al. 2008; Strickhouser & Edwards 2007)

- Increased bacterial growth and reduction in water quality in water supply lines due to reduced flow rate from conserving water fixtures (e.g., NRC 2006; Nguyen et al. 2008; Elfland & Edwards 2008)
- Abandonment in place of various systems such as solar hot water heaters, rainwater harvesting systems, and graywater reuse systems due to incompatibility with maintenance practices of adopting organizations (Pearce 2001; Pearce et al. 2005)

Although the facilities in each of these examples all offer the potential for improved environmental performance, they are ultimately unsustainable if they compromise the health, safety, or quality of life of their constructors, their occupants, or the personnel who operate and maintain them. How can the construction industry develop increasingly more sustainable facilities while avoiding potential problems that threaten the health, safety, and quality of life of the stakeholders of those facilities?

2. Research Objectives

The overarching goal of this work is to develop a new approach for designing and delivering more sustainable facilities by applying the methodology of Hazard Analysis and Critical Control Points (HACCP) to the capital project design and delivery process. The aims of the overall research are to:

- Identify previously unconsidered hazards in green or sustainable buildings that should be considered during and prevented through design
- Map critical control points and possible controls in the project design and delivery process that can influence those hazards, and
- Translate the findings of the investigation into a form that is useful for practice.

The objective of the exploratory study described in the paper was to evaluate the feasibility of using HACCP methodology as a means of identifying, prioritizing, and designing to avoid non-traditional failure modes in green buildings.

3. Approach

In this exploratory study, the research team used a new case-based approach shown in Figure 1 to identify examples of both non-traditional failure modes and exemplary performance cases in green projects. These examples were then used in the context of a pilot workshop where participants used a modified HACCP approach to identify potential problems and suggest possible solutions as part of a simulated design charrette. A charrette is an intensive participative design experience that occurs early in the project design phase and involves active input from a range of project stakeholders.

The focus of the initial study was on water service systems, defined as the technological components of built facilities that supply treated or untreated water for human and building-related uses, and/or treat, recycle, and/or dispose of stormwater and wastewater occurring on site. Water service systems in green buildings are designed and delivered to achieve economic, environmental quality, and resource efficiency objectives, but they do not always achieve their design intent, nor do they necessarily meet facility water service needs over time, as illustrated by the examples listed in the introduction. The reasons for this disparity can be explained in terms of fit between the capabilities of each technological innovation, the human/social performance requirements it is expected to meet, and the context in which it is being used.

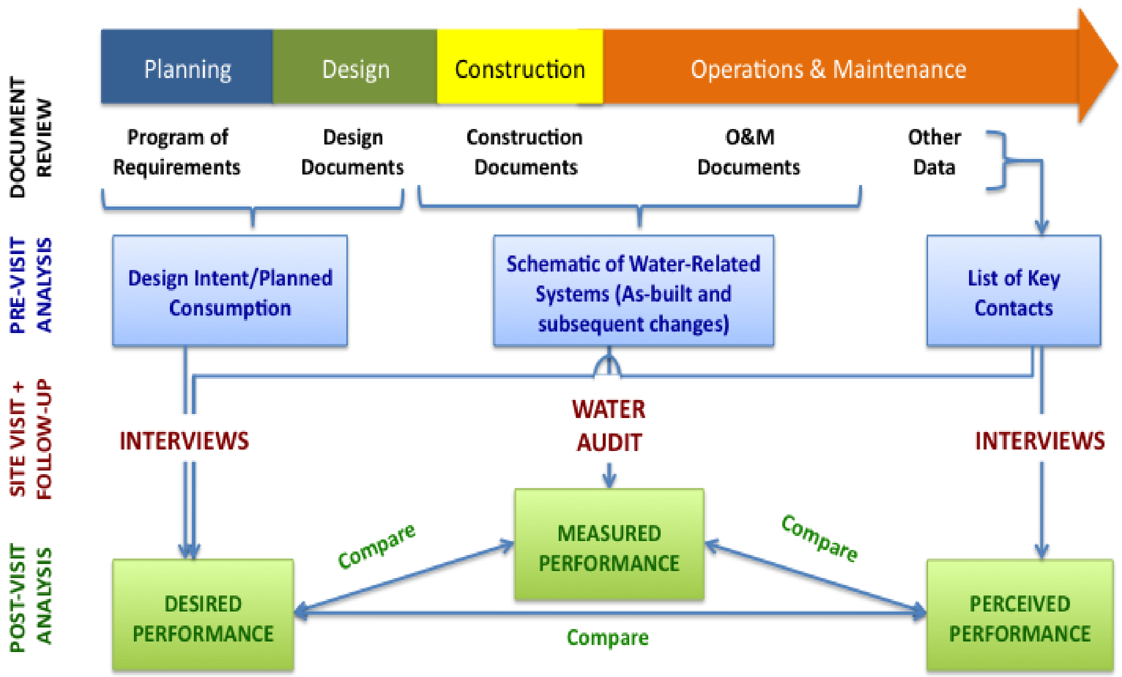


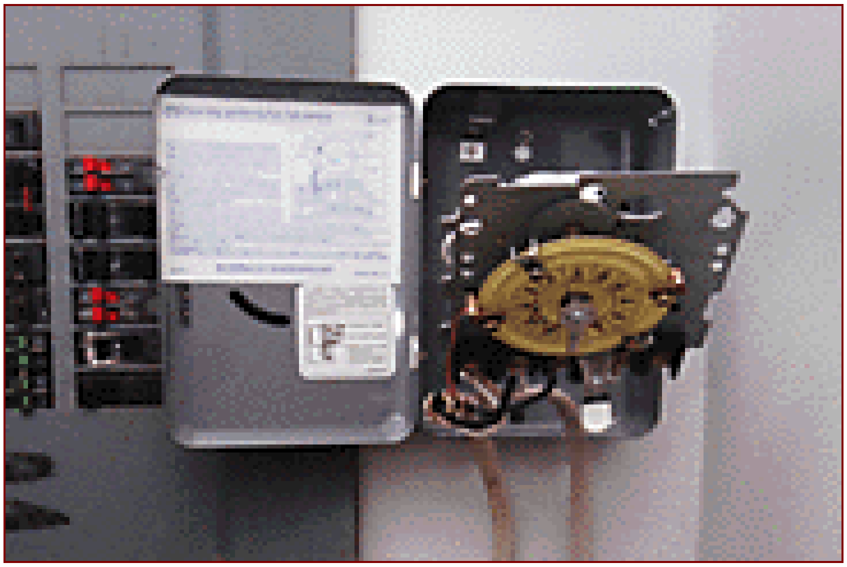
Figure 1: Case-based Methodology for Identifying Instances of failure and/or exemplary performance of water service systems in capital projects

To identify the widest range of both engineering and non-engineering hazards, a case study approach can be used to formally compare *desired* vs. *measured* vs. *perceived* performance in terms of water conservation, quality, and functionality for each case facility's water-related systems. Disparities between these three states indicate a potential hazard or failure if measured or perceived performance does not meet design intent. Each difference can then be explored in terms of contributing process, product, context, and other factors to determine proximate and root causes for the disparity. Methods adapted for this analysis include Fault Tree Analysis (FTA) and Failure Mode & Effects Analysis (FMEA) (DOD 1980; IEC 2006). These two deductive methods use complementary approaches to identify and relate causes and effects of failures in complex systems, and provide distinctive perspectives to validate results.

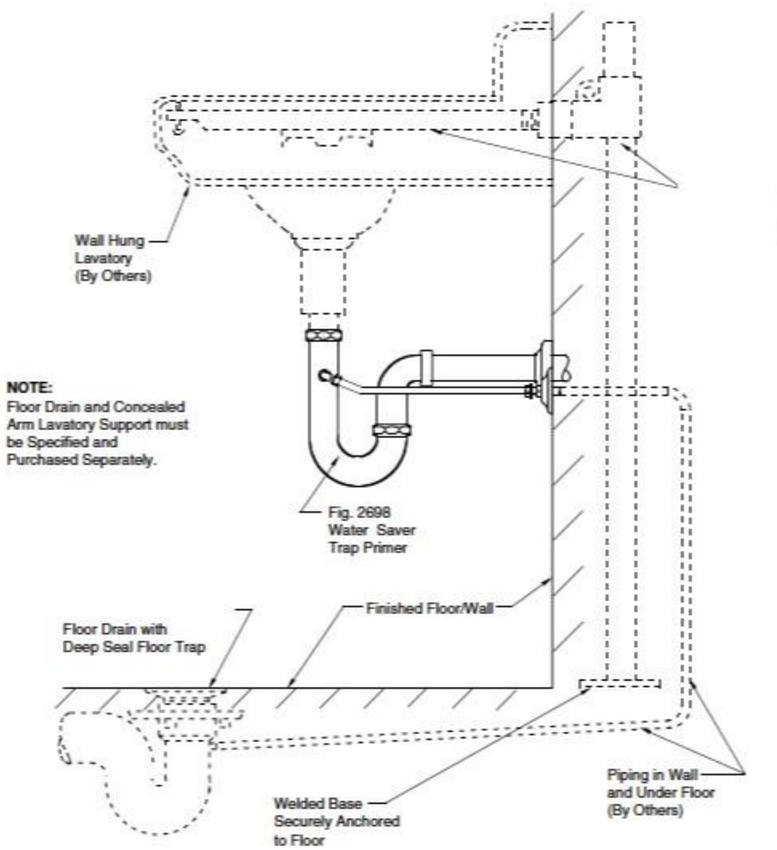
4. Findings

In the exploratory phase of the study, the research team used the approach shown in Figure 1 to identify an initial set of examples of water-related technological innovations (see Figure 2 for selected examples) that have either good or bad fit with performance requirements in the context of application. These examples were used to “seed” discussion at a participatory workshop of sustainability professionals held in Atlanta, GA as part of the 2011 GreenPrints conference. The workshop used a simulated charrette approach for a net-zero energy/water residential building proposed for the Atlanta area. Workshop participants were shown examples of technologies with both good and bad fit as a way to illustrate how combinations of human systems, technologies, and context of application can result in unanticipated performance consequences for these green systems. They were then asked to develop system schematics for the proposed facility’s water service systems and process maps of the project delivery process for those systems.

(a) solar hot water heating system abandoned in place due to mismatch with maintenance capabilities



(b) hot water heater timer for energy savings that can be disabled by users during operation, resulting in higher-than-expected energy use



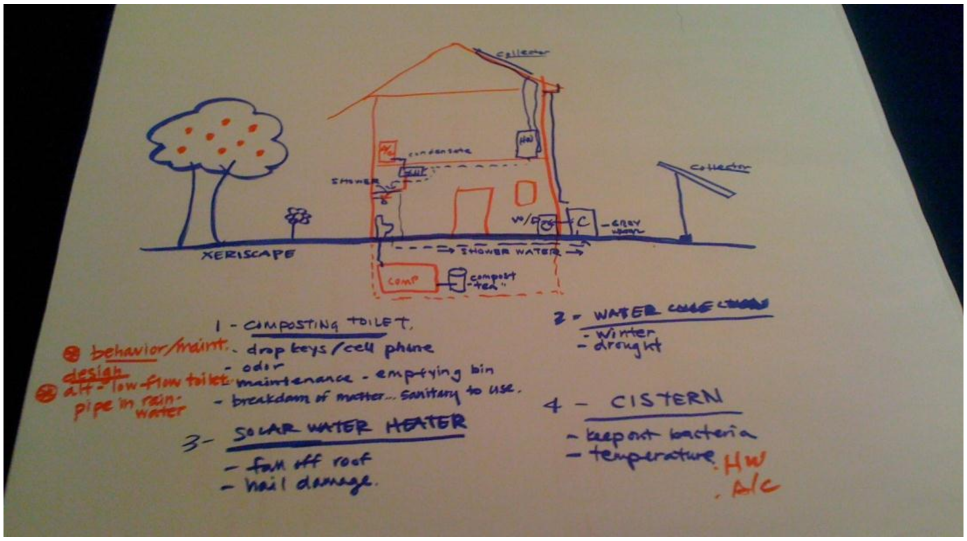
(c) floor drain trap primer using graywater from sink P-trap which, when employed in infrequently-used sinks, becomes clogged with soap residue and stops functioning

(d) storage-type hot water heater which, when temperature is set on energy-saving setting, serves as an ideal breeding ground for opportunistic pathogens

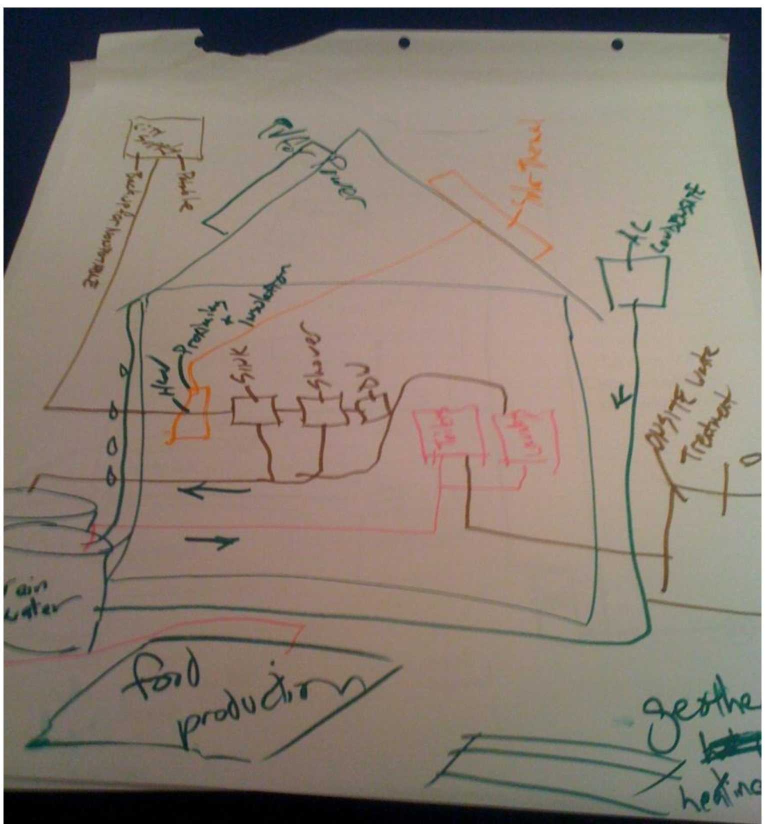
Figure 2: Examples of Failures used to Seed Charrette/Workshop

The methodology defined in ASTM E2590-09 for HACCP was adapted and employed for use in the charrette to guide participants in identifying potential hazards and critical control points associated with those hazards. Specific steps included (a) developing project delivery/use process representations for the facility, stakeholder interaction schematics, and water system schematics for each major type of water service system in the proposed project; (b) identifying hazards/failures observed (or plausible) at each step of the process diagrams/for each component of the water service systems using multiple failure analysis methods; and (c) determining critical control points and known/observed controls that could be employed at each control point.

Participants worked in teams of 4-8 people to develop independent design concepts and apply the HACCP approach to identify critical control points in the system design and delivery process. Each team then presented their schematic diagrams and identified critical control points and potential interventions or controls that could be employed to avert problems at each point. Figure 3 shows examples of the schematic diagrams developed by some of the teams in the workshop.



(a) schematic showing water-related components in net zero water home, including xeriscape, composting toilet, solar water heater, storage cistern, and other components



(b) Schematic showing rainwater harvesting used for non-potable indoor uses such as toilet flushing and to support outdoor food production in the landscape

Figure 3: Examples of System Schematics for Water-Related Systems in Net Zero Water Homes developed by Workshop Teams

Participants were able to identify a range of both engineering and non-engineering (i.e., human-based) hazards that might occur at various stages of the life cycle of the project. When reporting back, participants often described these hazards in the context of their own past experiences with water-related systems in capital projects. The grounding of hazards based on past experiences suggests that it may be fruitful in subsequent studies to repeat the study with groups of experienced stakeholders as a basis for developing a body of knowledge about most prevalent failure mechanisms across multiple projects.

5. Discussion and Future Research

The objective of the exploratory study was to evaluate the feasibility of using an adapted HACCP methodology as a means of identifying, prioritizing, and designing to avoid non-traditional failure modes in green buildings. Participants in the pilot workshop were able to use an adapted HACCP approach to systematically map system components and stakeholders, then identify potential problems that might occur at each phase of the system life cycle. Based on their past experiences, they were also able to suggest possible remedies or interventions for these hazards that could be implemented early in the project life cycle to avoid problems later.

The outcome of the exploratory effort is an initial protocol for case-based analysis of sustainable facility systems along with a proof of concept demonstration of the application of HACCP methods to identify critical control points using a workshop or charrette environment of project stakeholders. Specifically, the exploratory study identified examples of technological innovations that have either good or bad fit with performance requirements for application, and pilot tested a charrette-based approach seeded with those examples to apply a modified HACCP methodology to identify critical control points and design interventions to avoid unanticipated consequences.

Ultimately, the case-based methodology used in this study to identify instances of failure may be useful over time to develop a classification of causes to explain the fit problems underlying nontraditional failures with innovative technologies employed in green building. These causes will comprise a new taxonomy of sustainability-related hazards or failure modes that should be considered during project design and delivery to improve sustainable performance of technological innovations for sustainability in built facilities. Findings from case studies and the charrette conducted under the pilot research serve as a proof of concept for applying HACCP methodology to sustainable design and project delivery, thus serving as a point of departure for its application to a range of facility systems such as water supply, energy service systems, building envelope, and others.

With a formalized understanding of the science - physiochemical, biological, and sociological - underlying presently unanticipated consequences of sustainable water systems in buildings, future designers may be able to proactively consider new types of failure modes during the design and implementation planning of sustainable facilities. Anticipating these failures before they happen will reduce the likelihood that innovative technologies employed in green projects experience unplanned problems with negative consequences for public health, safety, and facility efficiency and performance. The methodology integratively addresses a variety of non-traditional threats to sustainable performance of built systems from the standpoint of multiple disciplines, and provides a prevention-through-design approach for sustainable facilities. Overall, this prevention through design approach will increase the success of sustainable capital projects by avoiding problems that lead to resistance to change by subsequent adopters of green technologies.

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Enhancing the Sustainability of BBS Implementation in Construction– Psychological and Organizational Perspectives

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Abstract:

A large amount of accidents in construction projects result in workers' injuries and deaths, as well as both direct and indirect financial losses. A practical and effective management approach is badly needed to improve construction safety performance.

Since unsafe behavior is the major cause of accidents, lots of researchers focus on the management of behavior, and Behavior-based safety (BBS) has become the popular topic in safety management. However, the psychological causation of workers' unsafe behaviors has not been explored and is still not clear. That is the reason why some of BBS intervention methods are not effective to specific behaviors. Besides, in most cases, the management of unsafe behaviors were excluded from intervention, which usually significantly influence workers' behavioral options. Therefore, the author argues that research on the role that management and individual causes played in generation of unsafe behaviors and the mechanism of connection between management unsafe behaviors and workers' unsafe behaviors is the way to enhance the sustainability of BBS.

In this paper, the author summarizes the main challenges of BBS in construction, and a case of BBS practice on construction sites in Singapore will be introduced and analyzed. The causation model of unsafe behaviors is developed focusing on both the individual and the management unsafe behaviors. Based on the model, the database of causes of unsafe behaviors could be built to reveal management and individual causes respectively. Consequently, the intervention scheme towards the two kinds of causations could be developed accordingly and specifically for construction.

Keywords: Behavior based safety; Safety culture; Psychological perspective; Management unsafe behavior; Construction

Enhancing the Sustainability of BBS Implementation in Construction Psychological and Organizational Perspectives

1. INTRODUCTION

Construction is one of the pillar industries all over the world. In China, construction has been taking higher and higher proportion of the national economy in recent years. In 2010, the total output value of China's construction sector was 9520.6 billion Yuan RMB, and accounted for 23.9% of China's GDP in 2010. Meanwhile, the number of Chinese construction employees is more than 40 million, being one of the biggest groups of labor workers.

However, construction is also one of the most dangerous industries in the world. A large amount of accidents in construction projects result in workers' deaths and injuries, work-related illness, delay and big extra cost, as well as other direct and indirect heavy losses. According to the statistics of the China State Administration of Work Safety, the number of deaths has surprisingly increased in recent years after a temporary decline. 2779 construction workers lost their lives in 2010. Construction safety is also a big challenge in developed countries. The United States Department of Labor reported 816 construction employees' deaths in 2009, listed No.1 among 15 individual sectors. There were 42 fatalities in construction in the United Kingdom according to UK Health and Safety Executive Statistics, representing 28% of total industrial fatalities.

Safety has become one of the most urgent obstacles to overcome. The current situation of construction safety has an extremely negative impact on the development and image of the industry. Therefore, a practical and effective management approach is badly needed to improve construction safety performance.

In order to improve the safety performance, people chose unsafe conditions and unsafe behaviors as two critical targets. In the past few decades, every country and every industry has made a lot of efforts to deal with unsafe conditions, such as machine guarding, housekeeping and inspection programs etc., Legislation reforms; safety management system building and innovation in technology were also the ways to solve problems in safety management to a certain degree. Nevertheless, such a pressing situation of construction safety reflects the limitations of the above discussion and solutions. More recently, unsafe behaviors have naturally drawn people's attention as safety theory has developed. Heinrich (1931) found that nearly 88% of industrial accidents were caused by human errors based on the analysis of 75000 accident cases. Williamson and Feyer (1990) also concluded that 91% of all occupational fatalities from 1982 to 1984 in Australia had connections with human factors. Due to the important role of unsafe behaviors in occurrences' of accidents, a method called behavior-based safety (BBS), which focuses on the intervention of employees' unsafe behaviors, has been proposed and developed.

The BBS study in the last 30 years has aimed to correct and reduce employees' unsafe behaviors as well as injuries. Both academic and industrial communities have showed great interest in BBS practice. Nevertheless, since different opinions exist among safety professionals and scholars, there have been a lot of debates on the investment and effectiveness of BBS implementation. BBS implementation in different countries and fields also display different results. Since construction has a critical safety record, many governments and companies chose BBS as one of the most popular approaches for improving safety performance.

Although BBS has been extensively applied in many industries, it needs to be adapted to suit the demands and characteristics of the construction industry. The authors' BBS practices in Mainland China, Hong Kong and Singapore were confronted with the challenges originated from the particular circumstances of the construction industry. However, since research on BBS implementation in construction industry is still limited, those challenges have not been fully observed and explored.

The authors have tried to review the literature on BBS study and practice and conduct grounded discussion on the challenges of traditional BBS implementation in construction. Based on problem analysis and previous BBS practices, the authors developed the causation model of unsafe behaviors from both psychological and organizational points of view and created a three-step intervention cycle, to improve the current BBS program and framework in construction. The principle of development and application of this model will be elaborated in this paper. The data sets collected from a real case in Singapore will be shown as the example of model application. The case study in Singapore has proven the effectiveness of such new BBS program. This paper aims to respond to these challenges from psychological and organizational perspectives, and to propose a way to build a long-term BBS program and framework and try to enhance its effectiveness and sustainability in the construction industry.

2. LITERATURE REVIEW ON BEHAVIOR BASED SAFETY (BBS)

BBS is a systematic approach to promoting behavioral support for injury prevention. The concept of BBS originated with the work of Heinrich (1931). This conclusion became the foundation of what BBS has come to be today. Komaki et al. (1978) carried out the first application for behavior-based safety when she used a behavior-based model for improving safety performance in one of her student's family bakery.

Meanwhile, content and methodologies of BBS have experienced great growth and evolution, and nowadays the meaning of BBS is quite different to different people. The initial model of BBS was an inexpensive, simple, top-down approach based on Skinner's (1969) operant conditioning, where supervisors observed and provided feedback, doling out reward or punishment as necessary. Then a move toward interventions led by the employees themselves, with peer-to-peer coaching and feedback was found in the early 1980s. In the 1990s, Copper (2009) suggested focusing on company culture with the inclusion of both management and employees to incorporate the employers' responsibility and commitment. Though the specific BBS schemes vary in observation form, intervention methods, and the complexity of the whole process, they share basic principles and elements in common. Nowadays, all the systems above are still in use.

Since the 1980s, BBS has been widely applied in light industry, petrochemical industry, transportation and offshore oil exploration in the USA, UK, and Australia etc., to improve safety performance. By virtue of meta-analysis, Stajkovic and Luthans (1997) reviewed all available published BBS research papers and reports from 1975 to 1995, and the findings showed that the average improvement of safety performance after the application of BBS was up to 17%, which is the apparent evidence of effectiveness of BBS. However, most current BBS research focuses on application study and result analysis on different intervention procedures. On the other hand, the internal intention and the external factors that could contribute to the generation of employees' unsafe behavior are neglected. Hence, the intervention methods in BBS are quite narrow. Goal-setting and feedback, material rewards and management action are the three common ways (Smith et al., 1986; Cooper, 1994; Zohar, 2003). Because of the lack of theoretical analysis and support, the above intervention methods did not mitigate against the causation of unsafe behaviors, so the safety performance usually returned to a low level after the removal of the intervention (Komaki et al., 1978).
Mattila (1998) and Lingard (1995) conducted studies on BBS in construction in Finland, UK and HK, and their research also proved the effectiveness of BBS on construction jobsite safety performance improvement. Yet Cooper's review of BBS academic papers since the 1970s showed that the result of BBS implementation in stable environment, such as manufacturing, was much better that in a dynamic environment, especially in construction. Lingard (1995) also concluded that a traditional BBS program, whose main intervention methods were simple goal-setting and feedback, could not help to diminish the number of certain behaviors on construction jobsites significantly, or were even in vain for several observed behaviors.

In summary, the traditional BBS methodology needs to keep doing the observation and feedback until the worker accepts the intervention and is willing to try the suggested recommendations. Although much related research (Copper, 2009) has found that the simple goal-setting and feedback intervention does not always work nor have a sustaining effect, there were few systematic studies on multi-level causes of employees' unsafe behaviors and reciprocal intervention methods' design. The connections of influence between two such factors in the process of employees' unsafe behaviors are not clear. The dynamic and complicated environment on construction jobsite should also be well considered in BBS research.

3. CHALLENGES OF TRADITIONAL BBS IMPLEMENTATION IN CONSTRUCTION

Although BBS has been extensively applied in many industries, the features about the construction industry are not particularly considered in traditional BBS program. The challenges that may negatively affect the success of traditional BBS implementation include: (1) lack of root cause analysis of unsafe behavior; (2) neglect of the role that organizational factors played in employees’ unsafe behaviors; (3) relatively poor safety culture in companies and projects, especially subcontractors, and low level training for employees; (4) the complicated environment and large amount of unstable and nonstandard behaviors on site; (5) high liquidity of the construction labor market and the diversity in employees’ background and experience.

Based on the above literature review, grounded discussion and the authors’ experience of BBS implementation, the main challenges of BBS implementation in construction are elaborated as follows:

1. The first challenge for BBS implementation in construction lies in the root cause analysis of unsafe behavior. Some scholars (Rasmussen, 1983; Reason, 1990; Doos et al., 2004) have studied the topic of unsafe behaviors. According to information processing, Rasmussen divided human unsafe behaviors into skill-based, rule-based and knowledge-based. Doos (2004) classified human errors into risk-creating human errors and risk-triggering human errors by the outcome of human errors.
   However, those studies merely proposed the possible rule of classification and could not promote root cause analysis of unsafe behaviors or the theoretical framework of BBS.

2. As more accident reports were collected, the role of organizational errors in accidents has been revealed gradually. Reason (1990) built the organization error theory to describe the combined action of organizational failures and the individual errors in accidents triggering and defense. Choudhry and Fang (2008) found that the organizational factors include lack of safety management measures, nonperfect safety procedures, idea of performance over safety, workers’ revolutionary behavior towards management etc.

   Unfortunately, most of current studies just aim to identify different kind of organizational factors that may influence employees’ behaviors, so the mechanism of action of management unsafe behaviors to individual unsafe behaviors is ambiguous. Traditional BBS usually neglect management unsafe behaviors and didn’t intervene.

3. Another challenge for BBS implementation in construction comes from the poor safety culture in construction projects and companies (Geller, 2001a). Although more and more construction companies enhanced their understanding on safety and paid more attention to new approaches for safety management, their commitment, involvement and substantial input to safety are still very low. In some cases, BBS implementation has become the excuse of management, and they try to attribute most accident and injuries to the workers’ own responsibility, which is a typical misunderstanding of BBS.

4. Since the data on efficacy are influenced by target behaviors in checklists, the value of intervention still much depends on behavior selection. Whereas, as discussed before, the conditions on construction sites are quite complicated, and most employees’ behaviors are not as standard as those in manufacturing factories (Geller, 2001b), so the general process of behavior selection in other

industries will not be suitable for construction industry. The target behaviors in BBS checklist should be filtered carefully and the criteria for such behaviors need to be well developed with the cooperation of management so that the site observation could be much easier and more accurate

5. Since construction employees usually transfer from one site to another quite frequently within several months, it would be hardly possible to accomplish the long term individual observation and feedback to each employee or peer-to-peer coaching and feedback on the construction jobsite. It is important to note that such one to one observation and intervention methods have been adopted by some safety professionals on construction sites in Europe and the United States, but it cannot be deduced to be common practice in the construction industry. The issue should be highly considered in China and Singapore, where the construction labor market is of high liquidity.

The grounded discussion above elaborated the challenges that may be the reasons why the traditional BBS program are not effective enough under the circumstances of construction. Therefore, the appropriate modifications to the traditional BBS approaches are crucial and necessary. Research on the role of management and individual causes played in the generation of unsafe behaviors and the mechanism of connection between management unsafe behaviors and workers' unsafe behaviors are ways to enhance the sustainability of BBS.

4. CAUSATION MODEL OF UNSAFE BEHAVIORS

Since there are some big challenges of traditional BBS implementation in construction, new ideas and methodologies needs to be integrated into the current model to overcome such barriers. A causation model of unsafe behaviors has been developed during the authors' BBS implementation in Mainland China, Hong Kong and Singapore. The model focuses on both the individual and the management factors and unsafe behaviors. It will help to track and analyze the internal and external causes of unsafe behavior. The discussion of role and regularity of individual and organizational factors in unsafe behavior occurrence will instruct the intervention methods development and enhance the sustainability of BBS implementation in construction.

The purposes of the model are as follows:

1. To build a comprehensive observation database and provide a helpful tool for causation analysis

2. To analyze the causation of unsafe behaviors and find out critical contributing causes of specific behaviors

3. To be an alternative to continuous one to one observation and feedback in the long term

4. To guarantee the effectiveness and sustainability of intervention schemes from psychological and organizational perspectives

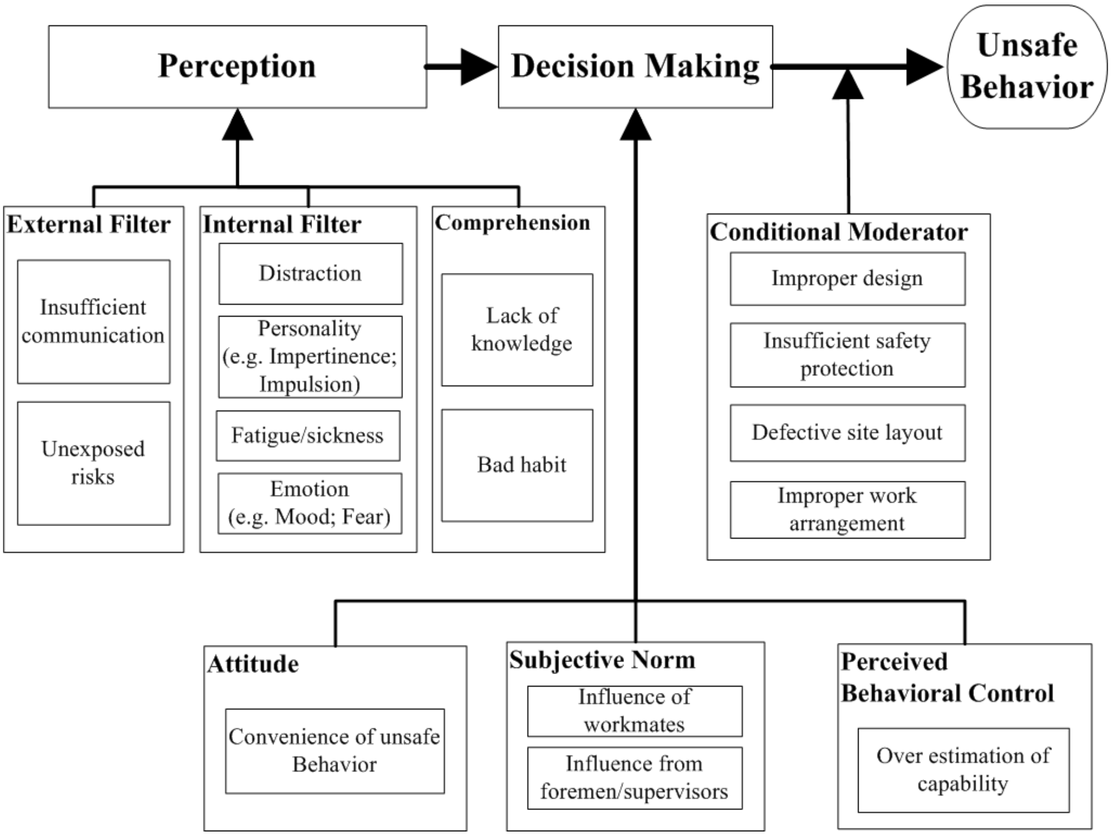

Figure 1. Causation Model of Unsafe Behaviors**.**

Development of causation model of unsafe behaviors

The causation model of unsafe behaviors shown in Figure 1 is generated based on the theory of cognitive psychology, describing the logical sequence of steps for an action/behavior. In accordance with the general flow of information processing and behavioral decision making, a human's behavioral decision can be divided into two key steps, perception and decision making. The internal and external factors (individual and organizational) in each step which may affect the final choice are incorporated simultaneously. Besides, the objective constraint conditions, most of which are management unsafe behaviors, could also change ones' final action. Therefore, the authors incorporate such constraints into the causation model of unsafe behaviors, named Conditional Moderator.

Perception is the start of a behavioral decision, which means a cognitive process in which information processing is used to transfer information from the real world into the brain and mind where it is further processed and related to other information. Both psychological and management factors could influence workers' perception, so the underpinning variables below, including external filters, internal filters and comprehension, will cover these two aspects.

- Barriers in external filters will cause the mistaken receiving of the external information by employees. Thus, they may have an unclear or even wrong perception of the risk. Variables under this element mainly describe management factors.
- Internal filters and comprehension refer to the latter part of information processing. Usually, people could not clearly perceive the risk because they are not ready/capable/willing to receive the necessary information. Some personal issues may cause the wrong internal filter or inaccurate comprehension, such as a lack of knowledge, fatigue or emotional problem.

Once the perception is formed in one's mind, the person would make a decision based on evaluation and judgment. Decision making can be regarded as the mental processes resulting in the selection of a course of action among several alternatives.

Since most behaviors on construction sites can be regarded as the outcome of planned rational decision making, the authors choose the Theory of Planned Behavior (TPB), one of the most predictive persuasion theories in psychology, to examine the relations among beliefs, attitudes, behavioral intentions and behaviors of the employees, and to model workers' decision making.

According to TPB, human behavior is guided by three kinds of considerations, namely behavioral beliefs, normative beliefs, and control beliefs. In their respective aggregates, "behavioral beliefs" produce a favorable or unfavorable "attitude toward the behavior"; "normative beliefs" result in "subjective norm"; and "control beliefs" gives rise to "perceived behavioral control."

Consequently, "attitude toward the behavior," "subjective norm," and "perceived behavioral control" would lead to the formation of decision making. Under each category, there are some detailed factors to describe the specific situations. Elements set by TPB could explain the mechanism of connection between individual and organizational factors in employees' decision making processes logically.

- Attitude toward behavior is an individual's positive or negative evaluation of self-performance of the particular behavior.
- Subjective norm means an individual's perception of social normative pressures, or relevant others' beliefs that he or she should or should not perform such behavior.
- Perceived behavioral control refers to an individual's perceived ease or difficulty of performing the particular behavior.

Conditional moderator refers to constraint site conditions that could affect the outcome of behavior choice. In some cases, such site constraints are the result of management unsafe behaviors.

- Improper design refers to the improper architectural or structural design which may cause unsafe conditions or difficulties in construction on site.
- Insufficient safety protection usually comes out when the safety protection is not sufficiently provided by contractors or subcontractors.
- Defective site layout means poor site layout (including bad housekeeping) leading to the potential risks for safe work.
- Improper work arrangement comes from improper construction methods, work schedules and even the orders issued by foremen or supervisors.

Case study- application of causation model of unsafe behaviors in Singapore

The authors have conducted a complete BBS implementation in Singapore in 2010. Two rail/road projects were chosen to be the subjects, in which a new BBS program with a three-step intervention cycle was developed and successfully implemented.

Considering the challenges discussed above, the authors developed an Intervention Cycle as a unit of a dynamic and flexible intervention scheme, in order to achieve continuous improvement during intervention period. The causation model of unsafe behavior was the core element of this scheme. By use of this model, 53 interviews were done, collecting data and getting a better understanding of causes of employees' unsafe behaviors.

During the three-week observation and six-week intervention period, 10682 samples of employees' behaviors were observed and evaluated. Three intervention cycles were conducted during the intervention period and each cycle generally comprised three steps: 1) feedback, goal setting and training for supervisors/foremen; 2) training for workers by supervisors/foremen; 3) observation and interaction with workers.

The causation model of unsafe behaviors covers every link in the generation of an action/behavior, thus, all unsafe behaviors occuring on the construction site could be attributed to one or several factors in the model.

Table 1 shows the examples of data collection of unsafe behaviors' causations. The data collection was conducted by the observer by face to face interview and discussion with the person who made an unsafe behavior. Based on the data collected through interviews, the observer could make the in depth analysis to find out the individual causes and the management causes of specific unsafe behaviors.

The description of the unsafe behavior observed on site should be recorded first and items in the first column in Table 1 will be checked one by one by the use of structured interview outline. The interview for each case will generate one set of data. Hundreds of data sets collected through interview and discussion will form a large scale database of unsafe behavior causes.

The purpose of building such a database is to further categorize the causes and specify the particular obstacles for safe behavior as well as good safety performance. Moreover, it was found that the pattern of cause distribution for a specific unsafe behavior varies from one another. Therefore, it is suggested that the particular intervention scheme and method from psychological and organizational perspectives should be developed towards each typical unsafe behavior based on the causation model of unsafe behaviors so that the intervention could be effective and sustainable.

By virtue of model analysis, it is found that the most critical contributing step in the whole process of a behavioral decision is the decision making section, which is the second step in the whole process. It represents more than 40% of all causations. As a result, major intervention schemes and methods have been specifically designed to deal with the mistakes in decision making, correcting workers' incorrect attitude, reducing the negative influence both from workers and foremen/supervisors, and train the workers to form good habits to better control their behavior and capability by themselves. The average score of two sites achieved 19.25% net growth. (Score of specific behavior ($Score_B$) = (Number of safe behaviors observed/Total number of behaviors observed). Furthermore, two weeks after the intervention period, the authors did a follow up observation, and the score of the two sites are 87.24% and 91.95%, basically equal to the score of last intervention cycle, which are 86.25% and 92.55% respectively. It shows the improved sustaining effect of the BBS program.

Causation	Case1	Case 2	Case 3
Description of the unsafe behavior	A	B	C
Perception – did you know it was unsafe?	Y	N	N
Internal filter	Y	N	N

Distraction/preoccupation	Y	N	N
Personality	N	N	N
Fatigue/sickness	N	N	N
Emotion (e.g. mood, fear)	N	N	N
External filter	Y	N	N
Insufficient information	Y	N	N
Unexposed risks	N	N	N
Background/knowledge	N	N	N
Lack of knowledge	N	N	N
Bad habit	N	N	N
Decision making –why did you perform like that?	N	N	Y
Attitude toward behavior	N	N	N
Convenience of unsafe behavior	N	N	N
Subjective norm	N	N	Y
Influence from workmates	N	N	N
Influence from foremen	N	N	Y
Perceived behavioral control	N	N	Y
Over estimation of capability	N	N	Y
Conditional moderator	N	Y	N
Improper design	N	Y	N
Insufficient safety protection	N	N	N
Defective site layout	N	N	N
Improper work arrangement	N	N	N

5. CONCLUSIONS AND FUTURE STUDY

The causation model of unsafe behavior developed by the authors provides a new approach to enrich current BBS schemes in construction. In addition, suggestions and recommendations for improving the BBS implementation in the construction industry are brought out as: (1) conducting safety culture survey among all parties of the project to identify the weak points of safety culture elements, which will facilitate BBS implementation (Zhou et al., 2011); (2) taking both the management of unsafe behaviors and workers' unsafe behaviors into account during the intervention period and correcting both of the two parts simultaneously; (3) emphasizing the involvement of foremen and supervisors in BBS implementation, for example, they are advised to train the front-line workers during daily tool box meetings.

Future study will develop and perfect the model by theoretical analysis and empirical study. The author is going to choose construction projects in China to do the interview and questionnaire survey to validate the model. Moreover, regarding the database collection, the structural equation modeling of mechanism of connection between the management of unsafe behaviors and workers' unsafe behaviors could be explored.

6. ACKNOWLEDGEMENT

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A Decision Support Tool for Integrating Safety Risk with Project Schedules

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ABSTRACT

Within the construction industry, the highway construction and maintenance sector is one of the most dangerous. Among different methods that has been employed to decrease number of incidents in the jobsite, preconstruction safety practices such as integrating safety risk in to the schedule of projects has been shown to be highly effective. Unfortunately, only a few studies have attempted to quantify safety risks or integrate existing risk databases with schedule tools. This paper aims to evaluate the reliability of integrating safety in to the schedule of construction projects. The risk data and a safety-schedule integration framework presented in the previous literature were used to develop and populate a Decision Support System (DSS) that integrates safety risk data into project schedules. In order to test the validity of the results, the decision support system has been applied to a real project. It was found that the output of the tool has a strong ability to predict high risk periods on actual projects. It is concluded, the safety-schedule integration approach has the potential to be used by construction managers to identify high risk work periods, to improve job hazard analyses, and prioritize limited resources.

Keywords: Risk Management, Safety-schedule integration, DSS

1. INTRODUCTION

Within the construction industry, the highway construction and maintenance sector is one of the most dangerous (BLS 2010). In 2005, this sector accounted for approximately 469 vehicle- and mobile heavy equipment-related deaths, 279 of which (59%) occurred in traffic work zones (Center for Construction Research and Training 2008). The presence of high-speed traffic near work zones, prevalence of nighttime work, use of heavy equipment, exposure to weather, and highly repetitive work tasks contribute to this relatively high number of injuries. Although the number of injuries and fatalities in all sectors of the construction industry has decreased significantly since the Occupational Safety and Health (OSH) Act of 1970, the injury rate in highway work zones remains unsatisfactory (Bai 2002; Bai and Cao 2003). The Federal Highway Administration (2004) estimated that a work zone fatality occurs once every ten hours and a work zone injury occurs every thirteen minutes (FHWA 2004). In fact, between 1999 and 2003 the number of annual fatalities in the highway sector increased by 18 percent and the number of non-fatal work zone injuries increased by over 40,000 despite the fact that the volume of construction work remained relatively constant (FHWA 2004; BLS 2001).

The current incident rate the highway construction and maintenance sector is alarming and requires more attention. Among different safety practices conducted in the life cycle of a project, safety preconstruction activities have shown to be the most influential. One of the reasons is that the potential to enhance safety and health conditions decreases in an exponential rate as the project commences (Symberski 1997). This implies that the most influential safety programs starts at early stages of a project such as the programming and preconstruction (Hallowell and Gambatese 2009; Rajendran and Gambatese 2009). Unfortunately, current methods for considering safety and health in these early phases are inconsistent, informal, and based primarily on intuition and judgment (Hallowell and Gambatese 2007). Therefore, improving preconstruction safety practices by developing innovative procedures, creating user-friendly tools, and increasing their use in all sectors of the industry is highly needed.

One of the preconstruction methods that have been shown to be highly effective is the integration of the safety in to the schedule of the project using safety risk data (Yi and Langford 2006). The major limitations of the existing schedule integration techniques are the lack of robust safety risk data for specific construction work tasks and a reliable tool that integrates safety risk data into project schedules. Hallowell et al. (in press) quantified safety risk interactions for highway preconstruction activities and presented a framework to integrate those safety risk data in to the schedule of projects; however, they did not test the applicability of their database to actual projects.

This paper aims to address this limitation by developing a Decision Support System (DSS) that integrate safety risk data into project schedules using the framework developed by Hallowell et al. (in press). It is expected that the output of the model will aid project managers in their preconstruction safety management activities and will be especially effective for safety managers who are responsible for multiple concurrent projects. Additionally, due to ease of use of the DSS, this tool has a strong potential to increase the usage of risk-based preconstruction safety management.

2. LITERATURE REVIEW

This study was guided by a large body of literature. In particular, literature that focused on the Highway construction work zone safety, safety-schedule integration, and decision support systems proved to be most helpful. This body of literature was used to obtain the risk data and to develop of a technique for integrating safety risk into project schedules. A review of the salient findings from relevant literature is provided below.

Highway construction work zone safety

There have been several studies that focus on the causes of work zone fatalities and shed light on the factors that contribute to the disproportionately high injury rate. In 1999, statistics for fatalities occurring on highway construction and maintenance projects between 1992 and 1998 were published by the Bureau of Labor Statistics. The most common primary sources of injury were trucks (45%), road grading and surfacing machinery (15%), and incursions (15%). Bryden and Andrew (1999) reported that highway workers are also at risk of injury or death from contact with overhead power lines, falls from machinery or structures, gas line explosions, or being struck by falling objects or materials. These risk factors are compounded by fact that highway construction and maintenance work is typically performed at night (Arditi et al. 2005; McCann and Cheng 2006; Bryden and Andrew 1999). Night-time highway construction has been established to be more hazardous for both passing drivers and construction personnel because of decreased visibility (Arditi et al. 2005).

To respond to the relatively high incident rate, several studies have been conducted to determine measures to improve site safety on highway construction and maintenance projects (NIOSH 2001; FHWA 2004). These studies outline the roles and responsibilities of the contracting agency (e.g., state DOT), the contractor, and policy-makers at the federal, state, and local levels with regard to work zone safety. The measures most highlighted are to assign a traffic control supervisor; document the work zone setup and changes throughout the course of the project; set up temporary traffic control devices; educate flaggers in topics such as traffic flow, work zone setup, and proper placement of channelizing devices; require all workers on foot to wear high-visibility safety apparel; develop an internal traffic control plan; provide alternative transportation modes and alternative routes for road users; and specify the use of temporary pavement markings to laterally move the traffic lane away from the work space. Although many research studies have focused on contributing factors to highway work zone injuries, project-specific preconstruction safety management techniques were not discussed.

Safety risk schedule integration

Recently, researchers have attempted to integrate risk data into project schedules as a means to identify high risk work periods and leverage scheduling controls to prevent periods of excessive risk. For example, Wang et al. (2006) developed a simulation-based model (SimSAFE) that integrates expected injury cost data for each activity in a network schedule. This stand-alone software system allows safety managers to identify work zones that are associated with relatively high risk as measured by cumulative potential accident costs. Yi and Langford (2006) took risk integration a step further by developing a robust framework for "safety resource scheduling" using patterns which are similar to the resource leveling technique for scheduling. Though Yi and Langford (2006) offered a strong framework for the integration of safety risk data with project schedules, there were no robust risk data as the database only included fatalities that occurred as a result of falls from height.

The major limitations of the body of literature are that there is not a robust safety risk database and the interactions among tasks were ignored. In another study, Sacks et al. (2009) proposed a model, called CHASTE, to considers spatial and temporal interactions of work tasks simultaneously by using information available in 4D geographic models and user-provided data for “loss-of-control events.” The chief limitation of this framework is that the hazards related to each task must be identified and quantified by the user, which can be time intensive and laborious.

In the most recent study, Hallowell et al. (in press) adopted Yi and Langford’s (2006) model and suggested a new framework to integrate safety risk data in to the schedule of a project by considering the effect of spatial and temporal interactions among tasks. In addition, they quantified safety risk interactions for highway reconstruction tasks using Delphi method. The major limitation of this work was that they did not test the applicability of the framework on active projects. The current research aims to address limitations of the previous studies by validating the highway construction safety risks for common work tasks quantified by Pandy (2009) and testing the viability of the framework presented by Hallowell et al. (in press).

Decision support system

As technologies have changed, attention has shifted from traditional computer applications to specific tools that increase speed and quality of decision making (Carter, et al. 1992). One of the genres of tools that has received an increasing attention is decision support systems (DSS), which are defined as “an interactive IT-based system that helps decision makers utilize data and models in making their decisions” (Carter, et al. 1992, p3). Two main objectives mentioned in the literature for using DSS are: (1) performing a given task in the decision making process more quickly or with fewer resources (efficiency); and (2) improving the quality of the outcome of decision making process (effectiveness). In addition, DSS helps a decision maker to: make better decisions, consider multiple alternatives, make decisions in reduced timeframes, and focus on salient problems. They also reduce complexity of the problem to manageable level, reduce uncertainty, provide intuition, insight, and understanding to the problem (Carter, et al. 1992). In order to make an effective DSS, it must be reliable, acceptable and receive buy-in from the key individuals in the adopting organization.

In construction, decision support systems are utilized for resource sharing (Perera 1983); contractor selection (Russell et al. 1990); optimization of heavy lift planning (Lin and Hass 1996); subcontracting construction work (Elazouni and Metwally 2000); resource leveling (Leu et al. 2000); making go/no-go decisions for international projects (Han and Diekman 2001); selecting design-build project (Molenaar and Songer 2001); scheduling steel fabrication works (Karumanasseri and AbouRizk 2002); site layout planning (Tam et al. 2002); assessing contractor’s competitiveness (Shen et al. 2003); selecting project delivery methods (Mahdi and Alreshaid 2005); providing support to deal with dispute on time extension for delays (Palaneeswaran and Kumaraswamy 2008); and selecting a contracting strategy for highway work zone projects (Bayraktar and Hastak 2009).

In addition to above mentioned applications, some DSSs have been developed to enhance decision making in the area of safety. For example, Kak et al. (1995) developed a knowledge-based program to facilitate access to the explicit safety knowledge in construction site. Their program can search applicable safety regulations (e.g. OSHA) for a particular task and provides suggestions to improve safety conformity with regulations. Gambatese et al. (1997) presented a DSS for incorporating safety related issues in design phase of a project called "Design for Construction Safety ToolBox". The DSS developed had the ability to identify project specific hazards and provide design suggestions to mitigate those hazards. Recently, Hadikusumo and Rowlinson (2004) applied visual reality concept to develop a design for safety tool to capture tacit knowledge of safety professional.

3. OBJECTIVES

This paper has three main objectives: (1) to validate base-level safety risk data for common highway construction tasks published by Pandy (2009); (2) to describe a DSS to integrate the base-level risk data and the safety risk interactions data published by Hallowell et al. (in press) into project schedules; and (3) implement the DSS on active highway projects to validate the DSS's output.

4. RESEARCH METHODS

In order to achieve the first objective, surveys were distributed to experts. The second objective has been fulfilled by developing a graphical user interface in Matlab to create safety risk profiles during the schedule of projects. Finally, objective 3 has been addressed by applying the DSS in on an active highway project.

Surveys

In order to validate Pandey's (2009) database, surveys were administered to highway construction safety experts. Panelsis were asked to rate the frequency and severity of injuries associated with twenty-five common highway construction tasks (see Table 1) on a Likert scale. Careful attention was paid to the qualification of the panelists. The expert panel was assembled using expert contacts provided on <www.workzonesafety.org>. Because this website provides no information regarding the qualification of any of the contacts as 'experts', the research team independently validated expert status by conducting an introductory survey of all 165 individuals listed. This survey solicited information used to qualify expertise according to protocol established by Hallowell and Gambatese (2010). Of 165 individuals contacted, 75 responded (45%), and 27 were qualified as experts (36%). According to Moser and Kalton (1971), this response rate is acceptable.

The resulting pool of individuals was very well qualified to participate in the study. The experts averaged over 25 years of highway construction and managing safety experience.

Over eighty percent of all respondents have a Professional Engineering (PE) license, are a Certified Safety Professional (CSP), or have at least a bachelor's degree in a related field. All respondents held upper-level management or executive experiences such as corporate safety manager, director of research, and senior project manager. It should be noted that, despite the relative large publication lists of some participants, the panel was largely professional in nature. This was preferred as accurately quantifying relative risks relies upon a wealth of professional experience. In the first part of the research, surveys included median and average risk values published by Pandy (2009). Experts were asked to either accept the medians or provide their new answers.

DSS development

One of the structured design methods to develop a DSS in a way that meet user's needs is prototyping (Andriole 1989). Different prototyping methods are suggested by researchers (Boar 1984). This research follows prototyping principals established by Boar (1984). The underlying assumption of prototyping is that developing iterative systems requires input from perspective users and should be refined through an iterative process (Boar 1984). A quick prototype that includes only the understood features will be evaluated for its acceptability in an iterative process (Adelman and Riedel 1997). By reviewing the literature and considering specific characteristics of the study, the authors defined two steps in developing this specific DSS: (1) task requirement analysis and (2) safety schedule integration framework.

Step 1: Establish user requirements. One of the steps in designing a DSS is establishing task requirements and identifying the tasks that system should perform. In this step, the designer should determine what they expect the user to do and how the user should interface with the system (Andriole 1989). According to Boar (1984), 20 to 40% of DSS's problems can be attributed to problems in design process, while 60 to 80% stem from insufficient definitions and descriptions of user requirements. Well defined requirements help to establish a link between users, tasks, and organizational need. Prototyping strategy assumes that, due to communication gap between designers and users, not all user requirements can be grasped in early stage of DSS development (Andriole 1989). Therefore, it is necessary to conduct several iterations during development (Boar 1984). In this research, a quick prototype has been made and its features have been modified after receiving feedback from users.

Step 2: Data integration. The second step of the DSS development involved the integration of the safety risk data gathered in this research with actual project schedules. As previously indicated, Hallowell et al. (in press) modified the risk integration framework established by Yi and Langford (2006) to consider the effect of temporal and spatial interactions on safety risk; however, they only quantified safety risk interactions. The result of this research will enhance Hallowell et al.'s (in press) attempt to integrate safety risk into project schedules with a valid and robust underlying base-level risk database. The integration framework is mathematically illustrated by Equation 1.

$$[SF_{Task}]_{1\times n} = [R_{Individual}]_{1\times 25} \times ([R_{Interaction}]_{25\times 25} \times [X_{Schedule}]_{25\times n}) \quad \text{Equation 1}$$

Where:
$[SF_{Task}]$: is safety risk matrix resulted from performing tasks by considering interaction among them and its members are total safety risk for each time unit (day, week, and month); $[R_{Individual}]$: is a matrix which includes safety risk values related to performing each task individually; $[R_{Interaction}]$: is a matrix which includes impact of performing each task simultaneously with other tasks on safety risk values of other tasks; $[X_{Schedule}]$: is a matrix which includes just 0 and 1. If in time t, activity i is performing, then $X_{it} = 1$, otherwise $X_{it} = 0$. In this framework, the safety risk data, which includes spatial and temporal interactions of work tasks, can be simply integrated with the schedule and the safety risk can be plotted over time.

DSS validation

In order to validate the output of the program, representatives from an active highway construction project were contacted. The participating company has more than 100 years of experience in the construction industry, revenue of approximately $100 million, and employs approximately 500 workers. The case project is a highway reconstruction project with a value of $4.5 million, duration of 6 months, and a unit price contract. The schedule of the project was obtained from the contractor and the tasks were identified and coded to be consistent with the underlying risk database. During this coding process, the project manager was consulted to ensure that the writers' bias did not enter into the results. After the tasks were interpreted, the schedule was entered into the DSS and a temporal safety risk profile was created. Then the safety manager of the company was asked to express his level of confident in the risk profiles provided. In addition, a video was created that showcases the abilities of the program and the method of use and the safety manager was asked to watch the video and answer questions about the decision support system's performance.

5. RESULTS

Validation of underlying risk database

Participants in the survey were given the option to agree with other group's collective assessment (median) obtained by Pandy (2009) or provide a new rating. In order to decrease bias, tasks were randomly arranged in each survey. Of the 27 surveys that were sent, 24 surveys were returned resulting in an 89% percent response rate for the validation. Absolute variance and standard deviation of responses were 0.19 and 0.43, respectively. Additionally, medians obtained in validation phase were the same as medians of each panel in Pandy's (2009) work, which is evidence of strong validation. The frequency and severity values for each task were independently quantified on a Likert scale to maintain consistency with the previous study. The result of this part of study is shown in Table 1.

Table 3: Safety risk data for common highway reconstruction work tasks

Task Name	Average Frequency	Average Severity	Unit Risk Scores
Construction zone traffic control	3.17	4.02	12.74
Install traffic control devices	3.27	3.33	10.89
Installing flexible pavement/patching	2.29	3.10	7.10
Pavement marking	2.25	3.07	6.91
Seal joints and cracks	2.29	2.98	6.82
Excavation	2.13	3.17	6.75
Install culverts, drains, sewers	2.23	3.02	6.73
Install culvert pipe and water lines	2.17	2.98	6.47
Reset structures	2.15	2.96	6.36
Heat and scarifying	2.08	2.94	6.12
Survey	2.17	2.58	5.60
Clear and grub	2.17	2.15	4.67
Recycle cold bituminous pavement	2.15	2.13	4.58
Install curb and gutters	2.13	2.15	4.58
Install rigid pavement (concrete)	2.06	2.15	4.43
Install cribbing	2.08	2.10	4.37
Recondition bases (compaction)	2.10	2.06	4.33
Install water control devices	2.08	2.06	4.28
Lay aggregate base course	2.00	2.06	4.12
Mobilization/demobilization	2.02	2.04	4.12
Prime, coat, rejuvenate pavement	1.96	2.06	4.04
Demolition of existing pavement	1.92	2.08	3.99
Landscape	1.31	2.02	2.65
Install field facilities	1.17	1.25	1.46
Watering and dust palliatives	1.10	1.15	1.27

Decision support system development

In order to provide user friendly environment to integrate safety risk and project schedules, a graphical user interface (GUI) was developed in MATLAB. The program is called Safety Information Modeling (SIM). SIM is essentially a knowledge-based system with a schedule integration engine. MATLAB was chosen for developing the program for two main reasons: (1) it is a strong programming language to develop graphical user interfaces and (2) it allows the research team to make a connection between project management software (e.g. P6) and safety risk databases by opening and accessing files in MS Excel.

The requirement analysis indicates that an applied DSS for integrating safety risk data in to the schedule of project should include two main capabilities: receiving the schedule from the user and creating safety risk profile. These capabilities have been considered during the development of SIM. By using the interface shown in Figure 1, the user can chose from 25 predefined activities and enter the start and end date for each activity for a particular project. By entering multiple project schedules, the user can built a portfolio.

It was determined that entering schedules manually can burdensome and time consuming. In addition, construction companies usually keep schedules of their projects in project management software such as Primavera or Microsoft Office Project. Primavera is one of the most popular project management software systems and is used for scheduling broadly in the AEC/EPC industry. In order to facilitate entering schedule process and to make it more practical for construction companies to use SIM, the researchers made a bridge between Primavera 6 and SIM, which allows a user to directly transfer a project schedule from Primavera P6 to SIM. After entering projects into the program, the user can save the schedules as M-file (*.m or *.mat). In addition, the program provides an opportunity for the user to open a saved file.

It is important to note that the system integrates both the base-level risk data and risk interactions when producing temporal output of safety risk. This results in relative risk values that include not only the tasks' isolated base-level risk but also the impact that concurrent tasks have on each other's base-level risk. This accounts for potential compatibility or incompatibility among tasks.

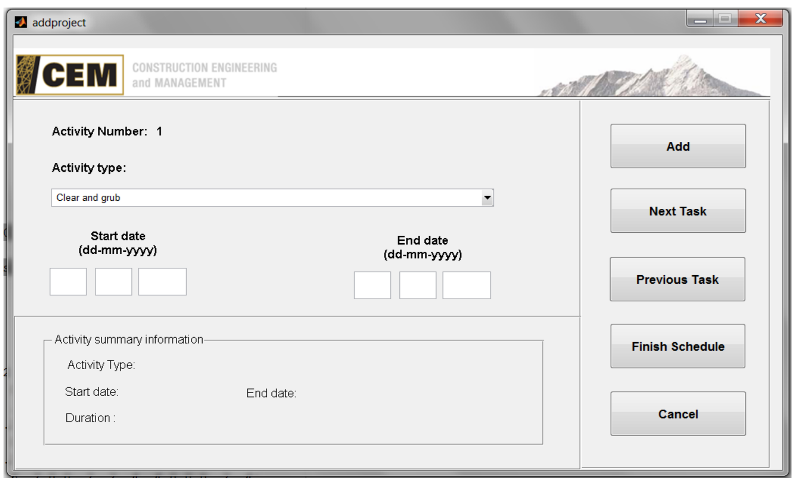

Figure 1. Entering schedule manually

By utilizing the integration framework presented in Equation 1, project schedules and safety risk data, SIM will plot safety risk over time. A sample report for the case study project is shown as Figure 2. Another ability of the program is to create a report for multiple projects. When a company has more than one project and the safety manager wants to compare safety risk profile of their projects simultaneously and identify critical periods from a portfolio or programmatic perspective, the multiple projects plotting function can be used to overlay concurrent projects. In addition, this function helps the safety manager to attribute the safety resources to different projects more efficiently.

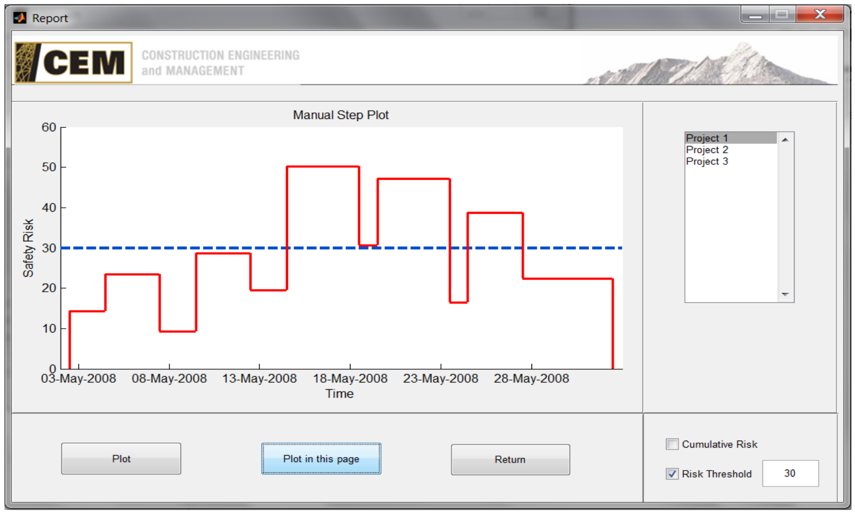

Figure 2. Safety risk profile for a single project with threshold

6. DSS VALIDATION

The last part of the study was to validate the developed DSS. For this case, risk profiles were created for three sections of the schedule. As indicated, the safety manager was asked to retroactively rate his confidence in the output. The average level of confidence of the safety manager on the results was 68% for all periods. This number indicates high level of validity of the developed DSS. After watching the video of the program, the safety manager strongly agreed that the risk profiles created by the DSS are useful and will enhance the current preconstruction safety management activities. In addition, he stated the program is very easy to use and there is no need for further training sessions. Nevertheless, additional pilot study project are required with a large sample to obtain external validity. A sample of one perspective is not sufficient.

7. CONCLUSIONS AND RECOMMENDATIONS

In this study, previous highway construction safety risk data were validated, SIM was developed to integrate safety risk data into project schedules, and the system was tested on a case study. This paper illustrates that safety risk values can be integrated into project schedules using common project management software systems such as Primavera P6 and spreadsheet software such as Microsoft Excel. The database created and the DSS developed can be used to identify high risk periods that may not be identified intuitively. In response, contractors can attempt to consume float to level risk, take extra precautionary measures during these high risk periods (e.g., lane closure), inform workers of high risk periods, and strategically design injury prevention strategies to focus on high risk tasks. When the risk profiles for multiple concurrent projects are overlaid in the same plot, a manager can identify when and where safety resources should be deployed and could evaluate the risk profile for the company's portfolio simply by computing the cumulative risks for all projects in the company's program and plotting the risk over time.

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Using Network Analysis to Model Fall Hazards on Construction Projects

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ABSTRACT

Safety risk quantification, integration, and management are emerging preconstruction strategies that have significant potential to impact construction safety performance. Unfortunately, current risk assessment strategies have limited practical application because every new infrastructure feature and construction method must be individually evaluated using laborious research processes and data from previous failures. In order to address this limitation, this research tested the hypothesis that the risk of worker injury in dynamic construction environments is the direct result of the temporal and spatial interactions among a limited number of identifiable and quantifiable task and object attributes. To test this hypothesis, a content analysis was conducted on 105 National Institute of Occupational Safety and Health Fatality Assessment and Control Evaluations reports. Attributes that contribute to incidents were identified and their relative risks were quantified according to frequency and severity of accidents that they have caused. Clusters and interactions among attributes were also modeled using Social Network Analysis (SNA) method. Ultimately, these research results can be used to improve the integration of safety information with building information models, project schedules, and architectural design. It is expected that the flexibility of the proposed approach will overcome most risk integration barriers that have been observed in the past decade.

Keywords: Safety Risk Management, Fall Accident, SNA

1. INTRODUCTION

Although the number of injuries and fatalities in the construction industry has decreased significantly in the past decades, construction still has the highest number of fatalities among all industry sectors in the United States (BLS 2010). Falls account for the highest number of fatal injuries in construction among the different proximal causes (Gillen et al. 1997; Hinze et al. 2005). In fact, falls from height account for approximately a third of all injuries in the US construction industry (Weeks and McVittie 1995; Hinze et al. 2005) and typically result in severe injuries (Lipscomb et al. 2004), which require longer periods of recovery and significant medical costs (Gillen et al. 1997; Janicak 1998; and Derr et al. 2001; Lipscomb et al. 2003).

Falls in construction is a key target area for intervention and prevention (Gillen et al. 1997) and many prevention practices have been discussed by researchers including: safety harnesses, railings around opened edges and skylights, modification of equipment such as ladders, training programs, and administrative interventions (Rivara and Thompson 2000). Although the importance of safety controls such as providing guardrails and personal protective measures have been stated in the previous literature (Winder 1973; Hinze and Pannullo 1978; Tarrants 1980; Stanton and Willenbrock 1990; Toole 2002), considering safety during the design of the facility has been (shown to be particularly effective (Gambatese et al. 2005; Navon and Kolton 2006). Key concepts in designing for safety include ***identifying*** and ***mitigating*** hazardous situations during the design of the permanent facility. Therefore, careful attention should be paid to identifying hazardous situations and mapping the risk factors on the site (Salelson and Levitt 1982; Young 1996; Abdelhamid and Everitt 2000; Hallowell et al. in press). In addition to prevention through design, risk analysis has shown to be highly effective due to its quantitative and systematic nature (Hallowell et al. in press).

In previous studies, risk at the trade level (Fredericks et al. 2005; Beavers et al. 2009) and activity level (Hallowell and Gambatese 2009) have been quantified. However, some unique temporal and spatial characteristics of construction jobsites such as continuous change in work environment, the dynamic composition of work crews, multiplicity of operations, and proximity of crews expose workers to unrecognized hazards and make it difficult to accurately predict hazardous environments (Helander 1991). In fact, one of the chief limitations of previous studies that focus on predictive analysis and control is that they do not account for the fact that construction is dynamic.

To address this gap in knowledge, the authors present an attribute-based risk identification and analysis method that helps designers to identify and model the safety risk independently of specific activities or trades. The key concept of the new model is that the safety risks can be mapped for any tasks at any time by utilizing fundamental hazardous attributes. In this method, accidents are considered the outcome of interaction among physical conditions of the jobsite, environmental factors, administrative issues, and human error. To illustrate the connections among hazardous attributes in case scenarios, Social Network Analysis (SNA) is utilized. This SNA cluster analysis is a novel way to identify the areas of possible intervention that break the chain of events that lead to accidents.

In order to limit the scope of the research, the authors focused on fall fatalities; however, the presented method has the potential to be applied to other proximal causes as well. It is expected that the presented attribute safety risk based model has the potential to enhance preconstruction safety activities for any construction environment.

2. LITERATURE

Subpart M of the OSHA standards (29CFR 1926.500 to 1926.503) provide the requirements for fall protection for general construction procedures. According to this law, construction employers are obligated to protect workers from fall hazards whenever they are expose to a fall of 1.83m (6 foot) or more. Johnson et al. (1998) evaluated the existing regulations, construction practices, and alternative fall protection measures and found that the current state of compliance is poor, fall protection plans are not prepared as required, and positive safety measures such as guardrails and personal fall arrest systems are not used. They claimed that the extreme competitiveness within the industry, unsafe worker behavior, design challenges, conventional construction practices, productivity pressure, and a lack of knowledge are the main reasons for noncompliance.

Researchers found that workers usually fall when they lose their balance while walking on the roof surface (Pearson et al. 1986), stand on skylights (Bobick et al. 1994), or slip off the roof edge when stepping on loose materials on pitched roofs (Suruda 1995). Additionally, Lipscomb et al. (2004) evaluated textual descriptions of injuries from the construction of the Denver International Airport to get a better understanding of falls and found that one third of falls from height are preceded by slips/trips and another third resulted from the collapse of work surfaces such as ladders or scaffolds. In a related study, Fredericks et al. (2005) evaluated the US Bureau of Labor Statistics (BLS) data and conducted surveys on roofing companies to determine the specific tasks that are linked with incidents in roofing constriction. They found that carrying heavy materials on slippery and inclined working surfaces was the main reason of fall from elevation. They also stated that falls from height involved ladders, scaffolding, roofs, work on other unsecured surfaces, unprotected openings, speed, and weather conditions.

Though previous studies have made significant progress in our understanding of falls in construction, there are several limitations that stem from two main factors: (1) the dynamic nature construction sites and (2) the data obtained and prevention frameworks developed cannot be applied effectively in preconstruction activities, especially design. Though some researchers have quantified risks for specific trades, one should note that risk varies over time depending on adjacent tasks, work in progress, mobile equipment, and other factors. According to Hallowell et al. (in press), spatial and temporal task interactions alone can increase base-level safety risk by 60 percent. Therefore, as previously mentioned, it is off great importance to find a way to quantify safety risks independent from the specific trades or tasks by considering the interactions among different attributes.

3. OBJECTIVES

The research questions of this study were: “What are the safety risk attributes that contribute to occurrence of fall accidents in the construction industry?” “What is their relative magnitude?” and “How can they be prevented and managed?” Consequently, the current study has two objectives:

1. Identify safety risk attributes that lead to fall fatalities and quantifying their relative safety risks;
2. Use cluster analysis to identify the most efficient safety intervention for a particular case.

These objectives were fulfilled in two distinct research phases. In the first phase safety risk attributes were identified by conducting content analysis on accident reports and in the second phase the interactions among attributes were analyzed using cluster analysis.

4. RESEARCH METHODS

Phase 1

In order to identify safety attributes and quantify their risk, the research team conducted content analysis on the accident reports. A rigorous content analysis protocol established by Neuendorf (2002) and Krippendorff (2004) was followed. Content analysis is a scientific method that provides valid inferences from a textual data, is empirically grounded, and helps researchers to quantify the frequency and distribution of content in text (Krippendorf 2004). Content analysis is appropriate for this research because hazardous attributes are latent in the accident report and identifying them requires recognizing patterns in written injury reports, which allows for the identification factors that are not reported in statistical data. This, in turn, helps to better understand the complete context of the environment in which injuries have occurred.

Content analysis commonly has four steps: (1) stating the research question, (2) sampling, (3) coding, and (4) reliability (Neuendorf 2002; Krippendorff 2004). For sampling, accident reports provided by the National Institute for Occupational Safety and Health (NIOSH) Fatality Assessment and Control Evaluation (FACE) program have been used for the study. The FACE program aims to prevent occupational fatalities by identifying and studying fatal occupational injuries (NIOSH). FACE reports have been chosen for this study because they provide descriptive information about the accident including facts and data on what was happening just before, at the time of, and right after the fatal injury. Therefore, it is easier to identify proximal causes of the fatalities and propose preventive strategies. In total, 105 reports related to falls have been used for this study.

As far as coding is concerned, accident codes presented in previous literature (e.g. Lipscomb et al. 2004; Beavers et al. 2009) have been reviewed. Each accident record has been coded in data sheet including but not limited to the following dimensions: safety attribute; accident category; demographic information of the employer; victims' experience; and activity involved. Observations were also recorded in a matrix and the frequencies were calculated for each attribute.

In order to organize the list of attributes, the authors classified them in to the two main groups: primary and secondary. ***Primary*** safety risk attributes mostly are mostly those physical conditions that contribute to occurrence of accident and can be identified in design and planning phase (i.e. prior to breaking ground). Primary attributes are created by decisions in early stages of the project and usually do not change during the construction phase. For example, designing skylights for the building may expose workers to exposed edges or holes that will exist during construction. If a designer does not eliminate primary attributes in design phase (e.g. through prefabricating roofs), s/he should provide some kind of mitigation strategies during construction (e.g. guardrails). ***Secondary attributes*** are those physical, environmental, and administrative conditions or workers' behavior that leads to falls in jobsite. Secondary attributes may change depending on construction strategies and controls. For example, trips/slips or lack of fall protection is not something that can be identified, managed, and controlled during design.

The last part of content analysis is measuring the reliability of the results. Carmines and Zeller (1979) defined content analysis reliability as the extent of achieving the same results in repeated trials by following a certain measuring procedures. Because the goal of content analysis is to identify and record reliable objective or inter-subjective characteristics of messages, careful attention must be paid to reliability. When human coding is used in content analysis, inter-coder reliability should be assessed.

Even if the principal investigator codes all of the materials, reliability should be tested by using a second coder (Evans 1996). Inter-coder reliability can be assessed by asking another person to code the same materials. Using multiple coders ensures that the results are not one individual's subjective judgment (Tinsley and Weiss 1975). Achieving an acceptable level of reliability of coding schemes indicates that more than one individual can use the coding scheme and reach to the similar results. Although, the number of studies that confirm the importance of reliability is increasing, evaluating and reporting the reliability of coded data has not received adequate attention in traditional research (Perreault and Leigh 1989; Kolbe and Burnett 1991).

One of the common methods of measuring inter-coder reliability is simple percent agreement (Neuendorf 2002), which has been used in this study. Percent agreement simply represents number of agreement over total number of measures from the below formula:

$$PA_0 = {}^{A}/_{n} \qquad \text{Equation 1}$$

Where PA_0 represents percent agreement, A is the number of agreements between two coders, and n is the total number of units that the two coders have coded. This test ranges from 0 (no agreement) to 1 (perfect agreement).

One of the key decisions in reliability assessment is to determine the proportion of the total sample that should be used for a reliability test. Wimmer and Dominick (1994) provided specific number such as 10 to 20% of the total sample. In this study, the authors asked another expert to recode 15% (16 out of 105) accident reports.

Phase 2

As was previously mentioned, accidents occur as a result of interaction among multiple factors. The second objective of the research was to identify the areas of possible intervention to prevent accidents by considering the relation among different attributes identified in Phase 1. In order to achieve this objective, a cluster analysis has been conducted on the safety risk attributes and their interactions were modeled using Social Network Analysis (SNA). Cluster analysis helps an individual to identify the effective ways of breaking chain of events that cause injuries when injuries are caused by multiple factors.

SNA has been chosen for two main reasons. First, it enables one to mathematically express relationship among attributes and position of an attribute in a network. Using well established mathematical indicators of the graphic theory provides the ability to analyze the relationships quantitatively and at the same time increases validity of the results (Chinowsky et al. 2008). Second, visualization techniques allow a researcher to understand patterns of interaction among different factors (Chinowsky et. al. 2010). Social networks were developed in this study by substituting nodes and arcs of sociagrams with identified attributes and interactions.

One of the fundamental metrics in social network analysis is centrality, which was originally introduced by Bavelas (1950) and refined by Leavitt (1951). Centrality represents potential importance, influence, or prominence of a node in a network (Freeman 1979; Borgatti et al. 2002). Measures of centrality have been developed to identify key individuals in a social network (Zemljic and Hlebec 2005). Freeman (1978) identified three main kinds of centrality measures: degree of centrality, betwenness, and closeness. From variety of measurements that can be made, the research team focused on network density and two centrality measures: degree of centrality and betwenness.

Network density measures the volume and intensity of the interactions among network actors. This measure represents the ratio between the actual number of links and the maximum number of possible links. Although this measure indicates the number of links in the network, it does not tell someone anything about arrangement of the links and that which attribute has the highest number of interactions. It is possible that some arcs are concentrated in the limited number of nodes. Therefore, other measures should be utilized to assess the importance of attributes and distribution of the relationships in the network. These measures are the degree of centrality and betweenness.

Degree of centrality is one of the key measures that indicate how interactions are distributed in the network. If the degree of centrality is high in a network, a limited number of attributes have the largest number of relationship with other attributes. In fact, the degree of centrality measures the importance of an attribute among other attributes that cause accidents. *Betweenness* is a measure of the number of attributes that has been connected via a specific attributes. This variable indicates involvement of an attribute in occurrence of accident. In fact, betweenness tells us which attributes make a bridge between other attributes to cause accidents. In order to analyze the data and calculate the quantitative measures, UCINET5 software (Borgatti et al. 2002) has been utilized by the research team.

5. RESULTS AND ANALYSIS

In total, 73 attributes were identified from FACE reports. Of these attributes, 21 were primary, 51 were secondary, and one has been classified as other. The frequency with which these attributes appeared in FACE reports was also tracked. Because all of the accidents in this analysis have the same severity (death), the risk can be assumed as equal to the frequency. The primary and secondary attributes identified and their relative safety risk are shown in Table 1. One should note that due to the lack of space, not all attributes are shown. The presented attributes can be broken down in to several sub attributes. For example, the attribute 'ladder' can be broken to work that requires ascending or descending ladders (primary), unsecured ladders (secondary), and using ladder inappropriately (secondary).

Table 1. Frequency/Risk distribution of safety attributes

Safety attributes		**Safety risks (%)**		
		All (73)	Primary (21)	Secondary (51)
Working at elevation	Ladder	2.07	4.41	0.80
	Unprotected edge	11.40	32.35	-
	Scaffold	6.22	12.50	2.81
	Structure frames	6.99	16.18	2.01
	Lifted workers	5.44	0.74	8.03
	Aerial platform	1.30	2.94	0.40
	Confined space	2.85	7.35	0.40
Job site situation		6.74	12.50	3.61
Carrying, handling, and lifting Materials		4.92	8.09	3.21
Equipment		1.55	0.74	2.01
Environmental issues		0.78	2.21	-
Managerial issues		11.44	-	17.67
Workers behavior		10.62	-	16.47
Insufficient injury prevention practices		27.46	-	42.57
Other		0.26	-	-
Total		100	100	100

The risk values provided in Table 1 are the summation of the sub-attributes' risk value. As one can see in Table 1, insufficient injury prevention practices, unprotected edges, managerial issues, and workers behavior have the highest risk values. Safety risk values for sub-attributes were also calculated. Among primary attributes, working in proximity of unprotected openings (5.96%), working on structure frames (include tower and tanks) (5.7%), and working near unprotected edge (5.18%) have the highest safety risk values.

One of the problems regarding the uncovered openings is that their risk perception is not high among workers and managers (Lipscomb et al. 2003). Among secondary attributes lack of fall protection (19.17%) and workers being uncoordinated or clumsy (4.66%) have the highest risk value, which is consistent with the previous findings (Lipscomb et al. 2003).

One may claim that the best way to reduce hazards is to design and implement specific safety practices that mitigate the effect of high risk attributes. However, focusing only on individual primary hazard attributes does not consider the interactions among attributes. As previously mentioned, these interactions can be significant (Hallowell et al. in press). In order to obtain a more comprehensive picture of interactions among attributes, SNA was conducted for all primary and secondary attributes using UCINET 5. The results are shown in Tables 2 and 3.

Table 2. Density and centrality measures for whole network of interactions among safety attributes

Attributes	**Density**	**Centrality (degree)**	**Betweenness**
All	4.78	36.06	12.72
Primary	0.71	10.91	28.89
Secondary	2.76	22.16	19.17

Table 3. Centrality measure for interactions among safety attributes

Safety attributes		**Centrality degree**			**Betweenness**		
		All	Primary	Secondary	All	Primary	Secondary
Working at elevation	Ladder	2.07	2.73	0.25	0	0	0
	Unprotected edge	18.80	15.46	-	1.1	37.78	-
	Scaffold	11.09	5.46	3.69	0.41	9.26	0
	Structure frames	14.29	6.36	2.21	0.14	1.48	0
	Lifted workers	8.46	2.73	8.35	1.97	0	0.91
	Aerial platform	1.69	0.91	0.25	0	0	0
	Confined space	6.20	9.09	0.25	1.98	15.56	0
Job site situation		14.66	16.36	4.67	3.14	35.56	0.91
Carrying, handling, and lifting Materials		12.22	8.18	4.91	4.73	27.04	0
Equipment		3.76	0.91	2.21	2.35	0	0
Environmental issues		2.07	2.73	-	0.16	0	-
Managerial issues		24.44	-	19.41	5.97	-	23.64
Workers behavior		21.81	-	15.48	9.27	-	23.64
Insufficient injury prevention practices		46.24	-	27.76	14.95	-	23.64

As is stated before, the centrality and betweenness values indicate the amount of participation of an attribute in occurrence of accidents via interaction with other attributes. For primary attributes, unprotected edges and jobsite situation are the two attributes that have the highest centrality and betweenness values. This means that these attributes play a more important role in accident occurrence because they interact in a strong, negative way with other hazardous attributes. One very interesting finding is that though jobsite situation is not a high risk attribute by itself, its high centrality and betweenness values indicate a very strong interaction with other attributes.

In the graphical representation, each attribute was represented by a node and each line in the network indicates interactions among attributes that lead to an accident that was identified and coded using content analysis. The frequencies of connections that have been shown to cause injuries are represented by the strength of each connection. The graphical representation is of great importance, because as Chinowsky et. al. (2010) noticed that some targeted networks may present similar numerical evaluations, but the actual graphical representation reveals variances, trends, and patterns not otherwise visible in the analysis.

The sociograms for primary and secondary attributes are illustrated in Figures 1 and 2, respectively. The sociogram of all attributes has not illustrated here, because it has 73 nodes and is bushy. As shown, unprotected edges and jobsite situation has the strongest link with other attributes for primary attributes. For the secondary attributes, insufficient injury prevention practices, managerial issues, and workers behavior have the strongest links. By removing these nodes one can break the link among the attributes and enhance safety in the jobsite.

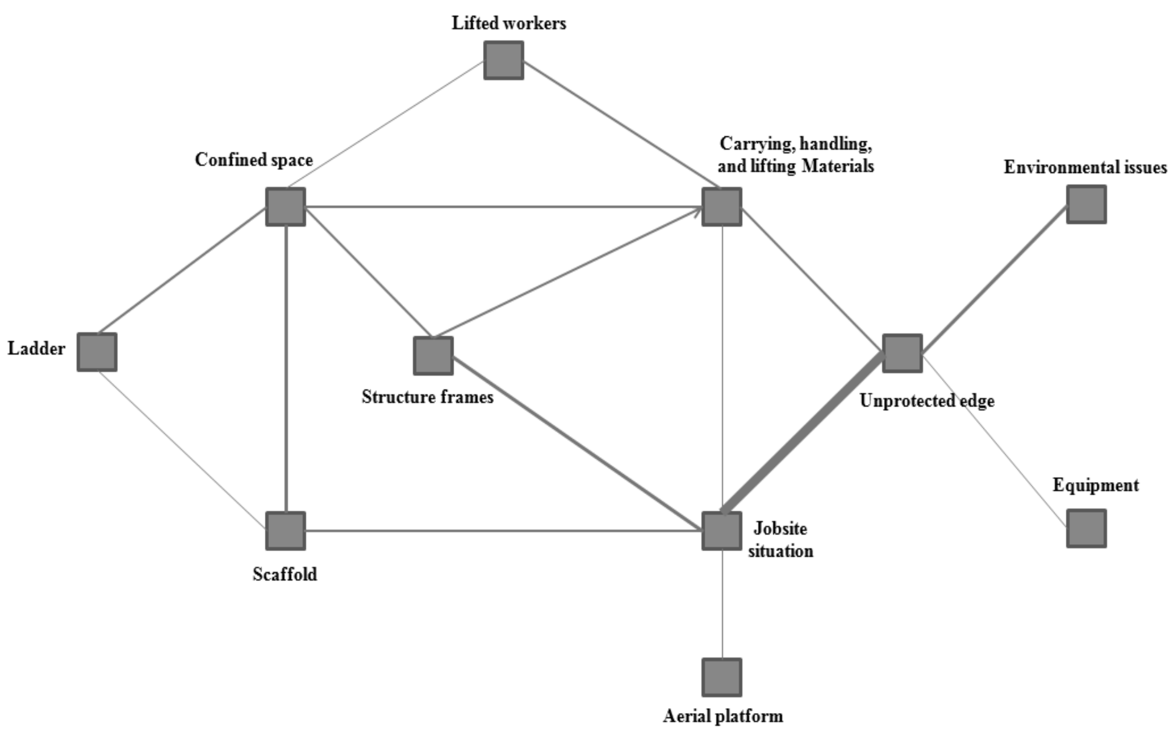

Figure 1. Sociogram of primary attributes

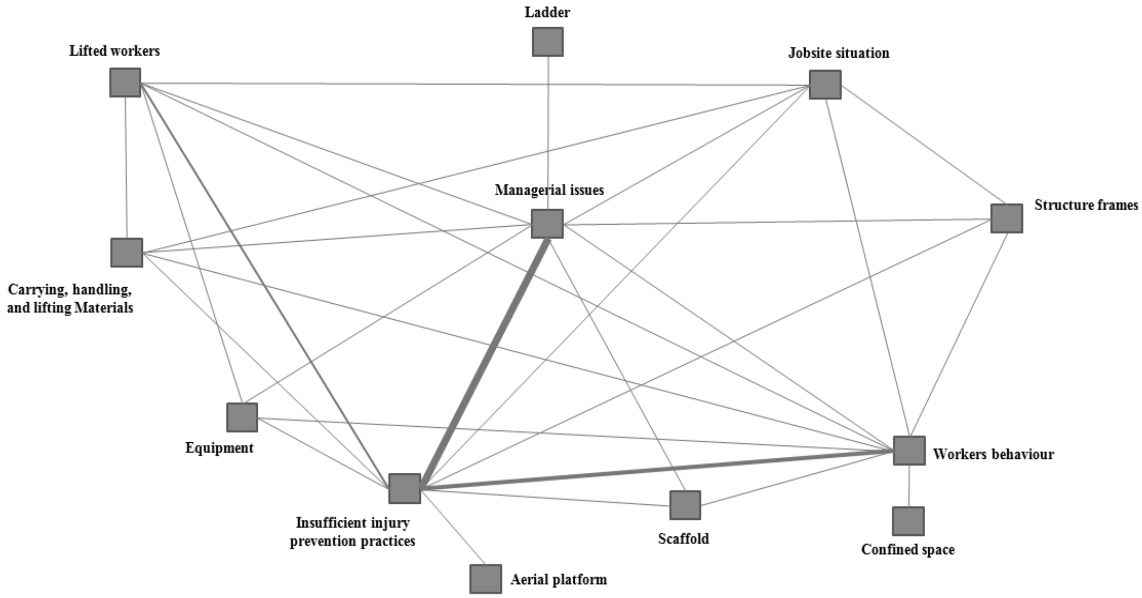

Figure 2. Sociogram of primary attributes

In order to measure and illustrate the influence of removing safety attributes (i.e., 'links' in the chain of events that cause injuries), unprotected edge and jobsite situation were removed from the primary attributes and insufficient injury prevention practices, managerial issues, and worker behavior were removed for secondary attributes. After these changes, the densities of the networks have been decreased to 0.42 and 0.22 for primary and secondary attributes, respectively. Lower densities in safety interaction networks indicate the fewer number of interactions (links) and as a result, lower safety risk in the jobsite. The new sociograms are illustrated in Figures 3 and 4. As one can see, the effect of interactions (links) decreases.

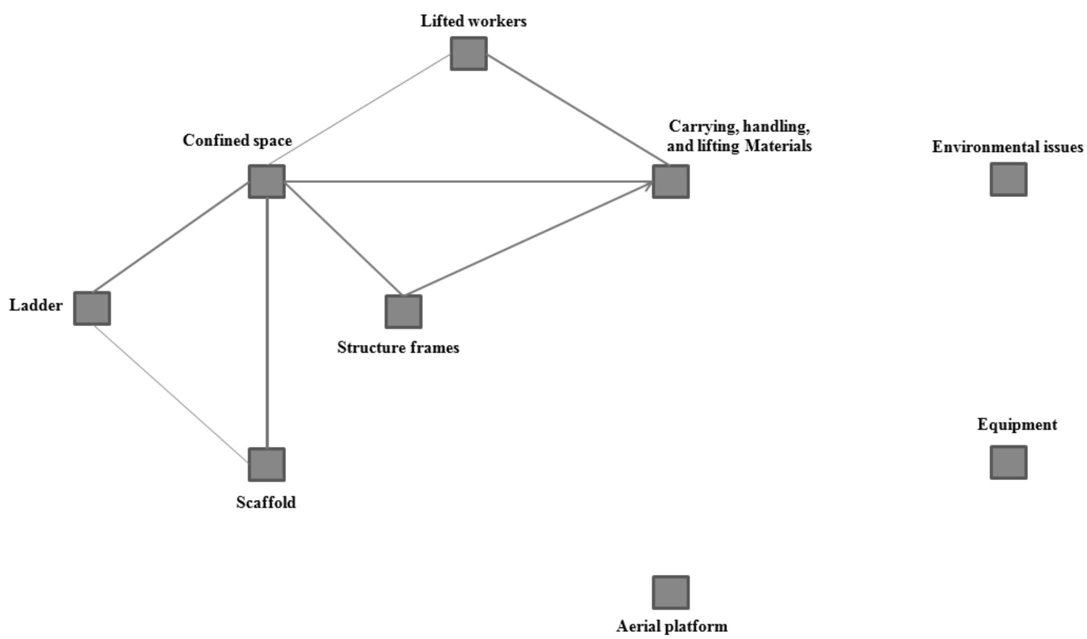

Figure 3. Sociogram of primary attributes after removing critical attributes

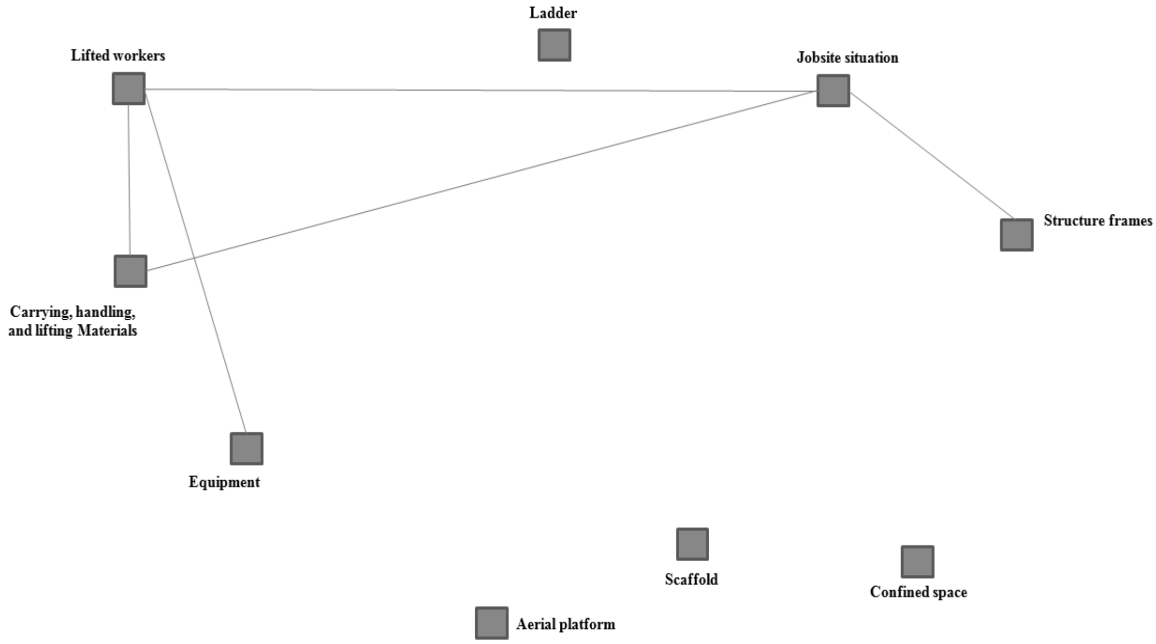

Figure 4. Sociogram of primary attributes after removing critical attributes

One should note that insufficient injury prevention practices, managerial issues, and worker behavior are secondary attributes and a designer does not have much control over them. Therefore, the designer should focus more on primary attributes such as unprotected edges, jobsite situation, configurations that require carrying, handling and lifting materials, and confined spaces and simply communicate to the constructor how they might remove the secondary attributes that exist within the final design.

6. VALIDATION

Unfortunately, there is no published 'acceptable' level of inter-coder reliability for content analysis (Krippendroff 2004; Perrault and Leigh 1989; Popping 1988; and Riffe, Lacy and Fico 1998). Krippendroff (2004) claimed that if meticulous attention has been paid to calculations, 67% agreement among coders can be considered reliable. However, other researchers reported that agreement should exceed 70% to be considered reliable (Ellis 1994; Frey, Botan, and Kreps 2000; Popping 1988). After obtaining the recoded data from the second coder, simple agreement has been calculated. The percent agreement between the two coders was 77.64%, which the writers consider to be an acceptable level of inter-coder reliability, according to the previous literature.

7. CONCLUSIONS

Construction accidents are costly (Everitt and Frank 1996) and falls from height is one of the prominent causes of fatalities in construction (Hinze et al. 2005). A risk attribute analysis technique was proposed to identify and model safety risk for potentially dynamic work environments. In addition, SNA was utilized to model clusters of interactions among attributes to find the most impactful intervention. The proposed model has several advantageous: (1) fall hazard can be identified and risk can be quantified in early phases of the project; (2) there is a unique focus on relationships among attributes; (3) the method is capable of illustrating the relationships among attributes in a graphical form and; (4) a bridge has been established between safety studies and social science. Finally, the flexibility of the presented approach makes it an applicable platform to be used for integrating safety risk data in to sensing technology and building information modeling.

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Utilizing Bluetooth Enabled Consumer Electronics to Determine Proximity to Construction Hazards

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Utilizing Bluetooth Enabled Consumer Electronics to Determine Proximity to Construction Hazards

1. Abstract

There are many consumer devices, such as cell phones, that use Bluetooth technology to send information over a short distance. This paper provides information on a system that utilizes unique Bluetooth electronic signals to assist in quantifying the proximity of the general public or a construction worker to equipment that might present a hazard, such as exposure to dust or noise. Bluetooth electronic signals can also be used to determine the exposure time of a worker to a potential hazard. This paper presents the results of a case study of a controlled test and a field test on a road construction site.

The results of the controlled test demonstrates that Bluetooth signal detection and signal strength can be used with reasonable accuracy to assess the proximity of a person wearing a Bluetooth device to a Bluetooth receiver. The test results indicate strong correlation between signal strength and distance from the Bluetooth receiver when the Bluetooth emitter is within the line of sight.

The results of the field test provided information on utilizing the system in an actual construction operation. The receiver system performed reasonably well in the field tests and the system was able to determine when workers were within approximately 50 to 100 feet of the construction equipment. However, signal disruption between the emitter and the receiver due to construction equipment and trucks was a significant issue. Based on this research, there is significant promise in utilizing the Bluetooth signal to detect worker proximity to construction hazards using low cost Bluetooth devices.

2. Introduction

Tracking Construction Workers and Equipment Location

There are a number of research efforts underway to detect and track workers and equipment in the construction environment. These activities have typically focused on reducing the likelihood of traumatic injuries through the use of technologies such as Global Positioning System (GPS), Radio Frequency Identification (RFID), laser detection and range finding (LADAR) and Ultra Wide Band (UWB) (Oloufa, et al, 2003, Jaselskis, et al, 2003, Wu et al, 2009, Teizer et al, 2007, Teizer et al, 2008, Venugopal et al, 2008). These technologies are typically designed on unique platforms requiring specialized equipment or tag systems, rather than readily-available consumer electronics. For example, the "SmartHAT" system which is currently being developed (Venugopal et al, 2008) utilizes an RFID tag on all worker hard hats in combination with a transceiver on the construction equipment to detect the tags on the worker hard hats. Safety warnings can then be initiated when a tag is detected near the construction equipment. While these systems offer significant promise to reduce traumatic injuries such as struck by accidents, the research has not been used to quantify or mitigate health hazards such as prolonged proximity to equipment producing excessive noise and or respirable silica.

Opportunities to Leverage Pervasive Bluetooth Enabled Consumer Electronics to Assess Worker Health Hazard Exposure

There are numerous consumer devices such as cell phones that use Bluetooth technology to send information over a short distance. These devices all have unique identifiers called Media Access Control (MAC) addresses. The ability to detect and identify a Bluetooth signal has recently been used for a variety of applications to track individuals. These applications include: travel time studies along arterial streets (Wasson et al, 2008, Brennan et al, 2009, Day et al, 2009) travel time through construction work zones (Haseman et al, 2010), and service time measures for pedestrians transiting airport security check points (Bullock et al, 2010). These applications have demonstrated the robustness of Bluetooth tracking techniques.

Bluetooth Address Detection and Signal Strength

Numerous consumer electronics such as cell phones, audio devices, GPS devices, and portable gaming systems use wireless short range Bluetooth signal protocols identified by a MAC address. The MAC address for a device is a unique 48-bit, 12 alpha numeric character, identifier that is assigned by the manufacturer (Wasson et al, 2008). The short range Bluetooth signal broadcast from a device can be read by a Bluetooth receiver and the corresponding MAC address can be logged and time stamped. Since each device has a unique MAC address, both the time the signal was initially detected by the Bluetooth radio and the signal strength can be logged. Based on this information, the amount of time the device was within range of the Bluetooth receiver and the signal strength can be determined. The antennas used for Bluetooth signals are divided by their approximate sensing range into three classes: Class 1 is for a maximum range of 100 meters, Class 2 is for a maximum range of 10 meters and Class 3 is for a maximum range of 1 meter. For this research, a Bluetooth receiver with a Class 2 (10 meter range) was used. The Bluetooth signal strength or Received Signal Strength Indicator (RSSI) is also transmitted with the MAC address. The RSSI is a measure of the power of the Bluetooth signal and can provide further information on the proximity of the Bluetooth signal broadcast to the Bluetooth signal receiving device.

3. Methodology

This paper documents the results of a controlled test and a field test of Bluetooth technology. The controlled test consisted of a Bluetooth receiver that logged the signals from three devices located at various distances from the receiver. The tests were performed in an open parking lot. A data collection platform was developed to log the signal information at various distances and configurations. The information gathered from the controlled test provided a method to quantity the properties of the Bluetooth signal, including the typical distance for signal detection and the signal strength, which varies depending on the distance between the receiver and the Bluetooth device. The results of the controlled test verified the potential for using Bluetooth technologies to identify workers in proximity to equipment that may be potentially hazardous, and laid the groundwork for the field test.

The field test was performed using the Bluetooth receiver and devices that were used in the controlled test. The field test was performed on an actual road construction site in eastern Indiana. In the field test, a Bluetooth receiver was mounted on a roller compactor and three workers were equipped with devices that emitted a Bluetooth signal. The Bluetooth receiver was connected to a laptop computer that logged the Bluetooth signal information. Each Bluetooth device and the Bluetooth receiver also had a GPS device that logged the location every second. The field test was video recorded to allow visual verification.

4. Results

Case Study: Controlled Test

Controlled testing was performed on surface parking lots free of physical obstructions and signals. Two devices that emit a Bluetooth signal were used throughout the testing. The first device was a standard cell phone (LG Model LX165) that was set to continuously emit a Bluetooth signal. The second device was a Bluelon Body Tag BT-002. This device is specifically designed as a Bluetooth tracking device. It is a small key size device that is commercially available. Figure 1 shows the Bluetooth devices used in the testing.

A data collection platform was set up to log the Bluetooth MAC address and the signal strength, RSSI. The data collection platform consisted of one Class 2 Bluetooth USB adapter which received the Bluetooth signals, and was connected to a small netbook computer (Figure 2). The information from the netbook data acquisition system was analyzed in conjunction with location data from survey equipment utilizing GPS linked to a ground based reference (Figure 2). Software was also developed to record each time a MAC address was detected (Wasson 2008, Brennan 2009). The data file consists of the MAC address, RSSI and timestamp. A strong signal strength is indicated by a small negative number (-35 to -60 dB) and a weak signal strength is indicated by a large negative number (-75 to -90 db).

A series of tests was performed in a parking lot to determine the repeatability of the Bluetooth detection and RSSI signal strength starting at a distance of 100 feet. Two Bluetooth devices, a cell phone and the Bluelon Body Tag, were moved towards the Bluetooth receiver starting at a distance of 100 feet. The devices were located on the front of the individual. The devices were moved toward the receiver in 5 foot increments up to 50 feet from the receiver. At 50 feet from the receiver, the incremental distance was changed to 2 feet. Figure 3 is a graph of data points for RSSI versus distance from the Bluetooth receiver for this series of tests with trend lines indicated.

The tests performed at 100 feet provided a good understanding of the signal strength relative to the location from the receiver (Figure 3). The results for both the cell phone and the Bluelon Body Tag are very similar. These tests indicate that within 30 feet, the signal strength is typically -75 dB or stronger. From this information, a system could be designed to sense the Bluetooth signal and evaluate the signal strength to determine if the individual wearing the device is within a close proximity (30 feet) to a construction hazard and how long they have been in this hazardous condition. Additional controlled tests have been performed for a variety of configurations (Hubbard, 2011).

Case Study: Field Test on a Road Construction Site

A field test was performed on a road construction site that consisted of milling and patching short sections of a road. The Bluetooth data collection platform used in the parking lot study was mounted at the front of a roller compactor as shown in Figure 4. A GPS device was also mounted on the roller compactor to determine position. Three workers were provided with a GPS device that also emitted a Bluetooth signal. The workers job duties were such that they would be working around the roller compactor. Video of the operation was also taken to allow visual verification of the proximity of the workers to the equipment.

The field test was performed for two hours during grinding and patching operations. The construction process and movement of workers created distinct events where the workers move closer to the roller compactor and then further away. It was determined through analysis of the GPS data and video that there were 5 to 7 distinct events where the workers moved into proximity of the roller compactor. Proximity was defined as a worker within 100 feet of the equipment. Table 1 provides information on these events for each of the three workers. Information in the table includes information on Bluetooth signal detection, video confirmation of the event, and distance determined from GPS data.

Results indicate that the Bluetooth system detected 66% of the events (12 out of 18). The video was reviewed to determine possible reasons that the Bluetooth system did not detect a worker within proximity of the equipment. The results of the video analysis indicate that the Bluetooth system did not detect the presence of a worker when there was a piece of equipment or vehicle between the worker and the roller compactor; in these cases the equipment or vehicle shielded the signal.

The signal strength and GPS data was also analyzed to determine correlation between the distance to the receiver and the Bluetooth signal strength. A graph of the combined signal strength and distance to the receiver for all three workers is shown in Figure 5. These results indicate that the signal strength is not a strong indicator of distance. This finding is not consistent with the results of the controlled study. A major difference between the field test on an actual construction site and the controlled test parking lot test is the effect of shielding of the signal by vehicles and equipment on the construction site.

5. Conclusions and Recommendations

This paper presents a new technique for utilizing Bluetooth signal sensing technologies to detect worker proximity to equipment that may present a potential hazard on a construction site. A controlled test and a field test demonstrated that a Bluetooth signal detection and signal strength could be used with reasonable accuracy to assess the proximity of a person wearing a Bluetooth device to a Bluetooth receiver.

Various controlled tests show a good correlation between signal strength and distance from the Bluetooth receiver when the Bluetooth emitter is within the line of sight. Testing on an active construction site provided additional insight into the potential use of the technology and some potential limitations. Bluetooth technologies can be used in research to quantify typical exposure rates for workers on a construction site. One limitation that this study identified is the shielding of the signal due to equipment on the site. Positioning the sensor at a higher level may help to alleviate some of these issues. Additional research is suggested to document these findings with a larger data set, and to quantify obstruction issues associated with using the Bluetooth signal as a proximity sensor.

Based on this research, there is significant promise in utilizing the Bluetooth signal to detect worker's proximity to construction hazards using low cost Bluetooth devices. Bluetooth devices have the potential to be used as a stand-alone technology or in support of other tracking technologies. The ability to sense the proximity of a worker to a health hazard and quantify the time near a health hazard is an important first step to develop appropriate mitigation measures, and ultimately, to improve the health and safety of construction workers.

6. Acknowledgements

The authors would like to acknowledge E&B Paving for their support.

7. Tables and Figures

Table 1. Events Logged in Two Hour Case Study (Proximity less than 100 feet)

Worker	Event	Bluetooth Signal Detected	Video Confirmation of Proximity	Distance[1]	Notes
Laborer	1	Yes	Yes	24 ft	
Laborer	2	Yes	Yes	58 ft	
Laborer	3	Yes	Yes	37 ft	
Laborer	4	No	No	N/A	Worker location was obstructed by equipment on video
Laborer	5	No	Yes	N/A	Two vehicles between worker and compactor
2-Way	1	Yes	Yes	24 ft	
2-Way	2	Yes	Yes	71 ft	
2-Way	3	Yes	Yes	97 ft	
2-Way	4	No	No	N/A	Worker location was obstructed by equipment on video
2-Way	5	No	Yes	N/A	
2-Way	6	No	Yes	N/A	Two vehicles between worker and compactor
Foreman	1	Yes	Yes	57 ft	
Foreman	2	Yes	Yes	95 ft	
Foreman	3	Yes	Yes	68 ft	
Foreman	4	Yes	Yes	88 ft	
Foreman	5	Yes	No	81 ft	
Foreman	7	No	Yes	N/A	Two vehicles between worker and compactor

[1] Distance based on GPS log when Bluetooth signal detected

Figure 1. Bluetooth Equipment shown with Surface Milling Operation using a Skid Steer Loader

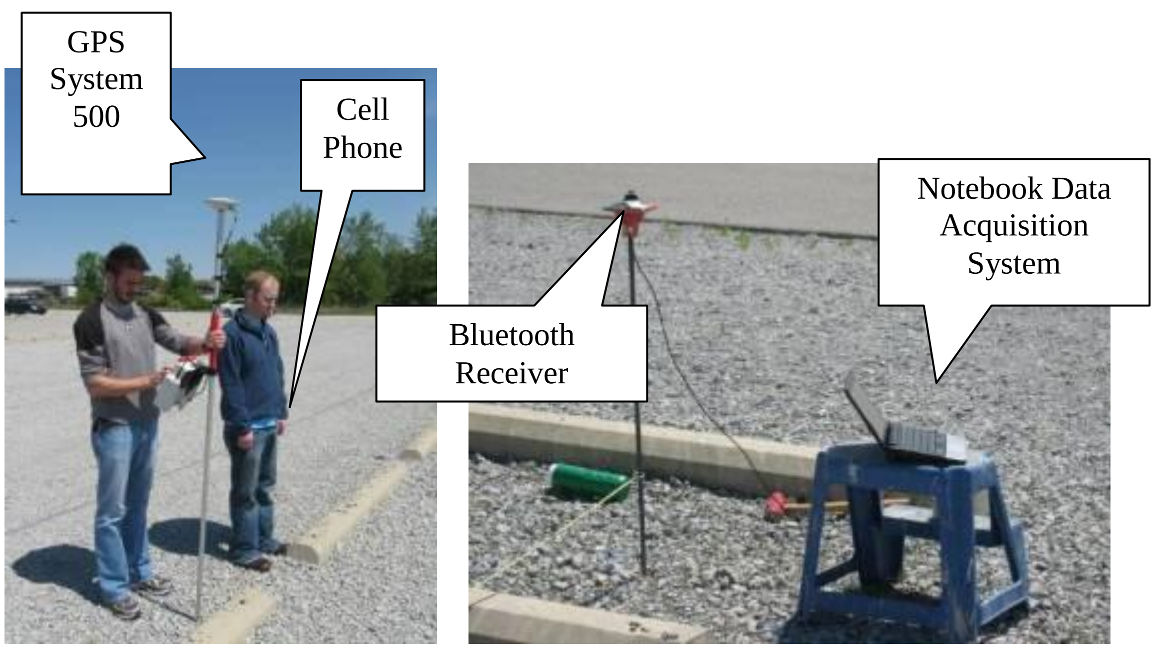

Figure 2. Bluetooth Receivers, Emitters and Data Collection Equipment

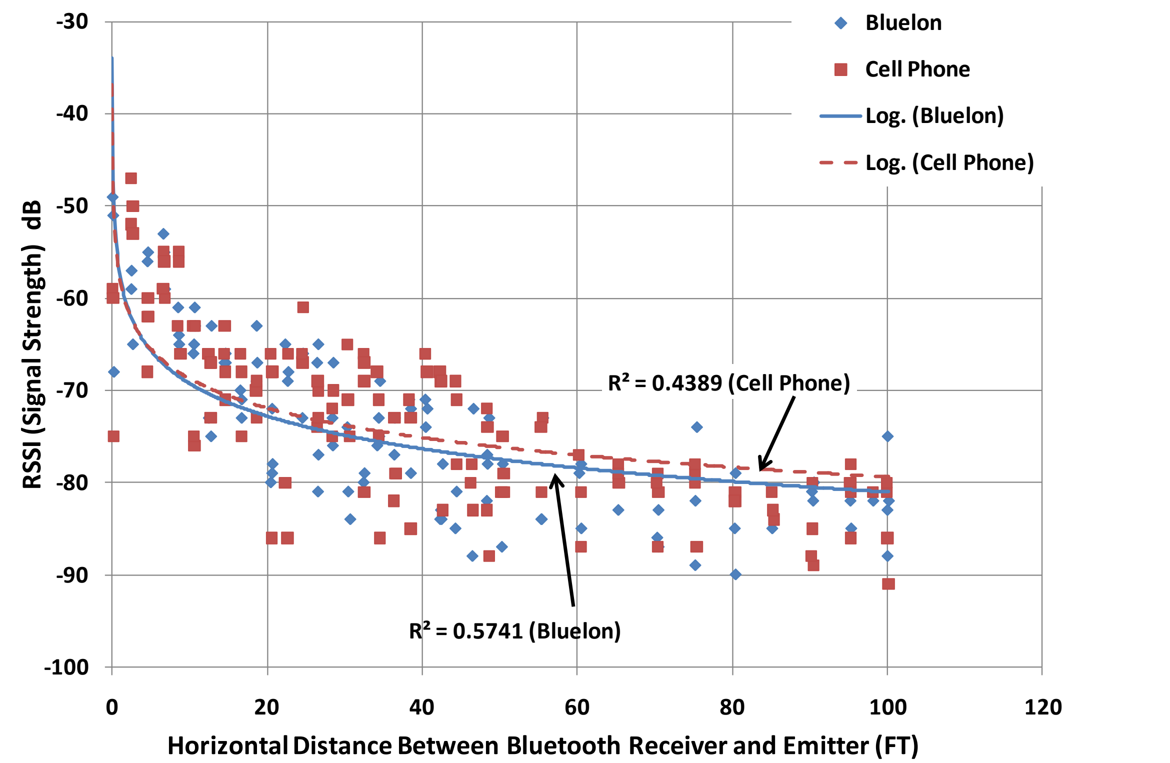

Figure 3. Test Series B, Multiple Tests of RSSI Signal Strength at 100 feet with Two Bluetooth Emitting Devices

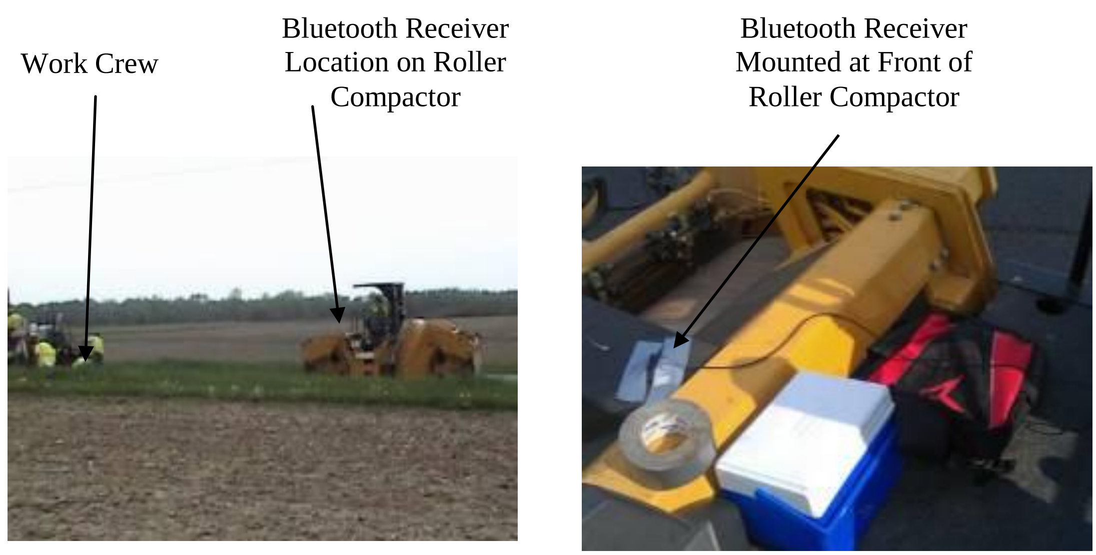

Figure 4. Roller Compactor Bluetooth Receiver Installation

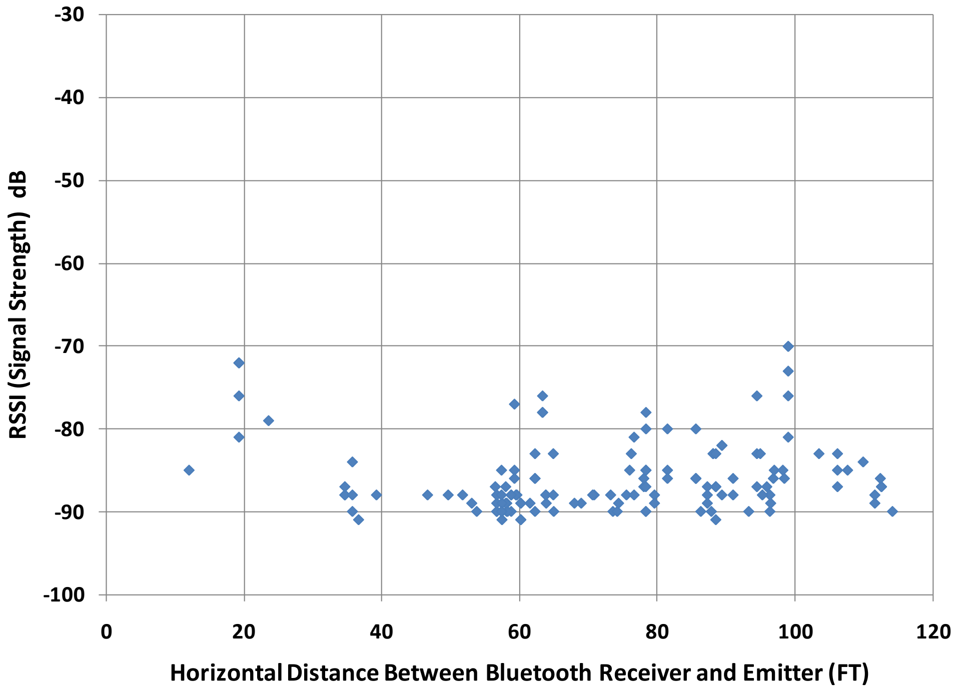

Figure 5. RSSI Signal Strength and Distance for Construction Site Field Testing

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An Analysis of Construction Worker Safety during Building Decommissioning and Deconstruction

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An Analysis of Construction Worker Safety during Building Decommissioning and Deconstruction

Abstract: This paper reports initial findings from our pilot research on understanding construction worker safety issues in building end-of-lifecycle operations specifically decommissioning and deconstruction. Although deconstruction is more environmentally friendly than demolition, it is more labor intensive and it requires more careful planning for critical health and safety issues. The data for this study comes from four buildings surrounding the World Trade Center. The buildings were damaged after September 11 and needed to come down.

Keywords: building deconstruction, worker safety, building decommissioning

1. Introduction

A building's end-of-lifecycle operations include various activities from decommissioning and remodeling to deconstruction and demolition. According to the United States Energy Information Administration (US EIA) 74% of all commercial buildings in the US are built before 1990 and 17% built before 1945 (CBECS, 2003). Similarly, 76% of all the housing units are built before 1990 and 19% is built before 1950 (RECS, 2005). Since the US building stock is relatively old, demolition or deconstruction of buildings to open space for new construction or, building renovation for new purposes have a significant impact on the construction industry. For example, in 2006, residential and commercial building renovation activities cost 36% ($438 billion) of the all building construction activities ($1.22 trillion) (DOE, 2006).

Building end-of-lifecycle operations also cause the construction industry to produce one of the largest shares of waste in the US. In 1998, 136 million tons of construction and demolition (C&D) waste was produced in the US. 48 percent of the waste came from demolition and 44 percent was generated through renovations (Franklin Associates 1998). A preliminary estimate claims that more than 160 million tons of C&D waste was generated in 2003, of which nearly 42 percent came from demolition activities and 49 percent was produced by renovation activities (EPA 2008, EPA 2009). The Environmental Protection Agency (EPA) estimates that only 40 percent of C&D waste was reused, recycled, or sent to energy facilities, while the remaining 60 percent of the materials was sent to C&D landfills.

From environmental sustainability perspective, there is a growing interest to divert building materials away from landfill disposal and provide cost savings and avoidance of virgin material use through reuse and recycling (Kibert and Chini 2000, Chini 2001, Chini and Shultman 2002, Chini 2003, Chini 2005, Crowther 2001, Crowther 2002, Durmisevic 2006, Hurley et al. 2002, Guy and Shell 2002, Hinze 2002, Te Dorsthorst and Kowalczyk 2002, Dorsthorst and Durmisevic 2003). In comparison to demolition, deconstruction is an effective way for reducing raw material consumption and protecting embodied energy in building materials. When buildings reach the end of their useful life, they are decommissioned and either renovated for new purposes or demolished and hauled to landfills. Demolition of a building through explosives or wrecking-ball style is convenient and offers a quick way for clearing the site. However, this method creates a significant amount of C&D waste and landfill costs. Deconstruction is defined as the process of selectively dismantling a building or parts of a building in order to salvage the materials for reuse, recycling, or waste management (Guy and Gibeau 2003).

This paper reports initial findings from our pilot research on understanding construction worker safety issues in building end-of-lifecycle operations specifically decommissioning and deconstruction. Although deconstruction is more environmentally friendly than demolition, it is more labor intensive and it requires more careful planning for critical health and safety issues. Early planning involves complex activities such as collecting and analyzing various information coming from different sources related to the existing structure. Deconstruction activities involve many of the safety hazards associated with the construction. On top of that, all building end-of-lifecycle operations have safety risks due to the unknown condition of the building. These might be caused by deviations from the original design and missing as-built information, unapproved updates, unknown state of construction materials, strength or weakness issues with the structure etc.

2. Significance

In simple terms, deconstruction is the reverse of the construction process, but it shows differences according to the condition and location of the building and building materials involved. In comparison to demolition, which generates waste for landfills, deconstruction produces materials that can be used again or remanufactured into higher-value goods. Two distinct types of deconstruction can take place on a project—non-structural and structural. Non-structural deconstruction is the removal for reuse of any building contents that do not affect the structural integrity. Materials such as cabinetry, windows/doors, and appliances can be salvaged relatively easily with minimum safety concerns. Structural deconstruction consists of more involved recovery activities that are harder to implement and contribute to the structural integrity of the building. Salvaged materials consist of roof systems, wood timbers and beams, brick and masonry elements, and framing (EPA 2001).

Increasing awareness of environmental safety and the need for properly disposing the potentially harmful waste, such as asbestos or other chemicals, requires buildings to be appropriately decommissioned at the end of their lifecycle. The environmental characteristics of building materials are an important issue that needs to be carefully tracked through the building lifecycle. In comparison to the construction processes, decommissioning and deconstruction deals with significantly different waste and debris that is more likely to be contaminated by potentially hazardous substances such as lead paints, stains, and adhesives. The physical and chemical composition of a material can be altered through the surface treatment and maintenance applications. For example, finished wood has a different composition from raw wood. The chipping or shredding of finished wood during recycling can expose people to the hazardous substances such as lead-based paint. (Dolan et al. 1999).

3. Methodology

One of the most critical building end-of-lifecycle operations are being done recently on the surrounding buildings of the World Trade Center (WTC) site after September 11. Five buildings on the immediate vicinity of WTC are decided to come down due to the structural damages: *130 Liberty Street, 4 Albany Street, 130 Cedar Street, 133-135 Greenwich Street, 30 West Broadway-Fiterman Hall*. Environmental Protection Agency (EPA) coordinated the federal, state and city agencies to ensure that the impacted buildings are decommissioned and deconstructed in a manner that protects the health of people who live and work in the area. Due to the nature of the event, all documentation related to these demolition and deconstruction events are publicly available from EPA's web site and collected for the purpose of this research.

Four of these buildings, *130 Liberty Street, 130 Cedar Street, 133-135 Greenwich Street, 30 West Broadway-Fiterman Hall*, have very detailed documentation of their operations. Although the nature of decommissioning and deconstruction was very different for all four buildings, the basic regulatory submittal included the following documents: work plan, environmental air monitoring plan, health and safety plan and waste management plan. In addition to these documents every project has building specific information such as quality assurance plans, façade characterization reports, environmental characterization reports, scaffold erection operations etc. In this research, we specifically focused on health and safety plans to learn from how construction worker safety issues are addressed in these cases.

4. Findings

The analysis of health and safety planning documents for all cases show that although they are prepared for different deconstruction projects they are more similar than different. The content of these documents is grouped under nine topics:

Site security, entrance to site, decontamination section describes the work zones in the site, entrance and exit procedures for containment areas, emergency access, and security protocol together with general building access and perimeter security. Equipment and personnel decontamination procedures are listed as well as contamination prevention methods.

Personnel training procedures are explained in detail in all four documents. This section covers basic site orientation, visitor orientation and safety meetings together with general health and safety awareness training, safe work permit, asbestos training and Hazardous Waste Operations and Emergency Response Standard (HAZWOPER) training.

Personal protective equipment (PPE) section describes the requirements of PPE for different tasks. Level D, Level C and Level B PPE work is expected in the site but Level A description is also provided as a precaution. Basic safety equipment descriptions involve respiratory protection and protective clothing.

Personnel responsibilities part lists key personnel for the project and their contact information

Hazard assessment, risk analysis is the most detailed topic in all four health and safety plans. This part of the document explains physical, chemical or biological hazards in the site and also gives a risk analysis for tasks involved in the work plan.

Air monitoring is part of the safety measures of these end-of-lifecycle operations since the project takes place in a very dense urban environment and all four buildings are heavily contaminated with the dust from the collapse of two towers. The monitoring involves total suspended particulate (TSP), asbestos, Polycyclic aromatic hydrocarbons (PAHs), Polychlorinated biphenyls (PCBs), mercury, lead, silica, cadmium and chromium.

Incident reporting, emergency reporting procedures differ in four cases with their scope. The basic emergency reporting involves the call to first responders through 911. In more detailed processes involve incident investigation, root cause analysis and incident record keeping with a copy of the OSHA 300 log.

Emergency planning is listed in all documents with possible emergency scenarios such as fire, explosion, power or structural failure together with evacuation plans and site logistics.

Communication section involves labeling and material safety data sheets together with general communication procedures, radio and telephone usage, emergency warning and hand signals.

In addition to these procedure descriptions, health and safety planning documents also give references to the various regulations that need to be followed during the decommissioning and deconstruction of buildings. In Table 1, 2 and 3 the regulations that are addressed in four documents are listed. The first group is the federal regulations that are identified by Occupational Safety and Health Administration (OSHA), the second group is local regulations of New York City and the third group of regulations is from other institutions which might not be directly related to the worker safety. The amount of regulations involved in these operations show the complexity of tasks as well as the depth of planning that is required before starting the deconstruction. In some cases such as asbestos regulations or hazardous materials there are more than one regulations at different levels and a careful planning is required to identify possible conflicting or overlapping specifications.

Table 1: ***Combined list of OSHA regulations referenced in four cases***

Federal OSHA Regulations for General Industry (29 CFR 1910)	Federal OSHA Construction Regulations (29 CFR 1926)
- Subpart C (General Safety and Health Concerns) - Subpart D (Walking and Working Surfaces) - Subpart E (Means of Egress) Health and Safety Plan - Subpart G (Occupational Health and Environmental Control) - Subpart H _ 120 (Hazardous waste operations and emergency response) - Subpart I (Personal Protective Equipment) - Subpart J (General Environmental Controls) - Subpart K (Medical and First Aid) - Subpart L (Fire Protection) - Subpart P (Hand and Portable Power Tools) - Subpart S (Electrical) - Subpart Z (Toxic and Hazardous Substances)	- Subpart C (General Safety and Health Provisions) - Subpart CC (Cranes and Derricks) - Subpart D (Occupational Health and Environmental Control) - Subpart E (Personal Protective and Lifesaving Equipment) - Subpart F (Fire Protection and Prevention) - Subpart G (Signs, Signals, and Barricades) - Subpart H (Materials Handling, Storage, Use and Disposal) - Subpart I (Tools-Hand and Power) - Subpart J _ 354 (Welding/Cutting on surfaces covered by protective coatings) - Subpart K (Electrical) - Subpart L (Scaffolding) - Subpart M _ 500 and 502 (Personal Fall Arrest Systems) - Subpart N _ 502 (Materials Hoists, Personnel Hoists and Elevators) - Subpart P _ 650 (Excavation) - Subpart T (Demolition) - Subpart X (Stairways and Ladders) - Subpart Z _ 1101 (Asbestos) - Subpart Z _ 1127 (Cadmium)

Table 2: ***Combined list of local regulations referenced in four cases***

Local Asbestos Licensing Regulations - The State of New York Department of Natural Resources and Environmental Control asbestos regulations. - The State of New York Department of Asbestos Licensing Regulation - City of New York Asbestos Licensing Authority - New York State Department of Labor Industrial Code Rule 56 (ICR-56) (proper identification, handling, removal, and disposal of ACM in public buildings)
New York City Local Law 45 of 198 (Designating a qualified specialist as a site-safety coordinator for all phases of construction)
New York City Building Code Subchapter 19 (Safety of Public and Property During

Construction Operations)
City of New York Department of Licenses and Inspections (Building Permit and Contractor Licensing Regulations

Table 3: ***Combined list of regulations from other institutions referenced in four cases***

U.S. Nuclear Regulatory Commission (10 CFR) (40-hour Radiation Protection Procedures and Investigative Methods (10 CFR 1912))
U.S. Environmental Protection Agency Regulations - 40 CFR Subchapter C - 40 CFR Part 61, Subpart A (General Provisions) - 40 CFR Part 61, Subpart M (National Emission Standard for Asbestos) - US EPA 40 CFR Subchapter 1 - 40 CFR Part 241, (Guidelines for the Land Disposal of Solid Wastes) - 40 CFR Part 257, (Criteria for Classification of Solid Waste Disposal Facilities and Practices) - US EPA 40 CFR Subchapter R Health and Safety Plan - 40 CFR Part 763, (Asbestos Hazard Emergency Response Act)
American National Standards Institute (ANSI) Publications - Z9.2, (Fundamentals Governing the Design and Operation of Local Exhaust Systems) - Z88.2, (Practices for Respiratory Protection)
Underwriters Laboratories, Inc. (UL) Publications 586 (Test Performance of High Efficiency, Particulate, Air Filters Units)
National Electric Code (Latest Edition)
American Society for Testing and Materials E 1368-99, (Standard Practice for Visual inspection of Asbestos Abatement Projects
National Fire Protection Association (NFPA) Standard 701, (Standard Methods of Fire Test for Flame-Resistant Textiles and Films)

5. Conclusion and Summary

In this paper we report from our initial study on the decommissioning and deconstruction of four buildings surrounding the WTC in New York City, which were damaged needed to come down after September 11. Our analysis shows that the health and safety planning for deconstruction of these buildings required detailed information about the buildings' condition and a careful preparation for expected or unexpected events. In comparison to construction, worker safety issues are different in the deconstruction operation because of various variables such as structural instability, hazardous materials and contamination problems.

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FINANCIAL PROVISION FOR HEALTH AND SAFETY (H&S) IN CONSTRUCTION

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Financial Provision for Health and Safety (H&S) in Construction

Abstract

Relative to other industries in South Africa and construction industries worldwide, the construction process generates a disproportionate number of fatalities and injuries and it is associated with disease, the direct and indirect cost of which contributes to the cumulative cost of construction.

Health and Safety (H&S) needs to be resourced and budgeted for. However, anecdotal evidence and research indicates that adequate financial provision for H&S by contractors is marginalised by a number of factors such as contract documentation and the non-facilitation thereof during the tendering / bidding process.

The purpose of the paper is to present the results of an empirical study conducted among members of the Association of Construction Health and Safety Management (ACHASM) and selected general contractor (GC) members of the Kwazulu Natal Master Builders (KZNMB) in South Africa to determine their perceptions and practices relative to financial provision for H&S.

The salient findings are that contract documentation, documents, and other references do not address H&S to the requisite extent. Furthermore, contract documents have not facilitated financial provision for H&S subsequent to the promulgation of the Construction Regulations on 18 July 2003. The mean percentage H&S constitutes of tender and project cost is 3.8% and 2.4% respectively, but according to KZNMB members is 1.6% and 1% respectively. However, ≤ 33.3% of respondents' organisations compute the percentage H&S constitutes of project cost.
The paper concludes that contract documentation does not facilitate adequate financial provision for H&S, the cost engineering / quantity surveyor stakeholder group is marginalising H&S, and the traditional project parameters of cost, quality, and time are more important than H&S to respondents' organisations and other stakeholder groups.

Recommendations include: contract documentation should include appropriate H&S related clauses; a detailed H&S section should be included in the Preliminaries; H&S specifications should be project specific, record residual hazards, be included in contract documentation, and be linked to the facilitating of financial provision for H&S; contractors should determine the cost of H&S, and built environment councils and voluntary associations should raise the status of H&S within their constituencies.

Keywords: construction, financial, health and safety

1. INTRODUCTION

All trades and aspects of construction require adequate financial provision at tender or bidding stage, and thereafter. However, the traditional construction procurement process (TCPS), which entails the design of buildings or structures by designers, the preparation of tender or bidding documentation by cost engineers or quantity surveyors, a competitive tendering or bidding process, and the invariable appointment of a contractor on the basis of the lowest price, has a number of implications for H&S (Rwelamila & Smallwood, 1999). In addition to the separation of design from procurement, and construction, contractors seek competitive advantage. Research indicates that while designers do influence H&S during design and construction, the attention is more prevalent during construction through supervisory and administrative interventions, than during design and procurement (Smallwood, 2004a; Smallwood, 2006). Furthermore, procurement systems do not engender commitment to H&S (Rwelamila & Smallwood, 1999), contract documentation makes limited reference to H&S (Smallwood and Rwelamila, 1996), and competitive tendering or bidding marginalises H&S (Smallwood, 1996).

Given the aforementioned research findings, anecdotal evidence, and a request from the Kwazulu Natal Master Builders regarding the optimum percentage financial provision for H&S, a study was initiated, the objectives being to determine the:

- perceived importance of H&S;
- extent to which H&S has been / is addressed by contract documentation;
- perceptions relative to the financial provision for H&S, and
- potential of interventions to contribute to an improvement in H&S.

2. REVIEW OF THE LITERATURE

Role of procurement in health and safety

Wells and Hawkins (2009) say that there are two reasons why H&S is an important issue to consider during procurement. First, clients have been made increasingly responsible for H&S and therefore need to ensure that H&S conscious designers, contractors and subcontractors are appointed. Secondly, although enforcement agencies are responsible for ensuring compliance through, inter alia, inspection of sites. However, the large number and dispersion of sites is such that enforcement agencies cannot visit all sites. Therefore, procurement has a major role to play in assuring H&S through the appointment of H&S conscious contractors and subcontractors. They also highlight the trend in developing countries, namely the award of contracts on the basis of competitive tendering, with tenders evaluated on the basis of price. Therefore, in order to win the tender contractors need to limit costs and consequently the winning tender is unlikely to make adequate provision for H&S equipment, welfare facilities, and a healthy and safe working environment.

The role of clients in procurement in terms of H&S in South Africa is addressed in detail by the Construction Regulations (Republic of South Africa, 2003). Clients are required to, inter alia, provide the principal contractor with an H&S specification which schedules the H&S requirements for the project, and to ensure that during the tendering process, the principal contractor has made provision for the cost of H&S measures.

The report *Construction Health & Safety Status & Recommendations* published by the South African Construction Industry Development Board (cidb) (2009) addressed the role of procurement in H&S in detail in terms of the recommendations. Key elements of the recommended strategy to improve construction H&S performance by public sector clients are: prequalify and / or select contractors with recognised H&S competencies; prequalify and / or select contractors with recognised H&S management system abilities applicable to the project risk; specify requirements for H&S management plans on construction projects; specify requirements for H&S management systems and plans from designers, and require the completion of assessment reports of contractors upon project completion, which can be used in selecting contractors during tender evaluation.

Contract documentation

According to the cidb (2009), the predominating standard forms of contract used in South Africa make explicit or implicit reference to the fact that the forms of contract are subject to legislation impacting on construction H&S. More specifically, however the:

- General Conditions of Contract (GCC) does not make any explicit reference to H&S other than the requirement for 'reporting of accidents';
- Joint Building Contracts Committee (JBCC) conditions of contract does not make any explicit reference to H&S, but does make explicit reference to the parties complying with all laws, regulations and bylaws regarding the execution of the works, and
- International Federation of Consulting Engineers (FIDIC) and the New Engineering Contract (NEC) conditions of contract, which are of overseas origin, do make specific reference to H&S. However, in some cases the terminology or referencing does not fully align with the requirements of the South African H&S legislative framework.

Clearly, scope exists for the standard forms of contract to include more direct reference to construction H&S, the Construction Regulations and the obligations of contractors – as well as providing for additional client driven H&S requirements.

Form of financial provision for health and safety

Wells and Hawkins (2009) state that to avoid misunderstanding of what is required and to facilitate the checking of contractors' financial provision for H&S, it is recommend that H&S items that can be separately priced be listed as prime cost items, provisional sums, or the use of another form of pricing mechanism. They provide examples of items that can be addressed in such a manner, namely the preparation and updating of an H&S plan; provision of temporary works such as scaffolding and hoarding, H&S Officer, H&S training, attendance of H&S Committee meetings, provision of welfare facilities, provision of personal protective equipment (PPE), and medical examinations. Wells and Hawkins (2009) also state that it is possible, and may be considered preferable, to take the cost of meeting the client's H&S requirements out of competition by pre-pricing H&S items, and they cite the approach adopted in Hong Kong in 1996 under the 'Pay for Safety' scheme.

Cost of health and safety

According to Wells and Hawkins (2009), the maximum payment for all H&S items in terms of the Hong Kong 'Pay for Safety' scheme was set at approximately 2% of the estimated value of the contract on small projects, and 1% on large projects. However, H&S items that are not delivered are not paid for.

In terms of research conducted to determine the cost of H&S, international findings vary. Research conducted by Lai in Hong Kong revealed that most contractors set aside an amount of less than 0.5%, and some even less than 0.25% of the contract sum for investing in H&S on their contracts (Tang, Lee, and Wong, 1997). Recent research conducted among a group of 'better practice H&S' general contractors (GCs) in South Africa included, inter alia, the question: "On average, approximately what percentage does the cost of H&S constitute of total project cost?" (Smallwood, 2004) Of the eight (88.9%) GCs that responded, two GCs (25%) recorded a percentage, namely 3% and 0.5%, and six (75%) identified ranges: three (50%) '0 ≤ 1%', and three (50%) '> 1 ≤ 2%'.

3. METHODOLOGY AND SAMPLE STRATA

The study was descriptive in nature and the quantitative questionnaire consisted of six questions, five being closed end and one being open end, the latter allowing for the recording of general comments. The five closed end questions included thirty-four sub-questions.

The national membership of the ACHASM and members of the KZNMB that achieved places in the 2010 regional H&S competition constituted the sample strata. 18 Members of ACHASM and 8 KZNMB's members responded.

4. FINDINGS

Analysis

The analysis of the data consisted of the calculation of descriptive statistics to depict the frequency distribution and central tendency of responses to fixed response questions to determine the extent of contribution, degree of concurrence, and the degree of importance.

To rank fixed response items according to the central tendency of responses, mean scores (MSs) were calculated as follows:

$$MS = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}{n_o + n_1 + n_2 + n_3 + n_4 + n_5}$$

The variables are referenced in Table 1.

Table 1: Definition of Likert scale points and related variables

Likert scale point			**Variable**
Unsure	Unsure	Unsure	n_o
Minor extent	Strongly disagree	Not important	n_1

Near minor extent	Disagree	Less than important	n_2
Some extent	Neutral	Important	n_3
Near minor extent	Agree	More than important	n_4
Major extent	Strongly agree	Very important	n_5

Findings

Table 2 indicates the extent to which documents / references address / mention H&S based upon a MS with a minimum value of 1.00, and a maximum value of 5.00, based upon percentage responses to a range 'minor' to 'major'. MSs > 3.00 indicate that the respondents can be deemed to perceive the extent to which documents / references address / mention H&S to be more a major than a minor extent, whereas MSs ≤ 3.00 indicate the extent to be more minor than major. It is notable that all the MSs relative to KZNMB members are higher than those relative to ACHASM members. Furthermore, all the ACHASM MSs are < 3.00 and in fact > 1.00 ≤ 1.80, which indicates that the members of ACHASM perceive the documents / references to address / mention H&S between a minor to near minor extent. Three of the six KZNMB MSs are < 3.00, namely the: JBCC, Model Preambles, and Standard System of Measuring Builders Work. However, two MSs, namely the NEC and FIDIC, are > 4.20 ≤ 5.00, which indicates that are perceived to address / mention H&S between a near major to major / major extent. The GCC MS falls within the range > 3.40 ≤ 4.20, which indicates that it is perceived to address / mention H&S between some extent to a near major / near major extent. The JBCC, Model Preambles, and Standard System of Measuring Builders Work MSs fall within the range > 1.80 ≤ 2.60, which indicates that they are perceived to address / mention H&S between a minor to near minor / near minor extent.

In terms of the mean MSs, with the exception of the NEC, all the MSs are < 3.00. This is attributable to the low ACHASM MSs. However, three of the KZNMB MSs are < 3.00.

Table 2: Extent to which documents / references address / mention H&S.

Document / Reference	**ACHASM**		**KZNMB**		**Mean**	
	MS	**Rank**	**MS**	**Rank**	**MS**	**Rank**
Contracts:						
• JBCC	1.40	3	2.43	5	1.92	5
• GCC	1.33	5	3.80	3	2.57	3
• NEC	1.60	1	4.75	1	3.18	1
• FIDIC	1.57	2	4.25	2	2.91	2
Model Preambles	1.31	6	2.17	6	1.74	6
Standard System of Measuring Builders Work	1.36	4	2.60	4	1.98	4

Table 3A indicates the basis on which contract documents have facilitated financial provision for H&S subsequent to the promulgation of the Construction Regulations (18 July 2003) according to ACHASM members.

20% of respondents maintain that provisional sums never facilitated financial provision for H&S and 66.6% > 0% ≤ 30% of projects. Only 6.7% identified each of > 60% ≤ 70% and > 80% ≤ 90% of projects.

13.3% of respondents maintain that preliminaries items never facilitated financial provision for H&S and 53.4% > 0% ≤ 30% of projects. Only 6.7% identified each of > 30% ≤ 40%, > 50% ≤ 60% and > 90% ≤ 100%, and 13.3% > 80% ≤ 90% of projects.

35.7% of respondents maintain that detailed H&S preliminaries items never facilitated financial provision for H&S and 42.8% > 0% ≤ 30% of projects. Only 7.1% identified each of > 30% ≤ 40%, > 50% ≤ 60% and > 60% ≤ 70% of projects.

21.4% of respondents maintain that detailed H&S 'trade' / section never facilitated financial provision for H&S and 42.8% > 0% ≤ 30% of projects. Only 7.1% identified each of > 40% ≤ 50%, > 50% ≤ 60% and 100% of projects.

Table 3A: Basis on which contract documents have facilitated financial provision for H&S subsequent to the promulgation of the Construction Regulations (18 July 2003) according to ACHASM members.

Form of provision	**Response per percentage extent (%)**												
	Unsure	**0%**	**> 0% ≤ 10%**	**> 10% ≤ 20%**	**> 20% ≤ 30%**	**> 30% ≤ 40%**	**> 40% ≤ 50%**	**> 50% ≤ 60%**	**> 60% ≤ 70%**	**> 70% ≤ 80%**	**> 80% ≤ 90%**	**> 90% < 100%**	**100%**
Provisional sum	0.0	20.0	33.3	20.0	13.3	0.0	0.0	0.0	6.7	0.0	6.7	0.0	0.0
Preliminaries 'item'	0.0	13.3	40.0	6.7	6.7	6.7	0.0	6.7	0.0	0.0	13.3	6.7	0.0
Detailed H&S preliminaries	0.0	35.7	21.4	21.4	0.0	7.1	0.0	7.1	7.1	0.0	0.0	0.0	0.0
H&S 'trade' / section	0.0	21.4	35.7	21.4	0.0	0.0	7.1	7.1	0.0	0.0	0.0	0.0	7.1

Table 3B indicates the basis on which contract documents have facilitated financial provision for H&S subsequent to the promulgation of the Construction Regulations (18 July 2003) according to KZNMB members.

33.3% of respondents maintain that provisional sums facilitated financial provision for H&S > 80% ≤ 90% of projects and 66.7% > 90% ≤ 100% of projects.

33.3% of respondents maintain that preliminaries items facilitated financial provision for H&S >50% ≤ 60% of projects and 66.7% >80% ≤ 90% of projects.

33.3% of respondents maintain that detailed H&S preliminaries items facilitated financial provision for H&S >90% < 100% projects and 66.7% a 100% of projects.

33.3% of respondents maintain that detailed H&S 'trade' / section facilitated financial provision for H&S >60% ≤ 70%and 33.3% a 100% of projects. 33.3% were unsure.

Table 3B: Basis on which contract documents have facilitated financial provision for H&S subsequent to the promulgation of the Construction Regulations (18 July 2003) according to KZNMB members.

Form of provision	**Response per percentage extent (%)**												
	Unsure	**0%**	**> 0% ≤ 10%**	**> 10% ≤ 20%**	**> 20% ≤ 30%**	**> 30% ≤ 40%**	**> 40% ≤ 50%**	**> 50% ≤ 60%**	**> 60% ≤ 70%**	**> 70% ≤ 80%**	**> 80% ≤ 90%**	**> 90% < 100%**	**100%**
Provisional sum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	66.7	0.0
Preliminaries 'item'	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	0.0	0.0	66.7	0.0	0.0
Detailed H&S preliminaries	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	66.7
H&S 'trade' / section	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	0.0	0.0	0.0	33.3

Table 4 indicates the extent to which respondents concur with fourteen statements based upon a MS with a minimum value of 1.00, and a maximum value of 5.00, based upon percentage responses to a scale of 'strongly disagree' to 'strongly agree'. In terms of the mean, 9 of the 14 (%) statements have MSs > 3.00 which indicates that the respondents can be deemed to agree as opposed to disagree, whereas the converse applies in the case of MSs ≤ 3.00.

It is notable that the top three MSs are > 4.20 ≤ 5.00, which indicates that the degree of concurrence is between agree to strongly agree / strongly agree. Notable, as statements directly related to the subject of the study such as 'A detailed H&S section should be included in the Preliminaries' and 'A provisional sum should be provided for H&S in the preliminaries, fall within this range. In the case of the former, both the ACHASM and KZNMB MSs are > 4.20 ≤ 5.00.

MSs > 3.40 ≤ 4.20 indicate that the degree of concurrence is between neutral to agree / agree: 'Competitive tendering marginalises H&S'; 'Standard contract documentation generally makes cursive reference to H&S'; 'Appropriate contract documentation promotes H&S'; 'Contract document enabled financial provision for H&S promotes H&S', and 'H&S specifications are project specific'. Although the latter statement is positive in terms of practice, the concurrence relative to the other four statements reinforces the role of contract documentation in promoting H&S, the negative impact of competitive tendering on H&S, and the current inadequacy of standard contract documentation.

MSs > 2.60 ≤ 3.40 indicate that the degree of concurrence is between disagree to neutral / neutral: 'H&S specifications are included with tender documentation'; 'Contract documentation promotes H&S'; 'H&S specifications highlight hazards', and 'Contractors are afforded the opportunity to price H&S on an equitable basis'; 'Contractors are afforded the opportunity to price items included in H&S specifications on an equitable basis'. H&S specifications should be included with tender documentation and highlight hazards due to the necessity for contractors to make adequate allowance for H&S. Furthermore, the current inadequacy of standard contract documentation is further reinforced.

Table 4: Extent of concurrence with various statements.

Statement	ACHASM		KZNMB		Mean	
	MS	Rank	MS	Rank	Mean	Rank
A detailed H&S section should be included in the Preliminaries	4.47	2	4.63	1	4.55	1
Competitive tendering without reference to H&S marginalises H&S	4.69	1	4.13	5	4.41	2
A provisional sum should be provided for H&S in the preliminaries	4.06	4	4.50	2	4.28	3
Competitive tendering marginalises H&S	4.24	3	3.88	7	4.06	4
Standard contract documentation generally makes cursive reference to H&S	3.76	5	3.75	8	3.76	5
Appropriate contract documentation promotes H&S	3.19	6	4.13	4	3.66	6
Contract document enabled financial provision for H&S promotes H&S	3.06	7	4.25	3	3.66	7
H&S specifications are project specific	3.00	8	4.00	6	3.50	8
H&S specifications are included with tender documentation	2.71	9	3.63	9	3.17	9
Contract documentation promotes H&S	2.06	12	3.63	10	2.85	10
H&S specifications highlight hazards	2.12	10	3.50	11	2.81	11
Contractors are afforded the opportunity to price H&S on an equitable basis	2.06	11	3.38	13	2.72	12
Contractors are afforded the opportunity to price items included in H&S specifications on an equitable basis	2.00	13	3.38	12	2.69	13
H&S specifications include designer 'design and construction' method statements	1.53	14	3.25	14	2.39	14

Given that the MS relative to 'Contractors are afforded the opportunity to price items included in H&S specifications on an equitable basis' falls within the range > 1.80 ≤ 2.60, the degree of concurrence can be deemed to be between strongly disagree to disagree / disagree. The current inadequacy of standard contract documentation is further reinforced.

Table 5 indicates the extent to which respondents' organisations compute the cost of H&S and the mean percentage H&S constitutes of tender and project cost.

It is notable that members of the KZNMB compute the percentage that H&S constitutes of tender cost and project cost to a lesser extent than ACHASM members do, even though they are not contractors. It is also notable that only 12.5% of KZNMB members compute the percentage that H&S constitutes of project cost. The absolute mean percentage that H&S constitutes of tender cost is 4.4 higher according to ACHASM members (6%) than KZNMB members (1.6%), and in terms of project cost is 2.7 higher according to ACHASM members (3.7%) than KZNMB members (1%).

Table 5: Extent to which respondents' organisations compute the cost of H&S and the mean percentage H&S constitutes of tender and project cost.

Cost type	Yes (%)			Mean (%)		
	ACHASM	KZNMB	Mean	ACHASM	KZNMB	Mean
Tender cost estimate	38.9	25.0	32.0	6.0	1.6	3.8
Project cost	33.3	12.5	22.9	3.7	1.0	2.4

Table 6 indicates the degree of importance of parameters to respondents' organisations based upon a MS with a minimum value of 1.00, and a maximum value of 5.00, based upon percentage responses to a range ‘not’ to ‘very’. Given that all the MSs are > 3.00 the respondents can be deemed to perceive the parameters to be important, as opposed to not important. However, MSs > 4.20 ≤ 5.00, indicate that the parameters can be deemed to be more than important to very important / very important. It is notable that in terms of the mean, project H&S is ranked fourth and that the absolute MS difference between first ranked project time and project H&S is 0.29, which indicates that project time is effectively 8.5% more important. Furthermore, it is also notable that project time, project cost, and project quality are ranked higher than project H&S.

Table 6: Importance of project parameters to respondents’ organisations.

Parameter	ACHASM		KZNMB		Mean	
	MS	Rank	MS	Rank	MS	Rank
Project time	4.47	1	5.00	2	4.74	1
Project cost	4.40	2	5.00	1	4.70	2
Project quality	4.33	3	4.88	3	4.61	3
Project H&S	4.27	4	4.63	4	4.45	4
Environment	4.20	5	4.00	6	4.10	5
Construction ergonomics	3.40	6	4.00	5	3.70	6

Extensive comments in general regarding financial provision for H&S were received from respondents, which indicates that ‘financial provision for H&S’ is a topical issue.

ACHASM

14 Comments were received from members of ACHASM, some lengthy, which equates to a mean of 0.78 comments per respondent. The comments are presented verbatim:

- “Project management companies, architectural firms, quantity surveying firms need to make use of international ‘best practice’ and take the lead on this issue. Further research needed.”
- “Financial provision for H&S has not been considered as contractual obligations by the client and the majority of contractors. Financing H&S is mostly perceived as a waste of project resources & time, not a priority it is. The cost of delivering a project must include H&S financials that shall not be negotiated between client and the designers who normally decide to drop it. The H&S agent must get the opportunity to estimate the cost of delivering a project in a safe manner. Prospective contractors must not be allowed to undermine their financial responsibilities in regard to H&S and hence their legal & contractual obligations on H&S.”
- “In our opinion, tenderers should be instructed to provide a detailed budget, but the P&Gs should not have a price due to the liability exposures.”
- “It is my opinion that when tendering on H&S, most clients do not understand the importance of measuring the cost for implementing SHEQ on construction sites. They leave it up to the contractor to decide how much money he wants to allow for H&S. This is often then neglected by the contractor to get the contract or to have the edge above others tendering for projects. Clients should drive the implementation of SHEQ

on projects and should therefore manage the financial allocation for SHEQ on projects. In my opinion this happens on most big contracts (R80 000 000 and up) in South Africa, but when it comes to the smaller contracts (R1 000 000 – R25 000 000) clients neglect to implement this. Management of SHEQ is therefore not funded on the smaller contracts; the risks therefore increase and serious accidents often happen on these projects."

- "There is inadequate financial provision for H&S in the primary contract document i.e. the BOQ. I suggest that H&S be identified as a provisionally measured BoQ trade item. An item by item (standard list) of H&S items should be inserted in this trade section e.g. heading (PPE) sub-heading (Excavations) "Allow for standard hard hats as per xy manufacturing Code 007" No. 10 price 200,000."
- "There is an ideal opportunity for the JBCC to be amended to include provisions for H&S on a measured basis given that it is under review at present with date for finalization being November. The cidb is also involved in this process and could drive the requisite changes. This opportunity must not be missed as there is a willingness to consider the changes that need to be made. The challenge that they see is how to elevate H&S in terms of 'compliance with legislation' above other forms of regulation and legislation. Which do they exclude? Where do they start and where do they end? This is a significant challenge with some legitimacy."
- "Quality is conformance to spec. Bad H&S spec bad (includes bastards that use generic) bad H&S performance on site which could lead to multiple fatalities. The so called construction professionals are seldom questioned by the Department of Labour unless there is a fatality. These same people cut, copy and paste specifications from one contract to another which does not deal with project specific H&S. Professional bodies-of these so called professionals do not educate their members who continually strive to be 'not liable'."
- "There is a very real problem in the construction industry. There has been little correlation between the Health and Safety Specification(s) and the actual bill of quantities when it comes to providing specific itemised issues to price. I feel that the Quantity Surveyors do not know where to start with this important process. Maybe one of the service deliverables of the appointed Health and Safety Agent should be to provide co-ordination of this process in the 'Concept and Viability' stage of the project.
- "Health and Safety and the Environment should be a direct cost to the contract and should always be included in the rates for design and rates for construction."
- "Since the introduction of the H&S Regulations (2003) it has been a struggle to get the smaller SMME, BEE, BWO companies to accept the importance of working safely. Their H&S costs are only there now since we have forced them to comply otherwise they are very reluctant to add any cost. The H&S paradigm shift with the smaller companies is almost non existent until they want to become a vendor for our company. Some how I believe the bottom line of the project should be separate to the H&S cost as we have contractors who do not qualify for the project due to H&S costs, yet they are the better contractor. The winning contractor has almost

always come in on a shoe string H&S budget to win the work. I have rejected the lowest tender due to insufficient H&S plan documentation as this is a forerunner on what they will deliver in terms of project H&S if the documentation is incorrect and insufficient. This has been met with great resistance. They refuse to spend money on H&S consultants or H&S officers to run the company's H&S. They believe in copying H&S plans or that regurgitating the H&S regulations will suffice. We have a standard line in our NEC for cost for the H&S plan and H&S file which they charge us, but still they seem to spend as little as possible in the field of H&S."

- "On projects where financial provision for health and safety, contractors will save that money as their profits, or they will compromise on PPE. Financial provision for health and safety should be a priority and then be monitored."
- "I believe that basic guidelines should be included in legislation. Further, that Quantity Surveyors must be made more aware of the importance of making provision. Client, employers and agents must be made responsible to ensure that provision is made and reported on at project meetings. NB Health and Safety costs are hardly ever reported on at site meetings. Incident statistics - numbers, extent, and cost are virtually never discussed either at project meetings or health and safety committee meetings. Clients and employers, as a general rule do not know what their COIDA assessment rates are, what-cost of claims are?"
- "Our company is in the H&S consulting business to help contractors to view H&S as a positive way of safe work procedures as well as reducing the amount of lost time causing injuries. However, we are faced with contractors who mainly approach us for service when they can only be given contracts if they also provide H&S for the project and it usually does not take long for us to realise that contractors are not really keen in the provision of H&S, and they usually view it as a hindrance and never mind to let us know that they either did not price for this H&S, and that they have been doing business for x-amount of years without this H&S. They normally view us as parasites who are affecting their profit margins. The few who are keen on promoting H&S in their projects. It is sad that some principal agents as well as client's representatives (esp. in municipalities and private clients) will not take it upon themselves to ensure that the contractor complies despite the H&S reports providing proof that compliance is at an all time low; their sole goal is to see the project completed. The project units in the municipalities and other should take it upon themselves to include and make H&S requirements in the tender documents. The Department of Labour should also train their inspectors to assist contractors without intimidating them. A positive attitude towards H&S will go a long way to ensure that workers also view H&S as a positive way of doing work."
- "Even in the rare instance when a detailed H&S section is included in the preliminaries, and, it has furthermore been made clear in the document / compulsory briefing that failure to price the items realistically will result in the tender being deemed non-responsive; tenderers tend not to utilise the opportunity; designers tend to recommend to the client the lowest tender / tenderer (regardless); clients tend to accept the 'preferred tender / tenderer'

even if recommendations made relative to H&S are not supportive / assuring."

KZNMB

6 Comments were received from members of ACHASM, some lengthy, which equates to a mean of 0.75 comments per respondent. These comments are also presented verbatim:

- "A provisional sum for H&S should be given to all contractors tendering, thus preventing contractors from under budgeting for H&S in order to win tenders."
- "Each project has its own specifications. A lot of 'cut & paste' is taking place, because I have noted several specifications that are totally irrelevant to the specific project. Projects differ vastly with regard SHE requirements, which have a major impact on costs. Example is that a number of companies do not carry out medicals (entry & exit) if it is not a requirement from the client. In our case we do it regardless because we care and want to ensure that our employees go home as well as when they have been when they became our employees or even better. Hazards are not always clear in tender documents and place extra cost on you as a contractor because you only become aware of it later during the contract. This also goes as far as environmental assessment studies, which are not always addressing the impacts. In my opinion the client should do a complete HIRA with all the relevant role players (principal and subcontractors) led by the client or his qualified representative. This will eliminate a lot of confusion and unnecessary costs."
- "The requirements for Health & Safety should be itemized as are normal bill items such that all competitors price the same legal requirements."
- "Contract value 3% for H&S should be a must to all companies to keep up standards as required by the MBA and Department of Labour & NOSA."
- "Clients with assistance from his consultants should specifically indicate what Health and Safety requirements to personnel etc. are required on the project to ensure all tenders match provision at tender stage."
- "The client does not normally take the cost of implementing & maintaining H&S for the project into consideration when awarding tenders. This then also filters down to the subcontractors appointed by the principle contractor and has an overall effect on the H&S for the projects."

5. CONCLUSIONS AND RECOMMENDATIONS

Contract documentation, documents, and other references do not address H&S to the requisite extent. Therefore, it can be concluded that the originators are not committed to H&S, do not view H&S as a project value, and that the overall construction environment is not conducive to optimizing H&S. The aforementioned is reinforced by the finding that contract documents have not facilitated financial provision for H&S subsequent to the promulgation of the Construction Regulations on 18 July 2003, H&S specifications included. The committees responsible for the development of contract documentation should commit themselves to raising the profile and status of H&S through the inclusion of appropriate H&S related clauses, which reflect the requirements of the OH&S Act and the Construction Regulations. H&S specifications should be project specific, record residual hazards, be included in contract documentation, and be linked to the facilitating of financial provision for H&S. Adequate financial provision for H&S should be facilitated through the inclusion of a detailed H&S section in the Preliminaries, or at the very least the inclusion of a provisional sum for H&S.

The mean percentage H&S constitutes of tender and project cost is 3.8% and 2.4% respectively, but according to KZNMB members is 1.6% and 1% respectively. Given that ≤ 33.3% of respondents' organisations compute the percentage H&S constitutes of project cost, it can be concluded that their project cost or cost reporting system does not facilitate the recording of H&S costs. Contractors should determine the cost of H&S. Furthermore, the mean percentage constitutes a dilemma as the percentage is dependent upon a number of variables, inter alia: project cost; duration; sector of construction; type of construction; type of building; number of floors; floor area; structural frame; number of workers, and degree of subcontracting.

Despite the intimate involvement of the members of ACHASM in H&S and the H&S achievements of the KZNMB respondents, the traditional project parameters of cost, quality, and time are more important than H&S. This finding leads to the conclusion that H&S is not a value in the overall construction environment nor is the latter conducive to optimizing H&S. Built environment councils and voluntary associations should raise the status of H&S within their constituencies.

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Conceptual Model of Safety Culture for Construction

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Abstract

An organization's safety culture has been identified as a significant determinant of a firm's safety performance. Previous research into safety culture in construction has lacked a fundamental conceptual model of safety culture in construction that reflects the bifurcated nature of a construction firm into home or corporate office and project sites. This paper presents a conceptual model of safety culture in construction based upon the Schein's model of organizational culture, Schneider's model of organizational climate, and Cooper's work on safety culture. The model incorporates the importance of viewing a construction project as a temporary, multi-organization. It also distinguishes organizational safety climate and workgroup safety climate.

Keywords: Safety culture, safety climate, conceptual model

1. Introduction

Characteristics of Construction

The development of a conceptual model of safety culture in construction requires an understanding of the characteristics of construction to understand why the concept of safety culture in construction is different from that of other industries. These characteristics are:

- In other than very small construction firms, there are two distinct parts of the organization: an office component responsible for obtaining and administering projects and performing corporate functions. There is also a field or project component responsible for performing the actual construction work. The office work environment is relatively free of hazards. The significant hazards and risks of construction are in the field. Therefore, the focus of construction safety culture must be on the construction project. However, the home office, particularly firm executives, will influence the safety culture of the project. The mechanisms by which the home office influences the safety culture of the project and the extent of that influence must be examined.

- A construction project is a temporary system (Bryman, et. al. 1987) established for the express purpose of constructing a facility. When that facility is completed, the project organization is disbanded. A construction project may also be termed a multi-organization (Cherns and Bryant, 1984) in that a project may involve designers, consultants, general and/or prime contractors, specialty subcontractors, fabricators, and material suppliers. Each of these has the potential to expose workers to a wide range of hazards or to protect them from those hazards. The project participants perform a variety of roles and are involved in the project at different points in the project's life-cycle and for differing durations. The critical issue for safety in this temporary, multiorganization is how to develop an integrated safety culture that minimizes the construction workers' exposure to hazards and related risks. The compressed timeframe exacerbates the task of culture creation given that many of the project participants may have little shared experience.
  The term project safety culture may be a misnomer because the duration of most projects is far too short to develop cultures of their own. Thus, Schein's (2010) analogy of culture as an iceberg is particularly relevant to construction. In terms of the project, the cultures of the owner, general contractor/construction manager, and the subcontractors lie below the surface. What can be seen above the surface are, in Schein's terms, the behaviors and artifacts of the project, i.e., the project's climate.

- In building construction, the prime contractor (the contractor with whom the owner has a contract) typically self-performs less than 20% of the total project with the remainder being performed by specialty subcontractors. In industrial construction, the prime contractor, in many cases, performs all of the work on the project using workers directly hired by the contractor. The task of creating an integrated, unified project safety culture on projects with extensive subcontracting is very different from doing so on a project with no subcontracting.

- In a 2009 decision, the Eight Circuit Court of Appeals in Solis v. Summit Contractors, Inc. and Occupational Safety and Health Review Commission 558 F.3d 815 (8^{th} Cir.2009) affirmed the application of the Occupational Safety and Health Administration's (OSHA) "multiemployer worksite doctrine" to general contractors and other employers (construction managers) who exercise control over construction worksites. These employers are considered "controlling employers" in that they have general supervisory authority over the worksite including the power to correct safety and health violations or require others to do so. Thus, the general contractor/construction manager may be held liable for safety violations and, therefore, has a vested interest in the development of an effective, integrated safety culture on the project as opposed to a collection of independent safety cultures, one for each employer on the project site.

- Construction differs from manufacturing in terms of the roles of personnel in the design and transformation processes. As 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 architect and/or engineer define the product to be constructed while the craft workers who will perform the work, plan the work process. He 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…" However, given the changes in construction (e.g., extensive deskilling) over the past thirty years, the extent to which the construction worker exercises control over the means and methods to be employed in constructing a project must be empirically determined

- A primary goal of a construction project manager should be to develop an integrated project safety culture that creates the safety environment needed to achieve zero incidents. The project safety culture will emerge from the interaction of the constituent cultures and the leadership of the project management team. Because the industry is characterized by personnel moving between projects and companies, a group's safety culture is a "learned product of group experience" (Schein, 2010) as to what worked in solving problems on the projects and within the various groups and organizations. The extent of congruence between the cultures of the various groups and organizations within a project (managers, engineers, superintendents, foremen, and craftworkers as well as contractors and construction managers) must be examined.

2. Conceptual Model of Safety Culture for Construction

Corporate Office Safety Culture

Figure 1 presents a model of corporate office safety culture and safety management system.

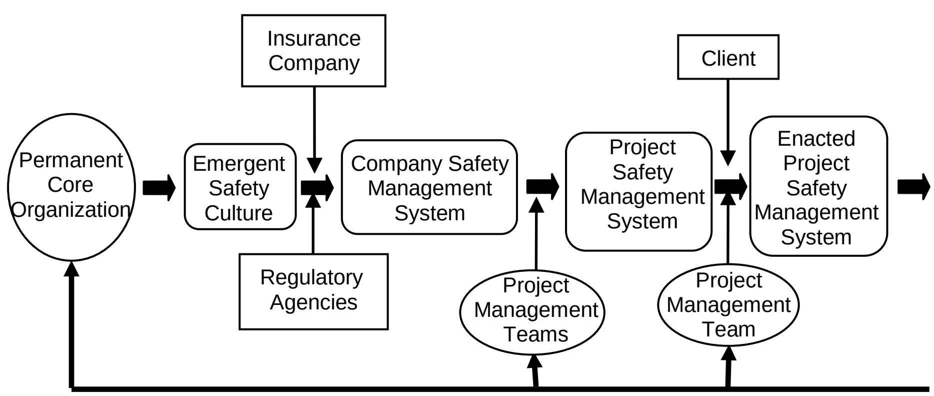

Figure 1 – Corporate Office Safety Culture and Safety Management Systems

Construction organizations may be viewed as consisting of three groups:

- Permanent core organization – executives, engineers, professionals, etc. who have varying lengths of tenure with the organization but are considered permanent employees.

- Quasi-permanent project management team – project managers, engineers, superintendents, etc. who are responsible for getting a project built within specified criteria. The members of this team are quasi-permanent employees in that they remain employed by the firm as long as the firm has sufficient project work. Absent that work, the members are released and rehired when additional work is obtained.
- Temporary supervisory and craft personnel hired on an as needed basis for a project.

The initial assumptions, beliefs, and values of the organization are brought to the organization by its founders. Over the life of the organization, those individuals in the permanent core interact with one another in a reciprocal influence process in the tacit or basic assumptions, beliefs, and values held by each person are shaped by experience with the result that a set of assumptions, beliefs, and values, shared by the members, emerges. These reflect the members' experiences as to what works in providing a safe work environment and may be termed the Emergent Safety Culture (ESC).

The Emergent Safety Culture is manifested in the organization's Company Safety Management System (CSMS). This system represents the espoused values of the organization and is a statement by the organization as to its values and how those values are to be embodied in the organization's policies, procedures, and practices. The elements of a Safety Management System were identified in a National Safety Council publication (Czerniak and Ostander 2005) and by others (Cooper & Phillips, 2004). These elements are incorporated into Reason's (1998) five levels framework in Table 2.

Level	Safety Management System Elements
Strategic	• Managerial Leadership and Commitment • Accountability
Tactical	• Assessments, audits and continuous improvement • Organizational communications and system documentation • Risk Assessment & Risk Management
Operational	• Hazard recognition, evaluation and control • Workplace design and engineering • Employee involvement & participation • Employee training
Behavioral	• Operations & Third Party Services • Motivation, behavior and attitudes
Defensive	• Information/Documentation • Maintenance • Management of Changes, • Incident Investigation & Analysis • Community Awareness & Emergency Preparedness • Operations Integrity Assessment & Improvement

Table 2 Safety Management System Elements in Reason's Framework

The Emergent Safety Culture can be assessed by mapping it on the Company Safety Management System (Johnson and Scholes 1993) along the following dimensions:

- Routines - how people routinely behave towards each other in relation to safety; and, what routinely occurs with regards to safety management.
- Rituals – how the organization reinforces safety behavior.
- Stories – the messages transmitted by employees' stories about safety.
- Symbols – the symbols used to communicate the importance of safety to employees.
- Power – the beliefs about safety held by the company's leadership and how it is translated into practice.
- Safety Structures – the formal and informal safety mechanisms are in place.
- Safety Controls – what the organization measures, monitors, and reinforces.
- Relative Importance of Goals – the relative importance of efficiency goals (e.g., schedule, budget, & quality vs. safety goals.
- Beliefs and Values – the beliefs and values that guide safety thinking.
- Underlying Assumptions - a summary description of the company's actual safety philosophy.

The Company Safety Management System (CSMS) cannot be developed in a vacuum. Two external entities may exert influence: (1) regulatory agencies such as the Occupational Safety and Health Administration, which impose a minimum set of requirements and (2) the firm's insurance companies who may require additional or more extensive elements in the CSMS to address issues of specific concern.

Because construction companies undertake projects to make money, the CSMS does not remain on a shelf in the home office but is taken out to the field by Project Management Teams (PMT). The PMT is charged with getting the project built within specified criteria such as budget, schedule, quality, and safety. As a result of feedback from the Project Management Teams, the CSMS is adapted to the requirements of the projects and becomes the Project Safety Management System (PSMS). The CSMS, which is developed at the corporate level, is modified to reflect project requirements to become the Project Safety Management System (PSMS).

The Client may impose more stringent requirements than those contained in the CSMS because the client, for a variety of reasons, desires a more rigorous system.

The PMT assigned to a project brings the PSMS document to life by implementing the policies, procedures, and practices, spelled out in the document, thereby transforming the paper document into people and processes. In doing so, the PMT may adapt, modify, or even ignore elements of it. It may establish differing priorities for certain elements than those established in the PSMS. In the interest of improved safety, the PMT may change elements. The PMT must also consider the Client's requirements, which may necessitate additional policies and procedures. The goal is not to have a safety management system, but a safety management system that works. Thus, the firm's PSMS becomes the project's Enacted Project Safety Management System (EPSMS).

Project Safety Culture

The Project Safety Culture Model is presented in Figure 2.

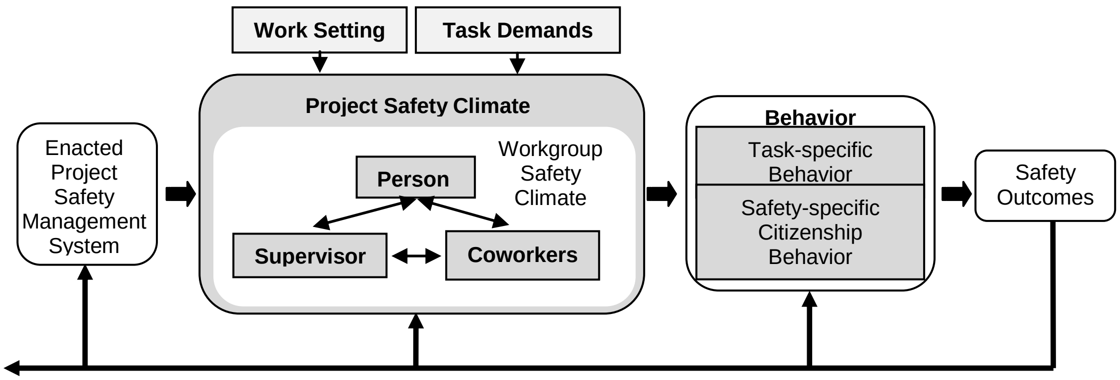

Figure 2 – Project Safety Culture

Construction work is performed by craft workers under the supervision of trade supervisors or foremen. These individuals are hired on a temporary basis to execute the work. This work is performed within a context consisting of: (1) task demands - the worker's perceptions of the physical and mental activities that must be performed to complete the task and (2) work setting, which has three dimensions (Riemer, 1975). These are: (1) structural components, which include the setting, i.e. the project site, the specific work location within the site, and the inanimate physical objects and their arrangement and the people within the setting as objects; (2) dynamic components that are the people within the site as actors; and (3) coordinating dimension, i.e. the location of activity within the coordinates of time and space.

Project Safety Climate (PSC) must be examined at two levels: (1) organization level – worker perceptions of the policies and procedures employed on the project and management practices with regard to safety and (2) group level - worker perceptions of their specific supervisor & the supervisor's expectations for safe behavior and his/her safety practices (Zohar and Luria, 2005; Lingard, et.al., 2009). In construction, workers have discretion as to the methods to be employed in the performance of a task. Tasks are rarely performed by a single worker; the workgroup has an influence on its members in terms of safe performance of assigned tasks. Thus, the workgroup must be considered as an element in safety climate. Worker perceptions of his/her workgroup, the expectations the workgroup has for safe behavior, the workgroup's perceptions of the risk involved in their work activities, the workgroup's practices with regard to safety, and the level of peer pressure exerted by the workgroup for compliance with group safety practices.

In addition, the worker's life experiences influence how the worker perceives the situation. The worker's perceptions are influenced by his/her history of injury, propensity for risky behavior, perception of risk in the work, and motivational state and desired rewards. The worker's perceptions of the contextual elements are taken into account in making the decision to engage in safe or unsafe behavior.

Culture provides a framework within which individuals decide how to behave. The product of safety culture can be defined as "that ***observable*** degree of effort by which all organization members direct their attention and actions towards improving safety on a daily basis (Cooper 2000)." Thus, behavior, which is observable, is the product of safety culture and provides the best indication of the nature of that culture.
Behavior must be examined in two distinct categories:

- Task-specific behavior – behavior with the objective of task performance and includes performance of all activities required to complete the task in a safe manner. Examples are wearing PPE, tying off when working at heights, wearing hearing protection when breaking concrete, etc.
  This behavior is typically addressed within a behavior observation system. Observers assess behavior in terms of whether it is safe or unsafe. For example, "When working at heights, workers are using safety harnesses with a double lanyard or using tool bags to life tools and small equipment." The percentage of workers observed using the safety harness with a double lanyard is tracked as the Percent Safe. The goal of the behavior observation program is to increase the Percent Safe to 100%
- Safety-specific behavior
  - Behavior that reflects a commitment to safety as an active citizen of the project community. This has been termed citizenship behavior (Hoffmann, et.al.., 2003) and includes behaviors such as volunteering for safety committees, making safety-related recommendations about work activities, and getting involved in safety activities to help my crew work more safely.
  - Behavior on the part of supervisors that reflects commitment to safety such as discussing safety performance with employees on a one to one basis, developing plans for corrective actions, and assisting an observer in providing team feedback.

This behavior results in Safety Outcomes, i.e., the lagging indicators, of the safety process, which: safe completion of the activity, near miss, accident, injury (nonfatal or fatal). Behavior and Safety Outcomes provide feedback to craftworkers, supervisors, project management personnel, and corporate office personnel to provide learning.

Operationalization of Project-Level Model

A worker makes the decision whether to perform a job safely within the context of the cultural milieu in which he/she functions. Safety culture can be viewed as the product of goal-directed interactions between people (psychological), jobs (behavioral) and the organization (situational) (Cooper, 2000) as shown in Figure 3.

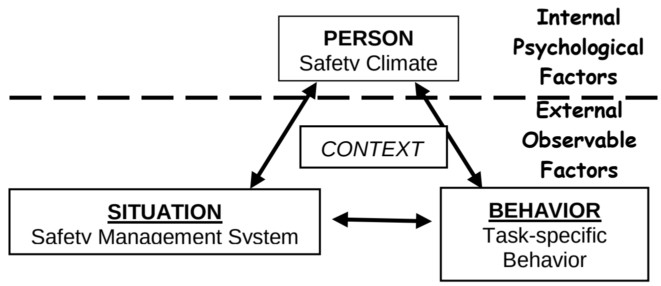

Figure 3 –Reciprocal Safety Culture Model

Context: the worker is assigned (1) to perform a task, which demands specific actions by the worker and (2) to perform the task within a specific setting.

Situation: all work on the site is to be performed in accordance with the tenets of the Enacted Project Safety Management System, which reflects the organization's safety culture, i.e., how things are to be done. The extent to which the EPSMS is implemented and followed may be determined through a system audit that yields a percentage score. Project management designs the EPSMS and, through their actions, implements it.

Person: The worker is influenced by three elements: The first is the individual's Knowledge, Skills, & Abilities, which are specific to the task and job for which the worker is employed. These are acquired through a technical socialization process reported by Riemer (1975). As a result of this process, which may involve formal off-the-job training, formal and informal on-the-job training, and experience, there is a relative fit between the person and the job.
The second element, psychological factors, encompasses factors that are inherent to the person as well as those that are a response to the person's off the job and on-the-job experiences such as injury history and perception of risk in the work. An inherent factor is the individual's personality and, in particular such dimensions as propensity for risky behavior. Off the job factors are influences on the person's mindset such as relationship with spouse and children, time demands, health, etc. On the job factors involve the person's reaction to the job and the organization and include such factors as motivational state and desired rewards, organization commitment, goal commitment, goal conflict, role ambiguity, job-induced stress, and job satisfaction (Cooper and Philips, 1995). It also includes the project's Safety Climate, which operates on two levels: project-wide and the workgroup.

People act based upon their perceptions, which are influenced by the worker's capabilities and psychological state of mind, of a situation; therefore, safety climate is believed to have a significant influence on a group member's behavioral decision-making. The strength of the workgroup's safety climate influence on worker decision-making relative to that of the organization's safety climate must also be considered.

Behavior: As a result of the influence of the situation and the psychological factors, the worker makes a decision as to whether to engage in particular behaviors. As stated above, the product or result of a particular safety culture may be defined as that "observable degree of effort through which all organizational members direct their attention and actions towards improving safety on a daily basis" or, in other words, behavior. Safety behavior can be divided into the three categories discussed above: compliance, citizenship, and leadership. The three behavior measures can be converted into a percentage score.

An overall measure of safety culture can be calculated as follows (Cooper 2008):
Safety Culture Score = (Safety Management System Audit Score + Safety Climate Survey Score + Safety Behavior Score)/3.

Product of Safety Culture

The product of safety culture can be defined as "that ***observable*** degree of effort by which all organization members direct their attention and actions towards improving safety on a daily basis (Cooper 2000)." What is observable, and, therefore, evidence of safety culture, is behavior. It is useful to distinguish between required and discretionary behavior. The task-specific and leader behavior discussed above can be considered as required job behaviors while the safety-specific behavior can be considered discretionary. The required behaviors are assessed and included in the Safety Behavior Score in the above equation.

Discretionary behavior has been termed citizenship behavior. Hoffmann, et. al. (2003) developed a 27-item safety-specific citizenship behavior scale that can be utilized in two ways. Craft workers can be surveyed to determine which of the behaviors are considered to be a core element of their job. The number of behaviors considered to be core elements should be related to the strength of the safety culture such that the stronger the safety culture, the greater the number of core elements. The frequency with which a worker engages in each of the behaviors should also be related to safety culture strength. Supervisors can assess workers on this frequency; the stronger the safety culture, the greater the frequency of engaging in these behaviors. An index of safety-specific citizenship behavior can be created such that this index score is a function of the safety culture score.

3. Conclusion

This paper presents a conceptual model of safety culture for construction organizations that reflects the influence of the corporate or home office on the project safety environment. The model addresses the influences on worker decisions regarding safe behavior. It provides the framework for extensive study of safety culture and the factors that influence it.

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Preventing Fatalities in Construction
A Report from the NORA Campaign Work Group

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Abstract

About 1,000 fatalities occur in construction every year in the US. The National Occupational Research Agenda (NORA) concluded that regulations and enforcement may not be sufficient to impact this number and recommended a national campaign to prevent fall fatalities. A campaign work group was set up by the NORA Construction Sector Council. Based on the data, the work group focused on falls from roofs, ladders and scaffolds. Subgroups are discussing each of these problems and developing strategies to address them. The work group is planning a campaign to begin in Spring 2012. This presentation is a status report on that effort.

Keywords

Falls, Fatalities, Campaigns

1. Introduction

Each year about 1,000 construction workers die on the job in the US. While this number has dropped in recent years due to the recession and 20 percent construction unemployment, it has been difficult to reduce and may tick up next year as employment improves. The NIOSH National Occupational Research Agenda (NORA) for the Construction Sector established 15 strategic goals in 2008. The first three relate to the prevention of traumatic injuries from falls, electrocutions and struck-by hazards. While additional research is necessary to fully understand these hazards and how to prevent injuries, the Sector Council acknowledged that we know, in general, how to prevent them and our primary challenge is to get contractors and workers to implement known interventions effectively. For that reason, Intermediate Goal 1.5 was developed: "Work with construction partners to develop and implement a national campaign to reduce fatal and serious injuries associated with construction falls to a lower level." A timeline of three years was given in the NORA goals to evaluate options and prepare a proposal for the campaign and the next two years to convene stakeholders to begin implementation. In 2010, a work group of the NORA Construction Sector Council was formed to develop a proposal for a national campaign. This paper is a status report on the work of that group.

Over the past decade there have been many public health campaigns to reduce occupational injuries and fatalities in Europe. In the US, such campaigns have been used primarily to address non-occupational hazards like smoking, drunk driving and seat-belt use. Campaigns in the US around Work Zone Safety and Worker Memorial Day have drawn attention to occupational safety, but these campaigns have not been targeted at specific hazards like preventing falls or electrocutions in construction.

The Sector Council and a campaign work group of the council met throughout 2010 to identify a focus for the campaign. After much discussion and evaluation of the research evidence, the decision was made to focus on prevention of fall fatalities, as this is the leading cause of construction fatalities in the US (representing about one-third of all construction fatalities), and it is aligned with the NORA construction goals. This focus was further narrowed to falls from roofs, ladders and scaffolds as these three problems combined represent about two-thirds of all fall fatalities and about a quarter of all construction fatalities in the US. Of the 332 fall fatalities in the US in 2008 (out of a total of 957 construction fatalities that year), 98 were from roofs, 64 from ladders and 52 from scaffolds. Campaign subgroups were set up to focus on and discuss each of these three areas. A charge was developed for the subgroups, requesting that each:

1) Research the problem to identify major causes and prevention strategies
2) Identify stakeholders and researchers working on this problem
3) Identify and review existing materials
4) Identify barriers and opportunities (perhaps through focus groups)
5) Develop a strategic plan based on the following questions:
    a. Who do we need to target?
    b. What behaviors do we want to change?
    c. What messages might be effective?
    d. Through what channels do we need to deliver the message?
6) Identify gaps that need to be filled in terms of materials and who will create them
7) Determine how to evaluate the effectiveness of the campaign

The subgroups began meeting in April, 2011, and should complete their work this summer. Below is a summary of discussions to date.

Roofing

A review of BLS CFOI data from 2006-2008 shows that about one-third of roof falls occur in residential construction. Almost half were falls from the roof edge. The rest fell through an opening or skylight or through the roof surface. About 37 percent of those killed were roofers. The rest were mostly laborers, carpenters and supervisors. About one-third occured in four states: California, Florida, Texas and Pennsylvania. One-third were Hispanic workers.

Roofing contractors and roofers are well aware of the fall hazards inherent in their work. The roofing contractor association and roofers union have worked for many years developing training and information materials on fall hazards to educate roofers and contractors. While most commercial work is done by larger, unionized contractors, many small roofing contractors, particularly those doing residential reroofing, do not belong to a trade association, and the roofers are not member of a union. It has been estimated that close to 90 percent of contractors do not belong to a trade association. Most of these small contractors do not have safety expertise on staff, rarely use any fall prevention measures and do not do any worker training. Many do not even know they are covered by OSHA. OSHA rarely inspects such sites as their enforcement targeting system captures primarily larger projects.

Recently, OSHA rescinded an over 20-year old compliance directive on residential roofing fall prevention which allowed employers to rely primarily on “slide guards” rather than guardrails or personal fall arrest systems. This change in enforcement policy may help a campaign focused on this sector since there will be both a new carrot (incentives and assistance) and a new stick (enforcement) to motivate them. The focus of a campaign aimed at these contractors would be to motivate them to use fall prevention measures. Many of them are small, family businesses that could be motivated to keep their family safe. This sector also has a very high percentage of immigrant workers, especially Latinos. Other parts of the campaign may need to be directed specifically at Latino workers, taking into account their reluctance to speak out about hazardous conditions for fear of losing their job or possible deportation.

Ladders

BLS CFOI data from 2006-2008 show that over a third of the 204 fatalities occurred at residential sites, and over half were at private residences. Laborers, painters, carpenters and roofers were the largest trades represented. About a quarter of the victims were Hispanic. The largest states represented were Texas, New York, California, Pennsylvania and Florida (40 percent of the fatalities were in these five states).

Ladder falls occur for a variety of reasons. These include: Using a ladder that is too short for the job; Transitioning from ladders to a roof of scaffold; Carrying materials up or down a ladder; Over-reaching; Using a ladder that is unstable, not set up properly or not secured; Using defective ladders. Without detailed ladder incident data (e.g., on activities of the workers at the time of the incident), it is difficult to narrow the focus. Too often, small companies may not have the proper equipment for the job, and, rather than get the right equipment and delay the job, they make do with the equipment they have. So one possible focus would be to emphasize planning, making sure you have the right equipment before the job starts. This group discussed a hierarchy for ladder safety:

1) Is a ladder necessary, or is there a safer way to access the work area?
2) If a ladder must be used, do you have the right ladder for the job?
3) If you have the right ladder, is it structurally sound?
4) If you have the proper, structurally sound ladder, is it set up properly?
5) If so, is it being used properly?

Programs have been developed to address some of these issues, for example, the "Ladders Last" program from Turner Construction to address the first issue and the Ladder Exchange program of the British Health and Safety Executive (HSE) for the third issue. Proper set up and use have been addressed by most training programs. However, while teaching proper use and set up, they often do not deal with why people may not use or set up the ladder properly. Just as incident investigations do not always deal with root causes, unless programs deal with the motivational aspects, they are unlikely to be successful in changing behavior.

Scaffolds

Almost 200 fatalities occurred from scaffolds in 2006-2008 in the US. The BLS CFOI data show that about a third occurred at private residences (32 percent). Over half (54 percent) were laborers, carpenters or bricklayers. Over one-third of these fatalities (38 percent) occurred to Hispanic workers. Four states (Texas, New York, California and Florida) comprised over 38 percent of the fatalities with 18 fatalities (almost 10 percent) occurring in New York City alone. Scaffold violations are the number one citation from OSHA in 2010.

There are many different types of scaffolds e.g., (supported, suspended, aerial lifts, mast climbing). Each has its own inherent hazards. Scaffold fatalities often involve improper construction of the scaffold (e.g., not sufficiently planked, not plumb) and unsafe methods for access. Scaffold erection and dismantling present unique fall prevention challenges. OSHA also requires a competent person to oversee scaffold safety, which could present an opportunity for intervention. A new scaffold safety law in New York City, where a large number of incidents have occurred, may help any campaign initiated in that area. In fact, NYC just launched its own fall safety campaign in April 2011, with the theme "Experience is not enough." Scaffold manufacturers have expressed an interest in partnering on this effort.

Campaign elements

The heart of any effective campaign is good materials. The main purpose of the materials is to raise awareness of a problem and motivate a change in behavior to increase protection and reduce the risk of injury or illness. Messages have to be short. They have to be field-tested to see if they are relevant and make a difference. They have to be distributed through communication channels normally used by the target audience. There may be several target audiences and different messages may be needed for each audience. For some audiences, the only effective message will be that they will get penalized (citations and fines) for not behaving properly. Thus, a companion part of the campaign needs to be enhanced enforcement efforts by federal and state OSHA programs targeting this sector and these hazards. For this reason, efforts are underway to obtain a significant commitment from federal (and perhaps state) OSHA to be a lead partner in this effort. Efforts have already been made to reach out to others in the process of developing similar campaigns, such as the Massachusetts Department of

Health and the Labor Occupational Health Program at the University of California at Berkeley (which is focused on preventing falls specifically among Latino workers).

Next steps

The three focused work groups will report back about their discussions at the June 2011, NORA Construction Sector Council meeting. At that meeting, the Sector Council will make some strategic decisions about moving forward. Several options will be discussed including, moving forward with a campaign in these areas simultaneously or sequentially; moving ahead with a campaign in one region as a pilot project (perhaps targeting one of the high risk states) verses nationally; making a significant effort to reach out to potential partners, particularly those who can make a financial commitment to the effort; developing a revised timetable for the campaign, a strategic plan and a budget (currently scheduled to kick off in April 2012) and; whether or how to include traumatic injury prevention in the campaign as well. A report on these discussions will be provided at the CIB conference in August.

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A CONCEPTUAL FRAMEWORK GENERALIZED INFORMATION MANAGEMENT SYSTEM UTILIZING QUICK RESPONSE CODE

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ABSTRACT

It is investigated that the size of construction site and safety disaster ratio are inversely proportional, and similar safety accidents are happened repeatedly. Therefore, KOSHA opens various safety accident cases by organizing as DB in order to prevent safety accident. However, when considering that safety disaster ratio happened at small & medium sized sites is high, it can be appointed that opened DB of KOSHA is not used efficiently to safety plan and employees training, which can be indicated that it has an actual problem in data delivery and utility rather than that in data level.

While, QR code developed accompanying with the development of mobile technology has a characteristic of being provided with necessary information via smartphone regardless of time & space. By using such characteristic of QR code, this article is to suggest the system which can search safety information of KOSHA efficiently according to due task in order to maximize QR code use in safety management. Suggested system has a generality, and it can deliver only vital information to due task to administrator & employee. By using this, it is judged that it can improve the limitation of safety management plan depending on limited safety training information and experiences used in small & medium sized sites.

1. INTRODUCTION

Construction disaster has the feature that similar types of disaster are repeated, and compensation due to safety accident is about 3.5% of total construction cost(Coble, 2000). To prevent the safety accidents, various researches on connecting method with process management(Yang, 2004), task linkage with PMIS and safety management (Kim, 2010), systematic attempts for the management supports like use of smart phone(Handikusumo, 2006) and safety education suitable for the labor's characteristics(Kim,2008) have been performed. Also, KOSHA provides information related to safety such as safety accident information and safety management manual with various types.

However, in spite of such efforts, safety accidents are occurred continuously, which means that existing safety management and training are not effective.

Meanwhile, existing accident cases among data which can be sued for the safety management can provide the good safety information because construction has almost similar orders and types of process, only different construction places(Go, 2001). Thus, for the accidents showing for each construction process, reason of disaster can be considered to establish the safety management plan suitable for project environment and situation.

However, if we look over the actual condition of safety management and education in Korea, there is limitation that safety plan establishment is only focused on personal experience because professional safety manage is insufficient in the construction site, other than few top most construction companies (Yang, 2004). Also, because labor safety education is executed formally, there are a lot of problems.

In such viewpoint, this study is to recognize the problems of safety management currently implemented based on existing documents to the recognition related to the safety of site administrator and employees and safety disaster status of construction in Korea first. For suggesting the solution to this, we intend to build the safety information system using QR code characteristics which can deliver vital information via smartphone regardless of time & space and the system which can effectively use KOSHA DB to safety management tasks.

2. LITERATURE REVIEW

In case of small sized companies, it is indicated that they have poor working environments due to capital shortage, not having qualified personnel, not equipping safety facilities, and not organizing safety rules or systems and have high disaster ratio comparing to large sized companies. In order to recognize such realistic problems in general viewpoint, we are going to search the importance of training in safety management and safety accidents per company size, and to investigate the actual state of safety management in Korea recognized in site.

Safety accidents by the project scale

Table 1 researched industry disaster ratio per company size distributed in whole industry and only in construction industry. When considering in whole industry, as company size is small, disaster ration increases. Disaster ration of construction industry of whole industry is 22%, and similarly to disaster ratio trend of whole industry, in case of small sized companies, disaster ratio increases. This means that in case of large sized companies, safety related system is equipped and by planning, implementing, and controlling safety management activities with qualified personnel, safety management is made systematically. In contrast to this, for small & medium sized companies, non-qualified personnel take charges in safety related tasks generally, and therefore, specialized knowledge are insufficient and systematical safety activities are not expected.

(An, 2008) In other words, it can be judged that the plan for reinforcing safety activities of small & medium sized companies is very urgently needed.

TABLE 1 DISASTER RATIO IN INDUSTRY

Business type \ Size		Total	1~5	5~9	10~29	30~49	50~99	100~299	300~499	500~999	1000~
Industry (100%)	**No. of company**	1,560,949	1,095,751	222,939	170,152	33,765	21,563	13,111	1,949	1,152	567
	No. of employee	13,884,927	1,919,024	1,439,956	2,720,329	1,269,793	1,475,474	2,118,527	736,018	784,354	1,421,452
	No. of Victim	97,821	33,663	14,647	21,936	7,613	6,745	6,778	1,551	1,549	3,339
	Disaster ratio (%)	0.7	1.75	1.02	0.81	0.6	0.46	0.32	0.21	0.2	0.23
Construction Industry (22%)	**No. of company**	236,747	167,701	28,012	24,936	6,052	4,677	3,773	862	507	227
	No. of employee	3,206,526	236,738	183,123	410,686	229,019	322,838	636,171	329,672	350,848	507,431
	No. of Victim	20,998	9,617	2,999	3,760	1,306	1,203	1,298	379	290	146
	Disaster ratio (%)	0.65	4.06	1.64	0.92	0.57	0.37	0.2	0.11	0.08	0.03

The Importance of Education for Safety

Construction disaster has the reason as all accidents have the reason certainly. Reasons can be divided into physical reason (Technical and management reasons) generated because there is no safety facility or protection equipment and human reason (Educational reason) starting from unsafe actions of labors or negligent of safety management. However, Heinrich (1980) states that most disasters are caused by human reason other than physical reason and takes 88% of total disasters.

As shown in above [Table 00], looking into frequency and ratio per cause of casualty in 2005 & 2009, the disaster caused by education was more than 40% before 2005 but being reduced to 20% currently seems that safety education has settled and has made good result in manufacturers & construction companies. (An, 2008) However, even until now, the disaster ratio by educational cause is 19.06% and in wide range, because task managing cause also has a close correlation with educational cause, the disaster ratio by whole educational cause is 61.33%. In such aspect, the size of disaster caused in Korea is same with that claimed by Heinrich. Also, personal factor which causes instable behavior contains physical limitation and knowledge, habit, and attitude to the work of each employee, and most of them can be removed through safety education. In such aspect, safety education is a vital safety countermeasure which can be used efficiently without independent limitation as well as has the most priority of means to reduce disaster. In other words, more fundamental efforts for removing educational & managing causes are required.

TABLE 2. CURRENT STATE OF OCCUPATIONAL ACCIDENT

Main Reason	Sub Reason	2005	2009
Technical Reason	1. Defect of structure and machine 2. Incongruent of material 3. Incongruent of construction method 4. Poor inspection and information retaining. 5. Etc.	41.53%	36.19%
Educational Reason	1. Lack of safety knowledge 2. Misunderstand of safety regulation 3. Lack of experience and training 4. Lack of work manner education 5. Lack of education of hazardous work 6. Etc,	41.10%	19.06%
Administrational Reason	1. Defect of safety organization 2. Absence of work regulation 3. Insufficient primary process 4. Insufficient headcount 5. Unsuitable job order 6. Etc.	17.28%	42.27%
	Total	100.00%	100.00%

The Actual Condition of Safety Management in Korea

To protect the labors working at the construction site, there are two methods. That is, work which make facility or environment safe, and execute the strict safety education for labors. However, because safety activity executed currently does not reflect the opinions of labors, but it is executed under the uniform plan of manager, it plays as the reason which reduces the efficiency of safety management (Hong, 2005).

To figure out the situation of safety management and problems in the construction site, this study summarizes the survey results executed for 20 managers and 85 labors in 30 construction companies within top 100 subcontracting capabilities (Hong, 2004) and survey for 150 labors working at the construction site (Kim, 1999).

- Court safety education: regular education, new employee education and special education has been executed for the safety education based on clause 1, article 33 of Industrial Safety and Health Ordinance. Regular education is the common education which all construction methods of workers are attended, so it is analyzed that characteristics for each construction method and work are hard to be reflected. Education for new employee is executed with the contents about work procedure and site facility status for more than 1 hour after attendance, so it is shown that reflection of characteristics for each work is insufficient. Because special education is executed only for the construction method regulated by law, education other than target construction method has not executed.

- Safety Management Organization: for the construction which construction cost is more than 12,000,000,000 won, two safety managers, and for more than 80,000,000,000 won, more than two safety managers should reside in the site to perform the safety management based on clause 1, article 12 of Industrial Safety and Health Law. However, for the site which construction cost less than 12,000,000,000 that safety manager does not have to reside, safety manger is not deployed due to labor cost, etc.

- Safety education method: most common safety education method is lecture (55.4%), audio and video (21.4%), accident case study (11.6%) and meeting (5.4%). However, 26% and 17.3% of respondents say that accident case study and practical training is required respectively for the efficient education method.

- Safety education text book: it is analyzed that safety education text book manufactured in the safety institute is modified in the head quarter and modified in the site depending on the condition. However, it is shown that characteristic for each type of work and work is hard to be reflected because this safety education is executed for relatively short period, 1~2 times monthly. Thus, it is necessary to create the systematic preparation of education contents based on detail work, construction method, and type of work and enforce its application.

- Safety education content and behavior: it is shown that most safety educations are executed in one place for workers of various methods, so education efficiency is low, and only 23% of educations are executed only suitable for the relevant method. Meanwhile, for safety education attendance behavior, it is shown that it is helpful (47%), mandatory (40%).

If actual condition of safety education is summarized, as subcontracting rank is lower, safety management manual and data supporting from the head quarter is insufficient. Also, due to lack of professional safety manager, safety relevant activity is planned only focused on personal experience. Thus, it is shown that common safety education and management which is not suitable for the method is executed.

For the plan to solve the problems of safety management and education in the small and mid-size construction site, this study sets up the goal with following contents. To find out the accident case needed for corresponding construction type, limitation of safety management plan establishment based on the experience should be improved and accident case suitable for the construction process executed by worker should be provided as the educational data to improve the efficiency of safety education.

3. THE CONCEPT OF GENERALIZED SAFETY INFORMATION SYSTEM

As a plan to solve the problems in safety management and safety education of small & medium sized construction sites considered in previous studies, this study suggests the concept of general safety information system like Figure 1. The goals of this system are as followings:

First, construct general system in order to utilize KOSHA information easily and efficiently. Through this, small & medium sized companies which have a difficulty in constructing self-safety management system can use many types of KOSHA information directly to safety management. As a next, if safety information related to due site or process is searched, partners & safety managers can select the most needed management element and education element at site from common system based on above. Such process can be a help to make a decision in reviewing similar cases of the limitation of plan establishment being dependent to experiences by reflecting various aspects of considerations. Finally, by selecting the information needed to be recognized by operator depending on task, it can be delivered with QR code. Through this, the effect of safety education can be raised by avoiding the limitation of typical safety education not considering characteristics per existing task and providing accident cases being appropriate to the process implemented by operator as educational data.

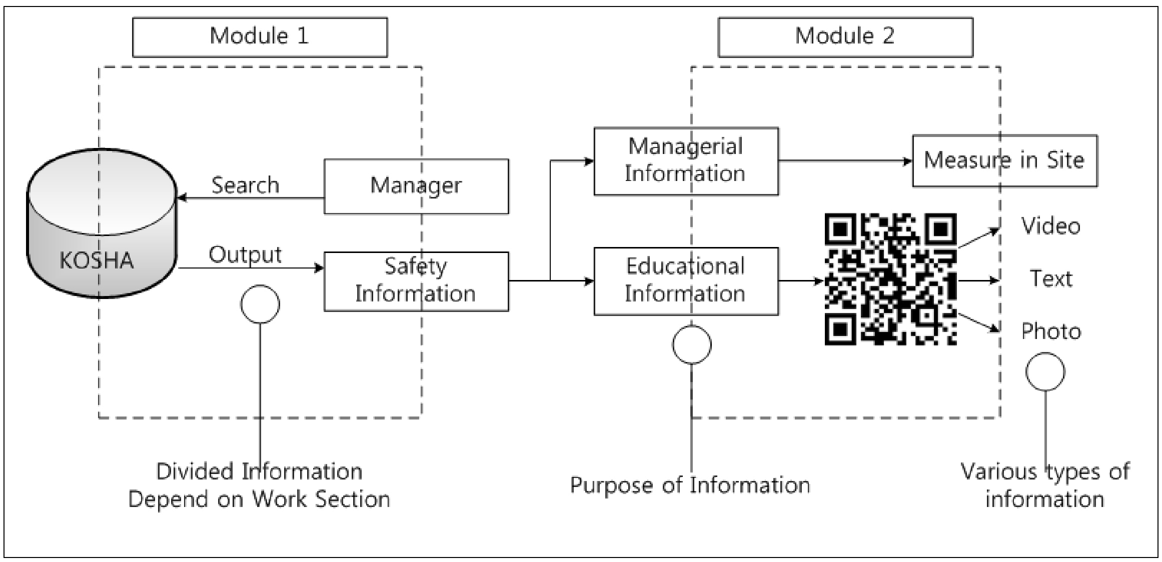

FIGURE 1. CONCEPTUAL SYSTEM STRUCTURE

This system suggests a plan to use database of KOSHA for its generality. This system is organized with total three modules such as searching module, index module, and virtual DB module like Figure 2.

Searching module implements searching functions by keyword and category. Keyword searching recognizes details to the information and is appropriate to the purpose of approaching to single case. This searching method is to search information by stopword processor for a word like keyword by synonym processor of index module. Also, category searching plays a role to arrange the information depending on work type by matching given tag when storing information by index module. At this time, arranged information has to be arranged from the order of high hits by page rank processor. Searched safety information creates virtual safety information DB per project on web by selecting the information only needed to project by administrator in project DB module. Therefore, safety administrators and charging staffs per work type can use DB needed to their own project anytime without organizing newly existing safety information DB and system and they can have a same type of information structure supported by system. Also, they can store new safety accidents or safety management countermeasure happened at site as a related category, and such information is stored to DB and continuous update and sharing can be made.

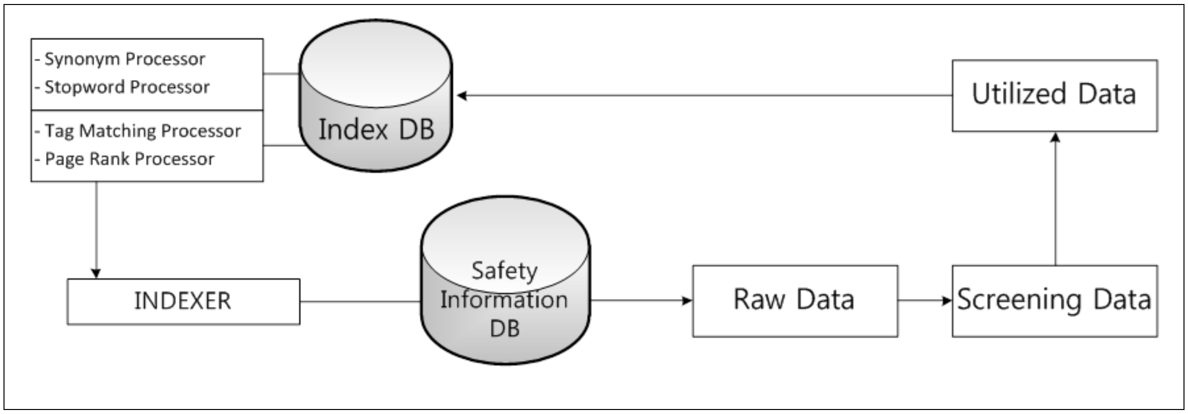

FIGURE 2 : SYTEM PROCESS

The most characteristic using QR code in safety management is to deliver selectively the most needed information. Such QR code delivers information via smartphone. Therefore, the delivery of information such as texts, pictures, diagrams, and videos which can be realized with smartphone is possible. By using the characteristic of such QR code, it is possible to deliver individually the most needed information to the currently implementing works. In other words, by directly using DB of KOSHA, the quality of education can be raised and because there's a differentiation of education information according to work characteristic and it can be avoided from temporal & spatial limitation of data reading, the effect of education would be improved.

Figure 3 shows the examples which can use QR code to the education of site employees. The information selected for employee training can be delivered to the company's manager who manages employees. Also, the information needed per work type and working group can be provided by attaching QR code to site working board. The providing information may contain many types of information such as videos, pictures, texts and news which manager feels to be needed.

That is, most of existing educations were made as a group education and same information was provided without the consideration to learners. Due to these, employees in non-related working type had no concern for learning and its effect was low. However, QR code can make users access to the selected information via smartphone. Therefore, individual employee can recognize disaster factor which can be happened at his/her work. If using this, it is judged that safety education being appropriate to employees per working type can be made by supplementing existing safety education with grouping method.

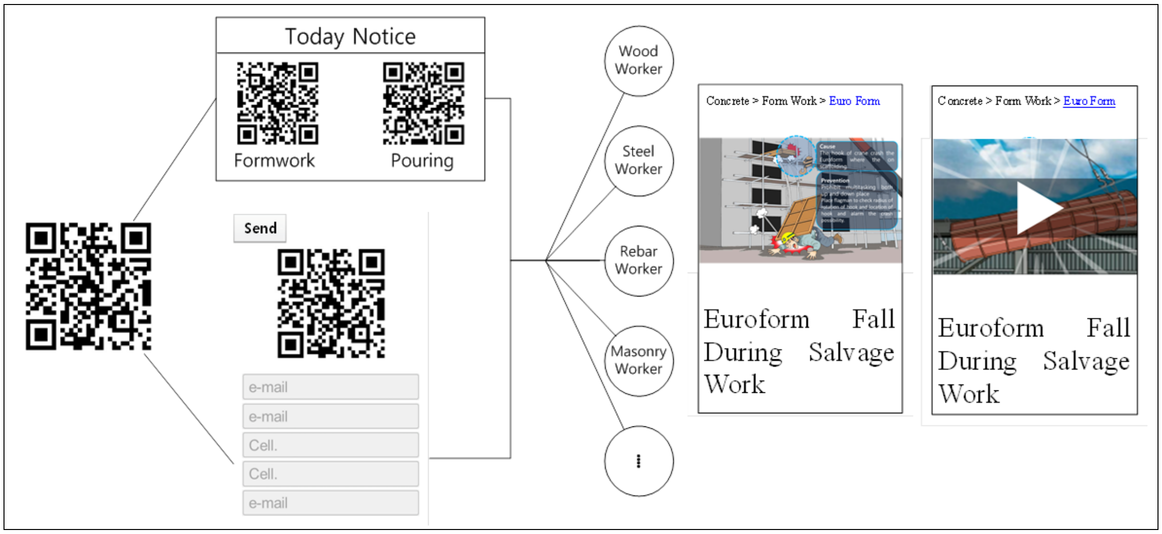

FIGURE 3. EXAMPLES OF UTILIZING QR CODE FOR SAFETY EDUCATION

4. CONCLUSION

In most small and mid-size construction sites which do not have the safety management system, safety management is not performed due to lack of safety education data and safety manager. Therefore, this article suggested the conceptual tool of general system which can use safety database provided by KOSHA in order to use safety disaster information efficiently even at site where safety managing system is not equipped.

This system makes safety manager search the major case information related to the construction types he/she executes, so it can help improving the limit point of the safety management plan depended on experiences. Also, Open Web-based system can be used in the small and mid-size construction sites where safety management system is not well applied without burden of costs. With this, searched case information can select the safety management information most required in the site through sharing and meeting with the manager in construction execution professional company. Information which should be recognized by the labor among selected safety cases will be changed to QR-code, so it can be posted inside of safety education center and construction site. This can provide the various types of education information (Text, illustration, video, etc.) provided from safety relevant institute to the workers through smart phone.

In order to realize general managing system suggested by this study, the system of institutes where safety related DB of KOSHA or OHSA has to be used, which has a limitation that the will of institutes is needed. It is judged that the level of currently organized safety information is so high. However, in an aspect using this, there are many limitations in recognition aspect to policy, economy, and safety. Therefore, this article intended to suggest a new concept to deliver & use of safety information by using developing mobile technology for spreading of safety information. In order to realize this, we continuously implement the study to test bed manufacturing of aforementioned system.

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Enhancing Ethical Reasoning in Design Education

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Enhancing Ethical Reasoning in Design Education

Abstract

The art of engineering is founded upon the science of physics and maths. In and of itself good design is that in which the constructed project tends towards achieving functional excellence. Conversely bad design tends towards its opposite and the structure will fail to meet its objective.

Green and sustainable design has emerged from ethical considerations about what is good for the environment and ultimately what is good for humanity. However when it comes to ethical design the values which guide the designer are founded in codes of practice and conduct which appear fixed and stemming from higher (professional) authority rather than from an objective science. This paper makes the case for the inclusion of a science of humanity in academic and professional studies as the foundation of the art and practice of ethical design. By understanding what human nature is and how we make determinations about what is good (and bad) for ourselves and others we can develop an ethical approach to what we design and build. As with good engineering or sustainable designs ethical design tends towards the construction of projects that are good for humanity in a holistic sense.

Keywords: Prevention Culture; Well-being; Ethics Reasoning; Human Rights; Responsibilities

1. Background to Ethics

Ethics at the beginning of the 21st century are informed by a number of theoretical and philosophical traditions concerning what it is to be a moral person. Of these there are three broad traditions that encompass various philosophical perspectives which stand out as dominant in their influence. This summary will not do justice to the merits of these great traditions being as they are but an outline of the current strands of moral reasoning.

Virtue ethics

Virtue ethics stems from the earliest period of classical thought and includes the works of Plato (Rouse, 1956, and Lee 1955) and Aristotle (Thomson 1953). Simply described, ethical behaviour is driven by the character of the individual who, in holding certain values to be virtuous acts in a manner that will enhance his virtuousness, e.g. where honesty is a virtue he will always act honestly and thus be more virtuous as a consequence. Conversely, any instance of dishonesty on his part negates not just that characteristic (honesty) but his general standing as a virtuous person. Virtue ethics can apply to a corporate body in a similar manner and what is considered a virtue the body and all its members are driven to act to enhance that virtue and its own virtuousness. However a difficulty with virtue ethics is that "virtues" are subjective and there are many obstacles to universalising them including the fact that not all virtues are agreed upon nor their essential nature having universal acceptance.

Deontological ethics

Deontological ethics is based on rules and ones a duty to adhere to the laws and conventions of society or the group that they profess membership of. In this the rightness of the act is based on whether it is according or contrary to the rules and duties imposed on the individual or body carrying out the act. Leading deontological thinkers include René Descartes, Gottfried Leibniz (Russell, 1900) and Immanuel Kant (Körner 1955) the former advancing a theory of Divine Command which in religious terms an act is right if God deems it to be right, whereas Kant, who was influenced by Leibniz, argues that acts are morally right when carried out from a sense of duty to act in ways that are good with the proviso that that which is good is intrinsically good. Difficulties with deontological ethics arise when the moral agent is confronted with a requirement to act but which ever action he takes will result in a breach of the rules. E.g. a prohibition against killing, which includes the requirement to prevent killing when it is within their power to do so places the moral agent in a paradox when in order to prevent a greater loss of life in war he must accede to war; if we go to war many people will be killed and if we do not go to war many with still be killed by the aggressor.

Consequential ethics

Consequential ethics judges the rightness of an action by its consequences; a good outcome means the act was good. Utilitarianism is one form of consequentialism and one version of utilitarianism is based on the principle of "the greatest good for the greatest number". Other versions include a hedonistic ethic based on the greatest happiness or the greatest pleasure principle. In respect of the greatest good element the example above means the going to war becomes a good act if it prevents an aggressive war and results in fewer lives lost. However problems arise with this perspective if one considers that one bad act may be considered permissible in order to achieve a greater good, after the fact. It becomes a question of what limits or constraints there are to such actions. This allows an "ends justify the means" morality but as the ends cannot be known until after the means have been executed the means remain in a Schrödinger-like right and wrong state until the outcomes are assessed. And without constraints all acts are thus permissible if the intent is good, though the judgment comes later. It is argued that no matter what the intent some acts are neither just nor permissible either in law or because they are so contrary to what it is to be human that they are abhorrent (Green 1881).

Whilst these theories all have their distinctions, in practice moral agents develop ethical reasoning using principles from all these and other traditions, e.g. the Nolan Principles in the UK are in one sense based on virtues of what a good public servant should be but then they codify the duties of the public servant. As the duty is to the welfare or benefit of the public they also draw on utilitarian principles too.

2. Ethics in the Prevention Culture

Article 23 of the Universal Declaration of Human Rights (UN General Assembly 1948) states, "*it is a basic human right for everyone to have just and favourable conditions of work*", the signatories of the Seoul Declaration (2008) interpreted this to mean a safe and healthy working environment. This is one of its two fundamental propositions (McAleenan 2008). In adopting the Seoul Declaration a series of new paradigms were provided in respect of occupational safety and health (OSH);

> OSH is a common responsibility assumed by every player in society;
> It shifted the fundamental concept from just focussing on accident-prevention activities to the creation of a culture enhancing workers' well-being and welfare; and
>
> It creates a new concept of a "Prevention Culture for Safety and Health" through forming and implementing preventative measures reflected in OSH policies, strategies and programmes. (McAleenan 2008)

At a time when 2.3 million workers are being killed annually as a result of workplace accidents and disease and 430m more suffer injury and ill-health can there be any question that the intent and propositions of these declarations are anything but appropriate and correct?

The answer is less obvious than would appear and in practice the continuing annual death, injury and illness toll would point to a non-acceptance of, certainly a non-compliance with some if not all the key points contained within the declarations. Corazon de la Paz, President of the International Social Security Association (ISSA) addressing delegates to the XVIII World Congress of Safety and Health at Work described globalisation as "*a race towards increased productivity at a cost of reduced safety and quality of work conditions*", (cited in McAleenan 2008). This was echoed by Juan Somavia, Director General of the International Labour Office (ILO) who referred to the "*unfair rules that emerged with economic globalisation*". Nor were failures in workplace safety laid solely at the feet of global corporations; governments came in for criticism from de la Paz who highlighted the fact that 80% of workers are working without adequate social security protection. Such views did not have full support from signatory organisations with dissention and contradiction coming from Antonia Peñalosa, International Organisation of Employers (IOE) who, contrary to ILO annual reports, stated that "*there were fewer accidents, as well as more work codes and better technology*" (cited in McAleenan 2008).

The Seoul Declaration (KOSHA 2008) states that "*the right to a safe workplace should be recognised as a fundamental human right*". This assertion can be viewed as having evolved from the work of the National Co-ordinating Committee (NCC) for UDHR50 (1998) who described human beings as having "*an innate sense of fundamental rights and freedoms that belong to us*". In that respect the sense of safe working conditions as being of intrinsic value, and therefore a matter of ethical necessity, has its roots in human consciousness and awareness of individual and collective well-being. Prevention of accidents is thus an ethical matter not least because it is wrong to have conditions that kill workers but also because the absence of activities and intent to prevent them runs counter to what it is to be human. Fromm (1947) states that "*the sole criterion of ethical value being man's welfare*" and materially the principles of good and evil are distinguished by what is good for man and what is detrimental to him.

3. Ethical Responsibilities

In the sphere of European construction the players are defined in statute (Eur-Lex 1992). In the UK and Northern Ireland (NI) the respective H&S laws place duties on employers and employees, and the Construction, Design and Management Regulations (HSE 2007) (CDM) specifies the duties for clients, designers, contractors and co-ordinators. Whilst these duties are focussed on the protection of workers and visitors to construction sites they are not limited in that respect. Construction projects must be undertaken with due consideration given to the whole-life of the structure; they are to be designed in a manner that ensures that they can be built, used, maintained and demolished in a manner that is non-injurious to workers and those who would use it (HSE 2007).

In this regard UK and NI statutes begin to knit with the Organisation for Economic Co-operation and Development (OECD) Principles of Corporate Governance (OECD 2004). Emerging from the principles were regulations and codes in various countries such as the Combine Code in the UK which later became the UK Code of Corporate Governance (FRC 2010) and the Sarbanes-Oxley Act 2002 in the United States.

The outworking of the principles saw several consequences not originally intended but subsequently embraced by the OECD, namely the adoption of the principles by non-financial sector companies, businesses and not for profit organisations who saw that benefits would accrue from organising their activities in accordance with the principles and the widening of the application of the principles to cover matters other than financial regulation. That is the principles guided companies on the overall governance of their organisations, (OECD 2004b). The consequence being that key stakeholders; as distinct from shareholders, now had an opening and a say in how companies were run, particularly when they were affected by the decisions and actions of the company.

Orr (2007) in his presidential address to the Institution of Civil Engineers (ICE) put ethical principles at the core of engineering professionalism. Integrity is at the heart of what engineers do and this involves responsibilities to clients, employers and the public at large taking precedence. Thus integrity is not limited to engineering competence and the recognition of personal limitations but it includes the ability to recognise and counter corruption whether it is in the delivery of less than what was paid for or in the accepting of financial inducements. Integrity also includes acting in the public interest at all times especially in regard to structural safety, sustainability, climate change and the global impacts of local actions.

Such thinking on the role of the engineer is not new. Henry Palmer's inaugural address to the ICE (1818) placed the engineer between the philosopher and the working mechanic

(Armstrong et al. 1999) whilst James Laurie first president of the American Society of Civil Engineers (ASCE) strove to embody the ethics of the engineering profession, which had a responsibility to represent the public interest in National affairs (ASCE 1991). If we accept this then, according to Armstrong et al (1999) "*the true professional needs and retains the freedom to act in accordance with personal judgment, unbiased by the overriding needs of his employer*".

The importance of ethical codes as a factor in safety performance is recognised by researchers into workplace safety (Kapp and Parboteeah 2007), who, while asserting that no previous work has examined the relationship between ethical climate and safety related behaviours found that there was a string correlation between the organisation's principled climate, compliance and participation in safety behaviours.

Adherence to the Code of Professional Conduct (ICE 2008) would ensure that engineers would be acting ethically, but as a deontological approach where they are expected to do their duty the development of ethics reasoning is not a specific requirement of the professional engineer, and without this the engineer is relegated to the role of technician. Many professional institutions have developed codes similar to the ICE Code.

4. Ethics Reasoning

Engineers are schooled at the highest levels in the technical aspects associated with construction and are well versed in the need to ensure structural integrity because of the high value placed on human life. None-the-less Rahman et al (2007) found that the construction industry is a perfect environment for ethical dilemmas with its low-price mentality, fierce competition and paper-thin margins. This situation is all the more acute 3 years into a global recession that commenced with the collapse of the property market and banking failures, leading to the failures within the construction industry in a number of major countries.

In recognising that profitability is a motivation for effectiveness Orr (2007) maintains that "*the desire for profit should not come before an engineer's duties and responsibilities*" and this is the very area where ethical dilemmas can be most acute. When social conditions are bad "*people adapt to them by lowering their intellectual and moral capacities but in doing so they are acting contrary to their nature which in turn leads to mental and emotional disturbances"* (Fromm 1947). Cathy Kopp, Executive Director at ACCOR addressing a health seminar in Korea highlighted the fact that although people are working less today than in the 1950s they are under greater demands and experience higher levels of stress, (McAleenan 2008). The objective conditions since 2008 are more severe and the demands put on workers and professionals are greater again. Fromm (1947) concluded that "*because man cannot change his nature, he resolves the contradictions by changing the circumstances in which he finds himself*".

When we approach the questions of prevention through design from an ethical standpoint it is necessary to understand something of what drives ethical behaviour and that arise from whichever standpoint we choose. From the founders to the current leaders of the profession the need for engineers to behave ethically has been a central tenet of what they do and what they believe should be the situation for their professions. The Washington, Dublin and Sydney Accords all stress the requirement for engineers and graduates to demonstrate ethical responsibility to public safety and to consider the impact of their activities on economic, social, cultural, environmental and sustainability requirements of society (IEA 2009).

The professions have encapsulated the requirement to behave ethically in their Codes of Professional Ethics. Engineering standards have been developed and published and are the required means of designing and constructing structures. Universal principles on integrity (OECD 2004a) have been applied and implemented in national codes (e.g. FRC 2010) and laws, (e.g. Sarbanes Oxley Act 2002) that corporations must follow, and health, safety and environmental duties are imposed by statute. For instance, in Malaysia the construction industry has introduced codes of ethics for contractors and the government requires stakeholders to enforce existing codes to protect the good name of engineering (Rahman et al. 2007).

The need for ethics in engineering has resolved itself generally as a deontological ethic with it being a duty to behave ethically and the ‘how to behave’ being codified. Notwithstanding the issues with deontology, problems arise not least because the rules are general in nature and are insufficiently defined to cover every situation, but also because the rules may constrain the scope for exercising professional judgement. Warnick (2010) has identified a number of other issues with ethics; respondents stated, amongst other things, that they wish they could have left college knowing “definitions of right and wrong and what is acceptable”, what are “international work ethics”, that “values are not absolute” and the differences in culture and how cultures should relate to each other.

Kohlberg advancing the work of Piaget on the development of moral reasoning (cited in Crain 1985) has identified six stages of moral development. Stages 1 and 2, defined as pre-conventional, are applicable to children up to early teens. Stages 3 and 4, called conventional morality because they are the levels of the values, norms and expectations of most members of conventional society. Stage 3 moral or ethics reasoning is fundamentally concerned with the individual’s perceptions of good and works well in close interpersonal relationships as between family and friends where people are expected to live up to the expectations others have of them and behave in good ways. Stage 4 is concerned with and is shaped by the need to maintain some kind of order and functionality in wider society. There is a greater emphasis on obeying the laws of society and respecting authority in order to avoid conflict and societal breakdown. There is a sense in which Stage 4 requires less moral reasoning to obey the rules than Stage 3 where the individual must determine what is good for others in his relationships. Rather than reversing the stages they could be viewed as co-equal. Kohlberg (cited in Crain 1985) answers this criticism by stating that subsequent stages do not negate prior stages but assimilate and take the learning to the higher level. Thus Stage 4 reasoning enhances stage 3 reasoning.

Post-conventional morality has two further stages. Stage 5 is concerned with how society could and should be, particularly when one considers that a well ordered and functioning society is not necessarily a good one. In this stage of moral development the moral agent considers in a Kantian way society in the abstract and what is good for it and what rights and freedoms its members should have.

Those who are reasoning at Stage 6 are considering the universality of ethical principles; what is good for one is good for all, indeed Fromm (1947) states that in order to know what is good for the self one must know what is good for humanity. For him the most general principles "*follow* [of necessity] *from the nature of life in general and of human existence in particular, and the first 'duty' of all life is to affirm and preserve its own existence*". In this respect ethical behaviour is on the basis of what is just rather than what the law required. However a difficulty Kohlberg discovered was that his subjects were not reasoning consistently at this level and he was finding it difficult to score them higher than Stage 5.

Kohlberg (cited in Crain 1985) distinguished Stages 5 and 6 as post-conventional because most young people arrive at Stage 4 some-time in their 20s but few develop or retain as a matter of course Stage 5 reasoning, thus it is, he argues, beyond the conventional mode of thinking of most people.

5. The Educational Deficit

What stands out in respect of professional ethics is the requirement to behave ethically supported by codes and regulations that direct professionals in the 'right direction'. Ethics thinking is not prevented but is constrained by the contradiction between a rules based approach, a society of laws and the requirement to act above and beyond any duty owed to employers and clients and put the public interest first.

College and university programmes do not omit ethical issues but when they arise the issues are often addressed through the provision of answers (or the gleaning of such from the students) more than the exploration of and deeper reasoning about them. Kohlberg's finding that Stage 5 reasoning rarely appears before the mid-20s and never becomes very prevalent (Crain 1985) means that normally students graduate before arriving at this level of reasoning and if they later arrive at this stage it is unlikely to become their prevalent mode of reasoning. Thus professional engineers may be facing their professional reviews with no more than a deontological, Kantian-like ethic. In other words if a professional is one whose duty is to the greater good of the public at large in all aspects, economic, safety, environmental, cultural and so on, he or she finds themselves limited to reasoning within the bounds of established conventional laws and rules about what is good for society rather than applying their own reasoning to what should be.

There are exceptions to this as is to be expected from any general assertion, but the exceptions are not found in the engineering projects that claim headlines with their creativity and ingenuity of design. Such projects emerge from the mathematical, scientific and engineering learning and competence of the professional.
The immediate benefits of any project may obscure the long-term or even distant negative effects. Out of town shopping malls for instance bring reduced prices and convenience to customers but bring about the loss of town centre businesses and the

sense of community engendered by vibrant town centres. In other cases, such as the spectacular creations in the Gulf state, the poor labour conditions on some projects with tens of thousands of migrant workers housed in over-occupied, amenities-poor accommodation and subjected to unsafe working conditions were overshadowed by the spectacle of the finished works (HRW 2009, and Hari 2009).

It would be wrong to suggest that it is all negative. The Aga Khan Award for Architecture demonstrate that substantial projects can be undertaken and be successfully completed where the primary objectives are social and aimed at the advancement in human needs in all the areas outline by the Washington, Dublin and Sydney Accords, (AKDN 2011).

6. Developing Ethics Reasoning in Design Education

Kohlberg's work has demonstrated that progress from one stage to the next is an invariant sequence; learners will always pass from one stage to the next in sequence, however this assertion is worth challenging. Though most people will arrive at and remain at Stage 4 sometime in their mid-20s, the method by which they can move to the next stage is open to to appropriate formal educational input. Blatt and Kohlberg (cited in Crain 1985) presented moral dilemmas to children and encouraged active group discussion including the presentation of arguments one stage above where most were at. This method was designed to induce cognitive conflict wherein the views of the learner becomes confused by information that was at odds with his view and consequently his means of resolution of the conflict is via the adoption of an advanced and more comprehensive position.

Under controlled circumstances half of the participants moved up one stage over a 12 week period of weekly discussions. Replication however did not produce the same level of results, but over a longer period one third of students moved up a stage. The general trend displayed is that discussion of ethical dilemmas, over several months, produces significant upward changes in moral reasoning in participants.

Ethics reasoning and the facilitation of its development is not about producing specific moral behaviours. It is concerned with the reasoning process and the output of a programme is graduates whose ethics development and subsequent ethical behaviour is a result of their own thinking and not imposed by rules or authority.
The exercises designed to facilitate ethics reasoning must be based on matters of social and individual good. Fromm (1947) describes technical competence in particular professions such as engineering as emerging from the sciences, in particular mathematics and physics. Without a foundation in these sciences, engineering competence is unlikely to occur. In respect of ethics he contends that an individual's ethics are based on what is good for him qualified by "*what is good for him is necessarily good for man in general*", and this is at the core of professional ethics. In order to know what is good for others, what is good for humanity there must be a foundation of knowledge and understanding about humanity, i.e. there is a need to know what it means to be human. This Fromm (1947) calls the 'science of humanity'.

Some work in this area has indirectly taken place in Limerick University (Philips 2008) and Ulster University (McAleenan C 2010). Phillips' engineering students were provided with case studies in which they were required to develop explanations and alternative solutions taking account of legal and philosophical matters, including lectures from those faculties. McAleenan tasked students with the development of disaster prevention and recovery solutions based on the lessons from the New Orleans Katrina disaster. Students were required to consider the social, cultural, religious and legal impact of their technical solutions and received appropriate supporting lectures from a range of disciplines.

7. Conclusion

Hann (1968) (cited in Crain 1985) found that students in Berkeley involved in the Free Speech Movement demonstrated very strongly post-conventional thinking where-as students not so involved did not demonstrate this level of thinking. Kohlberg has demonstrated that his methods for enhancing ethics reasoning are effective. To meet the ethical requirements that professionals need in order to assess the impact of their work on construction workers, end users and the general public now and into the future it will be necessary to introduce and integrate a short programme of ethics reasoning into the first and final years of undergraduate programmes with the objective of raising students level to Kohlberg's Stage 4 in the first year and to Stage 5 in their final year. The former to bring forward the age by which most young people generally arrive at Stage 4 and the latter to bring them to Stage 5 which is critical to objective professional reasoning.

The use of this method at undergraduate level in order to achieve a successful development of ethics reasoning at an earlier age can be effectively tested by the universities and the professional institutions when candidates come for their chartered/professional review. With this intervention the professions (and this is true for all construction professions) will develop the ethics reasoning capabilities of their cohort up to a level that is expected of true professionals.

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Preventing Accidents and Major Injuries on Major Alteration/Refurbishment Works: A Framework for Relevant and Effective Information Co-ordination

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Abstract

Major alteration and refurbishment works have accounted for a significant proportion of the construction activities in the UK over the last few years. This is due partly to the need to adapt buildings and other structures to the ever evolving user requirements and partly to the need to upgrade building performance. The scales of the projects vary substantially depending on the client requirements. However, evidence suggests that this trend is likely to continue in the foreseeable future as the industry continues to address the requirements of sustainable development. As a result, the aspects of Health and Safety management on these projects will continue to face dynamic challenges that will require a dynamic approach to providing solutions. More often than not, there are insufficient as-built details available to the designers and also there are time constraint limitations imposed by the need for such premises to still be operational whilst works are being undertaken. These risk factors, if not managed carefully by those responsible for the design and implementation of such works can lead to on-site accidents and major injuries.

The UK Construction (Design and Management) – CDM Regulations 2007 spell out the roles to be performed by the Duty Holders on a construction project. All Duty Holders are generally required to provide relevant, accurate and timely information as the project develops and one of them - the CDM Co-ordinator is primarily tasked with ensuring that all parties co-operate in the discharge of their duties.

Based on two UK projects presented herein as case studies, a framework which highlights key information provision and flow structure is hereby presented. Despite the complexity of both projects, the framework facilitated a regime of zero-accidents and provided a basis for contributing to best practice and further research.

Keywords: Duty Holders, Designers, Contractors, Accidents, Refurbishment

Preventing Accidents and Major Injuries on Major Alteration/Refurbishment Works: A Framework for Relevant and Effective Information Co-ordination

1. Introduction

The United Kingdom (UK) is witnessing a huge increase in major alteration and refurbishment works in recent times. This is due partly to the need to adapt buildings and other structures to the ever evolving user requirements and partly to the need to upgrade building performance (Fernandez, 2011). The scales of the projects vary substantially depending on the client requirements. At the domestic level, a substantial amount of such works entail permitted extensions, loft conversions, basement constructions and in recent times work involving retrofitting of old stock to make them more energy efficient. At the non-domestic level, alteration and refurbishment projects would normally entail a significant amount of demolition, extension and refurbishment activity. In some rare cases, and especially on the older stock, such works involve complete demolition and new build. Whichever way, however, evidence suggests that this trend is likely to continue in the foreseeable future as the industry continues to address the requirements of sustainable development (Thiemann, 2010).

Furthermore, in recent times, the UK has adopted the process of demolition rather than refurbishment to regenerate its ageing social housing stock. This approach has continued to pose challenges to meeting energy and climate-change targets. According to Power (2010), *'The demolition refurbishment of older housing has been an active policy area since the late 1880s in the UK, when the government first authorised the statutory demolition of unsanitary slums. The debate on demolition and new building has been intensified since 2003, with UK government proposals for large-scale clearance and new construction. Refurbishment offers clear advantages in time, cost, community impact, prevention of building sprawl, reuse of existing infrastructure and protection of existing communities and it can also lead to significantly reduced energy use in buildings in both the short and long term'.*

It is becoming increasingly important therefore that health and safety in the demolition, refurbishment and alteration of buildings will need to be properly managed (Chan, 2009; Clarke, 2010). Historically, most existing efforts have concentrated on the development of such safety management systems for new builds (Manase *et al*, 2011). Where such systems are in operation, accidents and major injuries can be substantially reduced in the light of the risks posed by construction work due to refurbishment activities (Theimann, 2010).

In many cases, there are insufficient as-built details available to the designers and the projects usually have time constraint limitations imposed (Dickson *et al*, 2009). In addition, there is the need for such premises to still be operational whilst works are being undertaken in some cases. These risk factors, if not managed carefully by those responsible for the design and implementation of such works can lead to on-site accidents and major injuries (Ikpe, *et al*, 2011). It is on this premise that this work seeks to facilitate the development of a framework that can aid the co-ordination of relevant and effective of the information by all parties on the project so that accidents and major injuries can be properly controlled (Oloke *et al*, 2007). The case-study approach used was based on two projects which both have substantial elements of demolition, alteration and refurbishment and the systematic procedures adopted underpinned the development of the framework.

2. UK Health and Safety Duty Holders

Since the advent of the Construction Design and Management (CDM) Regulations 2007, the UK construction industry has been witnessing a variety of efforts aimed at giving publicity to the Regulations (Chan, 2009). In particular, the Regulations considered that those with responsibilities under the Regulations (duty holders) should understand clearly what their responsibilities were. The CDM 2007 recognises duty holders as those with specific health and safety roles to play in the procurement and delivery of construction projects (Chan, 2009; Ciaran and Oloke, 2010). These include the: Client, CDM Co-ordinator, Designer, Principal Contractor and the Contractor. For the sake of clarity, the roles are now explained briefly as below (Ciaran and Oloke, 2010).

The Client

The CDM Regulations defines a Client as the person who seeks or accepts the services of another for the purposes of carrying out a project for him/her. The Client can also be a person who carries out a project him/herself.

For operational reasons, Clients are required to factor in sufficient time for setting up the proper procedures prior to commissioning work and generally co-operate with the Contractor to allow them to discharge their duties. This does not always happen in reality, however. Appropriate lead-in time should be allowed to account for the unique requirements of every project. The Client's work also has to be co-ordinated so that it does not affect the safety of other duty holders especially those doing the job on-site. It is also the responsibility of the Client to also ensure the Contractor has appropriate welfare in place before work starts. Very importantly, the Client is to ensure that they are provided with information about what has been built (by requesting for the Health and Safety File) to enable future management of health and safety in the building over its life and ultimate demolition (including partial demolition).

The CDM-Coordinator

A CDM Co-ordinator (CDM-C) serves as the Client's adviser in matters relating to construction health and safety. The role involves advising and assisting the Client in undertaking the measures needed to comply with CDM 2007, including, in particular, the Client's duties both at the start of the construction phase and during it. Particularly, information flow is a key requirement of the successful implementation of CDM 2007. The CDM-C has the basic responsibility for developing a strategy with the team for maintaining the flow of relevant health and safety-related information throughout the lifetime of the project. In this role, the CDM-C makes sure that what is needed reaches the appropriate members of the team in a timely fashion. Hence, the CDM-C is expected to promote the suitability and compatibility of designs and actively seek the co-operation of Designers at all project phases when dealing with the risk consequences of construction and workplace design decisions. This is key to preventing accidents and major injuries on site.

The Designer

A Designer in the context of the CDM Regulations is any person who modifies a design and/or arranges for or instructs any other person under their control to do so. Furthermore, when carrying out design work, Designers are required to avoid foreseeable risks to those involved in the construction and future use of the structure. 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. One way they can achieve this is to ensure that they provide adequate information about any significant risks associated with the design. The Designer is expected to exercise this duty on the very obvious risks which would normally be accounted for in the Contractor's method statement, and Designers are particularly required to ensure this is complied with. Finally, Designers are required to co-ordinate their work with that of others in order to improve the way in which risks are managed and controlled.

The Principal Contractor

A Principal Contractor (PC) is responsible for Contractors and workers on site. The PC implements the planning, managing and monitoring of the construction phase work in a way which ensures that, so far as is reasonably practicable, work is carried out without risks to health or safety. The PC is to ensure safe working and co-ordination and co-operation between Contractors and that a suitably developed construction phase health and safety plan ('the plan') is prepared before construction work begins. The plan should be developed in discussion with, and communicated to, all Contractors affected by it. It should also be implemented and kept up to date as the project progresses and reviewed prior to any significant changes. All factors for mitigating against the effects of residual risks on the project should be kept up to date in the plan to ensure that these are properly accounted for and managed throughout the project.

The Contractor

Contractors are to ensure that all of their sub-Contractors are informed of the amount of time that they will have for planning and preparation prior to the start of construction work. Their workers (whether employed or self-employed) should also be provided with any necessary information, including site induction, training, information from risk assessments, and relevant aspects of other Contractors' work, (where these have not been provided by a Principal Contractor) to enable them work safely.

It is the responsibility of the Contractor to also ensure that the risk of traffic and vehicular movement accidents is minimised as far as is reasonably practicable. They are to ensure: the safety of site traffic routes and the safe use of vehicles on site. The vehicles must be ensured to be loaded, operated, unloaded or towed in a manner which does not put the safety of driver, passenger, pedestrians, or other individuals at risk. This includes prevention of unintended movement of a vehicle, and taking steps to prevent the vehicle's fall into an excavation, pit, or water, or it overrunning the edge of any embankment or earthworks.

3. THE CASE STUDIES

Two case studies are hereby presented to illustrate the concept of effective information flow and co-ordination on demolition and alteration projects. The knowledge gained from these facilitated the development of the framework (Oloke, *et a*l, 2007; Fernandez, 2011). The two projects are thus hereby described.

Project 1 – Demolition and Construction of New Auditorium, Dartford, England

This development required the conversion of existing single and double storey buildings into functional areas which will create large seating capacities and other multi-purpose functions. The buildings originally belonged to a college and were bought over by a charity that needed space for a large auditorium and several other functional areas. Four buildings were eventually developed under the scheme. These were defined as: Buildings A, B, C and D. Building A which was originally a storey building with office, classroom, cafeteria and other smaller functional areas was re-designed to accommodate a 3,500 people-seating auditorium. The building therefore needed a substantial amount of alteration and structural stability works so as to facilitate the achievement of this objective. Buildings B, C and D also required such alteration works albeit to a lesser degree. The project was set a time frame of 5 months.

The works were thus carried out in three stages as follows:

> Stage 1 – Initial strip out and full structural appraisal. This stage also included the commission of utility/geotechnical/asbestos and other relevant surveys. Surveys were conducted and reports were used by the Consultants for design works. Information so obtained did not only prove to be useful for the design but also formed a substantial part of the designer's risk assessments.
>
> Stage 2 – Removal/demolition of partitions, first floor slabs and a limited number of beams. All columns providing support to the roof remained in place at this stage (Figure 1 and Figure 2).
>
> Stage 3 – Design and Construction works to enable the creation of the shell, infill structures, fit out and reinstatement - including site drainage and civil works (Figures 3 and 4).

Table 1 contains a list of the main risk elements assessed and the Duty Holders responsible for highlighting and/or mitigating the risks. As shown in the table, each risk factor was assessed and where the residual risk could not be eliminated, such risks were highlighted in the relevant documents – especially the drawings and work schedules. The CDM Coordinator facilitated the co-ordination of all relevant information and ensured that the appropriate actions to be taken were carried out by the relevant Duty Holders. In the absence of as-built drawings, the Client was tasked with commissioning surveys that led to the generation of existing plans by the designers after which a structural survey was embarked upon to ascertain the location, sizes and materials of the structural members. This procedure was considered most helpful to the Designers, PC and the Contractors.

Table 1: Project 1 - Project Risk Information Management Schedule

S/No.	Risk Factor (Population at Risk)	Party Responsible for Providing Information	Party Responsible for Mitigating
1.	Unauthorised Access to the site (Public)	Client	Contractor
2.	Movement of Vehicles, plant and equipment (Contractors and Public)	Principal Contractor	Principal Contractor
3.	Tripping (Contractors and public)	Principal Contractor	Contractor
4.	Contact with Hazardous Materials (Contractors and public)	Principal Contractor	Contractor/Workers
5.	Asbestos, Noise and Dust (Contractors and public)	Client/Principal Contractor	Workers
6.	Tripping/Falling from height (Contractors)	Principal Contractor	Contractor
7.	Security (Occupiers/Public)	Principal Contractor	Principal Contractor
8.	Collapse (Contractors/Occupiers/Public)	Principal Contractor	Contractor
9.	Lifting Operations – Heavy Steel Members	Designer/Principal Contractor	Contractor
10.	Excavations	Designer/Principal Contractor	Principal Contractor

As shown in Figure 1, the area to be demolished was marked out by the designer after the client’s requirements were evaluated. The contractor’s method statement was then checked to ensure that all issues highlighted in the Pre-Construction Health and Safety Information Pack was addressed accordingly. In particular, demolition work sequence was carried out in such a manner that guaranteed stability of the structure at all times, whilst also achieving the intended objectives. A similar approach was adopted for the first floor of the building (within the hatched section) as shown in Figure 2. The re-developed proposal is as presented in Figure 3. The creation of a double volume space in the central atrium meant that a new frame structure needed to be designed and constructed to allow for the removal of the intermediate columns. The newly introduced frame structure also meant that new pad foundations had to be constructed to carry the columns. The 3-D model of the new steel frame is shown in Figure 4. Delivery of the steel members to site and the erection followed a just-in-time process to minimise the requirement for storage on site and also health and safety considerations required for installing the new foundations and the handling of the long and heavy steel members. The proper co-ordination of these activities lead to a regime of zero-accidents on the site throughout the works.

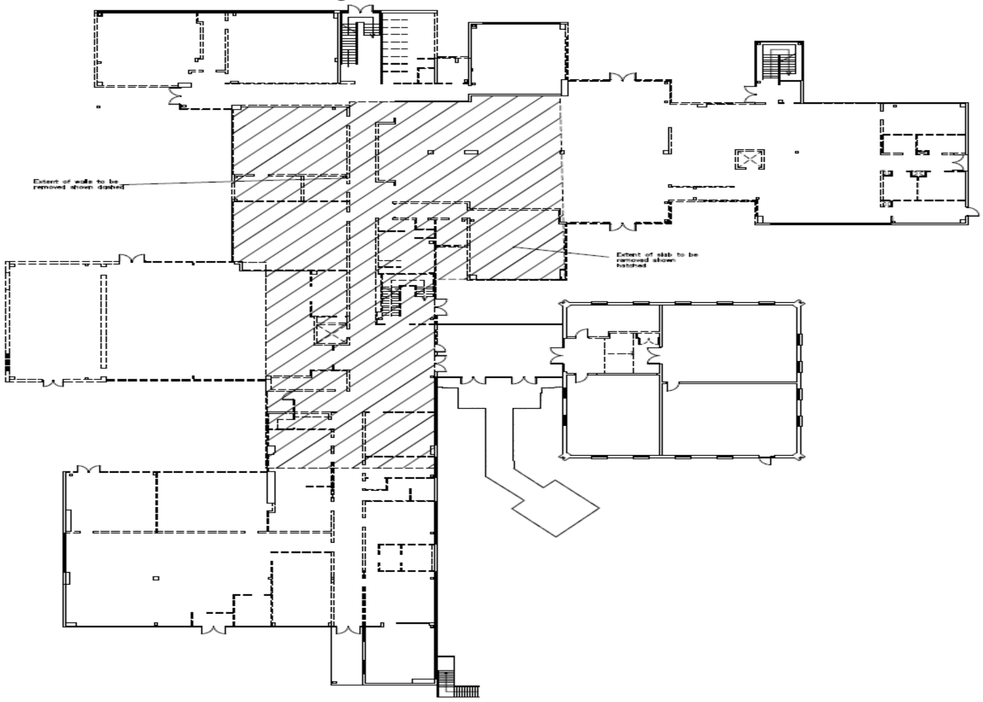

Figure 1: Ground Floor Plan of WMA Building showing Areas for removal of Partition Walls and Floor Slabs

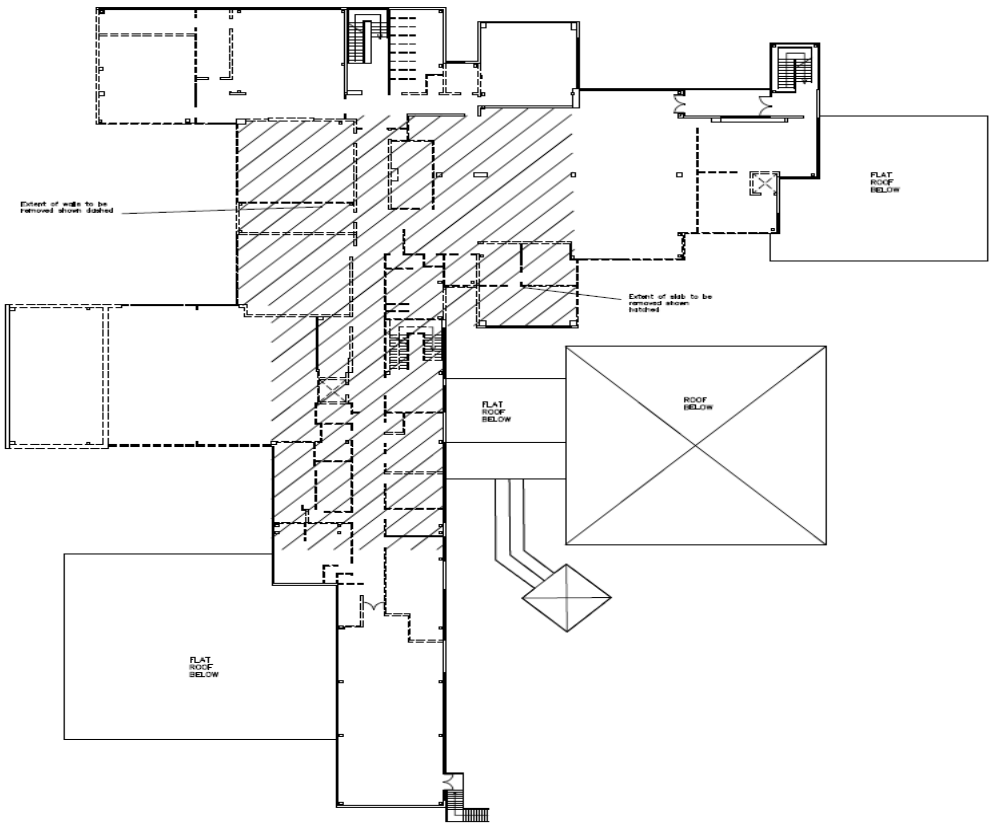

Figure 2: First Floor Plan of WMA Building showing Areas for removal of Partition Walls and Floor Slabs

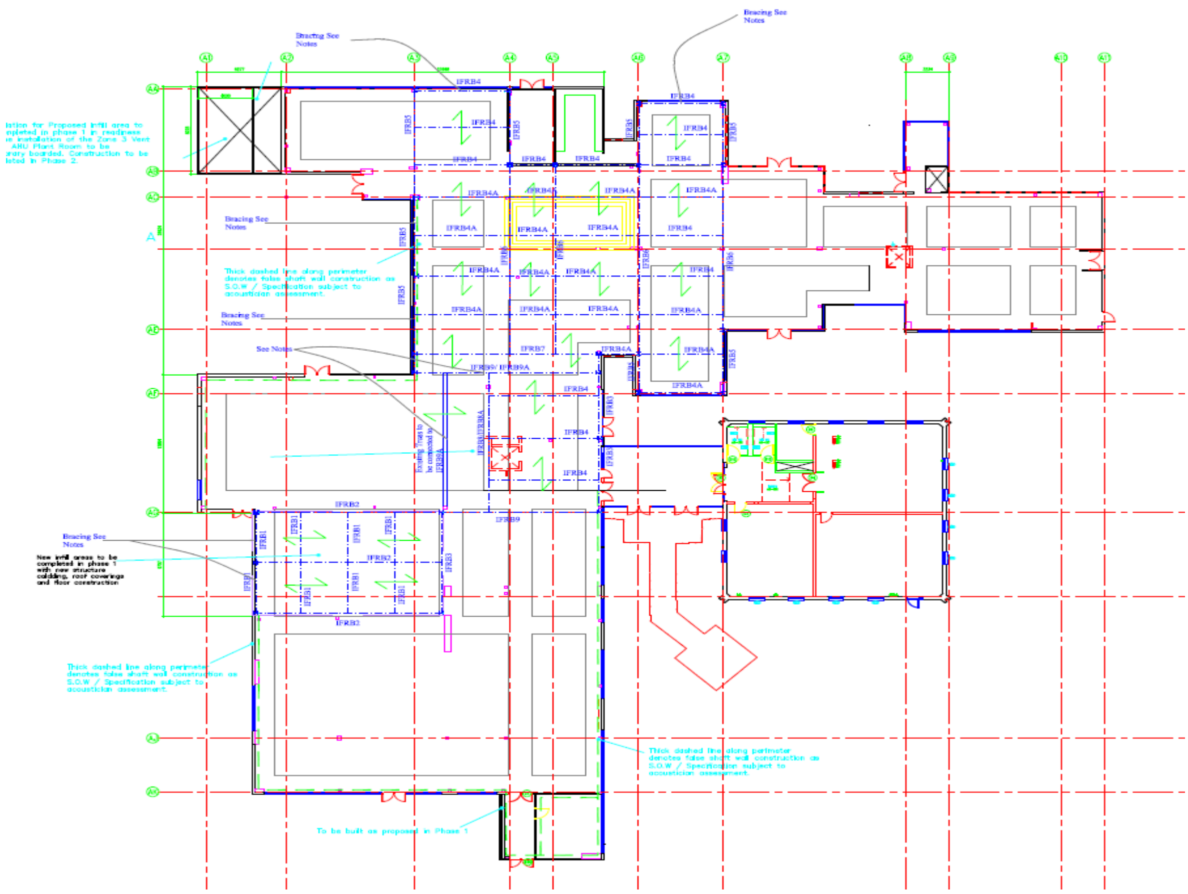

Figure 3: New Ground Floor Plan of WMA Building Showing new Structural Frame

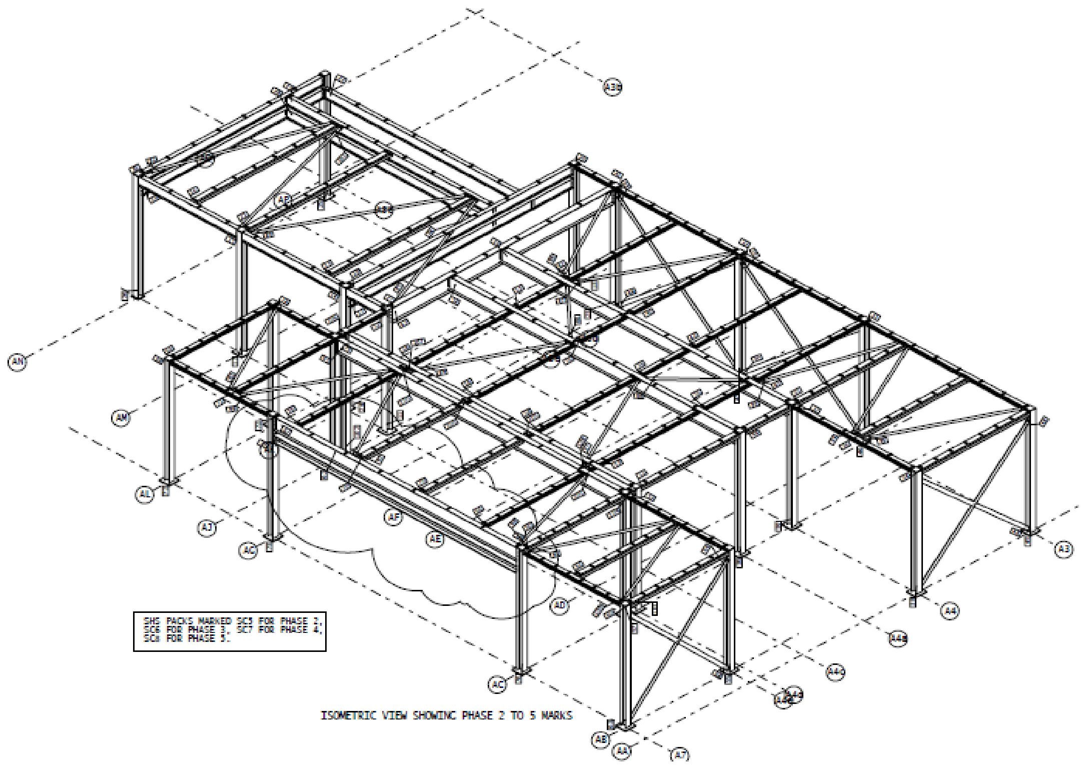

Figure 4: New Structural Frame 3 – D Model

Project 2 – Demolition and New Structural Floor Construction, London, England

The major aspect of this project was the demolition of an existing Cinema reinforced concrete seating area. The original building is a 200 year old listed building in the central part of London. The project entailed the demolition of a Cinema complex and several other rooms (Figure 5) to make way for the incorporation of an ultra-modern pod style hotel (Figure 6). The work was split into three packages: The enabling package, the engineering of the new second floor/transfer slab and the construction management aspects of the works.

1. Enabling Package. The following were carried out as part of the enabling works:
   a. Created site including hoardings within Trocadero, temporary lighting
   b. Stripped out cinema hall back to shell including:
      i. All concrete seating structure, walls and partitions,
      ii. Remaining stock, soft finishes and rubbish
      iii. Plant areas
      iv. Projector areas
      v. Stairs linking to means of escape
      vi. Wall dry lining
      vii. Block work skin to Shaftsbury elevation
      viii. Redundant plant & services
      ix. Lift

   (The ground floor remained trading throughout cinema enabling works)

   c. Stripped out ground floor retail unit (was undertaken while 2nd floor was being constructed to retain current tenant cash flow)
      i. All walls and partitioning
      ii. All soft finishes and fixings
      iii. Redundant plant & services

2. Structural Engineering - New 2nd Floor Structure package which included the design and construct new 2nd floor structure including new slab, beams, columns and structural ties, etc. to existing structure. (Floor structure was designed to take into account future Hotel loadings)

3. Contract Management works which included: Strip Out Works and New Construction Works

A summary of the project risk assessment is provided in Table 2. This schedule contains a list of the main risk elements assessed and the Duty Holders responsible for highlighting and/or mitigating the risks. Each risk factor was assessed for the residual risk so as to highlight possible mitigating measures in the relevant documents. The CDM Coordinator also facilitated the co-ordination of all relevant information and ensured that the appropriate actions to be taken were carried out by the relevant Duty Holders. The Client provided some as-built drawings; however, additional structural surveys were conducted to ascertain the location, sizes and materials of the structural members. This was necessary to ensure that the existing structure would be adequate for the new take down loads. The fact that parts of the building were to be kept operational throughout the phased works itemised above also introduced certain unusual risks.

Table 2: Project 2 - Project Risk Information Management Schedule

S/No.	Risk Factor (Population at Risk)	Party Responsible for Providing Information	Party Responsible for Mitigating
1.	Unauthorised Access to the site (Public)	Client	Contractor
2.	Movement of Vehicles, plant and equipment (Contractors and Public)	Principal Contractor	Principal Contractor
3.	Tripping (Contractors and public)	Principal Contractor	Contractor
4.	Contact with Hazardous Materials (Contractors and public)	Principal Contractor	Contractor/Workers
5.	Asbestos, Noise and Dust (Contractors and public)	Client/Principal Contractor	Workers
6.	Tripping/Falling from height (Contractors)	Principal Contractor	Contractor
7.	Security (Occupiers/Public)	Principal Contractor	Principal Contractor
8.	Collapse (Contractors/Occupiers/Public)	Principal Contractor	Contractor
9.	Lifting Operations – Heavy Steel Members	Designer/Principal Contractor	Contractor
10.	Demolition	Designer/Principal Contractor	Principal Contractor

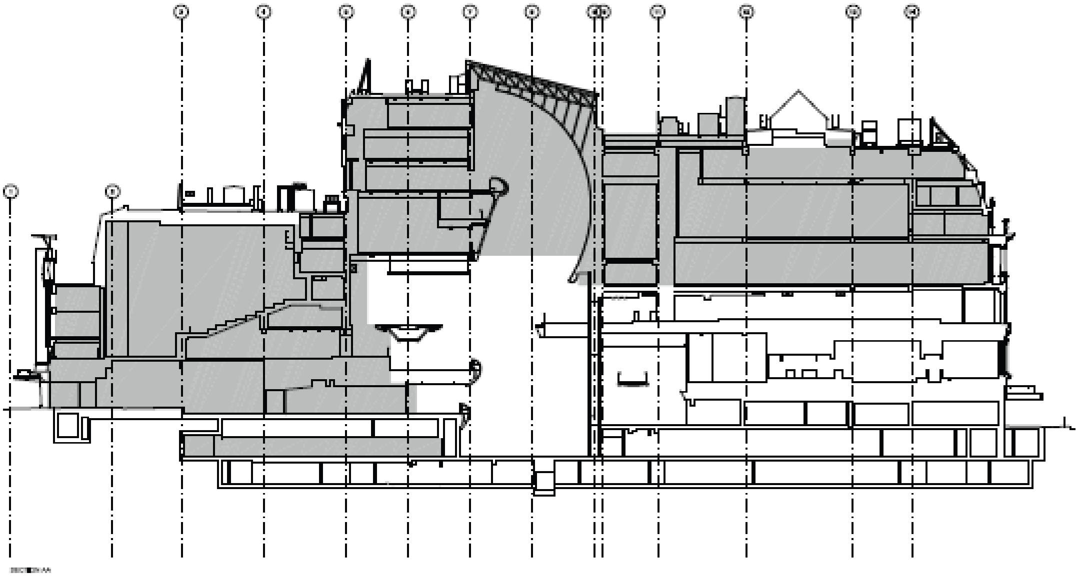

Figure 5: Project 2 – Existing Section through the Project Building

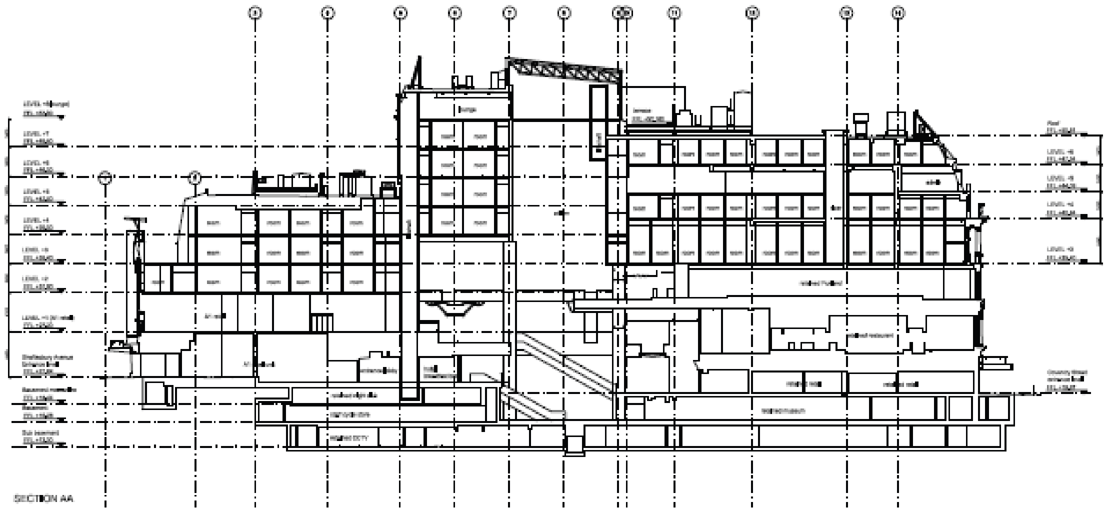

Figure 6: Project 2 – Proposed Section through the Project Building

4. PROPOSED FRAMEWORK

The ERIC (Eliminate, Reduce, Inform and Control) principle (Carpenter, 2010) recommends that Designers be obligated to (as far as is reasonably practicable) eliminate all risks associated with the implementation of their design. Where this is impracticable, they should ensure that reduce the impact of such residual risks, inform all concerned and also recommend that the appropriate controls are put in place. This process therefore requires a smooth information flow to and from the Designers. Based on this principle and the case study projects examined in this paper; a framework that is to facilitate the information flow between Duty Holders in the light of the uniqueness of these projects is hereby proposed.

The zero-accident success recorded in the information sharing and co-ordination procedures in both projects highlight the unique importance of information management within refurbishment projects – especially those with similar characteristics with the two projects. Key activities on such projects include: strip out, demolition, excavation, concrete works, temporary works, steel fabrication and erection, re-cladding and other related construction activities.

Figure 7 is a flowchart which shows the information flow process of the proposed framework. The process is based on the CDM Duty Holder functions with a specific focus on the salient details that should transpire in the information exchange between Duty Holders whilst undertaking alteration/refurbishment works. As stated, this framework has been based on experience from two case studies and so it is expected to provide a basis for information management on a general scale as opposed to being the rule. However, the two case studies have been carefully selected based on their coverage of several generic issues relating to the alteration/refurbishment categories of refurbishment works.

The Risk Register is a vital document which can be effective in the management of health and safety on site. However, the Register can only be as effective in controlling incidents on site in the light of its quality and application.

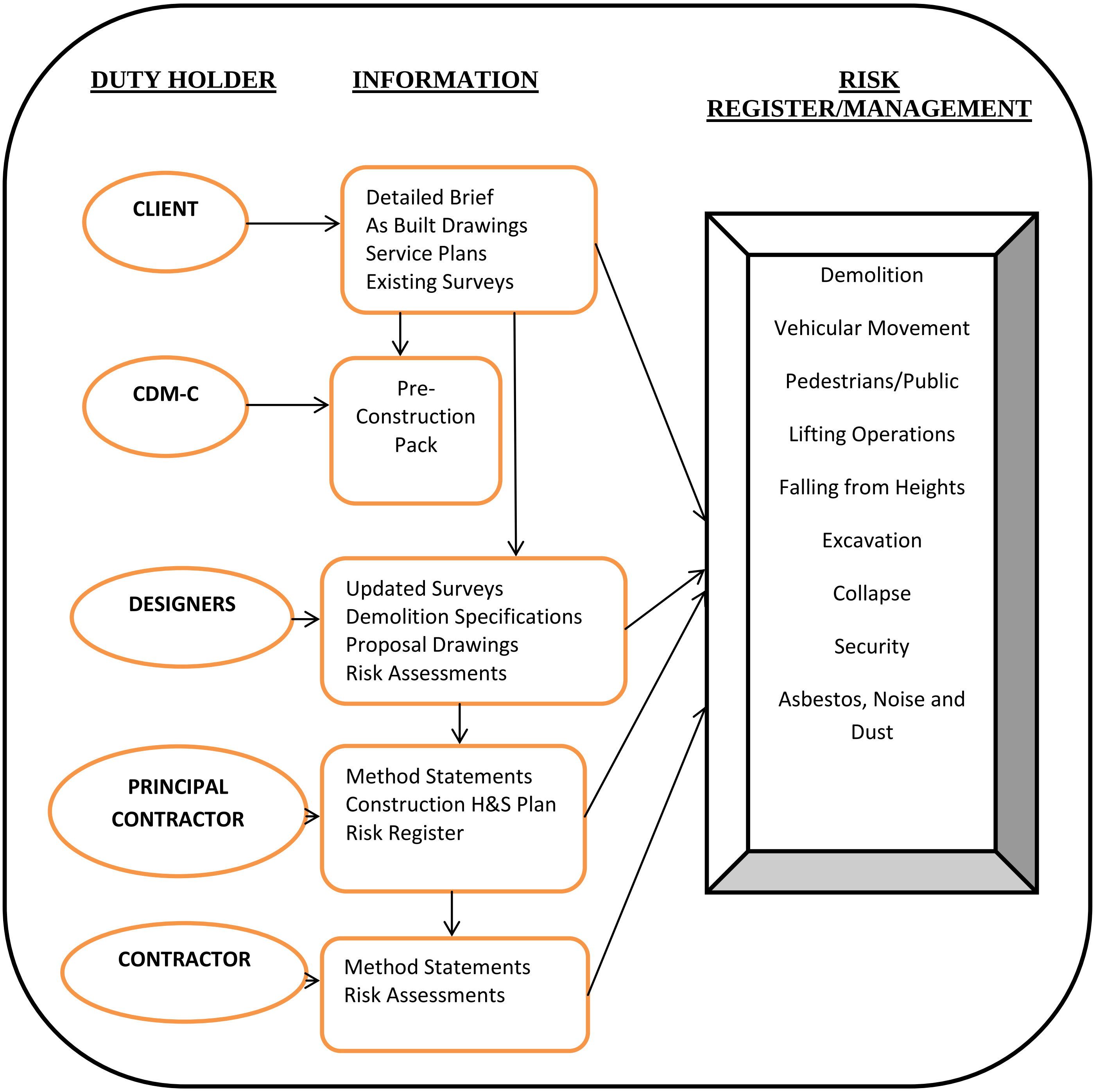

Figure 7: Proposed Information Flow Framework for Alteration/Refurbishment Projects

As shown in the framework in Figure 7, the quality of the Register can significantly be enhanced if the information-flow between the Duty Holders is systematic and comprehensive. The Client should generate adequate information to start the process. However, such requisite information is usually not fully available and the CDM-C should thus ensure that the Pre-Construction Information Pack gives a clear indication of requirements for additional surveys and other pertinent information. The Designers should consequently ensure that such surveys are conducted and interpreted in addition to generating the new proposals. Depending on the level of risk posed by the existing structure, access, etc. in the light of the proposals should be part of the Designers' Risk Assessments. The PC and the Contractors should subsequently build on this document to produce their method statements and inputs into the Risk Register. This procedure ensures that the Register accounts for the risks and all mitigation procedures. Also design modifications, which are usually inherent in these types of projects, should be reviewed in a similar manner and the risk register updated as appropriately.

5. CONCLUSION AND RECOMMENDATIONS

The management of health and safety in the demolition, refurbishment and alteration of buildings is becoming increasingly important due to the rise of the numbers of such projects in countries like the UK. Historically, most existing efforts have concentrated on the development of such safety management systems for new builds. A focus on developing systems more appropriate to the demolition, alteration and refurbishment projects implies that accidents and major injuries can be substantially reduced in the light of the risks posed by construction work due to such projects.

The ERIC principle recommends that Designers be obligated to (as far as is reasonably practicable) eliminate all risks associated with the implementation of their design. This process therefore requires a regime of smooth information flow to and from the Designers. To facilitate this and improve health and safety performance on demolition, information and refurbishment projects; a framework addressing the uniqueness of these kinds of projects is hereby proposed. Although based on the results from two case studies that have been carefully selected, it is proposed that this framework could aid the development of a procedure for information flow that will address the identification and mitigation of risks on alteration projects.

In the light of the development, however, further work can be conducted to facilitate the expansion of the framework. More case studies for example can generate additional risk factors and allow for the population of the Risk Register. In addition, risk management software and Building Information Management (BIM) based tools can also incorporate this procedure in the development of design and risk assessment tools as they relate to applications for demolition, alteration and refurbishment projects.

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Development of a Portable System for the Evaluation of Cumulative Physical Exposures and WMSD Risks Among Construction Workers

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Development of a Portable System for the Evaluation of Cumulative Physical Exposures and WMSD Risks Among Construction Workers

Abstract:

Approximately 35,000 work-related musculoskeletal disorders (WMSDs) are developed each year among construction workers. The purpose of this study was to develop a system to measure biomechanical exposures such that the cause of WMSDs may be better understood. In order to more realistically study the postures involved in construction tasks, the objective was to devise a non-intrusive mobile system for measurement such that it was feasible to record biomechanical data on job sites. The proposed system is the combination of an Xsens Moven^{TM} inertial motion capture suit, and a set of Parotec Paromed^{TM} pressure mapping insoles. An artificial neural network (ANN) was developed to predict ground reaction force (GRF), using kinematic motion capture data and force data from the insoles as inputs. As most construction site injuries involve workers' backs, spines, and trunks, the system was validated using an inverse dynamics approach to compare moment calculations about the subject's L4/L5 intervertebral disc. The first method of moment calculation is a "hands down" approach which considers the average percentage weight of individual body parts as a proportion of the subject's total mass; the moment of each body part is calculated about the L4/L5 invertebral disc and summed to calculate the total moment. The second, "bottom up" method of moment calculation is projected from the ANN-predicted GRF, such that the GRF is used to calculate the moment about L4/L5 invertebral disc. Results of moment calculations from trials including lateral bends and lower back flexion will be compared.

Keywords: inertial motion capture, pressure mapping insoles, artificial neural network, ground reaction force

1. Introduction

Approximately 35,000 work-related musculoskeletal disorders (WMSDs) are developed each year among construction workers (BLS, 2006). Current models to measure biomechanical exposures use estimated factors that may carry the risk of allowing over-exposure to physical demand. Furthermore, the changes in exposures due to physical variations, such as those experienced by construction workers on job sites, have largely been disregarded in biomechanical exposure models (Mathiassen, 2006).

The purpose of this study was to begin development of a portable method of measuring biomechanical exposures experienced by construction workers on job sites. This study sought to provide a system to quantify the biomechanical exposures on construction workers such that injuries may be better understood and prevented as previous studies have only been able to learn through observation. In order to achieve this objective, the study attempted to validate the use of an ergonomic evaluation system consisting of Parotec Paromed™ pressure mapping insoles and the Xsens Moven™ inertial motion capture suit in order to calculate the ground reaction force of a subject during both static and dynamics postures. The importance of this validation is that the system may be used in a field setting to quantify the ground reaction force (GRF) and moments about the lower back among subjects who perform tasks that carry a high risk of injury.

2. Methods

Objectives

The study sought to validate the usage of a portable system by means of three objectives:

1. Validate that the center of pressure (COP) from a set of pressure-mapping insoles was consistent with the known COP determined from force plates measurement.
2. Develop an ANN in order to predict GRF using inputs from an inertial motion capture suit and pressure-mapping insoles.
3. Use the ANN-predicted GRF as an input into a biomechanical model in order to estimate low back physical demand (moment about the L4/L5 invertebral disc) and compare the result to a traditional model of moment calculation.

Equipment

The devices used to complete this study include a Vicon™ Motion Capture system, 2 AMTI™ force plates, Xsens Moven™ intertial motion capture suit, Parotec Paromed™ pressure mapping soles with 24 sensors, Matlab™ Neural Network Toolbox™ and a 3-D quasi static biomechanical model including feet, shanks, upper legs, pelvis, a 3-segment trunk, upper arms, forearms, hands and a head.

Data Collection

Data were collected across four subjects, including three males and one female. In order to meet the first objective, subjects were first equipped with pressure-mapping insoles and reflective markers in order to capture motion capture data from the Vicon™ motion capture system, while standing on two force plates. The subjects were asked to make a gait stride onto the force plate in order to create an array of COP data points. Proceeding to the second and third objectives, subjects completed tasks such as marching and asymmetrical lifting while wearing the Moven™ motion capture suit and the pressure mapping soles.

A feed-forward, back-propagation artificial neural network (ANN) was created using the Matlab™ Neural Network Toolbox™. Data were prepared for inputs to the ANN as such:

ANN Input Data Preparation and Training

1. Find the downward force applied to each of the 24 cells in each of the pressure-sensing insole. For each frame of data collection, each of the cells outputs data. Data across all cells in a corresponding insole for each frame was summed in order to determine total force applied to the individual cells.

2. Find the position of subject's Center of Mass (COM). The position of each body segment was stored for each frame of motion capture collection. The subject's COM was subsequently calculated from the segmental data for each corresponding frame of motion capture.

3. Find the velocity and acceleration of the subject's COM. The first and second derivatives of the positional COM data were calculated respectively to correspond with velocity and acceleration.

Insole and motion capture data were both collected at 100 Hz such that the data could be simply associated in creation of a corresponding ANN.

In order to derive validation data for the ANN, subjects performed tasks while standing on two AMTI force plates- one designated to each foot. A neural network was created in order to model the z-component of force output from each of the two force plates, given the following inputs:

1. Individual force data from all 48 pressure-sensing cells (48 inputs)
2. Sum of force data for both insoles (2 inputs)
2. Velocity of COM (1 input)
3. Acceleration of COM (1 input)

Each of the data inputs were normalized with respect to maximum values. The neural network used a feed-forward linear architecture with two hidden layers. Using this architecture, data was presented to an input layer and subsequently multiplied by a weighted factor while passing to the first hidden layer. The weighted information was then summed and offset by a bias term. This offset summation is then processed by a transfer function in order to transfer to a second hidden layer to repeat the process. Adjusting the weights allows the network to become trained and produce relationships between the input and the output data (Savelberg, 1999). Given multiple data sets, the network progressively adjusted the weighting factors until it yielded accurate output predictions.

Inverse Dynamic Approach to Calculating Moments about L4/L5 Invertebral Disc

Upon completion of ANN training, an additional data set was collected in order to complete a second validation method of the Xsens™ and Paromed™ hardware. This second method of validation used an inverse dynamics approach to compare the moments of the upper body and the lower body. For the hands down approach, the moment of each body segment about the L4/L5 invertebral disc was calculated using accepted values of body part weights and positional data from the Moven^{TM} suit. This was compared to the bottom-up approach of calculating a moment about L4/L5 invertebral disc due to lower body components, with respect to the predicted values of ground reaction force from the ANN.

3. Results

The calculation of COP from insole data was highly correlated with the COP derived from force plates, as illustrated in Figure 1. R^2 for this exemplary trial was 0.94, with an RMS value of ~0.5 cm.

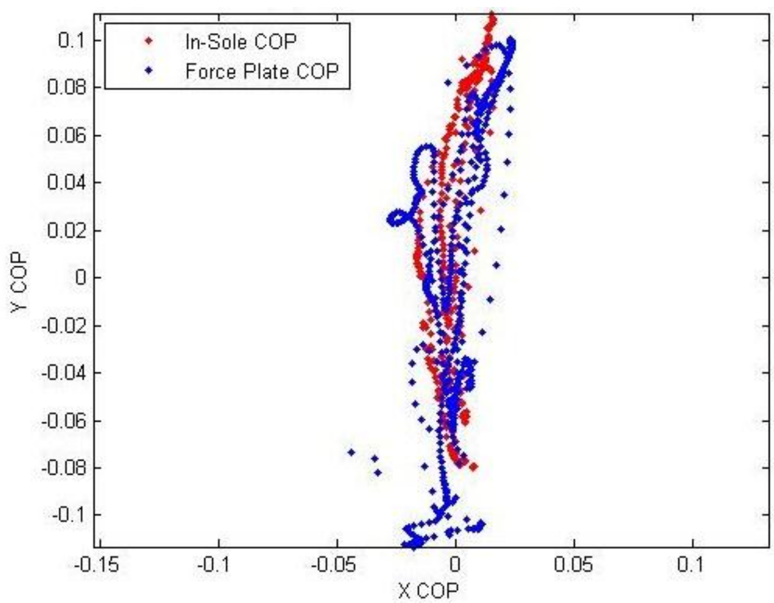

Figure 1: Center of Pressure of one foot as measured from a force plate (blue) and from the insole pressure-mapping system (red) during a single gait stride. Distances are in meters (m).

A comparison of the actual vs. predicted z-component of force for both of a subject's feet in a trial during which the subject was instructed to march in place is presented in Figure 2. Note that the actual data (solid line) is collected directly from a forceplate, while the simulated data (dotted line) was derived from an ANN, trained as previously described.

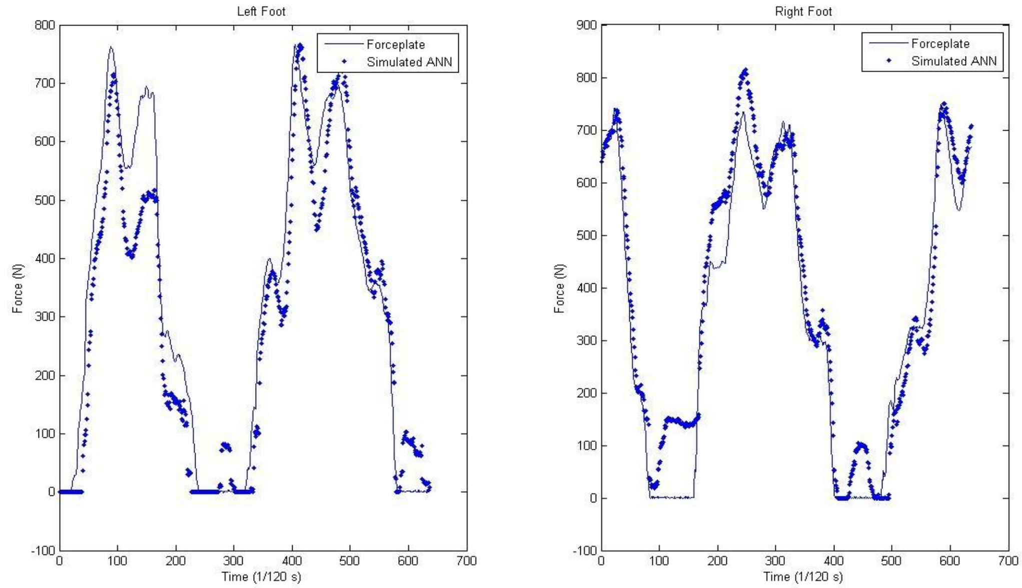

Figure 2: Simulated ANN data vs. force plate data for a Marching Trial

A comparison of the upper body and lower body moments during the lateral bend and flexion is presented in Figure 3. Note that the lower body moment is calculated from simulated ANN force data, while the upper body moment is derived from positional data and known body part weights. Root mean square values across all trials collected on the four subjects for lateral bending and lower back flexion trials were 20.01 and 35.46, respectively. The coefficients of determination (R^2) for lateral and flexion trials were respectively 0.61 and 0.52.

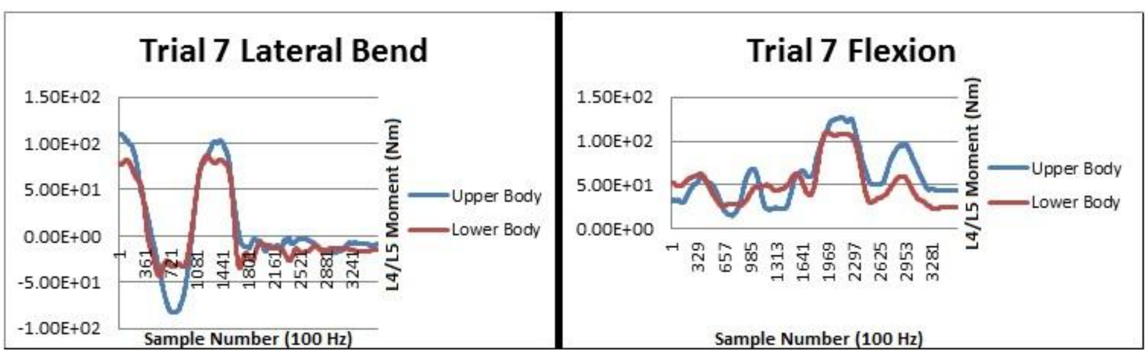

Figure 3: Exemplary Data Illustrating the level of Agreement Between Methods of Moment Calculation: Lateral Bend and Flexion

4. Discussion

Data that were simulated from the ANN closely match the force plate data (Figure 1). Note that figure 1 was shown for emphasis, as the trials used for moment calculation were less dramatic in impact since the feet remained grounded during these trials.

Previously it has been demonstrated that an ANN and pressure mapping insoles can be used to predict simple gaited movements such as walking or running with extremely high accuracy using similar methods (Zhang 2005, Fong 2008). The results of this study demonstrate that the portable system can be used for analyzing more complex movement than previously studied, such as lifting and marching, without the limitations imposed by an optical motion capture system and force plates.

The moments from the upper body and lower body follow the same shape in the lateral bend and flexion during the trials (Figure 3). The highest accuracy in both static and dynamic conditions with the Moven suit is achieved with slow movements (Cutti 2006). Therefore the motions performed with the suit were kept slow and controlled. This data validates the prediction of the ANN and further demonstrates that the network can be used to predict the GRF and used in biomechanical analysis of the body.

The R^2 statistic of the lateral bend across all four validation trials demonstrates that there exists a relationship between the moments in the upper and lower body. The relative weakness of this coefficient could be due to slight noise within the trials that appears stronger due to the low magnitudes of the moments of flexion. Additional source of error could be the absence of using foot shape as a factor in the ground reaction force as it has been determined that the shape of one's foot effects the distribution of pressure (Chuckpaiwong, 2008). Additionally, the act of wearing pressure mapping insoles carries the risk of altering natural foot movement during data collection (Kong 2009).

Limitations of the system are inherent to the use of the portable inertial motion capture suit and pressure-mapping insoles. In particular, the system does not typically respond well when feet are lifted from the ground. In the event of no pressure sensing, the insoles will report values of zero, which are subsequently fed into the neural network. However, the network's linear architecture is not well suited for handling zero values, and thus its predictions for GRF may vary. Refer to "zero" instances between the large positive steps on Figure 1, noting the manner in which the prediction drifts from zero.

The Xsens motion capture system may additionally impose negative influence on the system's accuracy. Errors in the accuracy of the Xsens motion capture suit can be attributed to a slight drift in the biomechanical model as well as any slight movement of the sensors in the suit (Damgrave 2009). The suit's coordinate system places its zero reference coordinate on the subject's right foot. In the event that the subject's right foot is lifted repeatedly, the system begins to incur a drift as its accuracy in reference to the original zero position is marginally effected with each lift.

After completion of data collection for this study, it was discovered that two of the 16 sensors in the motion capture system were defective. The quality of predictions would presumably benefit from the increased accuracy of the suit upon replacement of these sensors.

5. Conclusion

A subject's ground reaction force can be adequately quantified with the use of portable pressure-mapping insoles and an inertial motion capture suit. The system works best during slow movement during which a subject's feet are primarily grounded. Given the purpose of creating a portable system to measure cumulative exposures among construction workers in field settings, the system may be used for certain tasks as-is. In particular, the system may be well suited to tasks which require prolonged postures during which the feet remain static, such as repeated lifting or use of tools within a static space. Future considerations for the use of the system include investigating the elimination of the limitations imposed, under which the feet must remain grounded for accurate prediction, and re-analysing the system upon replacement of defective motion capture sensors.

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Issues Surrounding Complex Projects Interfacing With the Public

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Issues Surrounding Complex Projects Interfacing With the Public

Abstract:

For large scale projects refurbishment works are complex operations; however they have gained popularity in the United Kingdom in recent years. The job is made even more difficult when interface with the public is involved. Public interface is especially prevalent in complex environments such as rail and aviation hubs where essential services must be maintained during the build and safety of the public is, quite properly, of the highest priority. Little literature is available in the area of interface conflict in construction even though it is noted as an important topic. Wayfinding and evacuation are important where a phased construction process is present to ensure compliance and customer satisfaction. Birmingham is the United Kingdom's second city and Birmingham New Street is one of its largest rail stations with approximately 40 million passengers using the station each year and 12,000 using its facilities daily. The station is currently being refurbished as part of a multimillion pound construction urban regeneration project. Researchers at Loughborough University have been invited to carry out research alongside the build. The study will be a holistic review of the interface issue of wayfinding and evacuation in construction. This paper presents the initial stages of analysis which provide grounding for the project. To date the researchers have reviewed project documentation relating to wayfinding, assessed the public's views on the build and reviewed temporary emergency signage layout and placement. It is envisaged that results from the study will be used to form good practice guidance for public interface on construction projects especially wayfinding during temporary works.

Keywords: Public interface, temporary wayfinding, public safety

1. Introduction

The term construction refurbishment refers to upgrade, major repairs work, renovations, alterations, conversions, extension and modernisation of existing buildings, but it excludes maintenance and cleaning work (Quah, 1988). Refurbishment projects are among the most risky, complex and uncertain within the construction sector (Egbu et al., 1996). Even though these projects are difficult to manage they have gained increasing popularity in the United Kingdom over the last thirty years (Ali et al, 2008). Some of the most complex projects are the refurbishment of rail, air and hospital facilities where key services are provided and the building must stay open to the public during works. For example, the refurbishment of Heathrow terminal three, a major transport hub located in London with seven to eight million people using the facility each year. The facility needed to stay open during refurbishment works. Planning was meticulous; the major work was conducted at night with heavy equipment having to be removed before the facility could reopen in the morning. Routes had to change several times during construction; therefore changes to wayfinding signage had to be built into the program (Fawcett and Palmer, 2004). The refurbishment of King's Cross underground station completed in 2007 was another major refurbishment project. This station is London's busiest interchange with three mainline stations and four underground lines. The site also interfaced with the surface of one of London's busiest roads with up to three thousand cars an hour. There were complex relationships within the project which involved the maintenance of certain historic parts of the building and assets, supply chain, contractors and the relocation of major utilities. The project also involved continuous interface and meetings with external third parties such as the police, train operators and of course members of the public. The major challenge for this project was to keep services going and people moving, with 60,000 commuters passing through at peak times to use seven lines and two hubs. Each of the interface issues had to carefully plan in detail by the contractor. There was pre-planned design of twenty four temporary station layouts and new stair cases in order to maintain access in and out of the station. Each of the routes was PED (pedestrian) modeled to ensure the maintenance of evacuation capacity and also allow demolition, construction and station use (Taylor Woodrow, 2011).

Major refurbishment projects are not without issue and conflict can often arise. Awakul and Ogunlana (2002) highlighted that, in large scale construction projects, conflicts occur in two categories: internal conflicts and interface conflicts. Internal conflicts involve the project participants; on the other hand interface conflicts occur between the construction project and the groups outside the project. In large scale projects interface conflicts often arise as a result of conflicting requirements for different social groups. Egbu (1997) highlighted that the job dimension of public relations and the management of interface issues are important factors in the management of refurbishment operations. However, in current literature little guidance is given on how to solve interface conflicts, the majority of the literature focuses on internal conflict resolution. In the case studies at King's Cross and Heathrow, public interface played a major part in design, planning and management. Indeed, as the trend for major refurbishment works continues this will increasingly be the case. These projects were exemplary in managing interface issues. These projects were exemplary in managing interface issues. However, construction is a transient in nature and often ideas and best practice are lost from one project to the next. Moreover, while it remains a major concern little is written about the issue and no guidance or best practice is given especially where the public are concerned.

In the context of rail, aviation or healthcare projects one of the major issues is helping the public to wayfind or get to their final destination. Wayfinding may be defined as the process of finding ones way in the geographical or built environment. A person needs to be able to identify their current location and know how to get to their required destination (Fewings, 2001). On one hand wayfinding is dependent on personal ability where the wayfinder must build a cognitive map of the spatial relationships between landmarks in their current environment (Head and Isom, 2010). However, wayfinding is not just about personal ability: the wayfinder should also be aided by visual, audible and tactile cues to help them find their way around their environment. Where no prompts are provided it is difficult if not impossible for the wayfinder to find their way around. The accuracy of information to form a cognitive map can influence wayfinding performance (O'Neill, 1991). For a rail or air commuter in an environment affected by construction work which is liable to constant change using hoardings accurate and concurrent wayfinding data are essential to ensure public safety, ease wayfinding and arrival to a final destination. Of the visual cues available to the wayfinder the most commonly used is signage. Signage and emergency signage are of particular importance in an evacuation situation. Signage in the United Kingdom is strongly regulated by the British Standard 5499-4:2000 where particular attention is given to the user's familiarity with their surroundings, the use of the building and eliminating barriers to evacuation especially in conditions of stress. In the event of a fire, the amount of time spent trying to escape is a significant determinant of survival and escape behavior is influenced by sign recognition and cognition (Tang et al., 2009).

At a higher level, accurate wayfinding information is also critical in environments where goods and services are provided. The Equality Act (2010) and its precursor the Disability Discrimination Act (1995) make it unlawful for a service provider to make it unreasonable for a disabled person to use a service, which includes wayfinding (RSSB Report, 2006). Under the act disability is listed as physical, sensory and cognitive. Sensory impairments may include users who have hearing and/or visual impairments. Cognitive disability is a very broad term which may be minor, severe, temporary or long term which reduces a person's ability to process or understand information. It is unclear how the adequacy of this information is monitored in an environment affected by construction work. If this responsibility is passed to the contractor they make decisions on an isolated construction site and these decisions may not be consistent. There needs to be some coherence on how signage is placed and monitored within complex refurbishment builds.

Birmingham and Birmingham New Street Gateway project

Birmingham is the United Kingdom's second city and Birmingham New Street is the busiest station outside of London with approximately 40 million passengers using the station each year and 12,000 using its facilities daily. The station is currently being refurbished as part of a multimillion pound construction process. The project is worth £600m; it will double passenger capacity and according to the client, Network Rail will deliver:

- A concourse that is three-and-a-half times bigger than at present and enclosed by a giant, light-filled atrium
- More accessible, brighter and clearer platforms, serviced by over 30 new escalators and over 15 new public lifts
- A stunning new station façade
- Better links to and through the station for pedestrians with eight entrances
- New staff accommodation and facilities
- The stimulus for the physical regeneration of the areas surrounding the station.

In order for the reader to fully appreciate what will be achieved Figure 1 and Figure 2 have been included for illustration purposes. Phase one of the build has already started and the entire project is due for completion in 2015.

Figure 1 Current facade at Birmingham New Street Station

Figure 2 Envisaged facade at Birmingham New Street Station

The project will be completed in a phased basis as highlighted in Figure 3 and Figure 4. Expected completion date for phase one is 2012. A brand new concourse is being constructed at the site of a lower level car park next to the current station. When the new concourse opens it will provide approximately one and a half times the space of the existing building. When the new concourse opens phase two will begin where the current concourse will close for redevelopment. This part of the build will open in a largely phased basis and will eventually combine with the first half of the concourse in 2015.

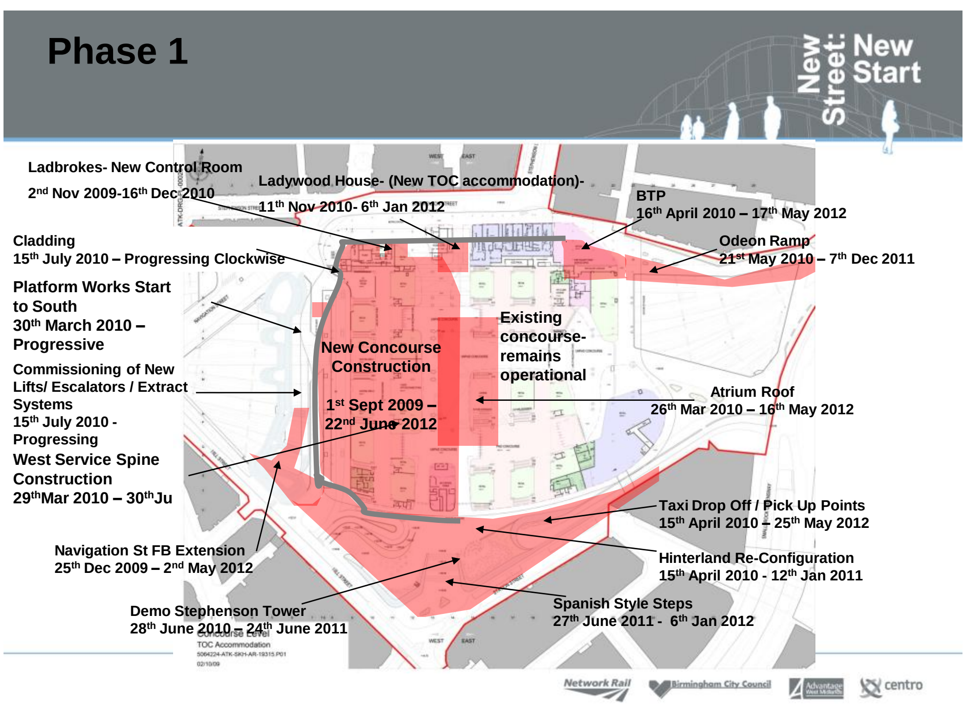

Figure 3: Phase 1 of the Birmingham New Street Gateway Build

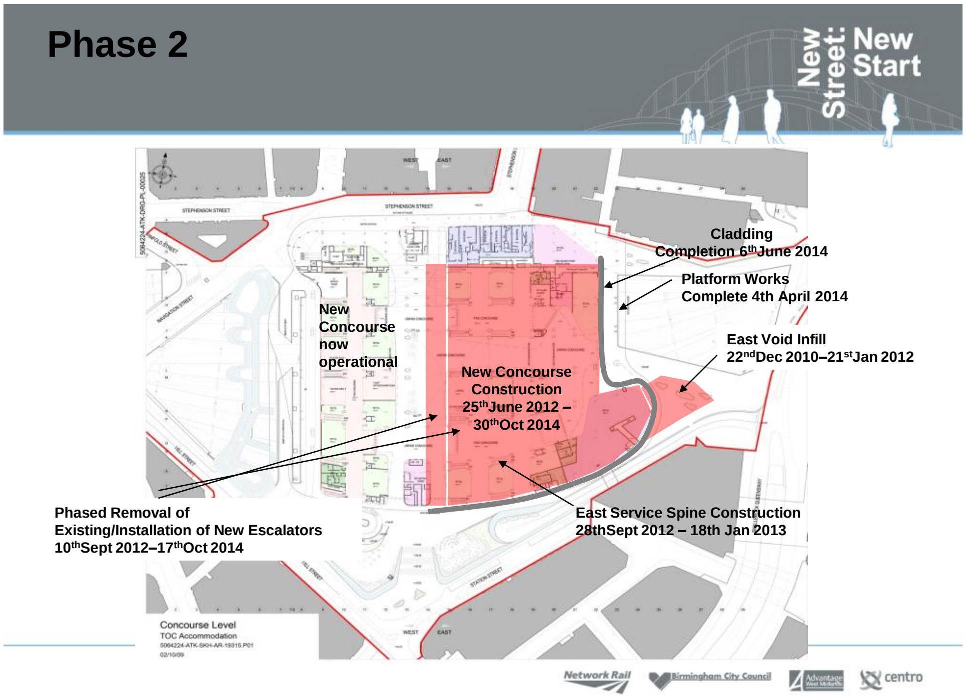

Figure 4: Phase 2 of the Birmingham New Street Gateway Build

Challenges at Birmingham New Street Gateway project

The Gateway project is a highly complicated refurbishment. Many challenges are present and more are likely to arise during the build. The following are issues related directly to the build, many of which result in particular challenges for the health and safety of workers and public alike:

- The station and retail area acts as a thoroughfare effectively splitting the city in half, the station must stay open to allow pedestrian access.
- The station is in close proximity to local businesses and housing and the goal is to minimize disruption during construction.
- The project managers Client Sponsors must interface with several external and internal project partners, including Train Operating Companies (TOC).
- Birmingham New Street Station is a major transport hub for the UK and is used primarily by commuters.
- Finding inconsistencies in the structure that was built in the 1960s will lead to project delays when designing remedial works.
- Relocation of utilities
- The contractors and developers must adhere to the policies of sub-terrain and rail construction.
- Constrained working areas.
- The station must remain operational throughout the build.
- Demolition.
- Tight and constrained working spaces.

- The station will see a surge in passengers during the London 2012 games as people will travel to and from the games, and the trains will run later from London to accommodate late running events.

Researchers at Loughborough University have been invited to complete research work alongside the build. The study will be a holistic review of wayfinding and interface issues in construction. The build is to be completed in a vibrant, metropolitan hub where complete demolition is not suitable due to the need to maintain the transport hub. Instead the construction work must be carried out as a largely phased operation. This offers an exciting avenue for research as many wayfinding issues such as evacuation and commuter familiarization of travel may arise. This paper sets the scene for the work that is due to be completed.

2. Method

Review of project documentation Atkins

Atkins is one of the leading design consultancies in the world and they have been tasked with designing the wayfinding strategy at Birmingham New Street station for both the temporary and permanent stages of the build. Following initial meetings with a Gateway project sponsor (project coordinator) and members of the Atkins and Gateway project team, researchers at Loughborough were given access to the data information share system used by the project. The information system provides access to meeting minutes and reports relevant to wayfinding. The researchers at Loughborough will review this information and collate it for input into a report based around best practice.

Wayfinding questionnaire and analysis using SignCirCAD.

Atkins are also the wayfinding designers for the permanent works and have completed a comprehensive report highlighting user demographics, demands, opinions and needs. However, the report did not address cognitive user aspects or subjective issues associated with the construction phase. A questionnaire for this part of the work was formulated based on a current valid and reliable questionnaire related to user opinion, cognitive ability (Kato and Takeuchi, 2003) and construction. We were interested to know if the current construction works disrupted their journey, if their own cognitive ability influenced their wayfinding decisions and to what extent and more importantly how much disruption and inconvenience they are willing and able to deal with. This work was facilitated by our project sponsor, station managers and interface staff at the station.

Loughborough University has a close working relationship with the University of Zaragoza, Spain. The Spanish researchers have developed an innovative sign placement and design, AutoCAD bolt-on software (SignCirCAD). One of the main characteristics of the tool is its ability to check if a whole area is properly covered with projected signs. For that, all of the different covered areas are associated with their respective individual signs, depending on their physical characteristics. The tool involves an extensive library of emergency evacuation and wayfinding signs. These safety signs can be easily placed in the digital plans of the building project, helping users to correctly obtain signed areas. Researchers were given access to construction drawings as well as platforms so that the drawings could be marked out and hoardings and signs located. The key features of the tool are as follows:

- Aids the placement of graphical symbols on architectural plans.
- Integrates with a commonly used design tool AutoCAD to allow design communication of design changes to the client as well as an interdisciplinary design team.
- Facilitates the placement of several sign types, flat, perpendicular to the wall and panoramic.
- Integrates a library of signage designs which meet the specifications of current standards.
- Analyses the signs areas of influence taking into consideration the size and physical shape of each placed sign. The designer may graphically visualise the specific area of coverage for each sign placed. This also allows the designer to verify that current regulations are adhered to, blind spots are covered and sign congestion is eliminated.
- Counts the total number of signs present in a drawing.
- Allows the user to place boundary tape and calculate the total length.
- Integrates pathways thus eliminating confusion when the designer considers sign orientation.
- Allows the user to consider visual obstacles which would limit the line of sight for the end user.
- Works using blocks in AutoCAD which implies that several different iterations of sign placement and design are possible. This is particularly beneficial from a usability point of view where a client may demand several variations for numerous users.

Two platforms (platform 1 and platform 12) are currently being renovated as part of the works. Platform 12 is completely closed off and there is no public access. Platform 1 has been handed back and is operational. However, construction work is not complete and hoardings and temporary signage are located along the platform. Hoarding and signage location will change continuously on this platform as construction work progresses. Researchers will use the tool to assess current signage locations for visibility and adequacy and make recommendations to the contractors on platform 1. The results presented here highlight the current temporary signage layout and sets the scene for work to be conducted alongside the build.

3. Results

Review of project documentation Atkins

A review of meeting notes between the Gateway project team, Atkins and the TOCs (Train Operating Companies) highlighted that an action plan for temporary wayfinding and signage design was pertinent during the construction phasing for logistical, commercial and safety reasons. Atkins also conducted a series of wayfinding reports and baseline studies for Network Rail. The following points regarding temporary signage design and placement have been highlighted as relevant to this work:

- It is important to provide information in a variety of formats.
- Temporary information signs should be free standing units which can be positioned so that they are readily visible among the main visitor routes or dwelling areas (where passengers wait for trains) and, if this is not possible, units should be placed along the wall.
- Temporary print information should adopt the same style principals of the permanent signage including appropriate use of color, text and symbology.
- The temporary information will remain mainly the same as the temporary signage but will be closely managed and altered to allow for the phased nature of the work.
- Care should be taken that temporary information or retail advertising should not obstruct passenger flow or visibility of other wayfinding signage.
- Surveys of other comparable stations or units are important to investigate past works and best practice.
- Proposed information points and clusters – five information clusters are proposed at concourse level. Clusters are provided in and around current access and exit points around the station. Allowances for temporary signage have been proposed around the cluster.

Wayfinding questionnaire and analysis using SignCirCAD.

157 questionnaires were distributed at Birmingham New Street over two days to investigate passenger’s opinions of the current wayfinding facilities, their personal wayfinding ability and if the current construction works had affected their ability to wayfind and how much disruption they were willing to endure. In general participants rated themselves as good wayfinders. If passengers were commuters they were generally happy with the wayfinding information provided. However, those who used the station less frequently had problems with the current wayfinding information. There was little impact of the current construction works on passengers’ ability to wayfind. The current station passengers said they are willing to endure a lot of disruption in order to see the station through to completion. It is envisaged that a second study will be completed in a year’s time to assess the passengers opinions once the second phase of construction works have gotten underway. The station will change frequently in layout and design during the next phase of construction.

Work is being completed in a largely phased basis at the station. Contractors are currently working on the refurbishment of platforms 1and 12. It was initially envisaged that platforms would be completely closed off during refurbishment works. However, due to project timelines and constraints platform one was handed back before works were complete. Hoardings were placed at platform level to separate the public from the works as illustrated in **Figure 5**.

Figure 5: Platform 1 with hoardings

While the presence, design and layout of safety signage is necessitated by law little consideration is given to the location of the signage and placement is often done on an ad-hoc basis. On construction sites it is often left at the discretion of contractors. Managers at the Birmingham build were particularly concerned about the placement of evacuation signage due the sub-terrain nature of platforms and the need to conform to stringent regulations. Results of experiments using virtual reality simulations to examine emergency evacuation of buildings (Tang et al, 2009) showed that the time to evacuate the building when no signs were available was three times the minimum time needed for emergency escape without error.

The researchers at Loughborough are using SignCirCAD to assess the temporary emergency signage design and layout of platform 1. This assessment will be completed throughout the build and feedback and guidance will be given to the contractor. Figure X shows a current overview of platform 1. As the build is only at its initial stages so too is our assessment. **Figure 6**, **Figure 7** and **Figure 8** guide the reader through an initial assessment that was completed on platform one (The real-covered areas are generated by the software based on the dimensions of the signage. All of the temporary evacuation signage is wall-mounted onto hoardings. The drawings have a number of call out boxes for clarity. The size of the emergency signs are 537x272mm, however SignCirCAD at present uses three sign sizes, as such the emergency signs are not accurately reproduced by this drawings viewing distances, which takes sizes 210x210 mm to give a worst case scenario. However, the analysis does highlight that there is some deficiency in the current sign design and placement strategy. Several blind spots were identified in the current emergency signage layout;

moreover one part of the platform had no evacuation signage. However, it should be noted that the gateway project is answerable to several regulatory bodies and has detailed evacuation plans Nevertheless, the analysis does highlight gaps in the current strategy It is hoped that the work at Loughborough will aid the contractors in assessing the best location for temporary signage at the construction stage. If contractors are able to pre-plan emergency signage location it is beneficial in the case of evacuation to improve escape times and ensure compliance with current legislation. Furthermore the current contractor employed to work on platform 12 has their own sign making business which would ease integration into the system as SignCirCAD works by drawing from several libraries so that the user may assess several signage layout scenarios in tandem. This means that researchers can highlight how the contractors can ensure compliance with current legislation on emergency evacuation and signage.

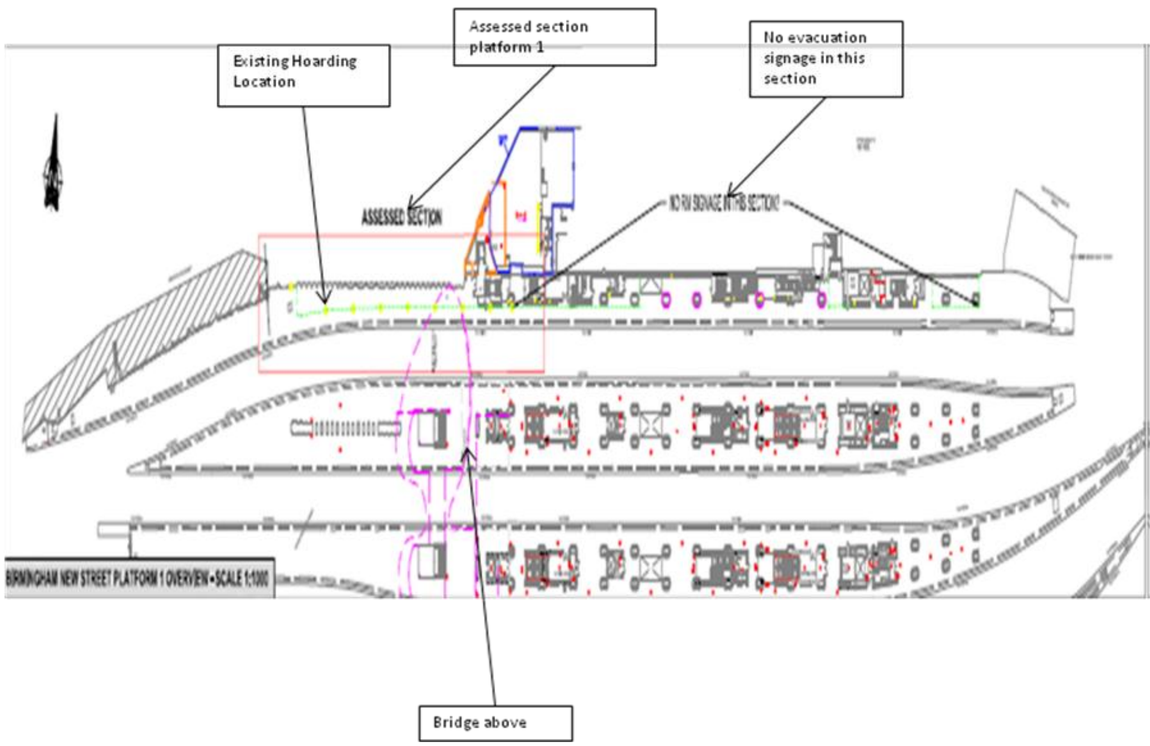

Figure 6: Platform 1 overview

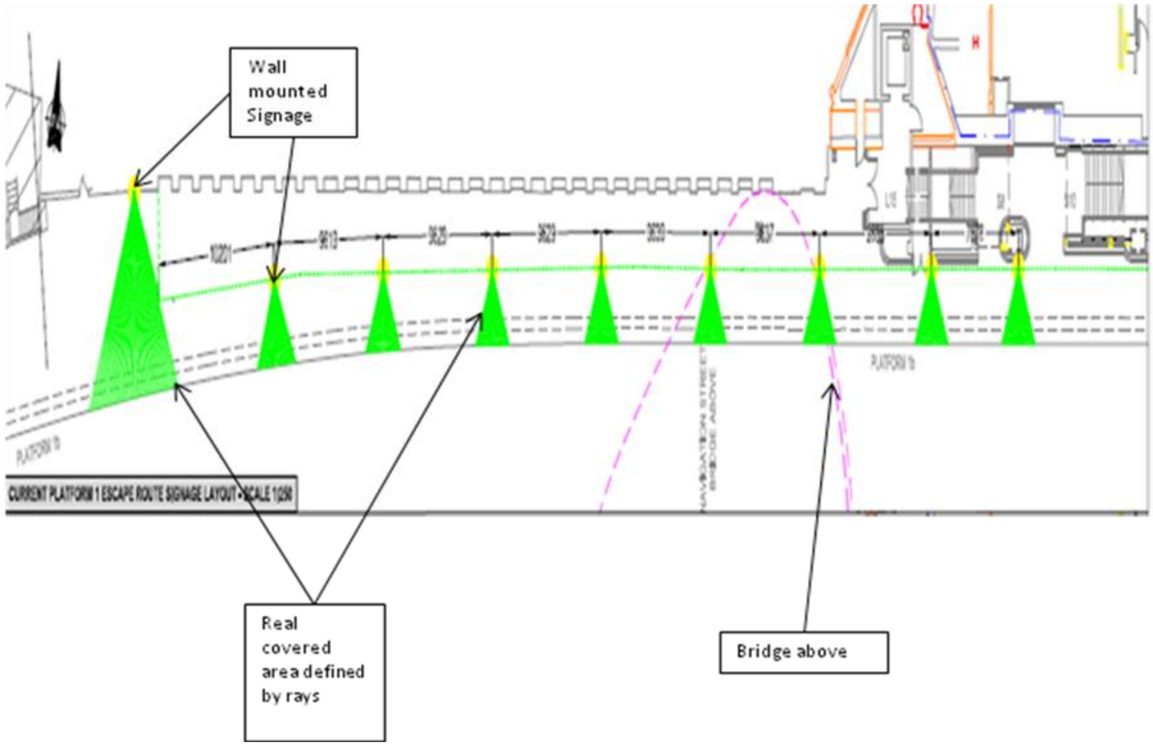

Figure 7: Existing signage placement and layout for platform 1 escape route

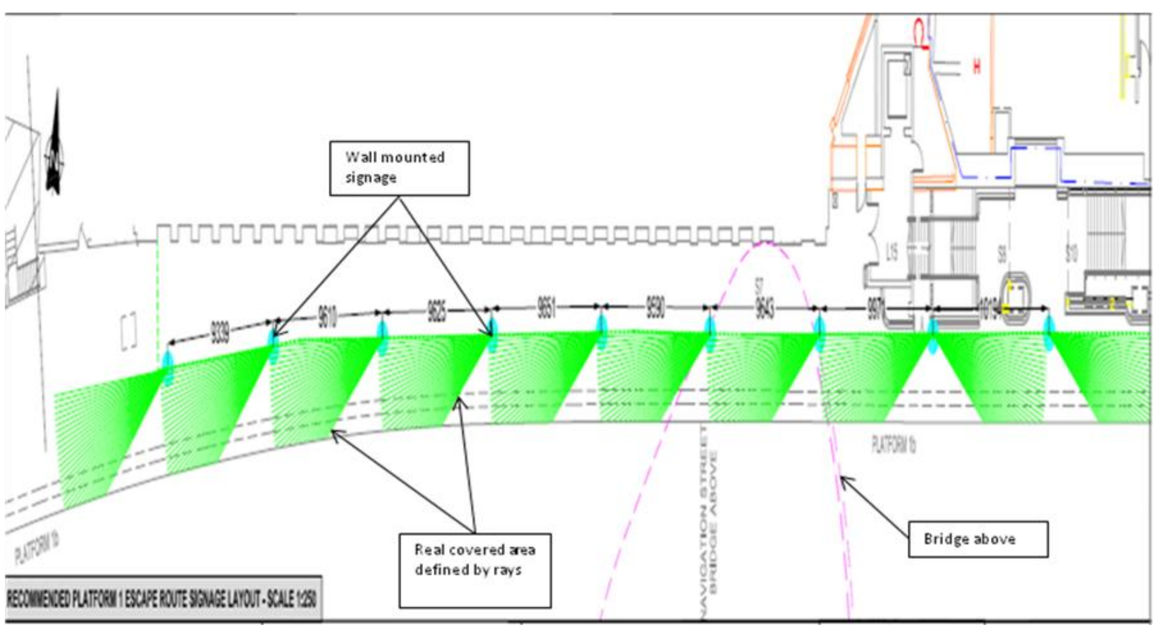

Figure 8: Suggested signage placement and layout for Platform 1 escape route

4. Conclusions

- Refurbishment works are among the most risky, complex and uncertain within the construction industry. Especially when the refurbishment is completed in complex environments such as rail and air hubs and where there is a need for interface with the public and the existing workforce.
- Several flagship projects have highlighted some important issues. However, the information was not collated or assimilated into best practice guidance.
- Literature has highlighted the importance of managing interface conflicts. However, the guidance is largely superficial with the majority of literature focusing on internal conflicts.
- Wayfinding and evacuation are important factors to consider for refurbishment works, especially where essential services are provided and the building must remain functional throughout the duration of the work.
- The Birmingham Gateway project is a flagship project which has several interface issues. It is hoped that the work at Loughborough University will be beneficial for future dissemination of best practice in these types of projects.

The analysis using SignCirCAD highlighted some limitations in the current layout of emergency evacuation signage. This point in part highlights the importance of guidance for signage design and placement especially in complex environments.

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Occupational Communities and Safety Culture

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Abstract

Schein defines organizational culture as "…a set of basic tacit assumptions about how the world is and ought to be that a group of people ***share*** (emphasis added) and that determines their perceptions, thoughts, feelings, and, to some degree, their overt behavior." Safety culture is a subset of organizational culture. Except for very small organizations, an organization's culture is not monolithic. Subcultures do exist; Schein identifies three: executive, engineer, and operative. The subcultures differ in the assumptions held by their members, which in turn influence the way the members approach problems. Engineers, for example, believe they can design perfect systems while operatives do not believe there is such a thing as a perfect system. In the fragmented world of construction, these subcultures are further splintered into occupational communities, which Van Maanen and Barley define 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.

In construction, each of the construction crafts, superintendents, project managers, and safety professionals may form separate occupational communities. The assumptions held by each group have been developed over time as the group has confronted and solved problems such as insuring the safety of group members. The potential for conflict exists when one group, for example, project managers, attempts to impose work methods on another group that are different than that group's traditional methods. Given that a construction project is a temporary, multi-organization, the issue of developing a project safety culture is highly complex.

The paper will examine occupational communities in the context of construction and the development of project safety culture. The question of whether a true project safety culture can be developed will be addressed. Recommendations for research will be presented.

Keywords: safety culture, occupational communities, cultural integration, project safety culture

1. Introduction

Interest in organizational culture and its influence on organizational performance began in the 1980s with the publication of such works as *In Search of Excellence: Lessons from America's Best-run Companies* (Peters and Waterman, 1982) and *Corporate Cultures: the Rites and Rituals of Corporate Life* (Deal and Kennedy, 1982). Rigorous academic examination of organizational culture began with Edgar Schein's *Organizational Culture and Leadership* (Schein, 1985) in which he defines culture as "…a set of basic tacit assumptions about how the world is and ought to be that a group of people ***share*** (emphasis added) and that determines their perceptions, thoughts, feelings, and, to some degree, their overt behavior." He observes that culture manifests itself at three levels:

- the level of deep tacit assumptions that are the essence of the culture;
- the level of espoused values that often reflect what a group wishes ideally to be and the way it wants to present itself publicly;
- the day-to-day behavior that represents a complex compromise among the espoused values, the deeper assumptions, and the immediate requirements of the situation.

The critical element of this definition is that the assumptions, values, and beliefs are shared.

Except for the smallest organizations, an organization's culture is not monolithic; it consists of a series of cultures developed within groups that are formed based upon a variety of factors: function performed, department, hierarchical level, geographic territory, etc. Schein (1996) identified three subcultures within organizations: executive, engineer, and operative. Each may have its own assumptions, beliefs, and values about how things should done, priorities, and problem-solving. He asserts that the executive and engineering cultures arise, to a major degree, from outside the organization because executives and engineers are members of occupational communities. 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.

Construction craftworkers or operatives appear to be members of a group that:

- undergoes a significant socialization process to become a member
- acquires a set of skills and technological capabilities necessary to perform a set of tasks that are readily transferable between employers
- constitutes an area pool of labor from which employers draw based on need
- possesses a strong culture

Schein terms these groups occupational communities, which Van Maanen and Barley (1984) define 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

Occupational Communities

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 effectiveness of the performance of its members. A critical cultural issue is that of control of the work process. 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 is to be performed and evaluated. *This is particularly true for construction craftworkers (Stinchcombe 1959).*
- Self-control refers to the occupational community's ability to dictate … how the content and conduct of a member's work will be assessed.
- …self-control is problematic to members of an occupational community only when organizational officials seek to impose certain "outsider" standards, goals, work tasks, evaluative schemes, and so forth upon the membership. In and of itself, hierarchy is not an issue. It is the use of hierarchical authority to direct member activities in ways the membership considers untoward that presents the problem and threat to self-control.

The opportunity for the development of occupational communities with their own cultures in the construction industry is great because of the fragmentation of the industry. Craft workers are grouped (loosely in the nonunion sector, but more tightly in the union sector) along jurisdictional lines such as carpenter, electrician, ironworker, and plumber, among others. For more than 100 years, craft workers have organized into labor unions based on jurisdiction and through them have been trained and socialized into the trade. First and second level supervisors typically have risen from one of the crafts. Executive, management, and professional personnel, through increasing professionalization and certification, have splintered into numerous professional organizations (For example, Project Management Institute, American Society of Safety Engineers, Construction Management Association, and various contractor organizations). Through interaction and professional activities, members of these organizations develop shared values, beliefs, and assumptions, i.e., their own culture.

Occupational cultures develop along a continuum ranging from very weak, which may be found in an informal group that comes together infrequently to extremely strong for a formal organization whose members interact frequently, which formulates standards and codes of behavior, and determines who is admitted to membership (Trice, 1993).

Potential construction occupational cultures may be identified using dimensions examined by Van Maanen and Barley (1984) and Trice (1993):

- extent to which members perform the same work; ;
- hold the same assumptions, beliefs, values, and attitudes toward, among other things, safety;
- hold the same attitudes toward the safety of their coworkers;
- socialize with one another;

- members control membership; engage in safety-specific citizenship behavior;
- similarities in perceptions of what you do vs. who you are; and
- the extent of socialization required.

Construction Organization-Occupational Community Interaction

In other than very small construction firms (Maloney 2011), there are two distinct parts of the organization: a home or corporate office responsible for obtaining and administering projects and performing corporate functions. There is also a field or project component responsible for performing the actual construction work.

Construction organization employees may be viewed as consisting of three groups:

- Permanent core organization – executives, engineers, professionals, etc. who have varying lengths of tenure with the organization but are considered permanent employees.
- Quasi-permanent project management team – project managers, engineers, superintendents, etc. who are responsible for getting a project built within specified criteria. The members of this team are quasi-permanent employees in that they remain employed by the firm as long as the firm has sufficient project work. Absent that work, the members are released and rehired when additional work is obtained.
- Temporary supervisory and craft personnel hired on an as needed basis for a project

The initial assumptions, beliefs, and values, i.e. culture, of the organization are brought to the organization by its founders. Over the life of the organization, those individuals in the permanent core interact in a reciprocal influence process in which they each influence one another and in turn are influenced by the others. In this process, the tacit or basic assumptions, beliefs, and values held by each person are shaped by shared experiences with the result that a set of assumptions, beliefs, and values, shared by the members, emerges. These reflect the members' experiences as to what works in providing a safe work environment.

Employees in the permanent core interact and influence and are influenced by the prevailing culture of the core organization. This culture reflects the subcultures present in the organization; there may be variations between the subcultures, but there is a prevailing culture for the contractor's overall organization.

Foremen and craftworkers are the primary individuals with a temporary attachment to the contractor's project organization. They are members of an occupational community that has its own culture. The degree of integration between the project organization's culture and that of the occupational community will significantly influence performance on the project. This integration can be viewed in terms of four distinct cases as shown in Figure 1. Which of the four cases occurs is a function of the nature of the relationship between the organization in question and the members of the occupational community and the duration of the relationship.

Case I is the situation whereby the organization hires an independent contractor. No effort is made to influence the contractor's performance of the work. The typical situation in construction is that of Case II. A contractor hires one or more craft workers who are members of an occupational community to work on a project for a relatively short, finite period. If one accepts the idea of culture as "The way we do things around here," there may be two distinct cultures co-existing on the project: the prevailing culture of the contractor organization and that of the craft worker community. Each may have its own way of doing things. Through a process of negotiation or mutual influence an overlap of cultures is obtained such that there is an agreement between the contractor organization and craft worker community on specific issues. On other issues, the contractor organization and craft worker community retain their own culture and way of doing things.

Case III arises when a group of craft workers are employed on a long-term basis by a single organization. The degree of integration increases as the scope of issues addressed by the occupational community's culture decreases. There are still identifiable differences between the two cultures. Over time, Case IV is the end result. The two cultures totally merge and are indistinguishable. Which case emerges is a function of the nature of the employment relationship between the organization and members of the occupational community, the length of the employment, and the degree of autonomy and independence granted members of the occupational community by the organization.

It is important to understand that integration is a process of mutual influence. The members of the occupational community influence the contractor organization and vice versa. The actual culture on a project emerges from this mutual influence process. Thus, it is more meaningful to focus on the emergent culture than it is on either the contractor organization's culture or the occupational community's culture. However, to understand the emergent culture it is crucial to understand the two cultures involved in the mutual influence process. Schein (1996) believes that many organization problems arise because of the lack of understanding by the members of each of each subculture of the other subcultures.

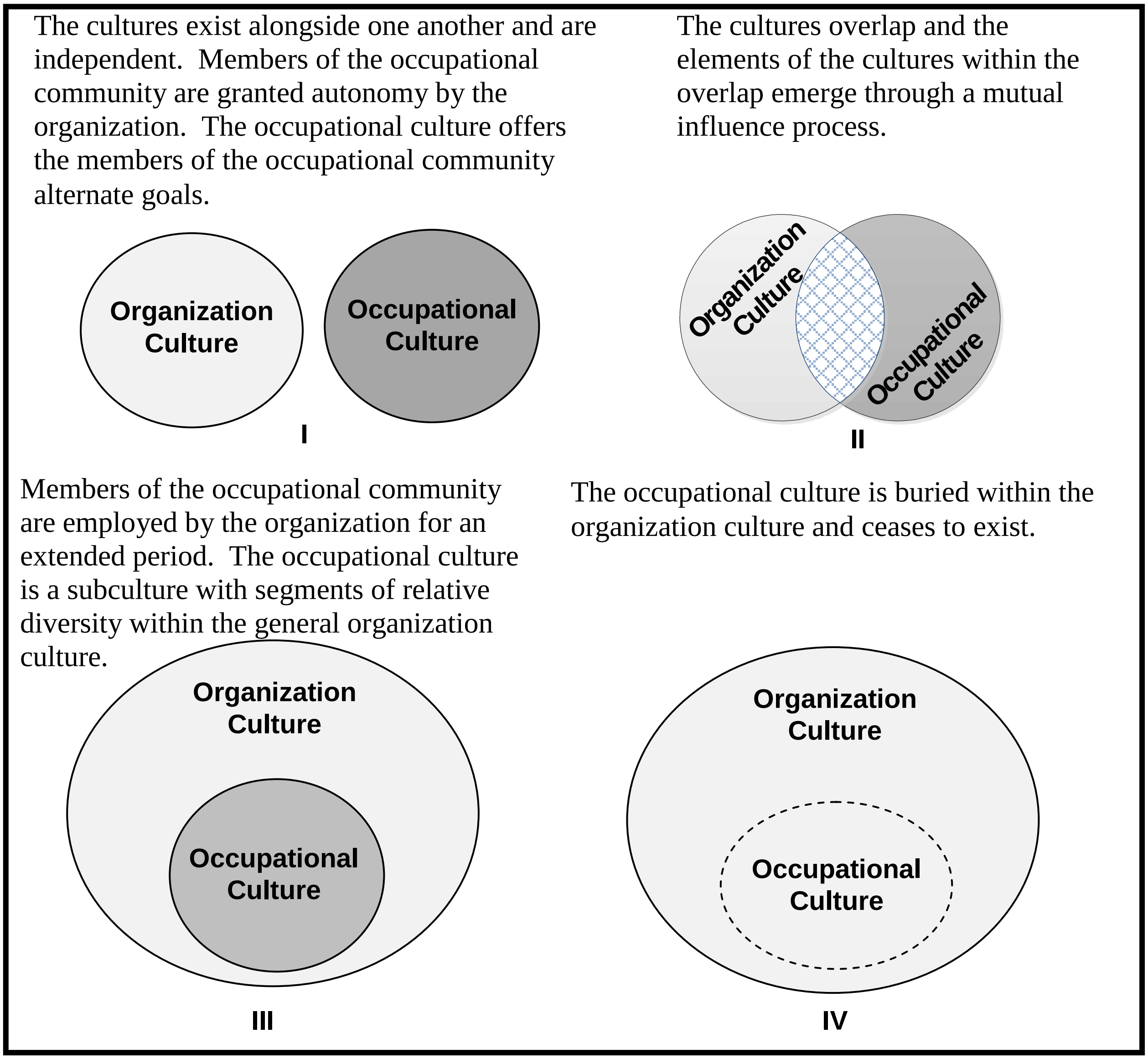

Figure 1 – Organization-Occupational Culture Integration

The issue of mutual influence needs to be understood in terms of Schein's definition of culture. An emergent culture is one that results from the interaction of two or more cultures and shared experiences. Schein (1996) discusses assumptions held by various subcultures. Engineers believe that they can design the perfect system. Operatives, on the other hand, believe that there is no perfect system and that they, because of their intimate knowledge of the process, know best how to do it.

Leaders play a critical role in creating the emergent culture. After a series of positive experiences, a leader who values operative input develops a belief that Individuals performing a task know best how to improve task performance. Continued positive experiences lead to the development of an assumption that worker engagement is desirable. If the operatives perceive these experiences positively, the result is shared values, beliefs, and assumptions, i.e., shared culture.

Figure 2 conceptually illustrates the overlap of occupational cultures where the overlap indicates sharing of assumptions, beliefs, values, and attitudes. The extent of overlap is a function of the relative strength of the occupational cultures and the time and experiences of individuals in the employing organization. Individuals and occupational cultures exist in relationships of reciprocal determinism such that the longer the relationship, the more the cultures will come to overlap. Thus, time is a key determinant in the development of a comprehensive shared culture.

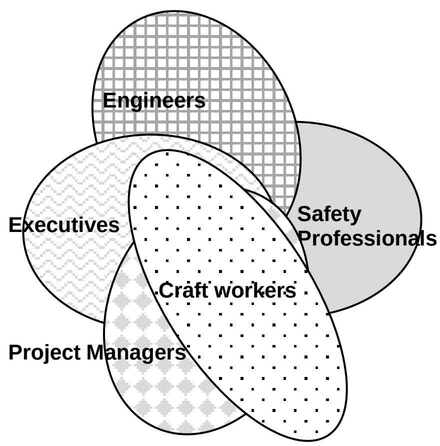

Figure 2 – Occupational Cultures

However, construction projects have a relatively short, finite duration. Individuals and construction organizations are employed on construction projects for highly variable durations, ranging from as little as a few days to years, depending upon the size and nature of the project. As Schein (2010) states, organizational cultures are long-term and enduring and not subject to radical and rapid change. Some organizational culture consultants believe that transforming an organization’s culture can require five to seven years, which far exceeds the duration of almost all construction projects.

A primary goal of a construction project manager should be to develop an integrated project safety culture that creates the safety environment needed to achieve the project’s safety goals, which must be zero incidents. The project safety culture will emerge from the interaction of the constituent cultures and the leadership of the project management team. Because the industry is characterized by personnel moving between projects and companies, a group’s safety culture is a “learned product of group experience” (Schein, 2010) as to what worked in solving problems on the projects and within the various groups and organizations. The extent of congruence between the cultures of the various groups and organizations within a project (managers, engineers, superintendents, foremen, and craftworkers as well as contractors and construction managers) must be examined.

On projects performed by a single construction organization, the concept of a project safety culture may be valid. The breadth and strength of that culture will be a function of the occupational cultures present within the organization and their relative strengths. In projects constructed with extensive subcontracting, there may not be a single project safety culture. Instead, there may be multiple safety cultures with some degree of overlap between them.

Given OSHA’s multiemployer worksite doctrine, the general contractor or construction manager considered to be the controlling employer for the project site must develop an integrated approach to safety on the project. That firm cannot impose its safety culture on other firms; each firm is unique in terms of its personnel, the experiences shared by them, and what they have found works in executing a project safely. The controlling employer cannot change the safety culture of another firm. Given that, the controlling employer, based upon its safety culture and requirements of the project owner, should develop a set of policies, procedures, and practices, i.e., a project safety climate, to achieve the project's safety goals and require that all firms working on the project abide by them. This will establish the safety climate at the beginning of the project. The relationship between culture and climate is shown in Figure 3.

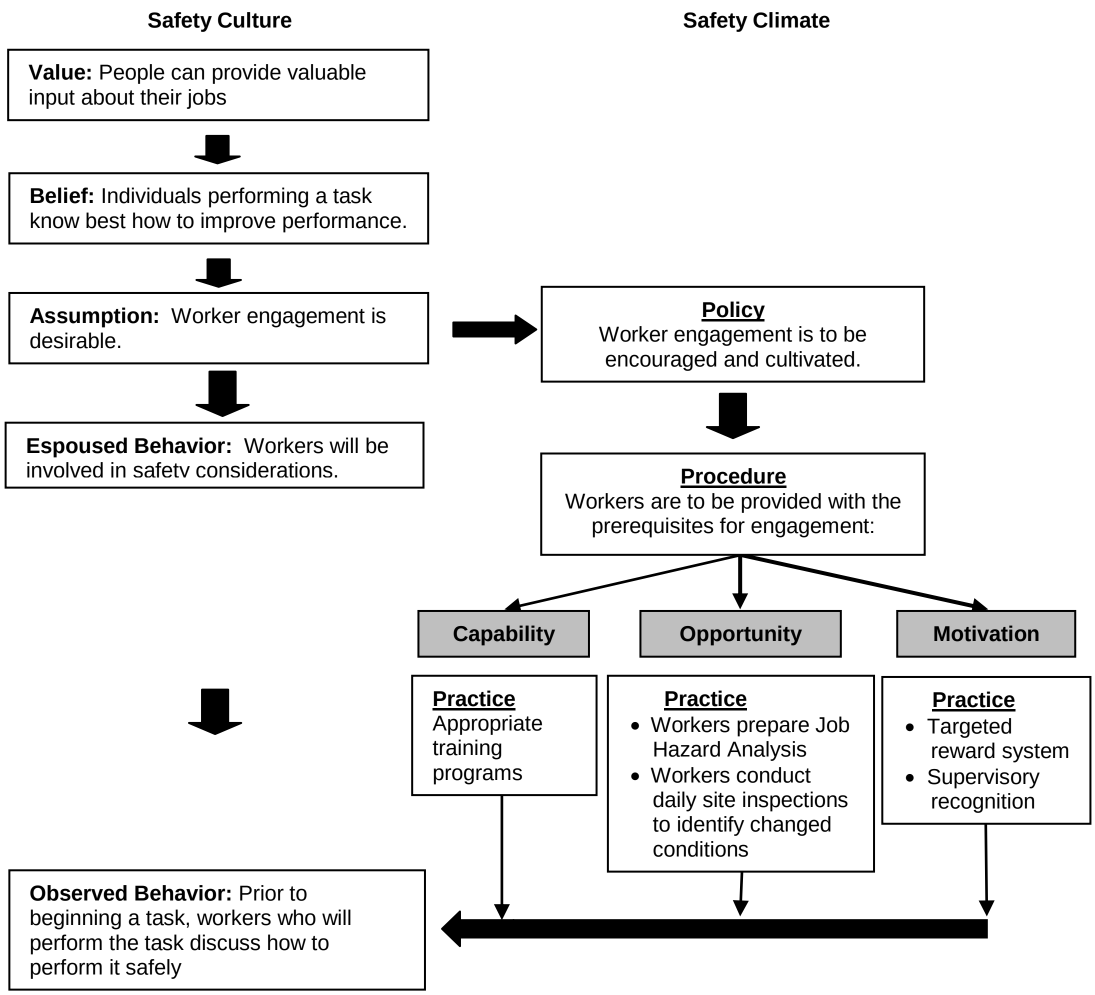

Figure 3 - Relationship between Organizational Culture & Climate for Safety

As the project unfolds, the controlling employer and the other construction organizations working on the project will be in a reciprocal relationship such that the project safety climate will evolve over the life of the project. The experience on this project will influence the assumptions, beliefs and values of the project personnel and the safety cultures of the participating construction organizations and occupations.

Multi-Level Safety Climate

Previous research (Zohar, 2000; Zohar and Lauria, 2005; and Lingard, et. al. 2009), has found that operatives are able to distinguish multiple levels of safety climate, i.e., organization and workgroup, general contractor and subcontractor. This has significant implications for project level safety culture and climate. A work group may strongly believe that the group's members should be directly involved in the development of safety procedures and practices governing the group's work, which may be in direct conflict with their contractor's top-down, engineering-driven policy.

As discussed in a companion paper (Maloney, 2011), the prevailing safety culture of an organization significantly influences the content of the organization's safety management system. Project managers adapt this system to the needs of the project and its execution establishes the desired or espoused safety climate on the project. Workgroups may have their own safety climate or practices on how things are done. And? For example, in the United States, for years, ironworkers erecting structural steel believed that they were safer not being tied off. After years of deliberation, the Steel Erection Negotiated Rulemaking Advisory Committee (comprised of labor, contractors, and industry representatives) was able to develop a set of guidelines to govern this work that reconciled conflicting beliefs.

Research Implications

Because of the long-term, enduring nature of an organization's culture, each organization has its own prevailing culture with some internal variation as a result of the subcultures present. Consequently, an organization cannot require another organization to adopt its safety culture. It can, however, require another organization to utilize a specific management system, which becomes the basis for project safety climate, i.e. the policies, procedures, and practices to be employed. Thus, the prime contractor for a project has options with regard to safety on the project:

- choose to establish no requirements on subcontractors,
- require subcontractors to submit their safety management systems for approval, or
- incorporate its own safety management system in the contract with the subcontractors and require them to adhere to it.

There are several research questions that arise from this:

- What is the relationship between the option chosen and safety performance on the project?
- As pointed out by Van Maanen and Barley (1984), occupational communities are characterized by self-control of the work and how it is to be done. If an external organization attempts to impose a safety management system on an occupational community such as a construction craft, how does the occupational community respond?

- While requiring the use of a specific safety management system, does the prime contractor attempt to change the safety culture by attempting to embed desired values by the actions of its project leaders by:
    - What they pay attention – communicating their values by their choices for comment, praise, and criticism
    - How they react to crises – reinforce values and desired behaviors
    - How they allocate resources – communicate and reinforce values by how they allocate resources such as time, money, and personnel
    - How they behave – communicate their values and expectations by their own actions and behaviors
    - How they allocate rewards – communicate the organization's values by selection of individuals for formal recognition
    - How they select and dismiss personnel – make explicit the behaviors expected of all employees by selecting candidates who possess those characteristics and dismissing those who do not show the desired values and behaviors
- Do the systems employed on the project reflect these values?

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Risk Analysis of Bridge Construction Projects in Pakistan

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Abstract:

Construction process is inherently prone to risks. The remedy to manage these risks effectively is in adopting a comprehensive risk management framework. Risk analysis, as the core part of the risk management process enables professionals to quantify and analyze risks which can pose a potential threat to performance of project in terms of cost, quality, safety and time. This research work attempts to identify and analyze the risks associated to bridge construction projects in Pakistan during their construction phase. A structured questionnaire was developed and administered. Risks affecting the performance of bridge projects were identified through interviews with engineers and managers working on various bridge projects. The impact of these risks on cost and schedule is analyzed using a case study which included analysis, results and discussion. The paper also shows insights of Monte Carlo simulation for project risk analysis. Through this research, risk analysis guidelines are provided that can be used for bridge construction projects in future.

Keywords: Risk Analysis; Monte Carlo Simulation; Bridge Construction; Pakistan

1. Introduction

Risk is the quality of a system that relates to the possibility of different outcomes. Schuyler (2001) defines risk as the contingency event, which either happen or does not. Subsequently, he argued that risk is a constituent of a threat and opportunity. Risk affects productivity, performance, quality and budget of a construction project (Akintoye and Macleod, 1997). Risk management is defined as a systematic controlling procedure for predicted risks to be faced in an investment or a project (Dikemen et al, 2004). In project risk management, strategy is to reduce the probability and impact of a threat and increase the probability and impact of an opportunity (Schuyler, 2001). Evidence has defined risk management as a stepwise procedure consisting of risk identification, risk classification, risk analysis, and risk response tasks (Flagnan and Norman, 1993). Risk analysis is defined by (Loosemore et al. 2006): the process of evaluating identified risks and opportunities to discover their magnitude, whether they merit a response, and how responses should be prioritized in the light of limited resources.

To cater for the needs of analyzing risks various techniques and models have been developed by researchers. Program evaluation and review technique (PERT) was devised by Dept. Of the Navy 1958, it can be considered as a schedule risk analysis tool. Advanced Programmatic Risk Analysis and Management Model (APRAM) is an example of a decision support framework that can be useful for the management of the risk of project failures *(*Dillon and Pate-Cornell, 2001*)*. Evaluating Risk in Construction – Schedule Model (ERIC-S): a comprehensive schedule risk model to estimate the pessimistic and optimistic values of an activity duration based on project characteristics (Nasir et al., 2003) . Construction schedule risk analysis model (CSRAM): is used to evaluate construction activity networks under uncertainty when activity durations and risk factors are both correlated in between *(*Ökmen and Öztas, 2008*)*. These techniques either address the schedule risks, budget risks or both. Also, some models like APRAM have been developed which analyze these risks along with technical risks such as quality.

Management of risk on a formal level is a practice scarce in Pakistan (Ahmed et al., 2009). A recent study undertaken to investigate the current state of adoption of risk management practices in the construction industry of Pakistan showed that the contractors in Pakistani construction industry are generally not practicing formal risk management and majority of projects suffer from risk causes resulting in low productivity, poor quality and cost overruns (Farooqui et al. 2007). Pakistan has faced the trauma of bridge failures and loss of life as a consequence in the Earthquake of 2005 and the recent Floods of 2010. The literature gives the idea that a pioneering research presenting risk analysis guidelines for Pakistani bridge construction projects is the need of this developing construction industry. Thus, the main objectives of this research are:

- To identify critical risks affecting the performance of bridge projects.
- To quantify and analyze these risks using Monte Carlo (MC) Simulation and to prioritize risks according to their impact on project performance (Cost & Schedule).
- To present risk analysis guidelines for bridge construction projects

2. Methodology

This research focusing on the intrinsic area of risk analysis was carried out in a systematic manner. Extensive literature was reviewed in the form of academic journals, books and published content. The following sequence was then decided by the researchers. a) Develop questionnaire to identify critical risk factors b) Identify survey participants c) Pilot survey d) Questionnaire survey & Interviews of selected participants e) Data analysis of survey by SPSS Statistics 17 f) Case study of a bridge project g) Quantify impact of risk on project schedule and cost by Pertmaster V8 h) Formulate the risk analysis guidelines for bridge construction projects.

The questionnaire was developed keeping in view the important research work done by (Masood and Choudhry 2010), (Ahmed et al., 2009) and (Farooqui et al., 2007) to extract risk factors more applicable to Pakistani Construction Industry. The questionnaire was divided into two parts, first part included questions about respondent's name, name of the company, and years of experience (Table 1). Second part consisted of a total of 37 risk factors divided into seven categories (Table 2). Before the questionnaire survey began, a pilot test was carried out, which included a panel of three professionals with more than 20 years of work experience in the construction industry. The respondents were requested to rate each risk factor based on its importance of impact on bridge project performance. The respondents were advised to rate the risk on a likert scale from 1 to 5. The respondents of the questionnaire were identified with the intent of obtaining accurate information related to bridge projects. This included the engineers and managers working on various bridge projects throughout Pakistan. The respondents were contacted through e-mail, fax and by personal interaction. A total of 100 questionnaires were distributed, an appreciable (77% response rate) 77 questionnaires were returned out of which 69 were usable for data analysis. The sample included 35% participants from public sector owners, 10% from private owners, 43% from consultants and 12% from contractors. It is pertinent to mention here that the majority of bridge construction projects are owned by public sector because of their complex nature and jargon of finances are required, which the private sector is hesitant to invest. The low response of contractors is an alarm, depicting their lack of awareness and interest towards research and development. To ensure survey validation, each participant involved in the survey had an experience of working on bridge construction projects. The participants of the survey ranged from project directors, general managers, project managers and specialist engineers. Majority of the participants had acquired a bachelor's degree in civil engineering. The average experience of surveyed participants in number of years is approximately 16.

3. Risk Factors and Categories

The risk factors were divided into seven categories namely financial risks, contractual risks, design risks, health & safety risks, construction risks, management risks, external risks. The risk factors of the seven categories are as follows:

Financial Risks

Comprising of a) unavailability of funds, b) inflation, c) hike in material prices, d) financial delays e) financial failure of contractor and, f) economic disaster.

Contractual Risks

a) change in project scope/ change orders, b) contractual anomalies, c) disputes & claims and, d) unrealistic cost estimates & schedules.

Design Risks

a) Design changes, b) incomplete design and, c) inadequate site investigation.

Health & Safety Risks

a) Accidents, b) equipment and property damage and, c) fatality

Management Risks

a) Inadequate project planning, b) insufficient engineers & specialist, c) lack of coordination, d) poor site management & supervision, e) strikes & theft and, f) subcontractor failure.

Construction Risks

a) Construction delays, b) defective work / quality issues, c) insufficient technology, d) labor productivity, e) material shortage, f) over-inspections/audits, g) scope of work not clear, h) unexpected site conditions (dewatering/rock), i) Unexpected weather (rain/windstorm) and, j) work interruptions / lack of space.

External Risks

a) Delay in approval from regulatory bodies, b) political instability, c) third party delays, d) Unstable government policies and, e) unavailability of land / right of way (ROW) not clear.

4. Data Analysis

The collected data from the questionnaires was analyzed using Microsoft Excel and the statistical software, SPSS Statistics 17. The type of Analysis performed on the data was to find a) Risk Importance Index (RII) as devised by Ghosh and Jintanapakanont (2004). b) Correlation of risk factors. The RII was calculated as shown in equation 1.

Relative Importance Index = $\sum (aX) * 100/5$ (Equation 1)

Where *a* is the constant that expresses the weighting given to each response, ranging from 1 (least important) to 5 (most important); and X = *n*/N, where *n* is the frequency of the responses; and N is the total number of responses.

Table 1: Part one of Questionnaire (Information of respondents)

Questionnaire on RISK ANALYSIS	
Name of Respondent	
Name of Organization	
Designation	
Years of Experience	
Please rate the risks mentioned below depending upon their impact on cost and time, on bridge construction projects. The scale indicates 1 being the least important, 2 somewhat important, 3 significant, 4 very important and 5 being the most important.	

Table 2: Part two of Questionnaire (Rating of risk factors according to their importance)

Category	**Scale**				
	1	2	3	4	5
Health & Safety Risks					
Accidents					
Equipment and Property Damage					
Fatality					

The relative importance index ranks each category in the descending order as financial risks, external risks, design risks, management risks, construction risks, contractual risks, and health & safety risks. The results from Table 3 also imply that the professionals are not categorizing health & safety as an important aspect of the bridge construction project.

The health & safety risks being rated so low could either mean a) there is a lack of awareness of importance of occupation health & safety amongst the participants b) lack of regulatory framework, which allows professionals not to be concerned about the physical hazards during the project.

Table 3: RII of risk factor categories in descending order

Risk Category	**Relative Importance Index**
Financial Risks	69.95
External Risks	66.67

Design Risks	66.28
Management Risks	65.17
Construction Risks	62.72
Contractual Risks	59.42
Health & Safety Risks	53.82

Table 4: Correlation among the seven risk factor categories

Correlations							
Risk Factor Category	Financial	Contractual	Design	Safety	Management	Construction	External
Financial	1	.442**	.306*	.098	.174	.113	.162
Contractual	.442**	1	.374**	.428**	.445**	.380**	.290*
Design	.306*	.374**	1	.341**	.374**	.250*	.399**
Safety	.098	.428**	.341**	1	.366**	.459**	.373**
Management	.174	.445**	.374**	.366**	1	.756**	.430**
Construction	.113	.380**	.250*	.459**	.756**	1	.605**
External	.162	.290*	.399**	.373**	.430**	.605**	1
**. Correlation is significant at the 0.01 level							
*. Correlation is significant at the 0.05 level							

The Pearson's correlation amongst the risk factor categories is displayed in Table 4. This was computed using SPSS Statistics 17. The highest correlation is among the construction and management risks 0.756 at significance level 0.01. It shows that many of the construction and management risks are correlated to each other and need to be catered by good construction project management. Another important correlation is 0.605 at significance level 0.01 among construction and external risks. External risks tend to impact cost and time more than the construction risks as shown in Table 3; they are in fact the second most important risk factor category. A positive correlation amongst health & safety risks and construction 0.459 at significance level 0.01 is a proof that how important health & safety is for a bridge project, during the construction process. As the construction risks increase, so does the physical hazards. The health & safety risks are positively correlated to contractual risks 0.428 at significance level 0.01, depicting the involvement of health & safety into the construction contracts might reduce contractual as well as health & safety risks.

The results of this study are comparatively consistent with that of previous research carried out in Pakistan (Ahmed et al, 2009). Table 5 shows the top 15 risk factors of this study in descending order of their importance. These risk factors are important for consideration of owners, consultants and contractors. The need of an effective risk management system and awareness programs amongst the stakeholders of Pakistani construction industry is required. Out of the 37 factors used in the survey, surprising results were that health & safety related risks were ranked the lowest by participants. This depicts that neither owners nor consultants lay emphasis on a contractor to have an appropriate health & safety management system. Management risks have also been rated important. One reason for this is lack of construction management experts in the country. Further to that, only few institutes offer a degree in construction engineering and management. There is also a least requirement of a contractor to higher qualified engineers and managers unless stressed by the owner or consultant. This picture urges the industry to have a behavioral shift towards construction project management education, research and practices. The external risks remain important after financial risks because of bureaucratic and political problems in the country.

Table 5: Comparison of this study with previous research in Pakistan

Risk Factor	**Relative Importance Index**	**Risk Rank**	**Risk Factors, Previous research (Ahmed et al., 2009)**	**Risk Value**	Risk Rank
Unavailability of funds	85.80	1	Differing site conditions	16.93	1
Financial failure of contractor	76.52	2	Inadequacy of project financing	16.36	2
Poor site management & supervision	74.20	3	Poor cost estimation (underestimation)	16.13	3
Inadequate site investigation	73.91	4	Inadequate/Inappropriate specification	15.72	4
Inadequate project planning	73.91	4	Incorrect/Inadequate site information	15.44	5
Construction	73.62	6	Internal cash flow issues	15.35	6

delays					
Unavailability of land ROW not clear	72.17	7	Construction change order/ directives	15.32	7
Defective work/ Quality issue	71.88	8	Lack of qualified craftsmen	14.61	8
Financial delays	71.01	9	Inadequate project planning	14.36	9
Insufficient technology	69.86	10	One-side contracts, Inappropriate contract terms	14.17	10
Insufficient engineers & specialists	69.28	11	Over-Inspection / audits	14.16	11
Delay in approvals from regulatory bodies	69.28	11	Poor site management & supervision	14.08	12
Political instability	69.28	11	Disputes / Claims and related issues	14.06	13
Unstable government policies	66.96	14	Defective work / quality issues	13.80	14
Unrealistic cost estimates & schedules	66.67	15	Labor productivity issues	13.78	15

5. Case Study of a Bridge Project.

The selected bridge project is constructed to facilitate an expressway connecting a highway with a housing society. The project is located in Islamabad, the capital of Pakistan. The bridge has the following salient features: a) To be constructed over a river with an annual peak discharge of 11170 cusecs, b) total length of bridge 544.67 ft, c) 4 spans, d) 56 piles of diameter 2.5 ft and depth of abutment piles 50 feet, depth of pier piles 30 feet, e) 12 pile caps, f) 2 abutments, g) 4 abutment walls, h) 12 piers, six each of 36 feet, and 44 feet respectively, i) 6 transoms, j) 24 precast girders 12 each of lengths 127.66 and 144.66 ft respectively, k) 47 feet width of each deck slab, l) 12 feet length of approach slab on each side and, m) length of asphalt 545 ft and guard rails on both sides. The bridge is designed for 6 lanes of traffic.

For the purpose of this research, a work schedule of the project was developed and saved as a baseline. Similarly, a base cost-estimate of the project was prepared. The estimate was prepared in a manner that each activity could be assigned a cost. To remove the bias of missing the project over-head costs, the estimate of each activity included the sum of material costs, manpower costs, equipment costs and overhead costs.

The risks identified through the questionnaire survey were then loaded into the schedule to quantify the impact of these risks on project schedule and cost. For the purpose of risk analysis, Primavera Pertmaster V8 was used. The inputs of Pertmaster for risk register are a) risk ID number, b) threat or opportunity (T/O), c) risk description, d) probability of occurrence, e) effect of this risk on activity, f) type of risk i.e. cost, time or performance, g) distribution type i.e. triangular, uniform, etc., h) correlation with other risk factors. The sample risk register shown below was created for the complete project. Inputs required by software, like probability, impact of risk on activity, risk correlation, etc, were entered with consultation of the same panel involved in pilot survey of the questionnaire (Figure 1 and Figure 2).

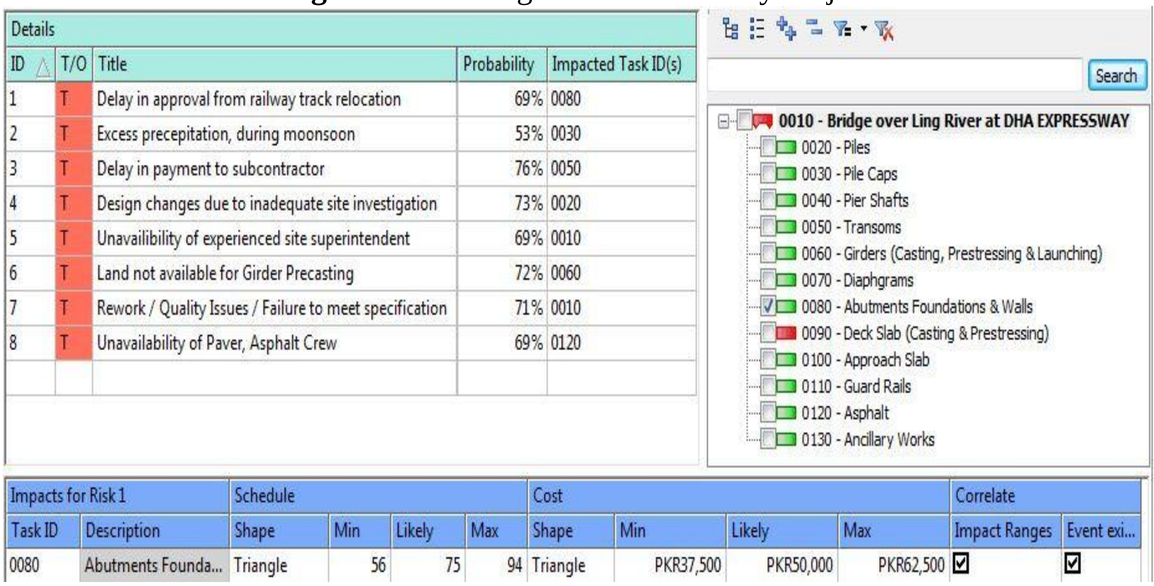
The work schedule which is loaded with costs and risks is subjected to risk analysis. The risk analysis function performed by the Pertmaster V8 is based on MC simulation. MC simulation is perhaps the most popular of the various management science techniques. The simple, elegant method provides a means to solve equations with probability distributions (Schuyler, 2001). MC simulation is a technique that uses random samples of the independent variables to obtain solutions of problems. Simple random number sampling and Latin hypercube sampling are among the possible many sampling techniques that can be used with Monte Carlo simulations (Lian and Yen, 2003). Further to embellish the study project it was decided that 1000 iterations are to be performed by the software (Figure 3 and Figure 4).

The cumulative probability distribution of project cost, finish date and duration were computed through MC simulations. Extract of project cost is shown in Figure 5. The cumulative probability distribution of project cost and duration is shown in Figure 6. Table 6 gives a summary of the risk impact on project cost and duration. The probability to finish project within cost is less than 1% and within time is 4%. Terms P80 and P100 represent the probability, 80% and 100% respectively. The arrows in Figure 6 are representing the project completion with 80% and 100% probability.

Table 7, 8 and 9 are drawing the comparison of simulation results with actual data of the case study project. The time of observation for the project was from November 2009 to March 2011; therefore, the comparison was drawn with the actually completed activities.

From the results it can easily be depicted that the risk estimation carried out for this study performed very well, the risks identified were actually effective and faced in the real time construction of the project. Nonetheless, due to a non-existent risk management framework none of the risks were managed or treated effectively. The case study project is built by self-performance project delivery method wherein the owner played the leading role in the construction of the project; similar studies can be carried out for other types of project delivery methods.

Figure 1: Risk Register of Case Study Project



Details				
ID	T/O	Title	Probability	Impacted Task ID(s)
1	T	Delay in approval from railway track relocation	69%	0080
2	T	Excess precepitation, during moonsoon	53%	0030
3	T	Delay in payment to subcontractor	76%	0050
4	T	Design changes due to inadequate site investigation	73%	0020
5	T	Unavailibility of experienced site superintendent	69%	0010
6	T	Land not available for Girder Precasting	72%	0060
7	T	Rework / Quality Issues / Failure to meet specification	71%	0010
8	T	Unavailability of Paver, Asphalt Crew	69%	0120

Impacts for Risk 1		Schedule				Cost				Correlate	
Task ID	Description	Shape	Min	Likely	Max	Shape	Min	Likely	Max	Impact Ranges	Event exi...
0080	Abutments Founda...	Triangle	56	75	94	Triangle	PKR37,500	PKR50,000	PKR62,500	☑	☑

Figure 2: Risk Correlation of Case Study Project

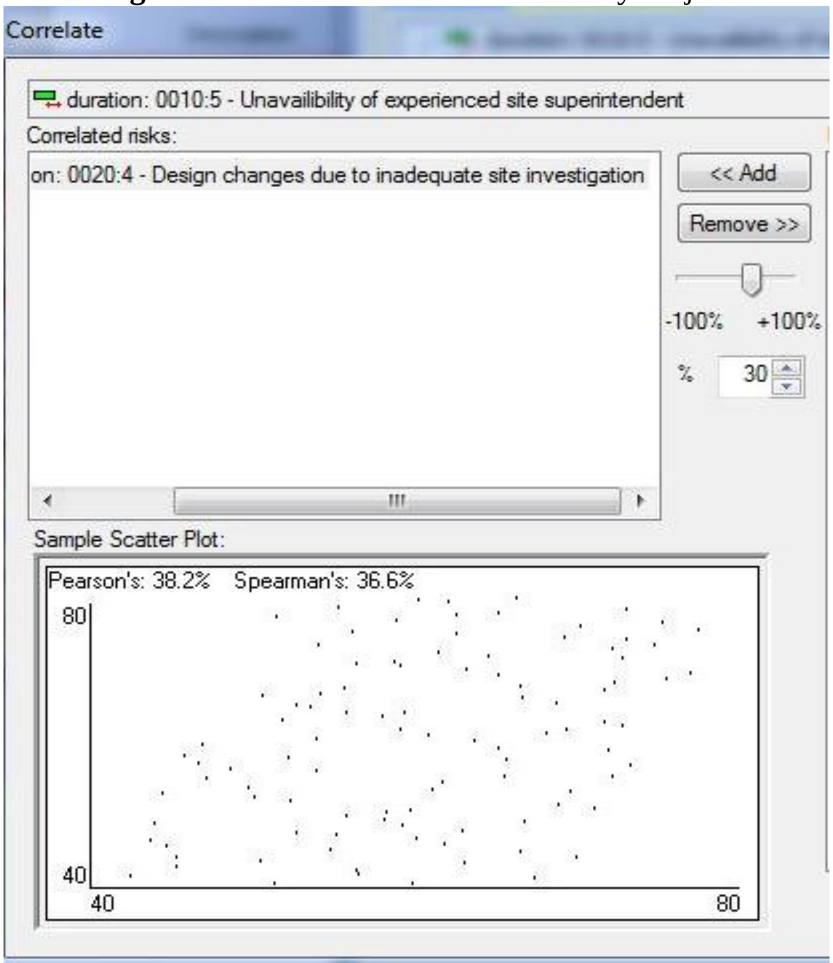


Figure 3: Risk Analysis in Pertmaster

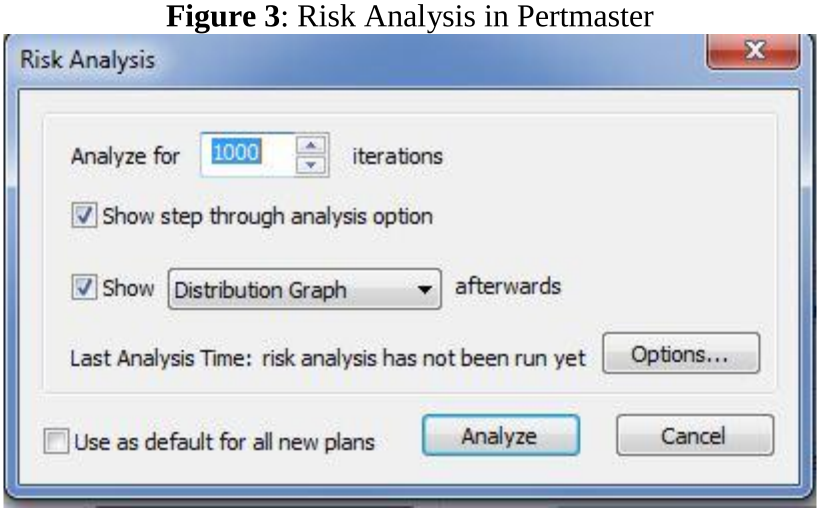


Figure 4: Iterations

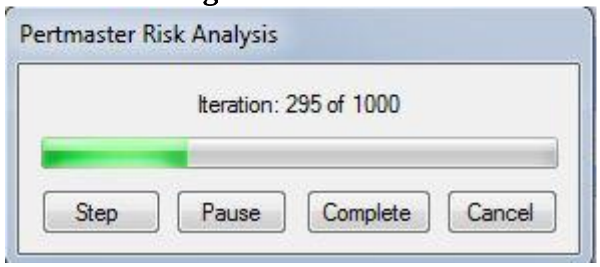


Figure 5: MC Simulation results and Impact of risks on project schedule

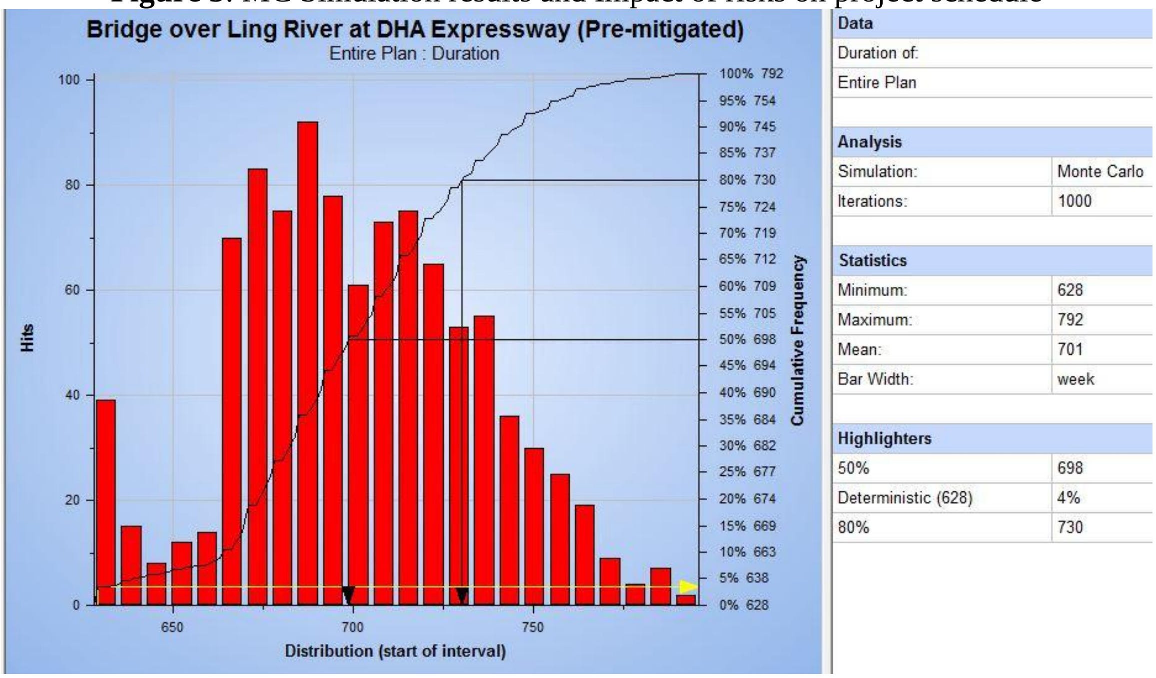


Figure 6: Impact of risk on Project time and cost.

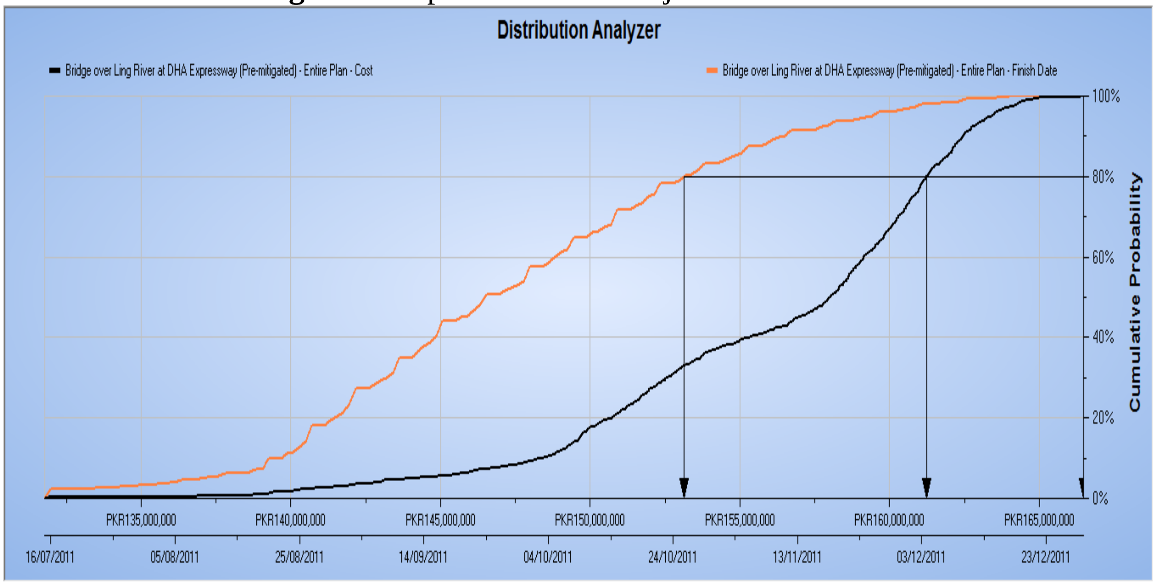


Table 6: MC Simulation Results of the Case Study Project

Description	Deterministic Value	Deterministic probability	Mean	P80	P100
Cost (PKR)	129,221,836	<1%	156,006,383	161,234,806	166,478,535
Duration (Days)	628	4%	701	730	792
Finish Date	15/07/2011	4%	25/09/2011	25/10/2011	26/12/2011

Table 7: Comparison of MC Simulation Results with Actual Situation (Start Date)

Activity	P80 Start	P100 Start	Actual Start
Piles	26/10/2009	26/10/2009	26/10/2009
Pile Cap	7/4/2010	18/4/2010	4/6/2010
Pier Shaft	4/7/2010	3/8/2010	10/6/2010
Transoms	23/8/2010	21/9/2010	1/1/2011
Girders	21/5/2010	3/7/2010	
Diaphragm	26/12/2010	27/2/2011	
Abutments	14/4/2010	25/4/2010	
Deck Slab	15/1/2011	19/3/2011	
Guard Rail	16/3/2011	18/5/2011	
Electrical Works	31/3/2011	2/6/2011	
Asphalt	4/10/2011	6/12/2011	

Table 8: Comparison of MC Simulation Results with Actual Situation (Finish Date)

Activity	P80 Finish	P100 Finish	Actual Finish
Piles	6/4/2010	17/04/2010	14/4/2010
Pile Cap	3/9/2010	2/10/2010	13/9/2010
Pier Shaft	18/11/2010	27/12/2010	27/10/2010
Transoms	28/01/2011	12/3/2011	31/3/2011
Girders	21/02/2011	25/04/2011	
Diaphragm	28/03/2011	25/05/2011	
Abutments	17/01/2011	8/2/2011	
Deck Slab	28/05/2011	17/09/2011	
Guard Rail	3/10/2011	5/12/2011	
Electrical Works	22/09/2011	24/11/2011	
Asphalt	25/10/2011	26/12/2011	

Table 9: Comparison of Costs

Activity	P80 Cost	P100 Cost	Actual Cost
Project	161,149,586	165,945,109	72,840,547
Piles	23,610,037	24,903,230	23,519,573
Pile Cap	17,950,572	19,539,369	18,868,638
Pier Shaft	19,673,635	21,374,974	20,326,544
Transoms	8,553,384	10,230,338	10,125,792
Girders	48,672,759	49,247,929	
Diaphragm	2,309,237	3,010,231	
Abutments	5,473,253	5,790,028	
Deck Slab	20,934,974	21,911,994	
Guard Rail	5,666,186	5,764,904	
Electrical Works	8,820,857	9,776,048	
Asphalt	3,045,760	4,008,724	

6. Risk Analysis Guidelines

Through this research it is intended to present the guidelines necessary for a successful risk analysis of bridge projects. A stepwise guideline is provided below, which shall help the professionals working on bridge projects. Guidelines are prepared by keeping in view the evidence of (Schuyler, 2001) and (Loosemore et al., 2006).

a) Develop the context (specify scope, stakeholder analysis, etc.)
b) Identify risks (checklists, brainstorming, historical data, etc.)
c) Quantify risks (likelihood, impact, correlation, distribution type, effect on activity)
d) Formulate the project cost-loaded schedule.
e) Load the schedule with risks.
f) Run MC simulations.

g) Understand the output and develop strategy to respond for the risks.

7. Conclusions

Amid the failure of various bridges globally and in Pakistan, this research is targeted to ensure the awareness of project stakeholders about the threats affecting the performance in the construction process of a bridge project, they are likely to face. This research is unique in a way that a project case study is used to develop a better understanding using the realistic data compared with computational simulation of risks. The potential risks related to bridge construction projects were identified, which included in descending order of importance financial risks, external risks, design risks, management risks, construction risks, contractual risks and health & safety risks. The guidelines are developed in a manner easy to adopt and implement. A step wise case study is elaborated in the light of these guidelines. From the results of the case study it showed that the forecasted results were approximately accurate and similar to those actually experienced in terms of project cost and time.

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Development of a Modified Research-to-Practice Process

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Development of a Modified Research-to-Practice Process

Abstract

Research-to-Practice (r2p) is a concept that describes efforts to translate research knowledge into practical use in the intended context. Researchers do not have consensus on how this process should be conducted. The Occupational Safety and Health Research Center (OSHRC) developed a conceptual model to facilitate translation of research findings to concrete and valid outcomes utilized by target groups and stakeholders. This model is compatible with the six stages to accomplish r2p that were proposed by the National Institute for Occupational Safety and Health (NIOSH). A modified research-to-practice (mr2p) process was developed by analyzing 37 projects that received the NIOSH Bullard-Sherwood r2p Award from 2005 to 2011. The mr2p process aims to strengthen the entire process by arranging and clarifying the sequence of the six stages with an emphasis on the stages that seemed most unclear after the analysis of the descriptions of the award-winning projects. This mr2p process may provide more clarity to researchers and can serve to enhance the types of research projects that are proposed and conducted, and ultimately support the NORA goals to benefit stakeholder communities.

Keywords:
Research-to-Practice (r2p), construction, conceptual model, translation

1. Introduction

Research-to-Practice (r2p) is a concept to translate research-based knowledge or technology into practical use in the real environment or intended context. The term has been used in the literature about drug abuse treatment (Simpson, 2002), interventions for individual and community health (Wandersman et al., 2008), and information systems (Rosemann & Vessey, 2008). Yet, researchers do not have consensus on how this process should be conducted. Confusion also occurs because different disciplines use different words to represent the idea of r2p, such as socially-compatible research, outcomes-based research, and translational research. This paper provides researchers with a new conceptual model that illustrates a process to facilitate translation of research findings to concrete and valid outcomes to be utilized by target groups and stakeholders in the intended contexts.

2. Method

An archival analysis was conducted using the National Institute for Occupational Safety and Health online database. We developed a new conceptual model of the r2p process conducting a thematic analysis of: (i) the original r2p established by the National Institute for Occupational Safety and Health (NIOSH, 2009a), and (ii) 37 projects that received the NIOSH Bullard-Sherwood r2p award from 2005 to 2011 (NIOSH, 2011a). The following describes these two reviews in detail.

Original NIOSH r2p Stages

NIOSH established the r2p initiative in 2004 to guide research focused on prevention of injuries, illnesses, and fatalities across all industry sectors (Gillen, 2010). NIOSH identified six stages to accomplish r2p: Prioritize, Partner, Target, Translate, Disseminate, and Evaluate (NIOSH, 2009a). Figure 1 shows these six stages and the associated descriptions of the original r2p (NIOSH, 2009a).

Prioritize	Conduct research that addresses the most important occupational health and injury issues facing workers.
Partner	Work together with both internal and external partners to encourage workplace adaption and use of research findings.
Target	Adapt research results into information products tailored to the target audience.
Translate	Transfer and translate research findings, technologies and information into prevention practices and procedures.
Disseminate	Use communication science to guide the movement of research into the workplace.
Evaluate	Build data collection into each program to determine effectiveness in preventing workplace injury and illness.

Figure 1. Original NIOSH r2p stages (NIOSH, 2009a).

NIOSH-Awarded r2p Projects

The descriptions of the 37 awarded (24 winner and 13 honorable-mentioned) projects by NIOSH were reviewed to investigate any common factors among those projects. Those projects were identified through the NIOSH website (NIOSH, 2011a). The descriptions were organized based on the award categories (Knowledge, Innovation, Technology) and the year awarded (NIOSH, 2005, 2006, 2007, 2008, 2009b, 2010, 2011b). Each description contained the title, authors, NIOSH divisions, issues on occupational safety and health, and method and activities to work on the issues. The target populations in those projects were mainly workers in construction, work zone, healthcare, mining, food production, and chemical materials.

To investigate the common factors, each project description was reviewed to identify the six stages of the original r2p (Figure 1). If available, further information was obtained through the project websites or NIOSH publications.

3. Results

Original NIOSH r2p Stages

NIOSH describes the original six stages of r2p as a guide for researchers who are conducting translational research. The purposes of each stage are listed and described (Figure 1), and are intentionally broad to allow researchers to fit customize the stages to their own needs. However, through conversations with researchers over a 2-year period, we discovered a need for a more detailed process to help researchers transform large amounts of data and information from research projects into practical, meaningful, and context-compatible outcomes.

Common factors in the NIOSH-Awarded r2p Projects

Through our archival analysis, common factors on the six stages of the original r2p were identified among the 37 awarded projects. The positive common factors were those that appeared to have positive impact by the original r2p, whereas negative common factors were those that might have existed, but were not mentioned. The following common factors were observed in the project descriptions.

Positive Factor: Strong Evidence of Partnering. Most of the project descriptions (35 out of 37) listed one or more partners with the organizations inside and outside of NIOSH. Those organizations are: another NIOSH institute, regulatory agency, safety professionals, industry, labor/customer group, manufacturer, or consultant. The main NIOSH division for the project appeared to have a strong partnership with other organizations.

Negative Factor: Unclear Descriptions of the Translation Stage. Almost none of the project descriptions provided clear procedures of how the research findings or technologies were transformed into practices or procedures. This unclear stage could mean that no consensus or standardized procedure has been developed, although standardized procedures may not be generalizable to all projects. Unclear translation may also indicate confusion or lack of consensus in the research community.

Negative Factor: Lack of Descriptions of the Evaluation Stage. Although all the awarded projects contain potential contribution to occupational safety and health, only nine out of 37 project descriptions mention the effectiveness of the project in preventing workplace injury and illness. This lack of descriptions in the *Evaluation* stage may be because a clear procedure has not yet been established, or some r2p projects were awarded before the Evaluation stage was completed.

Developing a Modified r2p Process

A new r2p process was developed by modifying the original NIOSH r2p stages (Figure 1). In the modified research-to-practice (mr2p) process, all common factors from the awarded r2p projects were considered for the mr2p process. The positive factor of strong partnerships was retained and the negative factors were removed by replacing them with solutions. The following describes the changes to the original r2p process in order to develop the mr2p process.

Function for Innovation Translation (FIT) model to Translate stage. One of the negative common factors among the award-winning r2p projects was the absence of a clear *Translation* stage. The FIT model (Center for Innovation in Construction Safety and Health/CICSH, 2005; Hung, Smith-Jackson, & Kleiner, 2008) was merged with the NIOSH Translation stage to provide descriptive procedures to ensure that the identified methods or tools provided a high level of usability for any technologies resulting from the research projects. The FIT model is described in more detail in the next section.

Evaluate stage is extended with two step. The other negative common factor was a lack of processes for the Evaluation stage. The mr2p has an extended description of the *Evaluate* stage. The first step is to determine the effectiveness of the new product or procedure in local or selected groups of workers for a short period of time.

Target stage comes before Partner stage. The original r2p process has six stages: *Prioritize*, *Partner*, *Target*, *Translate*, *Disseminate*, and *Evaluate* (NIOSH, 2009a). The sequence of the six stages was revised as the *Target* stage was moved before the *Partner* stage. This modification was made because the defined target audience will specify more appropriate types and/or ranges of external partner(s) needed for successful r2p projects.

Figures 2 and 3 depict the concept flow of the mr2p process. Figure 2 uses more academic-oriented terms, whereas Figure 3 was created with more practical, less academic terms so that the process will be widely understood by a diverse audience of communities of practice. Both “academic” and “industry” versions contain the six stages, along with key terms or steps for each stage.

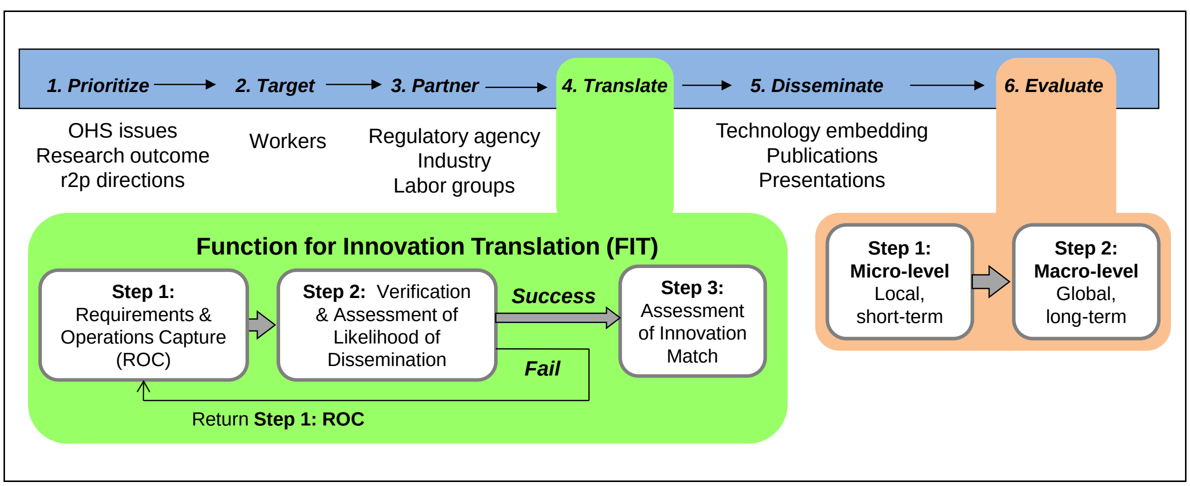

Figure 2. “Academic” version of the mr2p.

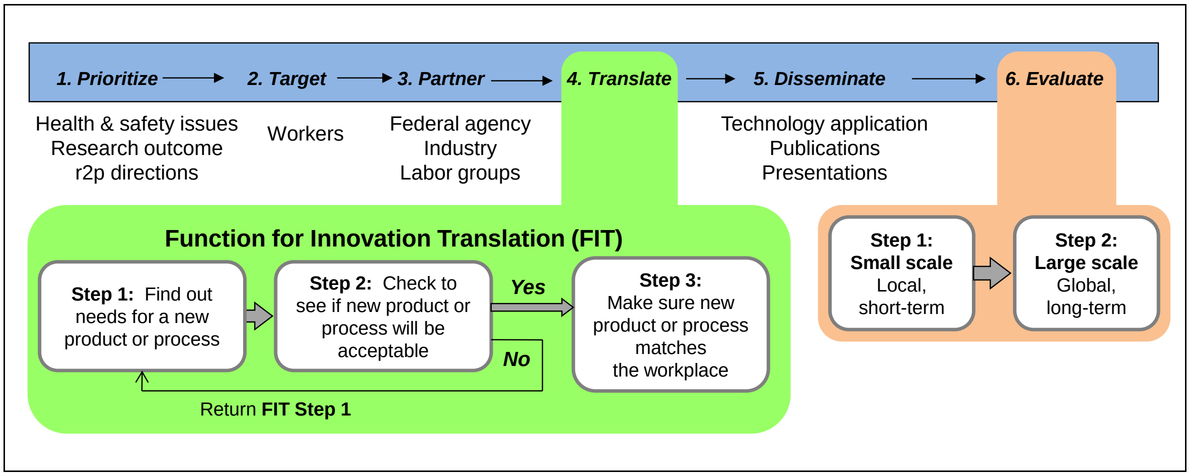

Figure 3. "Industry" version of the mr2p process.

Descriptions of mr2p stages

As depicted in Figure 2 and 3, the mr2p process has the same six stages as the original NIOSH r2p, and the purposes of the mr2p were adapted from the original r2p. However, the mr2p has a different sequence of the six stages and includes descriptive process steps at the *Translate* and *Evaluate* stages. The following describes details of the six stages as well as the FIT model.

Stage 1: Prioritize

> Purpose: *"Conduct research that addresses the most important occupational health and injury issues facing workers."* (NIOSH, 2009a)

When a new research project is planned, this stage begins with identifying critical issues about occupational safety and health that workers deal with. For the on-going or completed research projects, it is necessary to locate the issues to which the research outcome can be applied. It also helps for researchers to determine which of the NIOSH categories (Knowledge, Innovation, Technology) the r2p project and research outcome can contribute to. NIOSH awards r2p projects based on the three categories. This categorization indicates that NIOSH values r2p projects classified in those categories.

Stage 2: Target

> Purpose: *"Adapt research results into information products tailored to the target audience."* (NIOSH, 2009a)

This stage begins with identifying the target audience (workers) who would benefit from the research outcome. The type audience needs to be specified. For example, the target audience could be electrical contractors, roofing workers, crane operators or any other types of construction-related workers.

Representatives of the target audience in the r2p process should be included in design and evaluation so that the product is suitable for the needs of the target audience. Identifying the target audience will be followed by, searching, selecting, and contacting the groups or organizations of target audiences for collaboration.

Stage 3: Partner

> Purpose: *"Work together with both internal and external partners to encourage workplace adaption and use of research findings."* (NIOSH, 2009a)

Working with partners is a common factor among the award-winning NIOSH r2p projects. Partners can be federal regulatory agencies (e.g., OSHA), safety professionals (e.g., ASSE), industry, labor/customer groups (e.g., IBEW, SAE), and manufacturers (e.g., harness manufacturer for fall protection). Choosing the right type of partners is critical as they will play a key role in outreach efforts to distribute the new product or procedure to the target audience at the *Disseminate* stage.

Stage 4: Translate

> Purpose: *"Transfer and translate research findings, technologies and information into prevention practices and procedures."* (NIOSH, 2009a)

The award-winning r2p project descriptions did not provide clear procedures about how the *Translate* stage was conducted. The *Translate* stage in the mr2p process employs the FIT Model to provide a step-by-step procedure. There are three steps in the FIT model (Center for Innovation in Construction Safety and Health Research, n.d.):

Step 1: Requirements and Operations Capture (ROC)
Determine concrete tools and methods that the target group needs to reduce their accidents, injuries and fatalities.

Step 2: Verification and Assessment of Likelihood of Innovation Dissemination (VALID)
Work with external experts to get a realistic idea of whether the outcomes or tools from research can be transferred to the target groups and whether the outcomes or tools make sense for the work environments in which they will be implemented.

Step 3: Assessment of Innovation Match (AIM)
Understand the environment to make sure we are producing something that will be adapted or used by the target groups.

In the mr2p process, a successful result in Step 2: VALID leads to Step 3: AIM; however, a failed result in Step 2 brings the progress back to Step 1: ROC until a successful result is produced in Step 2.

Stage 5: Disseminate

> Purpose: *"Use communication science to guide the movement of research into the workplace."* (NIOSH, 2009a)

The translated product can be distributed by publications (e.g., booklets, pocket cards, web pages) or presentations at conferences, trade shows, or through media. Dissemination can also be promoted if the product becomes available through well-known retailers.

Stage 6: Evaluate

> Purpose: *"Build data collection into each program to determine effectiveness in preventing workplace injury and illness."* (NIOSH, 2009a)

The mr2p process comprises two steps consistent with the original process, micro- and macro-level evaluations. The micro-level evaluation will be conducted with local or a selected target group for a short period of time (e.g., three months), whereas the macro-level evaluation will be in a global, wide-range of the target groups for a longer period of time (e.g., one year). The size of the target group and duration of the evaluation should be considered during Stage 4: *Translate*, with the partners selected in Stage 3: *Partner* so that a reasonable size and duration can be determined.

4. Limitations

The mr2p process was developed based on the common factors in the 37 successful, award-winning projects accessible through the NIOSH website. It was not possible to verify that those common factors are unique and exclusive among the successful r2p projects. Some of the common factors could also be found among unsuccessful or moderately successful r2p projects funded by NIOSH, but these not-awarded r2p projects were not identified in the NIOSH website. The mr2p process would consist of more refined stages if successful r2p projects are compared and contrasted to other, less-successful projects.

Another limitation of the proposed mr2p is that it has not been applied to or tested with a construction or safety-related research project. A case study would add the credibility of the mr2p or would help refine the process for improvement.

5. Conclusions

A new, modified r2p conceptual model was developed based on the original NIOSH model, common factors among the awarded r2p projects, and FIT model. The proposed mr2p model offers step-by-step procedures to identify the research topics to disseminate and evaluate their successful translation for targeted workers' better safety and health. The primary future work should be to apply the mr2p model to safety-focused projects so that the mr2p will be equipped enough to facilitate a wide range of occupational safety issues and ultimately to support the NORA goals to benefit stakeholder communities. The research topics can be selected from the completed research projects whose translation process to practice has not been started. Another future work would be to invest the *Translate* and *Disseminate* stages so that safety or construction managers in an organization can apply the mr2p process to implement new tools or guidelines to their fellow employees.

Acknowledgements

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The Effect of Partnership Programs on Improving Safety in Construction Companies

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The Effect of Partnership Programs on Improving Safety in Construction Companies

Abstract

According to the Bureau of Labor Statistics in 2009 there were 816 fatal injuries in the United States in the construction industry. The Occupational Health and Safety Administration (OSHA) has a mission to ensure the safe and healthful working conditions for all working men and women. In order to achieve this goal OSHA has been setting and enforcing standards with a "command-and-control" system. However, recordable cases still occur on construction sites. The gaps within the "command-and-control" system have lead researchers and industry to look at other methods to improve the safety and health of workers. One such method is self-regulation. Self-regulation involves delegating some of the authority formally held by the government to industrial associations and individual firms. One self-regulation program is the Construction Health and Safety Excellence (CHASE) partnering program between OSHA and the Associated General Contractors of America. Using the CHASE program in New Mexico as a case study, the effectiveness of the self-regulation vs. "command-and-control" approaches on injury and recordable case rates has been studied. This research determined that there was evidence that members of the NM CHASE program have lower recordable case rates then non-members and a strong culture of safety.

Keywords: Construction safety, Safety culture, Partnership programs

The Effect of Partnership Programs on Improving Safety in Construction Companies

1. Background and Purpose

In 2009 there were 816 fatal injuries in the United States in the construction industry (US Bureau of Labor Statistics 2009). Fatal work injuries involving construction laborers accounted for approximately one out of every four private construction fatalities in 2009. Within the last several years, reductions in accidents and injuries have reached a statistical plateau (Construction Industry Institute, 2008;US Bureau of Labor Statistics, 2009), and it appears that governmental compliance is ineffectual in further advancing the cause of safety in the workplace (Rechenthin 2004; Weil 1996). Current research is being done to increase the development of safety culture within the construction industry (Tanner 2003; Artis 2007). In addition researchers are increasingly acknowledging that organizational factors are important in workplace safety (Hurst et al. 1991; Hofmann 1995). This trend indicates that as an industry, the construction field needs to implement new methods to continue bringing down the rate of injuries.

Currently the Occupational Health and Safety Administration (OSHA) oversees the health and safety of all workers in America. OSHA has traditionally approached regulation with a "command-and-control" approach. Compliance is won due to fear of punishment in this punitive system (Rees 1988). Since OSHA's inception this "command-and-control" method has been part of the decrease in injuries seen on job sites. However, researchers disagree if this is the best model for regulation. Research has also shown that the cost associated with injuries such as workers' compensation policy pricing plays a significant role in safety complacence (Weil 2001). Even with OSHA in place the cause of most workplace fatalities are predictable and preventable (Silverstein 2008). The construction industry is vocalizing these concerns and seeks regulator relief from the faulty traditional "command-and-control" model.

One method that is attempting to provide regulatory relief is partnerships between governing bodies and the construction industry, such as a partnership between OSHA and contractors. Partnerships are a form of responsive regulation which creates a voluntary compliance system. These partnerships allow for different standards of regulation. Companies that have a proven track record of compliance are allowed to self-regulate, which leads to higher voluntary compliance. Due to a lower cost, the voluntary compliance model claims to be more effective than the "command-and-control" method currently used (Shapiro & Rabinowitz 2000). Researchers have also shown that voluntary compliance can overcome the hostilities and resistance to regulation often exhibited by the regulated (Ayres & Braithwaite 1991). However, there are faults in every system. There is fear that if companies are not treated equally, some may try to take advantage of the system by skirting responsibilities once they have become self-regulating.

The New Mexico CHASE (NM CHASE) program started in 2001 with an agreement between the New Mexico Occupational Health and Safety Bureau (OHSB) and the AGC New Mexico Building Branch (AGC NM). The goal is to reduce injuries, illnesses, and fatalities in the construction industry. According to a study done in 2002 and 2003, the rate of incidences measured by days away, or with restriction and/or transfer, dropped for contractors that participated in the NM CHASE program (Associated General Contractors - New Mexico Building Branch 2007). This study seeks to understand if that drop was a one year phenomenon or if lowered incidence rates has become a long term trend. If the NM CHASE program is effectively lowering incidence rates this study also seeks to understand what makes the NM CHASE program effective.

In addition this study also seeks to look at the difference in recordable case rates of companies currently under the "command-and-control" regulatory approach, non-NM CHASE members, and the CHASE members who self-regulate. To determine if there was a change in recordable case rates a survey was created which collected recordable case rates and EMRs from NM CHASE members and non-members. The recordable case rates for NM CHASE members and non-NM CHASE members were compared. There was also a comparison of a company's recordable case rates pre-NM CHASE and post-NM CHASE. In addition, the EMR of NM CHASE members and non-NM CHASE members were compared.

2. Research Methodology

This research consisted of a survey that collected information from AGC-NM members regarding NM CHASE status and recordable case rates. The difference in recordable case rates between NM CHASE members and non-NM CHASE members was observed in this phase of research. A follow-up case study was performed on members of NM CHASE who participated in semi-structured interviews. These interviews were designed to answered questions about perceived changes in safety culture that arose from joining NM CHASE. This paper focuses on the survey results, while the interview results are being prepared for future publication.

Survey Design

Recordable case rates from members and non-member of NM CHASE were collected through a survey. This data allowed a comparison between recordable case rates for self-regulated companies and companies that were under a more traditional "command-and-control" form of regulation. It was determined that the information from the OSHA 300a form would be the most useful, easiest data to collect. Companies are required to file the OSHA 300a form every year and they are required to keep the forms for at least 5 years. With this in mind the survey asked for five years of historical data. The data that was collected from the 300a form included:

- Total number of cases with days away from work
- Total number of cases with job transfer or restriction

- Total number of other recordable cases
- Number of hours worked by all employees

This data was collected because it provided an overall picture of each company's recordable case rate. Companies were also asked to share their historical EMR rates for the last five years. Because the EMR rate is a 3-year running average it allows for a longer term view of a company's safety record.

Recordable case rate data is very sensitive. Due to concerns over confidentiality issues it was decided that all data collected would be anonymous. This meant that the survey did not ask for the respondent name, company name, or any other identifying information. This lack of identifying data means that this survey was not a statistical representation of construction firms in New Mexico. In order to compare NM CHASE members with non-members, the survey did ask about NM CHASE membership status. If the company was a member of NM CHASE, the survey asked when the company joined NM CHASE and what level of membership they held.

Case Study Design

A follow-up question asked, how does joining the NM CHASE program change safety culture within a company? To assist in answering this question, in-person semi-structured interviews were completed. The interviews were planned and conducted using Hancock & Algozzine's (2006) seven step plan. One phase of this plan was to break research questions into researchable sub-questions. The following sub-questions were developed:

1. How did the health and safety program at your company change after joining NM CHASE?
2. How did your relationship with OHSB and other safety professionals change after joining NM CHASE?
3. From the perspective of your employees, how did your company's overall safety culture change after company joining NM CHASE?

3. Survey Summary

Introduction

There were twenty respondents to the survey. However, six responses were not used because the respondent did not provide sufficient data. Of the fourteen valid responses three of the respondents were not members of NM CHASE during the survey time period, three of the respondents had joined NM CHASE during the past five years, and eight respondents were NM CHASE members of the course over the entire survey period.

Total Recordable Case Rate

One metric that can be used to measure a company's overall safety record is total recordable cases rate (TRCR). To calculate the total recordable case rate all reported cases are added together, multiplied by 200,000 and divided by the total number of hours worked by all employees in the company. This gives a normalized value of recordable cases bases on the number of recordable cases per 100 standard workers. Table 1 shows the TRCR for each company that participated in the survey. The shaded cells indicate that the company was not part of CHASE. Some companies chose not to report all five years of historical data. A dash is used to indicate that data was not reported.

Table 1: Total recordable case rate

Respondent ID	**2005**	**2006**	**2007**	**2008**	**2009**
Respondent 1	3.63	1.80	11.20	12.86	10.99
Respondent 2	-	-	2.24	5.07	1.48
Respondent 3	0.88	2.16	1.97	2.30	2.01
Respondent 4	-	-	3.83	2.48	2.36
Respondent 5	1.65	3.01	4.32	3.03	1.44
Respondent 6	3.05	3.67	3.51	3.12	3.05
Respondent 7	0.00	13.44	0.00	5.54	4.36
Respondent 8	-	-	1.61	0.89	1.97
Respondent 9	-	-	-	-	8.00
Respondent 10	2.44	2.06	3.76	2.08	4.58
Respondent 11	2.70	5.32	1.54	2.21	2.27
Respondent 12	3.12	14.10	23.37	5.50	0.00
Respondent 13	3.06	3.23	0.00	1.36	0.73
Respondent 14	2.17	1.72	2.96	0.00	4.77

☐ - CHASE Members ■ - Non-CHASE Members

Table 1 shows how dramatically a company's total recordable case rate can change from year to year. Respondent 7 is an example of this shift. In 2005 they reported a TRCR of 0, in 2006 13.44, and in 2007 they once again achieved a TRCR of 0. Respondent 7 is a small company and the jump in TRCR was caused by two recordable cases. Due to this variability in the data it was deemed practical to look at both the median rate and average rate of all gathered data to get a better sense of overall safety.

Recordable case rates can be calculated for each of the OSHA 300a categories in the same manner that TRCRs are calculated. Figure 1 shows the median number of recordable case rates in categories. As the figure shows NM CHASE members have lower recordable case rates across all three categories. In addition NM CHASE members have a lower EMR rate than non-members.

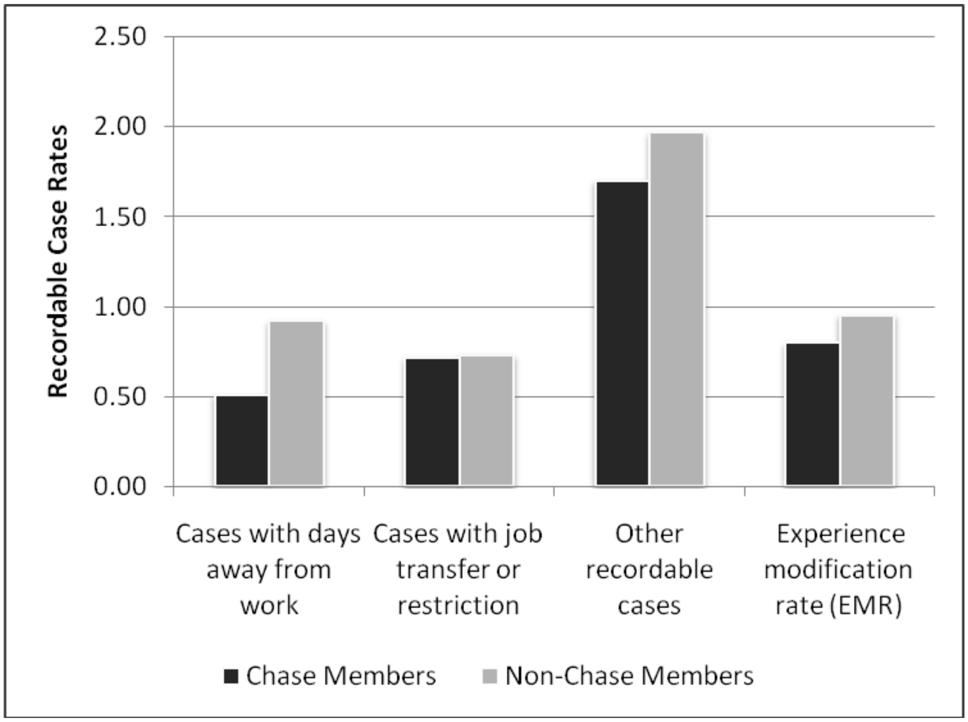

Figure 1: Median Number of Recordable Case Rates and EMR

Number of Recordable cases Recorded

The survey asked respondents to report the number of recordable cases in given categories. Often the response was zero, there were no recordable cases in that category for the given year. The number of reports of zeros recordable cases and the number of non-zero reporting answers is very close, 41% vs. 45% respectively. Figure 2 shows the number of zero vs. non-zero responses for each of the OSHA 300a form categories. The days away from work category includes the most serious types of injuries. As Figure 2 shows, the number of reports of zero for days away from work is significantly higher than the number of reports of non-zero days away from work. However, the number of reports of zero for other recordable cases is significantly lower than the number of reports of non-zero for other recordable cases. The number of zeros as responses can have a significant impact on the difference between average and median rates.

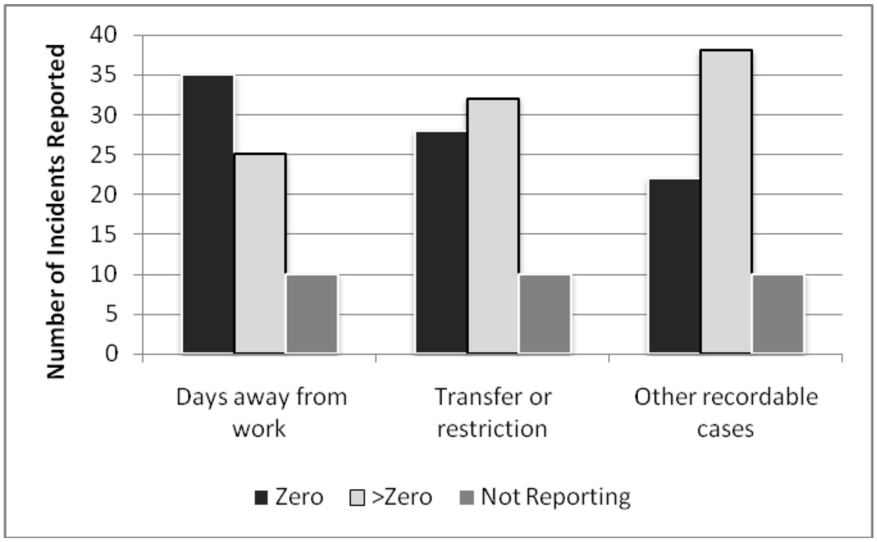

Figure 2: Total Number of Categories With and Without Reported Recordable Cases

Days Away From Work

In order for an injury or illness to count as days away from work, an employee must be too ill or injured to work as a result of an incident on the job site. This often includes a doctor's instructions to stay home. The OSHA 300a form specifies that the day of the recordable case is not included in the count of days away from work and if the count exceeds 180 days the employer may stop counting (Occupational Safety and Health Administration 2002). Figure 3 shows the median rate of cases with days away from work for NM CHASE and non-NM CHASE members over the five year period of the survey. In both 2008 and 2009 the median rate of cases with days away from work was zero for both NM CHASE and non-NM CHASE members.

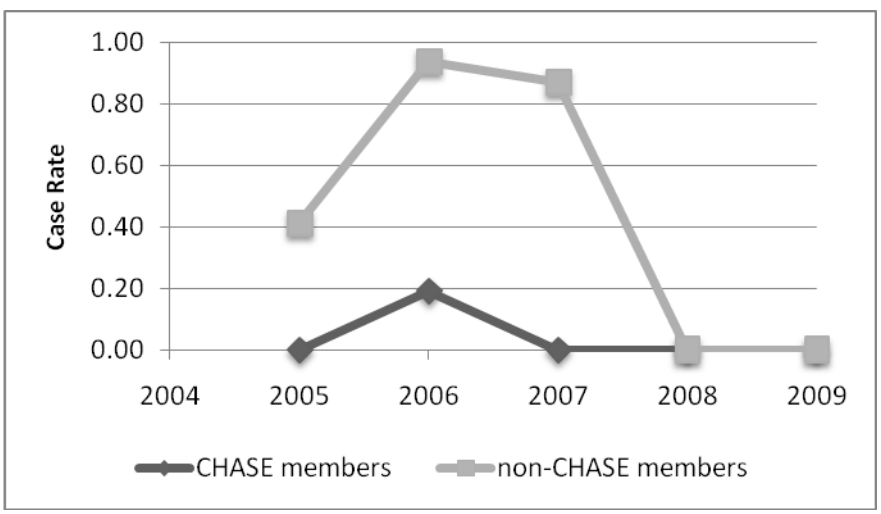

Figure 3: Median Rate of Cases with Days Away from Work

Figure 4 shows the average rate of cases with days away from work. The figures vary so greatly because of the impact that one recordable case can make. Figure 3 shows that the median rate of cases with days away from work for NM CHASE members is lower than or equal to the median rate of cases with days away from work for non-NM CHASE members. Figure 4 shows that for the year 2006 the average rate of cases with days away from work for NM CHASE member is significantly higher than that of non-NM CHASE members.

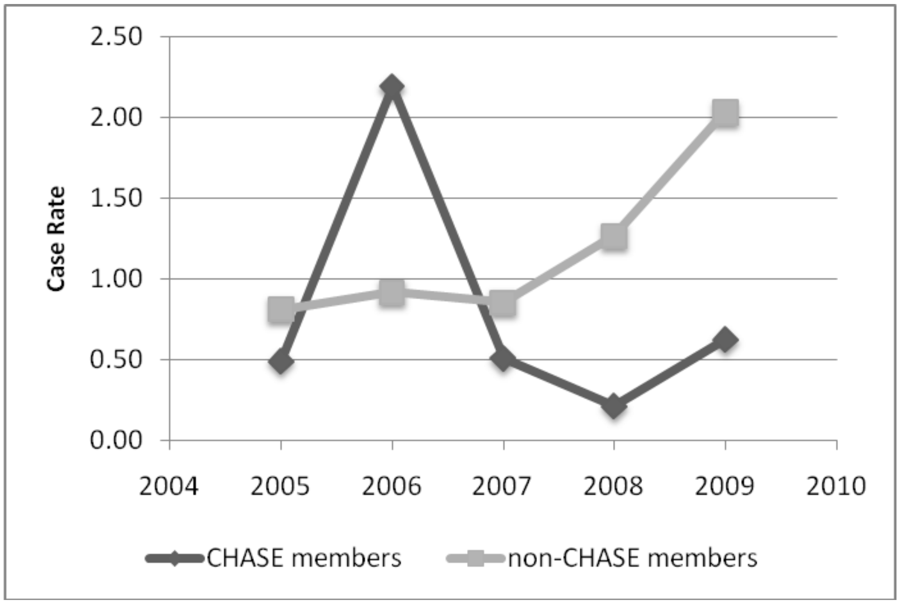

Figure 4: Average Rate of Cases with Days Away From Work

Job Transfer or Restriction

Job transfers or restriction are counted on the OSHA 300a form when, as a result of a work incident, a worker can come to work, but cannot perform their normal work duties as scheduled (Occupational Safety and Health Administration 2002a). Job transfer or restriction rates are counted the same way that days away from work are counted, starting the day after the recordable case and ending if the count exceeds 180 days. Any single injury or illness can create a situation where the worker has both days away from work and a job transfer or restrictions but any given day is only counted once. Figure 5 shows the median rate of cases with job transfer or restriction. In 2006 the NM CHASE members had a higher median rate of cases with job transfer or restriction then the non-NM CHASE members. In 2007 both NM CHASE and non-NM CHASE members had a median rate of cases with job transfer or restriction of zero.

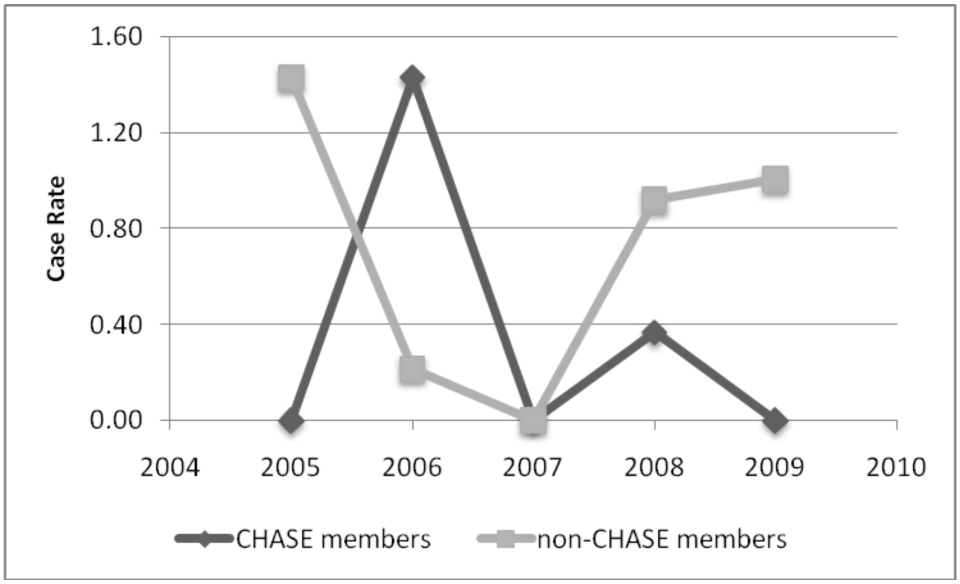

Figure 5: Median Rate of Cases with Job Transfer or Restriction

Figure 6 shows the average rate of cases with job transfer or restriction. In 2005 the NM CHASE members had a lower average rate of cases with job transfer or restriction. In 2008 NM CHASE and non-NM CHASE members had the same average rate of cases with job transfer or restriction. The three other years of gathered data show NM CHASE members with high average rate of cases with job transfer or restriction. Once again this shows a large amount of variability in the data.

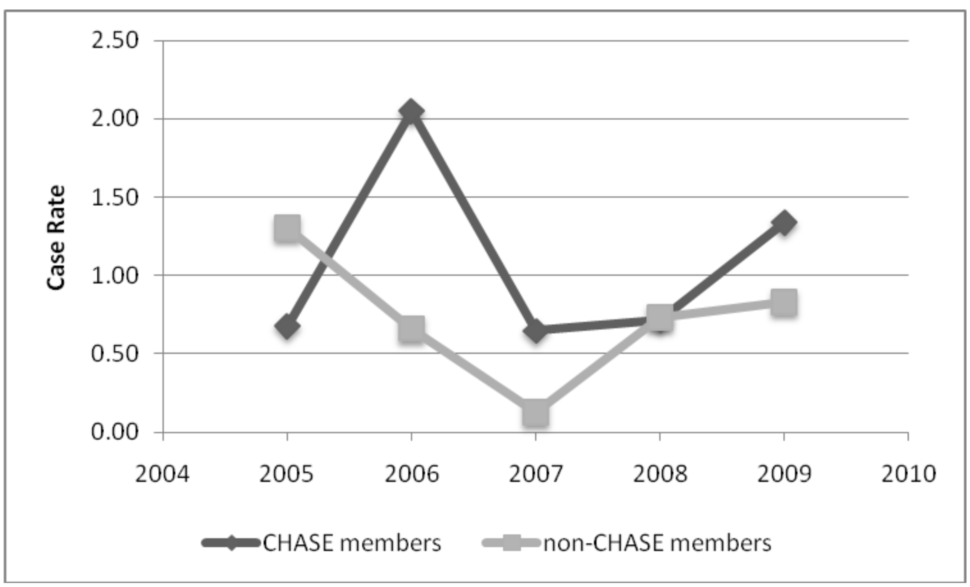

Figure 6: Average Rate of Cases with Job Transfer or Restriction

Other recordable cases

Other recordable cases include any injury or illness that requires medical treatment beyond first aid, but do not result in death or require days away from work, restricted work activities or job transfers. The OSHA 300a form gives a list of treatments that are considered first aid (Occupational Safety and Health Administration 2002). These include using non-prescription medication, applying basic bandaging and drinking fluids to relieve heat stress. In general terms, other recordable cases involve injuries or illness which require professional treatment but do not hinder the worker for more than a day. Figure 7 shows the median rate of other recordable cases. In 2005 and 2006 the median rate of other recordable cases for NM CHASE and non-NM CHASE members was the same. For 2007, 2008, and 2009 the median rate of other recordable cases for non-NM CHASE members was higher than that of NM CHASE members.

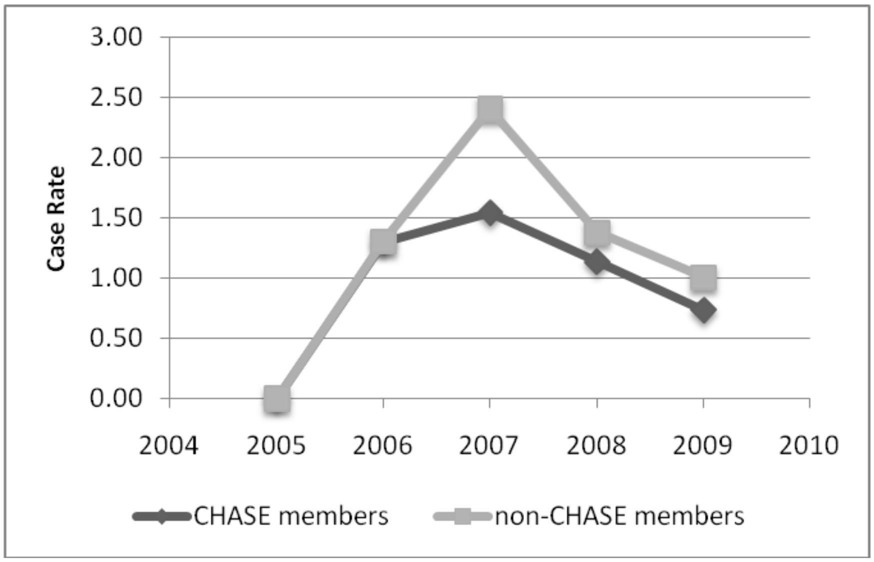

Figure 7: Median Rate of Other Recordable Cases

Figure 8 shows the average rate of other recordable cases for NM CHASE and non-NM CHASE members. In 2005 and 2006 the average rate of other recordable cases for NM CHASE members was higher than that of non-NM CHASE members. However, in 2007, 2008, and 2009 the average rate of other recordable cases was higher for non-NM CHASE members than for NM CHASE members. The difference in median and average values for rate of other recordable cases is similar to that of days away from work, and days with job transfer or restriction. Clearly, one or two recordable cases can make a huge impact. For example during 2008 Respondent 7 had one recordable case. This single recordable case changed their recordable case from 0 to more than 5.

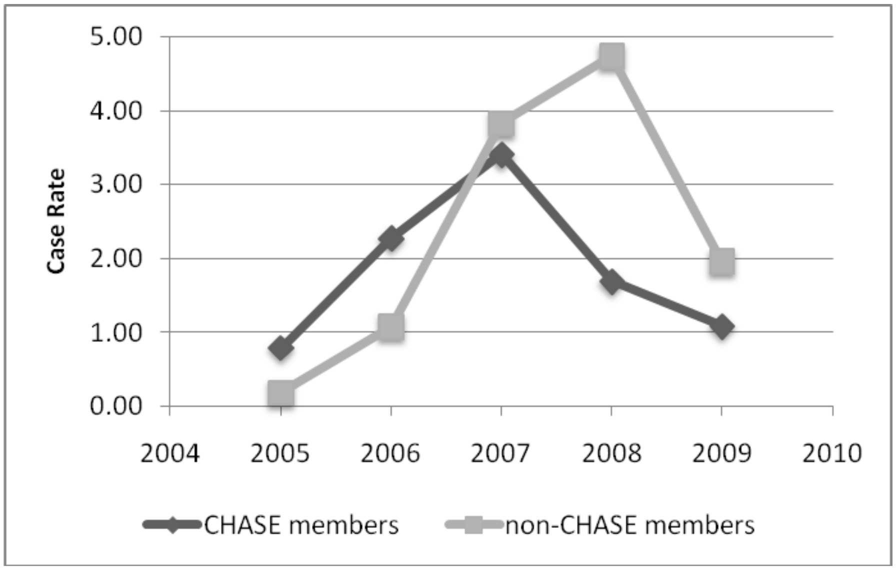

Figure 8: Average Rate of Other Recordable Cases

EMR

Figure 9 shows the average EMR rate for NM CHASE member and non-CHASE members. The EMR rate for NM CHASE members is consistently lower than that of non-NM CHASE members. The EMR is a three year rolling average. The longer term view normalizes many of the spikes seen in other data reporting forms. Due to this rolling average it was determined that the median rate of EMR would not be useful as useful a metric and average.

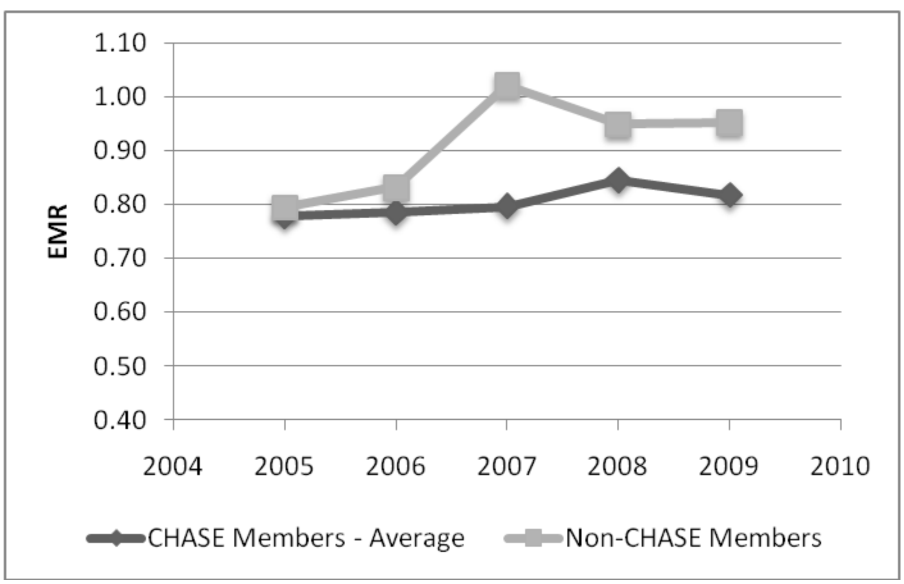

Figure 9: Average EMR Rates for NM CHASE Members and Non-Members

The results for the survey showed that in some limited cases, NM CHASE members have a lower recordable case rate. However, this data was not consistent with how NM CHASE members spoke about the partnership. With these differing viewpoints the researcher decided to conduct a case study on effects joining NM CHASE had on the perceived changed to safety culture.

4. Summary and Conclusion

The construction industry is an incredibly dangerous field to work in. Lowering the rate of injuries and fatalities is good for everyone involved in the construction industry from workers, to contractors, to owners. The method in which safety programs are enforced may have an effect on the outcome of said safety programs. This research examined "command-and-control" vs. self-regulation by studying the NM CHASE program which promotes a self-regulation approach. The goal of this research was to determine if the NM CHASE program had an effect on recordable case rates.

This research asked, "Is the NM CHASE program, a self-regulatory program, effective at lowering recordable case rates below that of the standard "command-and-control" program?" To answer this question a survey was completed. The results from the survey are summarized in Figure 1: Median Number of Recordable Case Rates and EMR. This figure shows that the median number of recordable case rates for NM CHASE members is lower than that of non-NM CHASE members across three categories. The three categories are based on the OHSB 300a form and are: rate of days away from work, rate of days with transfer or restriction, and rate of other recordable cases. Figure 1 also shows that the median EMR rate for NM CHASE members is lower than that of non-NM CHASE members.

This data does indicate that NM CHASE members overall have a lower recordable case rates than non-NM CHASE members. However, there are some limitations to this research. The first was the sample size, this research gathered only fourteen valid survey responses, only three of which were non-NM CHASE members. This limits how transferable the results are to other companies or other self-regulation programs. The survey gathered five years of historical data. To truly determine if joining NM CHASE will lower a company's recordable case rates, a comparison must be done of pre- and post-NM CHASE recordable case rates. This will help determine if joining NM CHASE makes a company safer or if safer companies join NM CHASE.

Even with the ambiguity over if joining NM CHASE lowers recordable case rates, contractors who are members of NM CHASE believe that the NM CHASE program is critically important. One member commented to the researcher: "NM CHASE is hugely beneficial to the state of NM." These beliefs that the NM CHASE program is important and efficient, lead the researcher to complete a follow-on case study asking if joining NM CHASE changed a company's safety culture. The case study results will be published in future works.

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Design for Safety: The Constructors' Experiences and Perspectives

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Design for Safety: The Constructors' Experiences and Perspectives

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Abstract

Based on the premise that effective design for safety practice requires early collaboration between the designer and constructor, structured interviews and online surveys were conducted with construction professionals working for general contractors and subcontractors. This paper presents the attitudes and experiences of constructors' regarding the design for safety concept, safety design tools and protocols, safety design implementations and use of BIM for safety design. The findings suggest that the majority of contractors have some experience in addressing safety concerns through constructability reviews. But there is a lack of broader and systematic understanding of the design for safety concepts by constructors and the respondents reported shortcomings of current tools for design for safety.

Keywords: Design for Safety, Constructor, Design, Constructability, BIM

1. Introduction

Under the imperative of integrated practice, Design for Safety (DfS) – a holistic view that addresses safety and health over the life cycle of a building – is becoming an important aspect of design. DfS emphasizes not only the safety of the general public and building occupants but also concerns the workers during construction, operation and maintenance stages. Within this context, the architecture, engineering, and construction (AEC) industry has begun to recognize the importance of addressing safety considerations during design rather than during the implementation stages. The advancements of legislation in European countries such as the UK Construction (Design and Management) regulations (1994; 2007), or the Australian Workcover regulations, and best practices of leading architectural and engineering firms (e.g., Foster and Partners, Arup, etc.) illustrate this paradigm shift and the growing societal demand towards safer environments. This trend is also observed within the US driven by the National Institute of Health and Safety Prevention through Design (CHPtD) Initiative, or in emerging project requirements by large owners (e.g., Harvard University, Intel, General Services Administration etc.), and design-build company practices (Jacobs Engineering, Bechtel, Washington Group, Parsons, etc.).

Collaborating for design for construction safety

The focus of designing for construction safety efforts is to eliminate and control hazards and risks through design considerations. This concept has been internationally pursued through various efforts. In the US, the recent PtD initiative is promoting design for safety in research and practice. In Australia, Queensland, South Australia and Western Australia and the New South Wales State Government require construction health and safety to be managed during the design process (Zou et al., 2008). In the UK CDM regulations, design risk management can be defined as an integrated design approach to managing health and safety (Griffiths and Griffiths, 2011) throughout the lifecycle of projects. This process involves a process of hazard identification and the design action to avoid, reduce or transfer the risk to another party for action.

The designer is broadly defined in the CDM regulations (CIRIA 2007) to include design practices such as architects, civil and structural engineers, manufacturers, etc.; anyone specifying or modifying design or a particular method of work or material such as a design manager or quantity surveyor; building service designers; those deciding purchasing of specific materials; contractors performing design work; temporary works engineers; interior designers; heritage organizations specifying work instructions; and those determining how buildings and structures are modified. Thus designing for construction safety involves the participation of a variety of parties that reach well beyond the architect and engineer who are traditionally recognized as the designer to participants such as the various contractors. Architects and engineers oftentimes lack the education and training in construction health and safety and construction means and methods (Maloney and Cameron, 2004). Moreover, hazards must be identified within the context of a specific project because the circumstance and activities represent unique sets of hazards and risks and technological change (e.g. materials, equipment, processes) result in highly variable means and methods. Thus effective consideration of construction safety during the design requires collaboration between the designer and the constructor (Maloney and Cameron, 2004).

Considering that the involvement of experienced construction personnel in the design phases has gained acceptance throughout the construction industry (Arditi et al., 2002), design for construction safety efforts should pay attention to how the involvement of the contractors can be encouraged. Song et al. (2009) emphasizes both direct and early involvement of contractors in the design process to deliver the best value to a project because contractors have a higher level of construction expertise; they are responsible for the actual construction operations; they can continually contribute from early design stages to construction, and they can collect lessons learned and track costs and benefits of their early involvement at adequate level of details. Coble and Haupt (2000) recommend increasing coordination between designers and construction foremen while Gambatese (2000) discusses a series of constructability reviews incorporating construction worker safety.

Previous studies have primarily examined the architects and engineers perspectives of designing for safety. Gambatese (2005) identified liability concerns, designer's lack of knowledge of the design-for-safety concept, and lack of design for safety tools and guidelines. DeVries and Grigg (2004), Hinze and Wiegand ( ) highlighted similar barriers to the engagement of architects and engineers in construction safety design.

However, relatively few studies have examined the role of constructors in design for safety (Behm, 2008; Weinstein et al., 2005). Considering the importance of enhancing the collaboration between the architects/engineers and constructors, this study aimed to identify a focus group of construction professionals that would be able to help understand the constructors' attitudes and context for design for safety practices.

2. Methodology

To identify constructors who have engaged with DfS, a questionnaire was distributed to 80 construction companies mainly based in the Mid-Atlantic region of the US who have ongoing relationships with the School of Construction at Virginia Polytechnic Institute and State University. The firms were contacted via email focusing on project or technology managers, safety directors, or other high level individuals who could represent the company's position. Based on the respondent's preference, a structured interview over the phone or online survey was conducted.

The data collection was conducted between December 24, 2010 and January 10, 2011. The questionnaire asked about five aspects of DfS:

1. Familiarity with design for safety concept
2. Experience with practicing design for safety
3. Experience with safety design tools and protocols
4. Experiences implementing design changes for safety
5. Experience with Building Information Modeling for hazard identification and analysis

Eleven out of the 80 contacted companies responded to the questionnaire.

3. Data and Findings

The eleven individuals that responded included vice presidents, senior managers, safety directors, project managers and technology managers. The companies included nine general contractor/construction management firms, two trade contractors (architectural metal and mechanical). Table 1 shows the positions and functional areas of the participants.

Table 1 – Respondents' demographics

	Senior Manager/Vice President	Director	Project Manager
Safety		2	
General Business	5	1	1
Technology (BIM & Process)			2

Familiarity with Design for Safety

The data shows that seven out of the eleven contractors had heard about the design for safety concept (Table 2). To further understand the contractors' understanding of DfS, we asked about the phases that DfS take place, the stakeholders involved, whether they consider it as part of the design process, the tools being used, and the documents produced as a result of the DfS. Among those that were familiar with the term, half indicated that DfS takes place from concept through final design and construction as long as the design can be changed with minimal consequences. Those also answered that all project stakeholders would be involved in the process, including, owners, architects, design engineers, construction managers, general contractors, prime subcontractors.

Others indicated that DfS takes place during design development, preconstruction, and described that all designers, safety coordinator, or BIM specialist and superintendant would be involved.

Most of the respondents thought that DfS is applied throughout the design process while two considered it as part of design reviews or safety design reviews.

In respect to the tools being used for DfS, most respondents were not aware of specific tools but two suggested that they include Building Information Modeling (BIM), lessons learned, spreadsheet tools and public templates.

Similarly, in regard to DfS document outputs most respondents did not have specific suggestions but one respondent mentioned plans and specifications, and another included the project schedule and site hole core lists.

Experience with Practicing Design for Safety

Following the first set of questions, the questionnaire presented the notion of DfS practices as defined below and asked if the participants had experiences with such practices. DfS practices were explained as "Under some Design for Safety practices, designers, in close collaboration with contractors or as part of contractors, would manage construction and/or maintenance and operation safety and health risks that may arise from their designs. This is done by designers through close collaboration with constructors identifying and prioritizing project specific hazards (major location and operation issues, system interface issues, and component details and assembly issues) and altering their design to avoid, reduce or control the hazards."

Table 2 – Respondents reporting familiarity and experience with DfS practice

	Have practiced DfS	Have not practiced DfS
Have heard about DfS concept	4	3
Have not heard about DfS concept	2	2

Table 2 illustrates that four of the respondents both heard about the DfS concept and practiced it, and three heard about the DfS concept but had not practiced it, and two were not aware of the DfS concept but were practicing it. Two of the respondents had neither heard nor practiced DfS. This finding indicates that more than half of the respondents either had heard about the DfS concept (7 out of 11) or had practiced DfS (6 out of 11). Nevertheless, there is room to raise the awareness of DfS concepts among contractors and also need for education to increase the implementation of DfS practices.

As a related question, we asked to what extend the contractors take design responsibilities. Eight contractors including five that answered they have practiced DfS, described their involvement through design-build practices, design reviews, and constructability reviews during design development. Constructability input and reviews would result in recommendations of design changes for costs and efficiency, LEED, and to address safety concerns. One general contractor mentioned that their international units are intensively involved in design stages whereas the US business would be rarely involved in design.

Additionally, the contractors described specifying and altering the use of particular construction methods of work or materials. For example, the contractors mentioned that they would suggest to the design team more cost and time effective systems (e.g., steel vs. concrete, or brick vs. precast) or alternative products, manufacturers, details, etc.

Experience with Safety Design Tools and Protocols

We then asked if the contractors had construction safety management protocols (guidelines, standards, procedures, checklists, etc.) for hazard identification, analysis, and design and planning. The majority of the respondents had guidelines, checklist, standards, and procedures for hazard identification, hazard analysis and safety planning. However, only a few respondents indicated they had protocols for safety design. Besides, the use of a loss prevention manual and a safety data reporting and sorting database were mentioned. One respondent from an international firm mentioned that they identify safety risks during the design in the Nordics business units but not within the US units because they are generally not involved in design.

All but one of the respondents answered that they use their safety management protocols on all projects. One respondent indicated that they use the protocols in design-build projects and in projects where they are allowed to have input.

To understand how hazard identification and analysis tools are used, the respondents were asked to provide examples. Two respondents mentioned the US Army Corps of Engineers (USACE) standard form which includes a risk level assessment and activity hazard analysis (AHA) procedure. The use of checklists includes equipment inspections, pre-task planning (i.e., tool used to assign working safely at the start of each day), superintendent daily reports, jobsite inspections, hole cover map/register/sign (i.e. to ensure that those are installed and secured properly with a documented verification two times a day). Two respondents explained that a meeting or checklist is used prior to start of any new phase of work with any new employee or subcontractor starting work or a new phase of work (e.g., for confined space, routine inspections, etc.). Each task is analyzed, discussed and planned for, to create the safest working environment for each worker. The attendees sign a specific job safety analysis form to confirm their understanding of the safety procedures set forth.

The respondents generally thought the tools were effective if the jobsite team finds an engaging way to use the checklists such as a team approach or a special assignment to someone. Otherwise the tools may not be as effective in identifying and eliminating hazards.

Regarding shortcomings and challenges to the use of hazard identification and analysis tools, a number of respondents mentioned that using onsite tools on a particular day can be a reactive way to eliminate hazards because they may not be used correctly or regularly. One the other hand, another respondent mentioned that documenting and analyzing activity hazards could add significant administrative burden that reduce production.

The various tools and protocols described by the respondents generally involve a breakdown of the job into steps and identifying specific hazards and control measures for each job step, and providing the worker with a documented set of safe job procedures. The USACE AHA standard forms also include a risk assessment matrix that lists the likelihood of a specific hazard and the severity of the consequences.

The current focus of general contractors seems to be on a systematic safety management process through the use of these tools to engage the workers who oftentimes do see this process as an inconvenience before seeing the benefit. One respondent explains, "Superintendents and project manager, or safety personnel are rarely involved in the design review and development process as they are accustomed to look at finished plans and planning around known quantities. It is a very abstract task for them to look at an incomplete design and project what 'might be' an issue that needs to be corrected in the future. The first step to achieving DfS is to help that group shift their thinking. Also, designers only know some basics, and several try to design safely, if they can identify issues. The problem is that they are not trained or knowledgeable enough of construction safety issues to be able to identify the issues at all. Education of the designer group, perhaps OSHA courses would be a start to meld the thinking of the two groups."

Experiences Implementing Design Changes for Safety

All but one of the respondents indicated that they would or had recommended changes to design to improve worker's safety. There were a number of commonly suggested design changes to prevent falls hazards such as raising the parapet height, including roof anchor tie-off systems, punching lifeline holes in steel columns and beams during fabrication, embedding anchor points into cast-in place slabs, columns, and precast floor sections. One contractor explained introducing embeds on the top of precast concrete wall elements for handrails to be installed on the ground. Another example is the engineering of a concrete foundation walls so they could be backfilled around immediately after pouring concrete and waterproofing instead waiting until a few sets of floor slabs are poured and backfilled. One respondent explained the double connection in structural steel floor beam construction. A typical detail will allow for two smaller floor beams to tie into the larger girder beam at the same point, effectively eliminating any torque that uneven loadings on the smaller beams would transfer to the girder beam. The same bolt, with a nut on each side, will connect each of the smaller beams. This detail is usually a cost effective solution for many large buildings as the girder beams are of smaller size. The contractor explained that they have solved the problem in most cases by requiring the erector to weld one beam in place prior to setting the "sister" beam. This eliminates the possible failure of the temporary bolt connection to the first beam, while the installation of the second beam is underway.

From a construction planning standpoint, changing the installation scope of exterior sheathing from the framing contractor's scope to the EIFS contractor's scope to facilitate installation and reducing risk to the number of workers performing on an exterior scaffold or lift or adding intermediate guardrail posts (to supplement those bought by structural trade) were mentioned. Another respondent added that visuals and images are better received by workers and that virtual models have been used to convey concepts or processes to improve communication through visual means.

Building Information Modeling and Design for Safety

With the growing application of building information modeling (BIM) in design and construction, the authors asked if the respondents had used BIM for hazard identification and analysis or jobsite safety analysis. Four indicated they had experience. Two respondents were from the same company, one a safety director, said they used it mainly for training purposes but also for conflict management, including building structure (embedded) anchor point location planning. A technology and process development manager from the same company mentioned the use of BIM for planning of scaffolding; trench excavation, mass excavation, benching, and safety railing. Another company's safety director explained their international units in the Nordics and the UK use BIM on select projects for hazard identification and analysis.

All of the respondents agreed that BIM can improve job safety hazard identification and analysis. Among the reasons mentioned were, watching the building get built digitally reveals hazards and other "opportunities for improvement" that might otherwise go unnoticed or not thought of; prompting memories and reviews of standards for future activities to visually identify issues and provide insight into potential safety hazards. One respondent cautioned that safety BIM would be helpful if the project team actively uses the BIM model to plan for all relevant activities on the project and updates the model regularly. Another respondent added that the entire team including the general contractor would need to be brought on board once the planning starts, so the process can be looked at jointly by not only owners and designers, but by contractors from the onset.

Considering that collaboration between the design and construction teams would be encouraged under integrated project delivery (IPD) arrangements, we asked if any of the respondents had previously worked under IPD teams. Only one out of the eleven respondents mentioned they had indirect DfS experience under IPD.

4. Conclusions

The small sample size limits the statistical significance of the findings but provides a focused view of constructors on design for safety that will be guide future focus group discussions.

The findings indicate that there is lack of a systematic understanding of the DfS concept among contractors. Nevertheless, safety concerns have been oftentimes somewhat incorporated by contractors via constructability reviews although there is a lack of safety design tools. A few contractors have taken design responsibilities as design-builders. Many of the respondents provided anecdotal evidence of suggesting design changes to eliminate falls hazards (e.g., by embedding tie-off points or handrail connectors, etc.). While most contractors have safety management protocols for hazard identification and analysis, the tools have not necessarily been used for collaboration with the designers. It was mentioned that both designer and constructors oftentimes lack the necessary skills to collaborate with each other. From the constructor’s standpoint, it is necessary to train the safety personnel, project manager and superintendents to be able to participate in reviews during the design development process before the final design is complete and the designers need to be educated and trained to identify hazards and assess risks when making design decisions. While BIM is being recognized as a potential tools to enhance hazard identification and analysis, specific applications have yet to be developed.

The data tentatively suggests that within the US context, the contractors may play a pivotal role in leading the design for safety process. To facilitate such practices, researchers should further examine the effectiveness of tools for hazard identification and analyses adapted for safety design purposes, and enhance the design understanding of contractors to be able to effectively communicate with designers.

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Measuring Safety Climate to Enhance Safety Culture in the Construction Industry of Pakistan.

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ABSTRACT

Construction is among the hazardous industries which raised the concern of stakeholders to improve safety performance by stream lining the safety management system attributing the safety climate perspective. The objective of this study is to assess the direction in safety management through determination of safety climate that would enhance safety culture and positively impact perceived safety performance on construction sites. A safety climate questionnaire has been surveyed (self interviewed and post mail) among 21 construction companies and 36 construction projects (diversified in type and location) in Pakistan, response rate was excellent (83.33%). By means of factor analysis, two significant safety climate factors were extracted, accounting for 23.567% of the total variance. Multiple regression analysis revealed two pivotal factors “Management dedication” and “Employees’ involvement” portraying workers’ perceptions of safety performance. This study indicates that high efforts of management needs to involve workers for safety related activities which helps for effective safety management system implementation and each employee to acquire safety knowledge which would develop capability for safe operation on construction sites. Finally, this work provides useful information for project managers and practitioners who desire to improve safety performance on construction sites.

Keywords: Safety Culture, Safety Climate, Safety performance, Pakistan.

1. INTRODUCTION

Construction industry has attributed to economically and socially importance but also recognized as most hazardous (Suao and Jaselskis, 1993; Hinze 1997; Sawacha et al. 1999; Choudhry et al.2008). Generally, construction sites are one of the most dangerous workplaces because of high incidence or accidents (Teo et al, 2005; Ahmed et al., 2000). Gradual increase in relative percentage of Construction with other industries for occupational injuries and diseases has been observed from 12.54 (2002) to 14.54 (2009), evident of poor safety practices at construction sites (Survey of Pakistan, 2002 - 2009). A mean value of Safety Performance Index of 0.52 indicates that even the basic practices required for safety are not present at most construction site in Pakistan. Also, the scattered safety performance levels of firms indicate lack of standard safety management system. (Farooqui et al. 2008). The construction industry is one of the most injury-prone industries worldwide in terms of serious injuries, lost work time, hospitalization, disability, and mortality, and there is great need to improve worker safety at construction sites (Kines et al. 2010). Improvements in working conditions and innovations in the equipment used in the industry are not enough to improve safety performance because organizational culture and human factors also play critical roles (Zhou et al. 2008). Construction safety culture is a subset of the overall culture of an organization and is seen as affecting the attitudes and beliefs of members in terms of health and safety performance (Choudhry et al. 2007), while safety culture is about good safety attitudes, it is also about good safety management established by organization (INSAG-4). Kennedy and Kirwan (1998) reveal that safety management is regarded as the documented and formalized system (policy, procedures, training, instructions, and resources) of controlling against risk or harm. The safety climate relies and focuses on current safety activities to establish the success of the safety management system rather than the system failure (Cooper and Phillips 2004; Choudhry et al. 2009). Safety performance portrays the occupational health and safety (OHS) status of construction work environment, which is measured in two ways i.e. reactive/lagging (Cohen 2002; Mohammad 2002; Hinze 2005) indicators and proactive/leading indicators (Hinze 2005; Choudhry et al. 2007). Positive performance indicator is stated to be safety climate "reflects employees' perceptions about the organization's safety management system including policies, practices procedures that how safety is implemented" (Choudhry et al. 2009). Neal et al. (2000) evaluated that organizational climate exerted a significant impact on safety climate and the effect of safety climate on perceived safety performance was mediated by safety knowledge and motivation. Guldenmund (2000) concluded that safety climate might be considered as an alternative of safety performance indicator. The power of the safety climate concept lies in its ability to predict safety performance (Pousette et al. 2008).

Present study is the pioneer effort to assess the safety climate in the construction industry of Pakistan as no prior valid research has been reported in this field.

1. To conduct a safety climate questionnaire survey on Pakistani construction sites that examine employees' perceptions for safety;
2. To determine the structural factors of safety climate which has major impact and need to be considered by management to improve the safety climate on construction sites;
3. To analyze the data statistically to evaluate the relationship between safety climate and perceived safety performance on construction sites; and
4. To suggest ways to improve the existing safety climate in the construction projects.

2. LITERATURE REVIEW

Zohar (1980) defined safety climate as "summary of molar perceptions that employees share about their work environment." The term safety climate refers to perceptions of policies, procedures and practices relating to safety in the work place. Glendon and

Stanton (2000) demonstrate that organizational climate refers to the perceived quality of an organization's internal environment. Flin et al. (2000) defined safety climate as the shared perceptions about safety values, norms, beliefs, practices and procedures. Mohamed (2003) stated that the safety climate is largely a product of safety culture and the two terms should not be viewed as alternatives. Choudhry et al. (2007) provided the definition that *safety climate reflects employees' perceptions about the organizations' safety management system including policies, practices, and procedures that show how safety is implemented in construction sites environments*.

Safety climate measures vary significantly, typically, factor analysis (FA) is employed to identify an underlying structure for questionnaire items. A cluster of obtained factors is interpreted to be as scales, factors, or dimensions of safety climate. Some studies have begun to explore the safety climate concepts in construction for example, Pousette et al. (2008) and Choudhry et al. (2009).

Dimensions of Safety Climate

Addressing safety climate dimensions specifically construction industry, Glendon and Litherland (2001) found six factors for safety climate in a road construction organization include communication and support, adequacy of procedures, work pressure, personal protective equipment, relationships, and safety rules. Mohamed (2002) has identified 10 dimensions of safety climate in construction site environments include management commitment, communication, safety rules and procedures, supportive environment, supervisory environment, workers' involvement, personal risk appreciation, appraisal of work hazards, work pressure, and competence. For Hong Kong construction industry, Fang et al. (2006) evaluated 10 dimensions as safety attitudes and management commitment, safety consultation and safety training, supervisor's role and workmates' role, risk taking behavior, safety resources, appraisal of safety procedure and work risk, improper safety procedure, worker's involvement, workmate's influence, and competence and Choudhry et al. (2009) reduced these factors to two as management commitment and employees involvement, and inappropriate safety procedures and work practices.

Safety Climate and Demographic Factors

The NIOSH studies demonstrated that safety climate was an important predictor of adherence to safe work practices, explaining far more variance than demographic or other individual factors (Hahn et al. 2008). Nonetheless, empirical justification for using personal demographics as a validation technique is required if safety climate research is to progress (Cooper and Phillips, 2004). Siu et al. (2003) investigated age difference in safety attitudes and safety performance in Hong Kong construction workers with data from 374 Chinese construction workers from 27 construction sites. The study found that the older workers exhibited more positive attitudes toward safety. Fang et al. (2006) used logistic regression to explore the relationship between safety climate and personal characteristics. Statistically, eight personal characteristics namely age, marital status, the presence of dependent family members, education level, safety knowledge, drinking habits, direct or indirect employer, and breaking safety procedures or not, were found to be related to safety climate perceptions. Five variables, including gender, work experience with the company, work experience in the construction industry, whether injured or not, and smoking habits were found to have no influence on perceptions of safety climate. Choudhry et al. (2009) found positive effects upon perceptions of older workers, who are married, and have more family members to support yet have little impact upon those who are in the youngest age, single, or have no family member to support. Workers with educational levels below primary had less perception of the safety climate. Respondents revealed that subcontractors' employees had a less positive safety climate as compared to the direct employees of the company.

Safety Climate and Safety Performance

Prioritizing and valuing safety (i.e., having a positive safety climate) have been shown to enhance safety performance and decrease employee injuries (Zohar, 2002). The influence of safety climate on individual safety behavior transfers to safety performance, termed as effective way (Fang et al, 2006)**.** Research studies provided evidence of correlation through identified dimensions or factors, a measure of safety climate with safety performance (Findley et. al, 2007). A safety climate is usually regarded as a subset of an organizational climate; similarly, safety performance is considered to be a subsystem of organizational performance. Hence, the safety climate can influence safety performance (Wu et. al, 2008). Recent meta-analytic evidence has confirmed that safety climate is associated with greater safety performance and decreased rates of accidents and injuries (Gentleman et al. 2010). Leading performance indicators (Safety climate) have the advantage of identifying weaknesses in safety management practices before they manifest as accidents (Mearns et al. 2003). This is supported by a previous study that if safety climate improvements are to have any impact on safety performance, then the survey must first produce changes in employee's knowledge and motivation (Neal et al. 2000). Mohamed (2002) developed a research model based on the hypothesis that safe work behaviours were the consequences of the existing safety climate in construction site environments. Broadly, safety performance measurement techniques can be categorized into statistical measures, behavioural measures, periodic safety audits, and a balanced scorecard approach. Guldenmund (2000) concluded that safety climate might be considered as an alternative safety performance indicator. Actually the power of the safety concept lies in its ability to predict safety performance (Pousette et al. 2008)

3. RESEARCH METHODS

From the literature review, potential safety attributes affecting safety performance on construction sites were identified. Based on the previous research by Choudhry et al. (2009), the present questionnaire was modified for measuring safety climate.

Questionnaire

Safety climate deemed to investigate the perceptions of the employees regarding management commitment or to identify areas to improve safety, safety climate was the preferred term when psychometric questionnaire studies were employed as the measurement instrument (Hale and Hovden, 1998).

As mentioned before a safety climate questionnaire survey has been conducted by Choudhry et al. (2009) in Hong Kong construction industry, derived two factors upon 31 safety climate statements by performing principal component factor analysis, to construct safety climate for the construction company (Gammon Construction Limited). In term to investigate the safety climate on Pakistani construction sites this 31 items safety climate questionnaire was adopted then 9 additional items were included to make the questionnaire suitable in accordance with the safety management systems operational in accordance with the safety management systems operational in Pakistan.

The questionnaires were prepared both in English and Urdu versions. The questionnaire in its final form consisted of 60 statements about safety issues at the organizational, group, and individual levels and consisted of four parts. The first part of the questionnaire related to the respondents' general information. The questions include respondent's project name, name of the company, department and working group. Further questions included the respondent's job information that is he/she a worker or clerical staff, supervisor or a manager. The second part consisted of 40 safety climate items which asked the participants to endorse the statements using a five-point Likert - type (from 1 = "strongly disagree" to 5 = "strongly agree") scale. The third part consists of four questions. Two questions measured respondents' perception on safety performance for the surveyed projects. The other two questions measured respondents' perception of safe work behaviour. Respondents were asked to indicate, on average, the percentage of time they and their co-workers follow all of the safety procedures for the job they perform. The fourth part of the questionnaire included 10 questions on personal information, including demographic information such as age, gender, marital status, and number of family members to support, education level, direct employer, and work experience with the company and in the industry, habit of smoking at work. In addition respondents' trade or work type has been asked, which is only for workers. At the end of the questionnaire suggestions regarding safety and survey has been asked, which was optional.

Data Collection

Ojanen et al. (1988) argue that the only way to measure the safety climate is by surveys. A questionnaire survey has been conducted on 36 construction projects visited located in or near major cities of Pakistan. This survey has taken around two months to visit each construction site except sites in Hyderabad, Karachi and Swat (post mail questionnaire received). These projects were also diversified in type of work as Bridge (2), Educational Building (8), High rise building (5), Hospital (1), Housing(2), Industrial building (7), Mosque(1), Office Building (5), Residential Building (1), Road (3) and Ware House (1). Around 21 construction companies were visited varied in categories of Pakistan Engineering Council (CA=9, CB=2, C1=2, C4=5, C5=1, C6=1, OA=1). There were average more than 150 employees engaged on each project at the time of visit (including company staff, company worker, sub-contractor workers and consultant/client representatives as well). To check and avoid the problem bias, self interviews conducted with 110 respondents and 40 respondents filled questionnaire under Manager monitoring. Overall response of construction companies for the survey is appreciated even though no obligation from client and administration body forced.

Sample

Questionnaire survey to 36 construction sites has resulted 150 valid responses which is 83.33% of questionnaire distributed, representing true sample of the construction industry. There was least response received from Managers, Supervisors and workers , which were in the ratio of sample as 1.6 : 1.0 : 2.0.

From the 150 employees hereinafter called the valid sample or sample, 37.67% were between 21 to 30 years old, 37.67% were between 31 to 40 years, 13.33% were between 41 to 50 years old and the rest 13.33% were older than 50 years (see Figure 3.1). Gender-wise, 100% participants were male. Considering marital status, 77.33% of employees were married and 22.67% were single respondents. When asked how many family members are supported by you; 11.33% employees responded none, 18% are supporting one to two family members, 38% are supporting three to four dependent family members, 22% are supporting five or six family members, and 10.67% are supporting seven or more family members. 46% of the participants had an advanced degree, 21.33% were college graduates, 21.33% had a secondary education, 7.33% had a primary education, and 4% did not have a primary education. Most of the sample (19.33%) was subcontractor employees, 6% were employed by the joint venture, and 74.67% were directly employed by the company. Approximately 16% of the sample had worked for the present employer for more than ten years, and 15.33% had worked for more than six years, 44.67% had worked between one to five years, and the rest 24% had less than one year working experience with the present employer. As for construction industry experience, 15.33% of the sample had less than 3 years working experience, 34.67% had three to ten years working experience, and rest50% had more than 10 years working experience. Approximately (63.5%) of the sample did not have a smoking habit; 16.9% responded that they did not smoke at work; and the rest 19.6% used to smoke at work. All this personal information provided useful data for the safety climate research and the sample was quite representative of the total workforce.

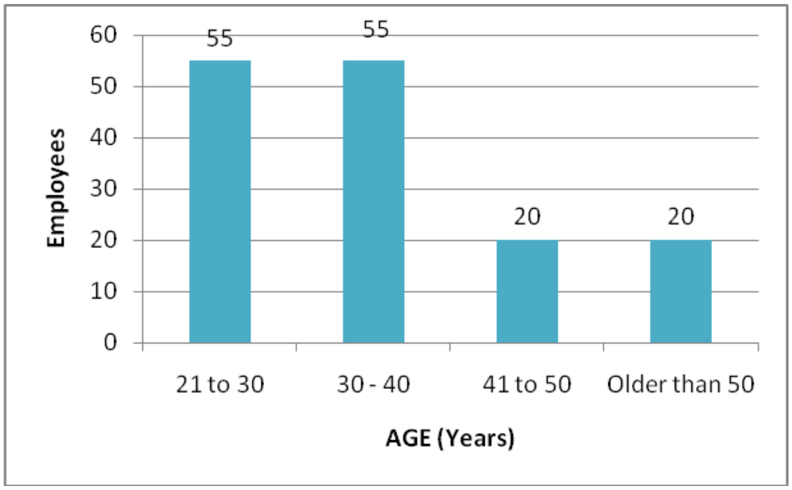

Figure 3: Age of participants of sample

The quantitative data collected was analyzed by statistical techniques adopted previously such as factor analysis and multiple regressions to evaluate the essential factors affecting safety climate and its impact on safety performance (Fang et al., 2006; Choudhry et al., 2009). SPSS version 17.0 has been used for statistical analysis. Lee (1998) found significant differences in safety climate scores by organizational level. Comparison of safety climate mean scores has been done for companies, projects (according to project type), and position, demographic factors (age, marriage status, family dependents, educational level, direct employer, industry experience and smoking habits).

4. RESULTS OF RESEARCH

Factor Analysis

The factor analysis technique was used to identify the underlying cluster of factors which affect safety climate. A principal component analysis (PCA) of factor extraction with Varimax rotation (converged in 29 iterations) on the 40 questions/statements (N= 150) was carried out through the SPSS 17.0 factor program. According to George and Mallery (2006, p.256), the KMO value (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) should be greater than the acceptable threshold of 0.5 and a value greater than 0.6 is mediocre, > 0.7 is middling, > 0.8 is meritorious and > 0.9 is marvellous for a FA to proceed. In this study, the KMO-value was equal to 0.818, which is well above the acceptable threshold indicating that the data was appropriate for factor analysis. Barlett's test for sphericity was used to test the hypothesis that the correlation matrix was an identity matrix. In this case, the value of the test statistic for sphericity is large (chi-square value = 2636.943) and the associated significance level is small (p-value = 0.000), indicating that the population correlation matrix is not an identity matrix as a factor analysis would be meaningless with an identity matrix (George and Mallery, 2006). A significance value < 0.05 indicates that the data does not produce an identity matrix or differ significantly from identity. The overall Cronbach's Alpha value is 0.819, indicating that there is good internal consistency reliability between factors as a value of

0.70 or above is acceptable as desired value of the Cronbach's Alpha (George and Mallery, 2006 p. 231; Lee and Harrison, 2000; Cooper and Phillip, 2004). Since the requirements of KMO measure, Barlett's test of sphericity and Cronbach's Alpha values were all achieved, the factor analysis for this research can proceed with confidence. A total of 12 components or factors were extracted from the 40 item questionnaire and from 150 valid responses accounting for 69.33% of the variance (see Table 4.3), which is comparable to other related research studies (Choudhry et al., 2009) i.e. 59.5%, for example Fang et al. (2006) was 47.6%. SPSS drops components 13 to 40 because their eigenvalues are less than 1.0, implying that they are less influential than the 12 obtained group factors. The original 40 safety climate influencing variables/statements were all included in one of these 12 underlying factors. According to Pallant (2007), smaller sample size (e.g. 150 cases) should be sufficient if solutions have several high loading marker variables (above 0.75 or 0.8). Items with low communalities (e.g., less than 0.3) and displaying low factor loadings in the rotated component matrix were removed (Pallant 2007, p. 196). In first attempt items C06, C11, C15, C20 and C36 with low communality values of -0.375, -0.658, -0.528, -0.476 and -0.442, removed. In second attempt two more items as C21 and C40 with low communality values of -0.316 and -0.398, removed. Lastly only one item C39 found with low communality of 0.321, which was removed. The removal of problem items is useful if one is interested to improve the scale after a survey. In result KMO value increased 0.829 (>0.5), for Barlett's test for sphericity chi-square value reduced 1956.953 but with associated significance level is small (p-value = 0.000), indicating that the population correlation matrix is not an identity matrix as a factor analysis would be meaningless with an identity matrix (George and Mallery, 2006). Varimax rotation is still valid and rotation converged to 11 iterations. Twelve components now reduced to ten components (cumulative variance of 68.651%) with more loading (>0.75) in first and second components but later components comprise of only of variable with loading more than 0.75, except component 3 and 4 (no variable above 0.75 found). Rotation sums of square loading are described component wise 1 (18.591%), 2(30.419), 3(36.625%), 4(41.864%), 5(46.994%), 6(51.971%), 7(56.507%), 8(60.577%), 9(64.619%) and 10(68.651%).

Table 4.1 contains the details of factor loading which indicates the strength of relationship between a particular variable (denoted by C01, C02 … C32) and a particular factor. Moreover no variable found under component 3 and 4 with loading above 0.75, so not inducted in the table.

Almost all loadings of the 32 individual factors were greater than 0.80, or close to 0.75 preferred (Pallant, 2007). Thus, the values show the degree of contribution of individual variables to each underlying factor. A positive sign of the factor loading means that the variable is directly proportional to safety climate, whereas a negative sign means that the variable is inversely proportional to safety climate. For example, accidents are inversely proportional to safety climate. Figure 4.13 is a scree plot between eigenvalue of each factor with component numbers. The gradual trailing off of the plot is the "scree" because it resembles the rubble that forms at the base of a landslide (George and Mallery, 2006). The Figure 4.1 confirms that derived factors are influential as with low variance differences these merge on elbow of scree plot, considered for research model.

No.	Item	Factor Loading
Factor 1: Management dedication; Eigenvalue 5.949; % of Variance 18.591 ; Cumulative % 18.591		
Q 23	Management motivate site employees for working safely	0.783
Q 24	Management clearly communicates safety issues to all levels within the organization	0.760
Factor 2: Employee's engagement; Eigenvalue 3.785; % of Variance 11.827 ; Cumulative % 30.419		
Q 28	It is in my interest to maintain a safe workplace.	0.786
Q 33	I participate in safety planning, according to our safety policy if being asked	0.757
Q 32	My aim is to achieve high levels of safety performance	0.748
Factor 5: Employee's partcipation; Eigenvalue 1.642; % of Variance 5.130 ; Cumulative % 46.994		
Q 02	Suggestions to improve health and safety are seldom acted upon.	0.813
Factor 6: Employee's involvement; Eigenvalue 1.592; % of Variance 4.976 ; Cumulative % 51.971		
Q 03	I feel involved when health and safety procedures / instructions / rules are developed or reviewed.	0.867
Factor 7: Inadequate implementation of safety rules; Eigenvalue 1.452; % of Variance 4.536 ; Cumulative % 56.507		
Q 26	Current safety rules and procedures are so complicated that some workers do not pay much attention to them	0.826
Factor 8: Work pressure; Eigenvalue 1.302; % of Variance 4.070 ; Cumulative % 60.577		
Q 04	Productivity is usually seen as more important than health and safety by management.	0.831
Factor 9: Insufficient Safety knowledge; Eigenvalue 1.294; % of Variance 4.042 ; Cumulative % 64.619		
Q 12	People are just unlucky to suffer an accident.	0.801
Factor 10: Responsibility for safety; Eigenvalue 1.290; % of Variance 4.032 ; Cumulative % 68.651		
Q 05	People here always work safely even when they are not being supervised.	`

Table 4.1 Factor Structure by Principal Factors Extraction and Varimax Rotation.

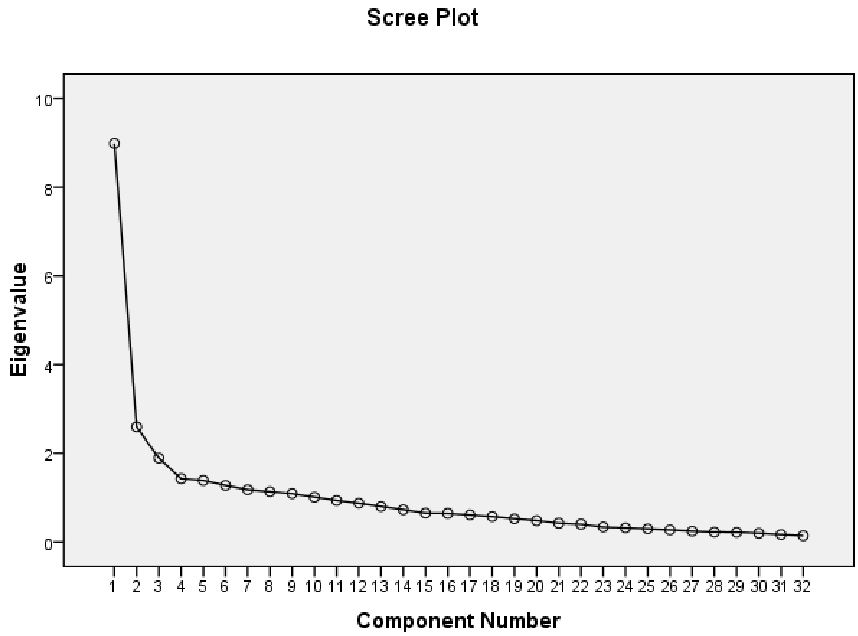

Figure 4.1: Scree-plot of the 32 variables influencing safety climate

Table 4.1 lists the grouped safety climate influencing factors (8 numbers) in descending order of significance to determine underlying features that linked them as Factor 1 (Management Dedication), Factor 2 (Employee's engagement), Factor 5 (Employee's participation) , Factor 6 (Employee's involvement), Factor 7 (Inadequate implementation of safety rules) Factor 8 (Work pressure), Factor 9 (Insufficient Safety Knowledge), Factor 10 (Responsibility for safety)

Model of Safety Climate and Safety Performance.

A regression model is a mathematical model that can relate a number of independent variables to a dependent variable and can summarize data or the relationships among variables (Chan et al., 2005, p.34). A regression model having more than one independent variable is called a multiple linear model. Multiple linear regression analysis was used in this research to study the relationships between safety performance (dependent variable) and safety climate factors (independent variables). A stepwise variable selection was adopted as it is the most frequently used method for model building (Norusis, 2005; George and Mallery, 2006) to identify the critical success factors. The stepping method criteria selected the p value = 0.05 for a variable to enter the regression equation and p value = 0.10 to remove an entered variable (Norusis, 2005; George and Mallery, 2006). The model gives an equation which contains a constant (intercept) and partial regression coefficients for each of the critical success factors. Eight safety climate factors extracted by factor analysis from the 32 variables were used as independent variables in evaluating the relationship with perceived safety performance (dependent variable question Q41) on the 36 construction sites. Dependent variable question Q41 asked respondents to evaluate the overall safety performance of your site on a scale of one to five (from 1 = Poor, 2 = Marginal, 3 = Average, 4 = Good and 5 = Excellent).

Independent Variable (Safety	Un-Standardized Cefficients (β)	Un-Standardized Cefficients (β)	Adj. R^2 (Partial)	Adj. R^2 Change (Part)	t-value	Sig.
y-intercept (i.e. constant)	0.727				2.099	0.038
Factor 1: Management dedication	0.575	0.501	0.258	0.239	7.082	0.000
Factor 6: Employee's involvement	0.145	0.163	0.036	0.025	2.309	0.022

Table 4.2: Results of Stepwise Multiple Regression
(Note: Dependent Variable – Please evaluate the overall safety performance)

Table 4.2 shows the un-standardized and standardized regression coefficients (β), adjusted R2, R2 change, t-value and significance level for the sample. Employee's engagement (Factor 2), Employee's participation (Factor 5), Employee's involvement Inadequate implementation of safety rules (Factor 7), Work pressure (Factor 8), Insufficient Safety Knowledge (Factor 9) and Responsibility for Safety (Factor 10) were excluded from the regression model because they failed the entrance criteria of stepwise variable selection described above. Management dedication (Factor 1), Employee's involvement (Factor 06), were significantly different from $p \leq 0.000$ to $p \leq 0.044$. Hence the Multiple Linear Regression equation for safety performance is:

Safety Performance = 0.727 + 0.575(F1) + 0.145 (F6) **[Equation 4.1]**

The equation 4.1 gives the relationship between perceived safety performance and significant safety climate factors. Wherein the β values indicate the relative influence of the entered variables, that is F1 (Factor 1) has the greatest influence on safety performance (β = 0.575) followed by F6 (Factor 6) with β = 0.145, with positive Direction. An R square change value of 0.239 indicates that 23.9% of the variance in safety performance is explained by Factors 1, followed by 2.5% by F6. On separate note adjusted R square value of model is 30.5% with Pearson correlation of independent variables as 0.221 present strength of relationship.

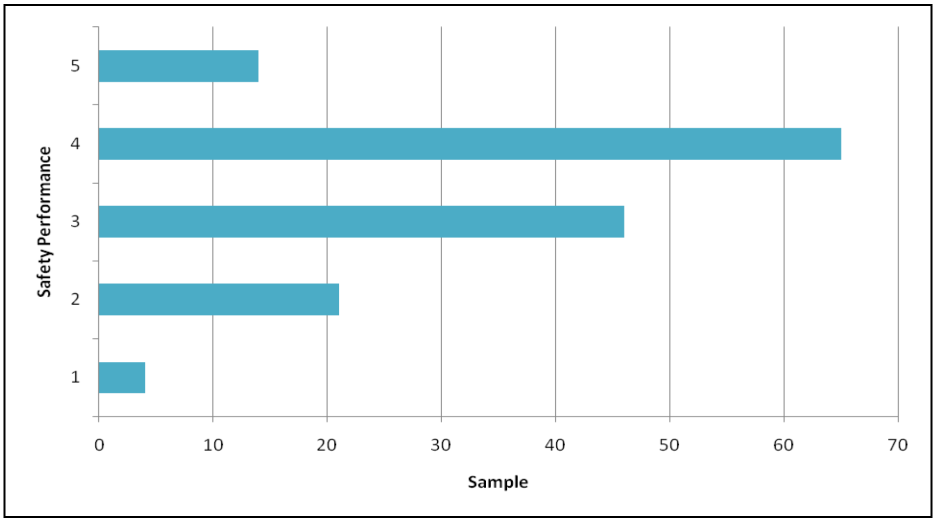

Figure 4.1 Frequency distribution diagram for the sample (N = 150)

Figure 4.1 exhibits the frequency distribution of the safety performance measure for all respondents of the sample. The x-axis represents the number of respondent and y-axis represents the safety performance scores entered by the respondents ranging from 1 to 5. The result shows that only 2.7% respondents rated a score of 1(poor), 14% of 2(Marginal), while a score of 3 (average) is rated by 30.7%, score of 4 (good) by 43.3%, and score of 5 (excellent) was rated by 9.3% respondents meaning that 52.7% respondents consider that safety performance of their company is good.

Demographic Factors and Safety Climate

Mean safety score has been analysed in accordance with demographic factors to investigate the perception about safety climate as age group (41 to 50 years), married respondents, respondents with more than 7 dependents, all respondents with basic education, respondents employed in joint venture projects respondents having more than 16 years experience and respondents who do not smoke, have clear perceptions.

5. DISCUSSION

Safety Climate Factors/dimensions

The discussion is concentrated on only two factors derived from Multiple regression analysis i.e. Management dedication (Factor 1) and Employee's involvement (Factor 06). Management dedication/commitment as potential dimension for the development of positive safety climate and widely accepted in many studies (e.g., Zohar 1980; DeDobbeleer and Beland 1991; Flin et al. 2000; Mohamed 2002, Fang et al. 2006 and Choudhry et al. 2009). Genuine and consistent management commitment to safety, including: prioritization of safety over production; maintaining a high profile for safety in meetings, personal attendance of managers at safety meetings and in walkabouts; face-to-face meetings with employees that feature safety as a topic; and job descriptions that include safety contracts (Mearns et al. 2003). Several studies show that the management's commitment and involvement in safety is the factor of most importance for a satisfactory safety level (Jaselskis et al. 1996). An insight of this factor portrays the perceptions regarding the proactive management involvement, managers' safety related communication and enforcement of safety programmes. Managerial policies and practices develop the level of commitment inducing the responsibility. Management's accountability for emphasizing on safety drive the dedication embedded with leadership approach. Employee commitment for safety is associated with management commitment and leadership. The pragmatic approach stemming with management's dedication for safety positively influence the employee's perceptions for safety. Safety knowledge and safety performance are also enhanced with real dedication of management for safety. The role in the capacity to management' support, involvement and commitment have on the efficiency and success of any safety performance scheme. (Sawacha et al, 1999). It can be evaluated from the discussion above that strong management commitment to safety and to demonstrate this dedication to employees at all level will enhance safety culture in positive direction.

Employees' involvement to develop or review safety rules/procedures address the significant role of workers to improve safety which is supported by studies (e.g., DeDobbeleer and Beland 1991, Mohammad 2002, Fang et al. 2006 and Choudhry et al 2009). Involvement of employees including; empowerment, delegation of responsibility for safety and encouraging commitment to the organisation (Mearns et al. 2003). Workers' involvement includes such issues as procedures for reporting injuries and potentially hazardous situations (Mohammad, 2002). In stance to encompasses the ability to address specific project objectives in relation to safety, appraisal of physical work environment, and workers' constructive involvement. (Mohammad, 2002).

Safety Performance Model

The results of multiple regression analysis identified the critical safety climate factors affecting respondents' perceptions of safety performance on construction sites. The results showed that the two factors, i.e., "management dedication" (Factor 1) and "employee involvement" (Factor 2) were significant contributors to perceptual safety performance on the construction sites (see Eq.4.1). "Management dedication" is found to be the most significant factor which affects perceptual safety performance but "employee involvement" found to be less significant. This finding consistent with Choudhry et al, (2009) that derived "management commitment and employee involvement" as first factor and "inappropriate safety procedure and work practices" as second factor. Current findings reduced to first factor and develop the significance of each element of the factor separately. Further the current factors are consistent with Jaselskis et al. (1996) that management's commitment and involvement in safety was the most important factor for a satisfactory safety level. This factor also emphasized the importance of employees' involvement and safety resources available for safety on the construction sites. Cheyne et al. (1998) have recently reported management commitment as a prime factor in their predictive model of safety behaviours, giving some support to the primacy of this factor. Employees' involvement in safety inspection enhanced the safety conditions as the hazards are identified on work site, but critical in nature due to varied attitude for safety.

Employee involvement can include seemingly simple practices such as input in decision making; yet, interventions or programs that are solely determined by management can fail to promote change at the level of front-line workers (Gittleman et al. 2010). Both the factors derived from multiple regression correlation has positive relation (positive coefficients) with safety performance in regression equation. There is need of dedication from management which is previously derived as commitment, stipulated with the intervention of employees, will enhance the safety culture.

5. CONCLUSION

Stakeholders' awareness on construction safety culture and safety climate plays an important role in making construction sites a safer and healthier place to work. From FA, two principal components were established and they are namely: (1) management dedication and (2) employee involvement. These two factors are regarded as the most embracing attributes for this research in construction site environments. These factors have been regressed with the perceived safety performance scores to establish the causal relationship between safety climate and perceived safety performance. During the multiple regression analysis, the two underlying factors were used as independent variables in evaluating the relationship with perceived safety performance. All two factors were identified as significant in explaining the perceived safety performance in Pakistan from the multiple regression results. The regression results showed that "management commitment and employee involvement" were the most significant factors relating to perceived safety performance because it contributed the most for establishing positive safety climate on construction sites. Finally, the findings of this study may be useful in creating safer construction sites.

7. ACKNOWLEDGEMENTS

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Application of Safety Project Interview Data to a Cyclical Research Model of Translation

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Application of Safety Project Interview Data to a Cyclical Research Model of Translation

Abstract

There is growing recognition that academic research outcomes must directly relate to industry, need to be targeted, useful, and mutually beneficial. Academic research does not always translate to successful industry practice, let alone adoption, and vice versa. Many have proposed and explored barriers based on either academic or industrial variables or both. Several attempts have been made to analyze barriers and propose solutions in order to address the translation of research to practice. This work focuses on one previous model, in particular, that considers translation as an iterative approach to establishing research-to-practice-to-research (r2p2r). The 'translational research model' was designed by researchers, from the Royal Melbourne Institute of Technology (RMIT) and Virginia Tech that creates an iterative relationship among both academia and industry. A series of research pilot projects conducted with the Occupational Safety and Health Research Center (OSHRC) at Virginia Tech, covering a diverse range of NORA research goals, will be analyzed utilizing this cyclical model of r2p2r. The goal of this analysis is to establish a methodology for application of each projects' aims of development and outcomes (actual implementation) for the translational research model. Each project's data were further verified by principal investigators of the projects for validity and additional insight. The goal of this work is to set the stage for further insight into impediments and fragmentation between academic research and industry adoption in practice.

Keywords: Pilot projects, Research Translation, r2p2r, innovation, industry

1. Introduction

There is potential for a mutually beneficial partnership between academia, industry and government that can help foster innovation in society (Butcher and Jeffrey, 2005). However, there happen to be several barriers in the translation of research to industry implementation. What are the possible reasons that research outcomes from academic institutions do not always relate directly to industry? This question has been posed many times, investigating both the academic research institutions and the industry for possible barriers or variables that may lead to better understanding of this situation. Some have theorized and investigated that the root of this issue is academic arrogance (Destler, 2008). Other research has suggested that certain barriers may originate from fundamental differences between industry and academia, drawing connections to industry partners (Mudambi and Swift, 2009). It is apparent by viewing both sides that there is a combination of these barriers and variables that are at the root of the situation. Therefore, a systematic approach to analyzing research aims and outcomes, taking both industrial and research perspectives into consideration, is needed to better understand and translate the underlying issues. Blismas et al. (2009) addressed this topic and proposed a cyclical model of research translation, incorporating a research-to-practice-to-research (r2p2r) basis for the model, to create an iterative relationship between research institutions and industry. This model applied a systematic approach to analyzing research outcomes and establishing the basis for a comparative analysis between industry and academia.

More information is needed to better understand how these relationships develop and function. With added information, findings can be used to better recommend translation of research outcomes to industry practice and vice versa, per the continuous improvement of iteration. The goal of this project is to build upon the existing body of work that has been investigating this very topic of research translation to industry practice. In the US, the National Institute of Occupational Safety and Health (NIOSH) has made research translation a core value of its proposal criteria, similar to other federal funding agencies. Based on similar criteria, a cyclical translational research model was developed by researchers at the Royal Melbourne Institute of Technology (RMIT) and Virginia Tech (Blismas et al 2009). Data for this work will be assessed as interview data from recent Virginia Tech Occupational Safety and Health Research Center's (OSHRC) Granata Pilot Projects. The Pilot Research Projects are a collection of 13 projects in total, conducted by researchers from Virginia Tech and partnered institutions that investigated a range of topics with a focus in several NIOSH construction safety categories. The overall goal of the pilot program is to translate outcomes from these projects into further NORA funded research opportunities. The pilot program is an ideal candidate for study in this area due to NIOSH needs for emerging research that are targets industry concerns.

2. Background

Interaction between academia and industry

The relationship between academia and industry has been researched thoroughly in previous studies. This research shows a potential for useful knowledge to be gained from a relationship of interaction and learning between researchers, industry and government (Polt et al. 2001). The academic environment is unique, providing a wide range of potential services and knowledge base (McAdam and McAdam 2008). Because of this potential, industry has been known to seek out universities for potential scientific knowledge and experience, and universities are often seeking funding for further research (Crespo and Dridi 2007). It is a natural fit for both academia and industry to form partnerships in pursuit of a competitive advantage for industry partners (Blismas et al. 2009).

However, there are numerous significant factors from both academia and industry that become obstacles for effective partnership opportunities (von Hippel 2005). Academics are known for their share of issues that impede effective partnerships: academics often have differences in culture and incentives (Butcher and Jeffrey, 2005); are disillusioned by industry (Henderson et al. 2006); have unrealistic demands (Destler 2008); are unwilling to research outside initiated projects (Destler 2008); and ineffectively communicate research findings (Bielak et al. 2008). From another perspective, industry is not exempt from factors that become obstacles to effective partnerships between academia and industry. Industry shares in responsibility for several of these factors: industry often turns to consultants due to differences in values (Mudambi and Swift 2009); requires quick outcomes for competitive edge (Destler 2008); reluctance to commit to long-term R&D due to short-term shareholder expectations; and often have relatively quick changes in expectations (Henderson et al 2006).

Several obstacles are rooted in academia that often impedes an effective partnership between academia and industry. According to Butcher and Jeffrey (2005), the values, purpose, culture, procedures and incentives differ from industry often and impede partnerships. Destler (2008) describes unrealistic royalties and intellectual properties demands that lawyers of universities seek in collaborative projects with industry that lead to unsuccessful opportunities. Destler also emphasizes that meeting their own professional goals and aspirations of research often motivates researchers of academic institutions. In addition, these researchers tend not to be as open to conducting research generated from outside their ideas. The pace, with which research projects are conducted, as shown by a typical Research Council grant, is time consuming and moves at a much slower pace than industry. Another major issue with the academic environment is with the methods that research findings and conclusions are communicated. The outputs from academia are mostly communicated through peer reviewed journals and publications targeted mostly to societies of scholars. This is simply not an effective way to communicate with industry due to the lack of accessibility by potential industry partners. Bielak et al (2008) explains that researchers are given more praise for research that is peer-reviewed by other academics and competitive grant awards. Research that is industry based is often not given as much praise and thus does not receive as much attention by researchers. Finally, due to the sparse research outcomes encountered by researchers who work with industry, partaking in training and consultancy, results in disillusionment on the part of the researcher (Henderson et al 2006).

On the other hand, industry contributes several factors that impede effective partnerships with academia. Mudambi and Swift (2009) describe the differences in belief systems between researchers and managers, shedding light on some of the potential differences between industry and academia. The core values and culture differ between the two sides, pushing industry to entertain consultancy rather than invest in partnerships with academia. This is primarily due to the similarities between the values of industry and consultancy. It is also due to the quick turnaround that consultancy offers that academia often cannot. Destler (2008) reinforces this relationship and need for a fast turnaround from industry that allows them to remain competitive within their environment. Another factor that creates this need for a quick return is short-term shareholder expectations within the industry. Henderson et al (2006) summarizes that industry often needs to reel back goals set forth at the beginnings of projects due to increases in business pressures, dynamic structure within business models, and updated time constraints. Even if a partnership between industry and academia is established, any of these latest factors can play a role in reducing the effectiveness of the partnered research.

Understanding that both industry and academia play a role in impeding potential effective partnerships, with numerous factors that are inherent to both, research into the relationship and potential solutions to these issues can be argued as necessary (Blismas et al 2009). Bielak et al (2008) argues that a linear model of research translation is not necessarily the solution to effective dissemination and adoption by a wider audience by industry. Blismas, McCoy and Lingard suggest new models of cyclic translational research of 'research-to-practice-to-research' may be more effective (Blismas et al 2009). The concepts of the model integrate industry best practice and research knowledge base to achieve a more effective partnership between industry and academia.

Cyclical Research Translation Model (r2p2r)

Traditional models of research translation to practice are generally linear in approach. It has been the norm for research projects to follow this model due to the more scientific nature of the research targeted towards industry, especially the construction industry. However, Bielak et al (2008) argue that a linear model is not necessarily the best application of research translation between research institutions and industry. In construction research, the most common methods for translation of research findings are through methods that include peer-reviewed publications, industry booklets or pamphlets, workshops, and continuing education programs or training modules (Blismas et al 2009).

Another approach to translation of research findings is a non-linear approach of problem identification, analysis, communication and interaction (Butcher and Jeffrey 2005). A model developed by Blismas et al (2009), based on Ledford (2008), is a cyclical model of translational research, built on the premise of improving the translation of research findings to practice from older previous models of translation. The model itself is depicted as a circle divided into 2 halves with 3 divisions each, equaling 6 separate areas within the model (Figure 1).

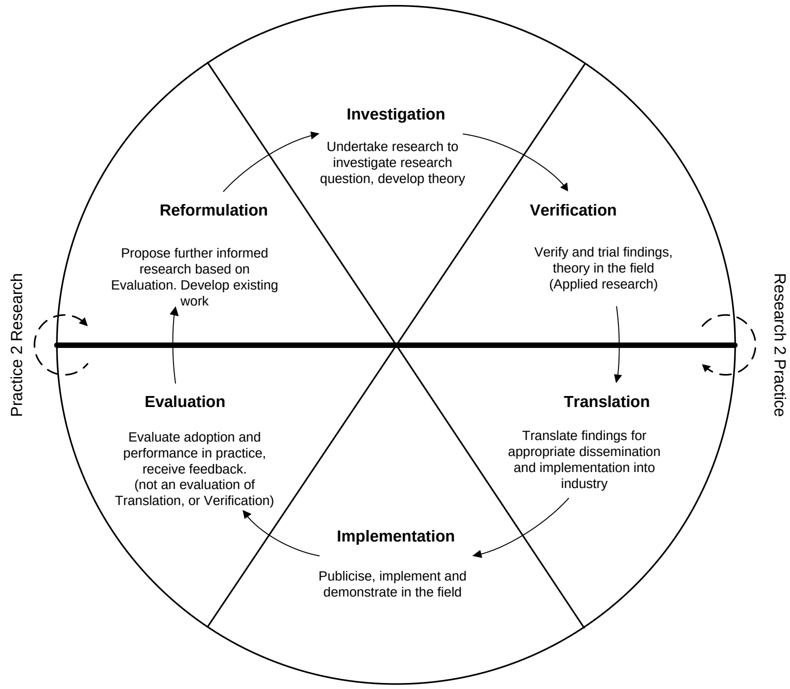

Figure 1*: Cyclical model of research translation (Blismas et al 2009)*

Due to the cyclical nature of the model, there is no given starting point for a research project, as a traditional linear model would incorporate. Instead, the cyclical model is divided into 6 main areas of focus: Investigation, Verification, Translation, Implementation, Evaluation, and Reformulation. Blismas et al (2009) provides definitions and explanations for each category, in cyclic order: the proposal of further informed research based primarily on Evaluation and the development of existing work is what forms the category of Reformulation. Investigation is comprised of research to investigate a research question and develop a theory based on the research. The next step in the process is Verification, or to verify and trial findings and theory from Investigation in the field. These three categories, as can be seen in Figure 1, are the ‘Research’ half of the cyclical research translation model. The translation of the research to industry occurs between Verification and Translation categories, as represented by the bold line in the model. Translation translates findings of research for appropriate dissemination and implementation into the targeted industry or public. Implementation is next in the process, and is the publication, implementation and demonstration of the resultant idea/product in the targeted field of application. The proceeding step in the model is Evaluation, which evaluates adoption and performance of idea/product in practice, and receives feedback from Implementation (Blismas et al 2009). Translation, Implementation and Evaluation are the three categories that comprise the ‘Industry’ half of the cyclical model. As shown, there is no clear starting or ending point within the model as Evaluation is designed here to translate back to Reformulation. Still, traditional “starting” points might be delineated through the dotted half-circle for reference. Blismas et al (2009) also argues that this new translational research model is effective because of the joining of the two halves along the centerline. This allows for industry and academia to constantly assess obstacles to the research and re-define the relationship between them as needed. It is also argued that in order for this model to be effective, researchers must maintain awareness of the position of the research within the model and effective communication and interaction between the two sides must be significant (Blismas et al 2009).

Presently, some argue that for many current research projects, the iterative cycle of translation, as shown here, is not complete. One reason promoted is that researchers are often unable to properly communicate the implications of their basic research to outside the academic society (Roland 2005). Blismas et al (2009) reiterates that academics have become highly skilled in conveying in publications the processes and findings of research projects undertaken, but may in fact be increasing the disconnect between themselves and the potential users of the research. One goal of this work is to close this disconnect, not widen it. Therefore, researchers must be aware of and communicate larger goals towards bridging the translational gap.

Blismas et al (2009) argues more reasons and factors that impede the effective completion of the translational research cycle based on: lack of feedback mechanisms for research that analyzes and evaluates actual implementations of the research; traditional academic processes that are based on linear models that encourage the disconnect between industry and academia; and industry's need for quick 'consultancy-type' project timelines due to the nature of industry, more specifically here the AEC industry and their uncertainty towards the benefits of academic research (Barrow et al 2003). These factors alone, or in combination, can result in the failed completion of the cycle.

Cyclical translational research models, specifically the model designed by Blismas et al (2009), aim to improve the interaction between researchers and industry adopters by analyzing research projects targeted towards industry, applying them to the developed model, and interpreting the findings to further develop the model and improve potential partnerships between academia and industry. There is not much research that has been conducted utilizing this new model, and there is a need for more information in order to validate the model in the future. This project is aimed at building upon such a body of information.

OSHRC Granata Pilot Research Projects

Virginia Tech's Occupational Safety and Health Research Center (OSHRC) Granata Pilot Research Projects are a group of pilot research projects, thirteen in total, funded in part by a grant from the National Institute of Occupational Safety and Health (NIOSH). Each project addresses at least one of the National Occupational Research Agenda's (NORA) strategic goals related to construction, in conjunction with NIOSH (NORA 2008). The strategic goals set by NORA cover construction-specific safety concerns, including; falls, electrocution, struck-by hazards, hearing loss, silica exposure, welding fumes and illnesses, musculoskeletal issues, culture, safety, organization, training and education, disparities in health and safety, hazard prevention, surveillance, and raising awareness (NORA 2008). Each interview documents such information for safety pilot grants, aligned with at least one NORA strategic goal, through project aims set forth by researchers' proposals, and reported outcomes.

3. Purpose and Objectives

The main objective of this work is to establish a standard methodology towards populating the cyclical translational model. More specifically, this project aims to build upon the growing body of information supporting cyclical translational research models that are being developed to address successful interaction between academia and industry. The specific objectives of this project are:

1. Distilling aims and outcomes of OSHRC Pilot Research Project from expected deliverables and impacts as reported by proposals for the work.
2. Articulating an effective research methodology for measuring translation along the cyclical research models.
3. Based on the translational model, mapping reported aims and outcomes of selected Pilot Research Projects along the stages of the cyclical translational research model developed by Blismas et al (2009).
4. Verifying, through interviews of principal investigators of Pilot Projects, the teams' placement of aims and outcomes along the model.

4. Methodology and Research Plan

Methodology

The ultimate aim of this project is to establish a standard for a methodology for future studies focusing on cyclical translational research models between academia and industry, more specifically construction safety in the construction industry. Currently, based on previous work, quantitative metrics are needed for r2p2r modeling. This project aims to capitalize on this need and through interviews of principal investigators within safety for translational research.

The subjects of this study were the Virginia Tech Occupational Safety and Health Research Center Granata Pilot Research Projects. The body of projects selected as the subjects of this study were: a collective group of projects targeting construction industry safety; small scaled- NIOSH funded; targeting specific NORA goals ranging from falls to safety awareness; and intended to result in future research opportunities. Further, Pilot Projects aims and outcomes targeted specific state-of-the-art construction industry issues, all pertinent to industry adoption.

Pilot Project proposals provided the base data needed to map within the r2p2r cyclical translational research model (Figure 1). Data validation required that research team interpretations were examined by principal investigators. For this reason, and the need for quantitative information for future studies, semi-structured interviews were chosen as the method for operationalizing this project.

Pilot Project	NORA Goals	Project Aims	Outcomes
Case Title	12. Disparities	Project Aim 1	Outcome 1
	12. Disparities	Project Aim 2	Outcome 2
			Outcome 3
	12. Disparities	Project Aim 3	Outcome 4
	12. Disparities	Project Aim 4	Outcome 5
			Outcome 6
			Outcome 7

Table 1*: Example relationship table of NORA goals, Project Aims, and Project Outcomes.*

Interviews were designed to establish and verify relationships between NORA goals, project aims, and project outcomes (Table 1). It was also designed to establish and verify the position of each project aim, as well as project outcome separately, within the r2p2r model (Table 2).

	Research			Practice		
Project Aims	**Reformulation**	**Investigation**	**Verification**	**Translation**	**Implementation**	**Evaluation**
1. Project Aim or Outcome 1		X	X	X	X	
2. Project Aim or Outcome 2		X	X	X		
3. Project Aim or Outcome 3	X	X	X	X	X	X
4. Project Aim or Outcome 4	X					X

Table 2*: Example of interpretation and verification of Case aim's (or outcome's) location within r2p2r model.*

Lastly, the interview was designed to provide a quantitative numerical value (from 1 to 3: 1 – low impact on pilot project, 2 – medium impact on pilot project, 3 – high impact on pilot project) for each project aim or project outcome's occurrence within the r2p2r model (Table 3).

Project Aims	Research			Practice		
	Reformulation	Investigation	Verification	Translation	Implementation	Evaluation
1. Project Aim or Outcome 1		3	2	2	1	
2. Project Aim or Outcome 2		2	2	1		
3. Project Aim or Outcome 3	3	3	3	2	1	1
4. Project Aim or Outcome 4	2					1

***Table 3**: Example of survey response giving numerical value of 1 to 3 to Case aim or outcome's position within r2p2r model.*

Survey Participation.

The survey participants were provided with several important pieces of information ahead of each scheduled interview for the survey. This information included, along with the specific interview questions:

1. Diagram and definitions of r2p2r cyclical translational research model utilized in this project. Verification of understanding and agreement with the model are gained from each participant (Figure 1).
2. Chart outlining interpreted NORA goals, Project Aims, and Outcomes for the specific pilot project case being surveyed. Each category, project aim, outcome, and their relationship within the organizational chart are subject to verification and alteration if needed, all by the participant (Figure 2).
3. Project Aims chart and Outcomes chart, with each of the verified or changed project aims or outcomes and their interpreted placement within the cyclical translational research model of r2p2r as represented by an X in each of the categories that may apply (Figure 3). The cyclical translational research model is represented in table format, separated by the two main categories of Research and Practice, to facilitate ease of data collection. All interpretations of each project aim or outcome's placement within the model is subject to change and verification by the survey participant.

The participants were provided with the organizational chart of NORA goals, Project Aims, and Outcomes, as well as the project aims and outcomes charts interpreted ahead of time by the research team in order to keep the duration of the survey as minimal as possible and also in order to help explain to the participants the type of information required. All aspects, from the NORA goals, project aims, outcomes, the relationship between the three categories, and their placement within the model were subjected to modification and verified by each survey participant.

Phasing.

The organization of this project consisted of two major phases. Phase 1 comprised of three sequential main tasks. Phase 2 consisted of three more major tasks that lead to the publishing of this study. Each task and phase was assigned a duration within the research plan, while the methodology was separated into two phases: the data collection of Virginia Tech's OSHRC GPRP phase and the application, verification, and analysis phase based on the r2p2r cyclical translational research model.

Phase 1 of this project consisted of three tasks: background investigation, data collection, and data articulation. The first task, background investigation, was comprised of a literature review into the paradigm of academia and industry, the factors that contributed to impediments between the two, translational research models, and more specifically cyclical translational research models.

Phase 1, Task two, data collection, collected data from the existing Virginia Tech OSHRC Pilot Research Projects to be studied and utilized as the basis of information in this project. Each project was individually interpreted and integrated into the model by the research team.

Phase 1, Task three, data articulation, consisted of the organization of the data from Virginia Tech's OSHRC collected in the previous step into table format for application of the r2p2r cyclical model application. The model framework was divided first by project, and then by project aims, followed by project outcomes that related to each aim, and finally have the NORA goals associated with each project assigned with each project aim.

Phase two consisted of three main tasks: r2p2r cyclical translational research model application to Virginia Tech's OSHRC, principle investigator interview and verification of task four, and the analysis of task four and five to produce valuable information to be used in future research targeting construction and industry.

Task four was the application of the cyclical translational research model of r2p2r developed by Blismas et al (2009), to pilot project data collected and articulated in tasks two and three.

Task five was the semi-structured interview survey administered in person or over-the phone. Data collection utilized a consistent set of questions between all projects.

Task six was the last of the phase and project, consisting of the analysis reporting of findings in order to provide valuable information designed to support the topic of translational research, more specifically cyclical translational research models.

Application of r2p2r Cyclical Translational Research Model

The application of the model to the Pilot Projects, referred for the remainder of this section as interviews (1-9), is key to determining where each case exists in the translational model. This is accomplished by determining where its project aims and project outcomes occur within the translational research model utilized in this project.

Findings for this project were obtained through means of a semi-structured interview survey. The survey was developed as a method to ultimately provide quantitative information to future researchers or industry partners in the subject field of translational research, specifically cyclical translational research. The survey is designed to obtain further insight and verification from Principle Investigators of Cases' project aims and outcomes' position, as well as relative importance to the overall Case, within the cyclical translational research model of r2p2r. Research participants completed positioning of each project aim and outcome, deliverable, and impact in the model for each interview by means of denoting in tables, which stages within the model were applicable to each project aim or project outcome, deliverable, and impact. Table 4 is a demonstration of this method of articulation used in the interview.

	Research			**Practice**		
Project Aims	**Reformulation**	**Investigation**	**Verification**	**Translation**	**Implementation**	**Evaluation**
1. Project Aim or Outcome 1		X	X	X	X	
2. Project Aim or Outcome 2		X	X	X		
3. Project Aim or Outcome 3	X	X	X	X	X	X
4. Project Aim or Outcome 4	X					X

***Table 4**: Example of interpretation articulation used for the survey.*

With this portion of the survey completed for each project aim and project outcome, deliverable and impact, participants assigned a weight (based on a scale from 1 to 3: 1 – aim/outcome has low impact on the project, 2 – aim/outcome has medium impact on the project, 3 – aim/outcome has high impact on the project) to each applicable translation category occurrence verified in the previous step (Table 5).

Project Aims	Research			Practice		
	Reformulation	Investigation	Verification	Translation	Implementation	Evaluation
1. Project Aim or Outcome 1		3	2	2	1	
2. Project Aim or Outcome 2		2	2	1		
3. Project Aim or Outcome 3	3	3	3	2	1	1
4. Project Aim or Outcome 4	2					1

***Table 5**: Example of quantitative translation of cyclical translational research model.*

The boxed region in Table 5 displays the r2p2r model in table form. The presence of a number, ranging from 1 to 3, indicates both the occurrence within the r2p2r model category for the project aim or outcome and the weight associated with that occurrence. The lack of a number in the table thusly indicates the lack of an occurrence for that category per aim or outcome.

Project Aims	Research			Practice		
	Reformulation	Investigation	Verification	Translation	n	Evaluation
1. Project Aim or Outcome 1		3	2	2	1	
2. Project Aim or Outcome 2		2	2	1		
3. Project Aim or Outcome 3	3	3	3	2	1	1
4. Project Aim or Outcome 4	2					1
Average occurrence number:	**0.5**	**0.8**	**0.8**	**0.8**	**0.5**	**0.5**
Average rating per occurrence:	**2.5**	**2.7**	**2.3**	**1.7**	**1.0**	**1.0**

***Table 6**: Example of average information based on cyclical translational research model quantitative data.*

Table 6 shows the information that is derived from the data in each table. The two categories of information calculated are the average occurrence number and the average rating per occurrence. The average occurrence number tallies the number of occurrences for each category within the r2p2r model as denoted by the presence of a number, and then divides that total number of occurrences by the total number of project aims or outcomes. The average rating per occurrence is calculated by adding the rating for each category occurrence, then dividing that number by the total number of occurrences for that category. The results are two robust bodies of quantitative information, shown in table form, that provide an overall view of the average placement of a Case to the r2p2r model and the weighted rating or impact each category has to the interview, according to the principle investigator.

This information is then separately applied to cyclical diagrams that display the information in a visual form different from the table and closer to the original diagram in Figure 1. The diagrams are separated into 2 types: a cyclical model displaying the average occurrence number for either project aims or project outcomes, and a cyclical model displaying the average rating per occurrence for either project aims or project outcomes (Figures 2 & 3).

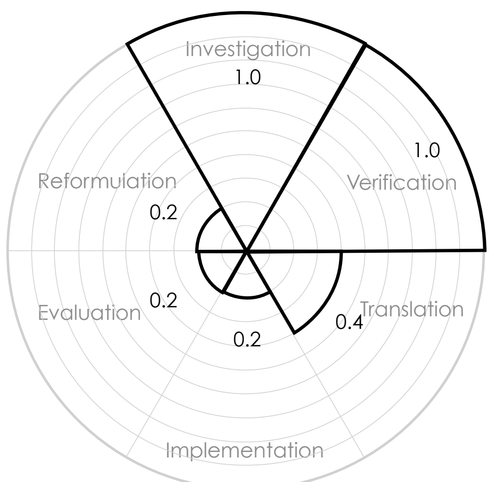

Figure 2*: Example of average occurrence of interview aims or outcomes*

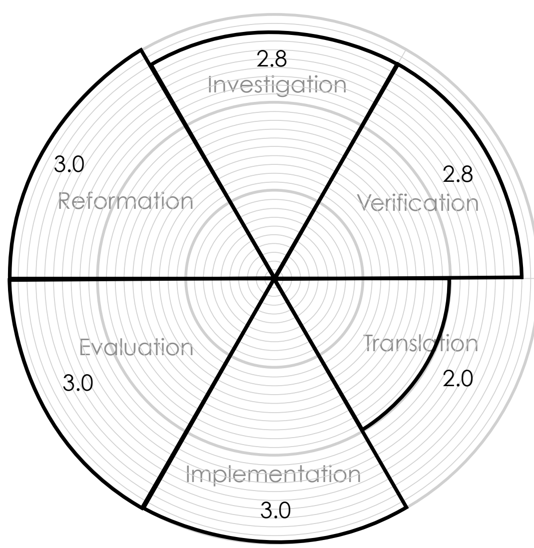

Figure 3*: Example of interview aims or outcomes' average rating per occurrence*

The results from the survey investigation are broken down by project. Each Pilot Project has been labeled as an interview, ranging from interview (1) through Case (9). Each interview finding's section will include the original interpreted project aim table and outcome table along with the participants' responses. The graphical display of this information is to represent data from tables on interview data.

5. Findings

Granata Pilot Research Project Interview Summary

The summary section of the findings chapter reports data collected that mirrors the individual interview information. Information from each interview, the average occurrence number and average rating per occurrence for both project aims and project outcomes are combined and a summary average is calculated for each category. The information is presented in table and diagram form, similar to the individual cases for comparison.

	Research			**Practice**		
Interview Summary aims' average occurrence number	**Reformulation**	**Investigation**	**Verification**	**Translation**	**Implementation**	**Evaluation**
Case (1)	0.5	0.8	0.8	0.8	0.5	0.5
Case (2)	0.0	1.0	1.0	1.0	1.0	0.0
Case (3)	0.3	1.0	1.0	0.6	0.6	0.3
Case (4)	0.0	1.0	1.0	0.0	0.0	0.0
Case (5)	0.0	1.0	1.0	0.0	0.0	0.0
Case (6)	0.2	1.0	1.0	0.4	0.2	0.2
Case (7)	0.2	0.6	0.8	0.6	0.6	0.4
Case (8)	0.5	0.5	0.5	0.5	0.0	0.0
Case (9)	0.3	0.8	0.8	0.3	0.0	0.3
Interview Summary aims' average occurrence number:	**0.2**	**0.9**	**0.9**	**0.5**	**0.3**	**0.2**

Table 7*: Interview Summary of project aim's average occurrence*

Interview Summary aims' average rating per occurrence	Research			Practice		
	Reformulation	Investigation	Verification	Translation	Implementation	Evaluation
Case (1)	2.5	2.7	2.3	1.7	1.0	1.0
Case (2)	N/a	3.0	3.0	2.0	1.0	N/a
Case (3)	3.0	2.0	2.0	2.5	2.5	3.0
Case (4)	N/a	3.0	2.0	N/a	N/a	N/a
Case (5)	N/a	3.0	2.0	N/a	N/a	N/a
Case (6)	3.0	2.8	2.8	2.0	3.0	3.0
Case (7)	3.0	2.0	2.0	2.3	2.0	3.0
Case (8)	2.0	3.0	3.0	3.0	N/a	N/a
Case (9)	2.0	3.0	3.0	1.0	N/a	2.0
Interview Summary aims' average rating per occurrence:	**2.6**	**2.7**	**2.5**	**2.1**	**1.9**	**2.4**

Table 8*: Interview Summary project aims' average rating per occurrence*

Interview Summary outcomes' average occurrence number	Research			Practice		
	Reformulation	Investigation	Verification	Translation	Implementation	Evaluation
Case (1)	0.3	0.1	0.3	0.6	0.3	0.3
Case (2)	0.7	0.8	0.7	0.7	0.3	0.7
Case (3)	0.4	0.4	0.5	0.6	0.5	0.4
Case (4)	0.6	0.8	0.8	0.0	0.0	0.0
Case (5)	0.0	1.0	1.0	0.0	0.0	0.0
Case (6)	0.3	1.0	1.0	0.6	0.3	0.0
Case (7)	0.1	1.0	1.0	0.3	0.3	0.1
Case (8)	0.2	0.2	0.2	0.8	0.0	0.0
Case (9)	0.3	0.8	0.8	0.5	0.3	0.3
Interview Summary outcomes' average occurrence number:	**0.3**	**0.7**	**0.7**	**0.5**	**0.2**	**0.2**

Table 9*: Interview Summary of project outcomes' average occurrence*

Interview Summary outcomes' average rating per occurrence	Research			Practice		
	Reformulation	Investigation	Verification	Translation	Implementation	Evaluation
Case (1)	3.0	3.0	3.0	3.0	3.0	2.5
Case (2)	3.0	3.0	2.8	2.8	1.5	1.5
Case (3)	2.7	2.7	2.0	2.0	2.3	2.3
Case (4)	1.3	3.0	1.8	N/a	N/a	N/a
Case (5)	N/a	3.0	2.0	N/a	N/a	N/a
Case (6)	2.0	2.0	2.0	2.0	1.0	N/a
Case (7)	3.0	2.0	2.0	2.3	2.0	3.0
Case (8)	2.0	3.0	3.0	3.0	N/a	N/a
Case (9)	3.0	2.3	1.7	3.0	3.0	3.0
Interview Summary outcomes' average rating per occurrence:	**2.5**	**2.7**	**2.3**	**2.6**	**2.1**	**2.5**

***Table 10**: Interview Summary project outcomes' average rating*

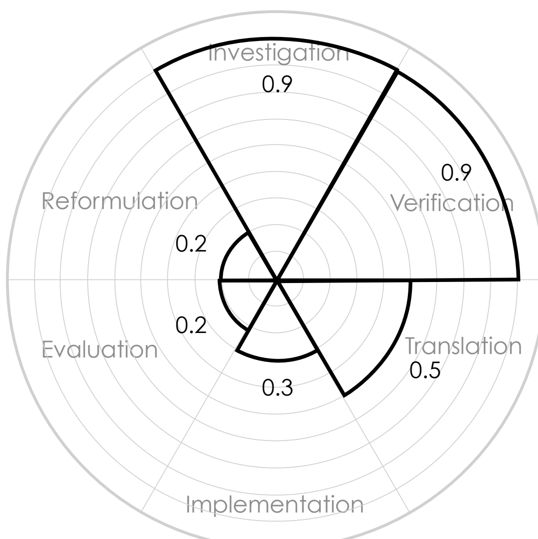

***Figure 4**: Project summary average occurrence*

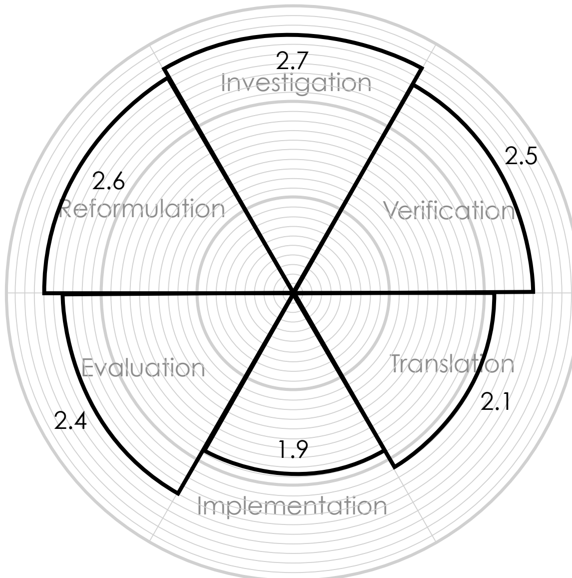

***Figure 5**: Summary of Project aims' average rating*

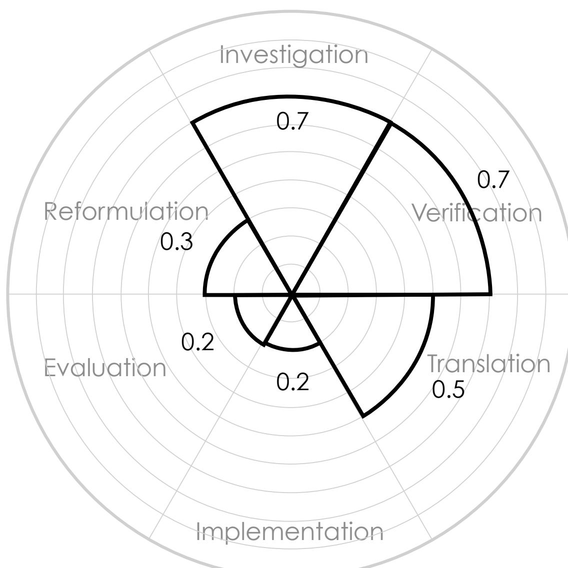

***Figure 6**: Average occurrence of Case outcomes applied to r2p2r model.*

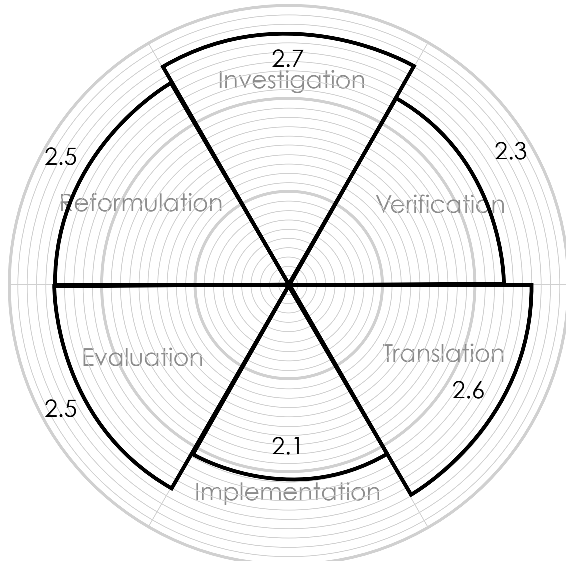

***Figure 7**: Average rating per occurrence to Case when applied to r2p2r model.*

6. Conclusions

The main purpose of this project is to establish a standard towards a methodology for articulation, application, and verification of cyclical translational research models to be applied to a base of existing and future research targeting industry issues. Eventually after development of the methodology the findings can be utilized by research targeting the relationship between academia and industry. The findings from the project based on the survey data collected provide a set of quantitative information from primary sources, the principle investigators, and articulate that information in two main forms: tables showing the data collected and the calculated averages for each category from the r2p2r model, and cyclical diagrams that articulate the information in a form that more readily identifies with the nature of the r2p2r model. The hope is that the methodology developed in this project along with the various forms of articulation will be developed and utilized by future research projects in cyclical translational research models.

Highlighting some of the potential future uses of the information provided in this project, there are many ways to utilize the information provided. For research in the areas industry and construction, further studies that develop and use a methodology similar to this study can be conducted to provide feedback and information for similar studies, or based on the industry's perception of the research projects' application to the cyclical translational research model of r2p2r. This could span to similar models as well. Future studies using the information provided in this project could explore the implications of this information in conjunction with other studies on industry and their interaction with academia.

Academic research using the information in this project can begin to develop hypothesis and further studies concerning the methodology and information developed in this project for similar areas of research. Again, the information provided from the results of this project can be interpreted in several ways that can be utilized in support of more developed methodologies based on the methodology developed here and implications on both academia and industry, and their interaction.

Another potential beneficiary of the information provided in this project, and even more so with future projects of similar scope and method, could be NIOSH. There is information present within the project clearly relating to the interaction between industry and academic research through NIOSH programs. From which, NIOSH can analyze the information provided and potentially use the information to better align academic research projects with direct industry issues that help foster a better relationship between research outcomes, industry adoption, and reformulation into new research.

The limitations of the research project are as follows:

- Self-reporting bias – the survey participants for this research project are the principle investigators for the corresponding pilot project case, and therefore subject to potential bias based on their personal involvement with the pilot project.
- Sample Pool – the Virginia Tech OSHRC GPRP are a set of small projects that have NORA goals for NIOSH, but are not necessarily designed to require outcomes that can be implemented by industry, but rather are designed to address specific safety issues in the construction industry with the goal of larger R01 or R21 NIOSH funded research projects. As well, the sample pool is a convenient data set that facilitated the development of a useful foundation for a methodology developed throughout the course of the research project that can be further developed and utilized by future research of similar topics.

The potential for great mutually beneficial relationships and interactions between academic research and industry adoption is present. Researchers are actively seeking solutions in various forms including models of translational research to improve these interactions. The information in this project is designed to address and potentially support further research in these areas. The methodology developed throughout the project is a strong start to an effective methodology to be used in future academic research into cyclical translational research models applied to safety in the construction industry, and potentially to a wider area of industry.

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The Impact of Images on Tool-Box Training

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Abstract

Strategies adopted in UK construction to communicate with non-English speaking migrant workers include the use of pictorial aids. The aim of this paper is to establish whether delivering hazard information and instruction, using pictorial aids, can be linked with improvement (better than text-only materials) in targeted competences amongst second language (migrant) workers.

Method: Targeted themes were identified for tool-box-talks to assess impact on knowledge. Knowledge was measured via a 24 question test. Each group acted as the control for the other by using text-only versions of the corresponding tool-box-talk.

Main findings: mean knowledge test scores after using pictorial aids increased in all cases more than those with text-only versions; ANOVA of knowledge test scores found very significant interaction effects over all the sites.

Pictorial aids are merely a method of communication and do not ensure compliance. However, the benefits of pictorial aids to help improve health and safety knowledge should be disseminated to the construction industry and beyond. The next area of analysis will be to assess the impact of images on worker behavior.

Keywords: Communication; images; pictorial

The Impact of Images on Tool-Box Training

1. Introduction

There are many programmes and permit schemes that attract migrants to work in the UK, for example, The Highly Skilled Migrant Programme, Sector Based Scheme, and the Worker Registration Scheme. There are no precise figures available for migrant population working in the UK because data is collated from various sources, such as the International Passenger Survey, Labour Force Survey, and work permit applications. But it is estimated that there are approximately 2 million construction workers employed in Great Britain, and that migrant workers account for approximately 8% (HSE 2009). Migrant workers are mostly employed on short term contracts (HSE 2006a), with Eastern Europeans dominating (HSE 2009). 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. Moreover, the number of undocumented migrants working in the UK is unknown; although estimates have been made these figures are thought to be inaccurately low (Salt 2006).

Strategies adopted by construction companies to communicate with non-English speaking migrant workers include pictorial methods of communication. This strategy is supported by legislation such as The Construction Design and Management Regulations 2007. The associated Approved Codes of Practice (ACOP) for these Regulations include recommendations that information be "provided in a format that can be understood by the worker" which can include "providing translation, using interpreters, and replacing written notices with clear symbols or diagrams" (HSC 2000; HSE 2007).

The aim of this paper is to establish whether delivering hazard information and instruction, using pictorial aids, can be linked with improvement (better than text-only materials) in targeted competences amongst second language (migrant) workers.

2. Existing Research

Several studies have attempted to improve communication via the introduction of visual methods, such as pictorial images (Brunette 2005; Jaselskis et al 2007). However, these studies tend not to evaluate the success of the pictorial images in terms of behaviour change or knowledge retention. For example, a construction specific study was conducted targeting Hispanic workers (Brunette 2005) highlighting that 'well planned safety training interventions' are required and that in achieving this a linguistically and culturally sensitive approach is essential. The research developed a 10 hour safety training programme with additional educational materials, such as a Hispanic – English dictionary of construction terms and various audio visual materials. The materials were developed in consultation with the Hispanic workforce using the participatory approach. This research targeted vulnerable workers within construction, but there are a number of limitations: it is specific only to Hispanics and does not encompass other migrant groups or natives with a poor grasp of English; and, despite the fact that an Instructional System Design model, including evaluation, was incorporated into the research, there is no evidence to show the success of the materials. The article states that ‘a protocol for testing and evaluating the Spanish language materials among Hispanic workers will be developed’, and that questions regarding usefulness of the language and graphics will constitute part of this, however it is unclear from the research paper, if, and how, this has been achieved. Consequently, despite the requirement for improved health and safety communication methods, there is a severe lack of any evidence based research with concrete validation techniques.

Jaselskis et al (2007) examined the issue of cultural integration and differentiation as well as assessing cultural training programmes. Part of the research involved the development of Toolbox Integration Courses to facilitate communication between a Hispanic workforce and American Supervisors. The toolbox talks used flashcards and survival phrases to meet this objective. The report states that ‘flashcards were a crucial element of this course’, however neither the content nor design of the flashcards is given. An important point considered by the authors is that the individual conducting the toolbox course must be trained to use the materials and understand the information within, to effectively convey the safety messages. Unfortunately, the research does not stipulate the criteria used to develop the flashcards nor does it indicate the content, it merely lists the modules covered by the toolbox integration course. The research is more focused toward the delivery of the toolbox course, and the perceived success of this, and is less concerned with the actual content of the training materials.

3. UK specific research

Research investigating worker engagement in construction (HSE 2006a; HSE 2006b), have 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, the management of health and safety. These studies have made recommendations for further research communicating with non-English speaking workers to ascertain how these language barriers can be overcome. An array of research conducted to date has reached similar conclusions, for example, a study examining migrant construction workers in England and Wales concluded that “migrant workers are at increased risk due to their inability to communicate effectively with Supervisors, particularly in relation to their understanding of risk” and “have limited access to health and safety training with difficulties understanding what is being offered where proficiency in English is limited”. Therefore, the study recommended that: particular use of non verbal means of communication be investigated; employers assess migrant workers knowledge of English and literacy in order to develop appropriate training materials, tailored to the individual; and the award of an English kite mark system be considered to encourage employers to facilitate the learning of English (HSE 2006a). Similar recommendations have been made by Loosemore & Trajkovski (2005), Bust, Gibb, and Pink (2008). Wogalter (2006) also summarises the use to which pictorial images could be put: “symbols are increasingly being used to communicate to individuals or groups who have limited or no reading skills in a particular language and are unable to read a printed text warning. Well designed symbols serve to facilitate comprehension”.

Another piece of research, entitled ‘The Trojan Horse’ (HSE 2005), involved cartoon format images being placed in conspicuous areas throughout construction sites. The participants were then tested for awareness and knowledge transfer by performing a site survey of the operatives. The conclusions from the study were very positive, for example, site operatives were generally highly aware of the messages and also recall and interpretation among operatives was very good. However, an issue of concern with the research is that of habituation. As the Trojan Horse messages become established, operatives may become accustomed to seeing the recurring messages, which potentially could result in the messages losing their impact. The research proposed several methods of circumventing this problem, “constantly refresh the messages, rotate the media/format of the messages, and use the messages as part of toolbox talks”. However, these methods were merely suggestions and had not been tested, therefore it was unknown at this stage whether or not any longitudinal effects would result from the research. This sentiment is reinforced by Kalsher and Williams in Wogalter (2006) discussing product familiarity, “the more familiar people are with a product, the less likely they are to look for, read, and comply with a warning placed on a product”.

4. Comprehension

A comprehension and retention study was conducted by Wogalter and Sojourner (1997) which tested existing pictorial images. The study highlights the importance of careful design in the creation of images, but primarily focuses on the influence of training on the comprehension and retention aspects. All respondents were provided with a pre – training test which involved the participants being shown pictograms and writing down their meaning. The respondents were subsequently given two scenarios: firstly, pictograms with a simple phrase or accompanying statement, and secondly with a more comprehensive explanatory sentence. Following this, half the group were subjected to an immediate post training test whereby the respondents were shown the pictograms in a randomized order and asked to write down their meaning. The other half of the group were then required to return one week later to undergo the same testing. Finally, 6 months later, the participants were subjected again to the same comprehension test. The results of the study demonstrate that comprehension and retention can be influenced in several ways. Training has a significant impact on the two factors as was highlighted by the scores from the pre training and post training exercise. Furthermore, the increased levels of comprehension were maintained at the one week post trial stage and even more reassuring was that there was no significant difference between the weekly and six monthly comprehension results; however the number of respondents available to take the test at that stage was limited. Overall findings from the research indicate that long comprehensive statements accompanying pictograms are not helpful, instead only a short description is required. Also, brief training prior to being introduced to the pictograms, for example, providing an associated verbal label substantially increased comprehension of those pictograms classed as ‘difficult’.

Literature suggests that comprehension amongst migrant workers can also be influenced by culture. Culture is generally defined as ‘the shared beliefs and values of a group, the learned way of living. It encompasses what we are taught to think, feel, and do in any given situation by the society in which we were raised. As well as providing content, our cultural conditioning affects how we are to think, feel, and behave’(Laroche & Rutherford 2006). These shared features have developed over the course of a lifetime and through life long interaction with others which inevitably influences the meaning attributed to a message. Thus, communication and culture are inextricably linked. The authors above explain that once an idea has been formulated and communicated verbally or non- verbally, this communication then passes through a culture filter before being interpreted by the receiver, thus highlighting the importance that culture plays in communication, and the precarious nature of interpretation if cultural influences are not accounted for.

Various authors have concluded that there is scope to apply pictorial images to bridge the communication gap, due in large part to the increase in migrant labour. However, as indicated, there have been few construction specific studies and, in these, few validation techniques have been applied to gauge the success of the communication methods.

5. Method

The experimental design developed was a repeated measure before and after design. To control for other extraneous factors, groups were paired in such a way that each intervention group had a comparable control group within the same organisation. The ‘pictorial aids’ were a suite of four tool-box-talks using a mixture of pictograms, sketches and photographs. The ‘target competencies’ were represented through workers’ knowledge of four tool-box-talk themes:

A. Exclusion zones
B. Materials storage
C. Portable tools
D. PPE

Knowledge was measured via a pictorial test (summarised in Table 1), covering the issues contained in the interventions, showing a specified number of safe and unsafe conditions/behaviours relevant to the themes. The number of correct items identified in the test resulted in a numerical score. Since knowledge is crucial to competence it can be considered a part measure of competence that can be administered without specific knowledge of individual languages.

Table 1: Item test criteria

No.	Theme	Test criteria	Group
1	A: Exclusion zones	Crane lifting operations	**Group 1** Intervention on Themes A&B
2		Scaffold being altered	
3		Work at height	
4		Permit to Work (PTW)	
5		Pedestrian route	
6		Scaffold stability	
7	B: Materials storage	Stacking pallet loads	
8		Sheeted materials	
9		Circular/tube materials	
10		Storage at height	
11		Waste packaging	
12		Ground conditions	
13	C: Portable tools	Lanyards at height	**Group 2** Intervention on Themes C&D
14		Correct use of chisels	
15		Housekeeping	
16		Cartridge guns	
17		Electrical tool faults	
18		Electrical tool voltage	
19	D: PPE	Mandatory PPE	
20		Position of hardhat	
21		Using earplugs	
22		Dust masks	
23		Eye protection	
24		Defects	

The four OSH items were measured across four sites. At each site two of the OSH items were covered by the interventions and two were the controls as shown in Table 2. Thus, if there was an intervention on one set of OSH items and they improve but remain unchanged (or only show minor change) on the control sites then it could be deduced that the improvement was not a result of merely receiving textual information.

Table 2 Intervention and control sites

Sites	Intervention group	Control group
1 & 3	A&B Pictorial	C&D Text only
2 & 4	C&D Pictorial	A&B Text only

The picture-based tests were administered by the researcher. These consisted of 24 pictorial scenarios with three multi-choice options for each: two options were unsafe and one was safe. The respondent (migrant worker) was asked (in their own language by their supervisor/interpreter) to tick the box of the 'safe' choice. Since there were six scenarios for each theme (Table 1), testing the impact of the intervention on two themes together (e.g. A&B) meant a maximum score of 12 could be achieved for each measure of knowledge.

The intervention required the images to be printed in colour on A3 size paper, mounted on a ring binder flipped over to create a mini flip-chart. These were complemented with A5 size booklets for each worker, also printed in colour. Speaker packs were printed with additional notes on how to interact with the images when delivering the talks. Text versions of the ‘control’ tool-box-talks were also printed. The procedures for the intervention consisted of:

1. A 1 hour training for the site manager/ supervisor on how to use the materials (Tool-Box-Talk presentation and worker booklet);
2. Use of the materials, by the site manager/supervisor during the talk;
3. Worker participation during the implementation (the materials supplemented existing procedures for communicating with second language workers i.e. buddy/interpreters)

After the interventions the knowledge test was re-run. The test was also repeated one month later on sites 1 and 2 to check for memory decay.

The knowledge test had already been developed as part of previous work for Construction Skills during which test sets of 25 questions (from a pool of 83) were used. Results from this previous work returned a mean score of 20.47 (Max. 25) and a standard deviation of 2.45 with migrant workers. Using this data with a desired power of 80% and 5% significance level, it was estimated that a sample of 15 would be able to detect an increase of one standard deviation in the knowledge score. However, the study design involved 24 questions, of which 12 related to each intervention (1 – 12: A&B; 13 – 24: C&D see Table 1). Therefore, 30 workers was estimated to be the desired minimum. It is also good practice to allow for possible drop-off of respondents, therefore, 40 was considered appropriate. Since two sites would be implementing the same intervention (Sites 1&3: intervention A&B; Sites 2&4: intervention C&D) the numbers could be spread across each pair of sites i.e. 20 workers per site, 40 between each pair of interventions.

Statistical analysis consisted of a two factor repeated measures ANOVA. The two factors were ‘Group’ and ‘Time’. The Group Factor contained two levels: ‘Intervention’ and ‘Control’ depending on whether the workers received the pictorial or text versions of the tool-box-talks. The Time Factor contained two levels for initial analyses: ‘before’ and ‘after’ the intervention. Then when further analysis was performed using only Sites 1&2 with a third Time level of ‘later’, the Time Factor required three levels. The analysis was undertaken using the knowledge test results as the dependent variable (marks out of 12).

6. Findings

Demographics

All four sites needed to be large enough to employ at least 20 migrant workers operating within a designated area of the site. The sites also needed to be long enough in duration to allow data collection over the three month period of field work. These criteria resulted in the following sites being chosen:

> Site 1: Location London; retail and office development; cost £200m; duration 120 weeks; completion due late 2010
> Site 2: Location Manchester; broadcasting and media development; cost £415m; duration 3 years; completion due mid 2010
> Site 3: Location London; office development; cost £50m; duration 40 weeks; completion due mid 2010
> Site 4: Location London; media development and refurbishment; cost £400m; duration 5 years; completion due 2012

Homogeneity between the sites was desirable to facilitate valid comparisons. Previous studies have shown country of origin, age and experience to be important factors in relation to non-English speaking workers being able to understand pictorial images. All workers were from Eastern European countries. Table 3 shows the other demographic data.

Table 3 Demographic data per site

Site (n=20 each)	**Age Age (Years)**		**Construction Experience (Years)**		**Time on site On site (Months)**	
	Median	**Min/Max**	**Median**	**Min/Max**	**Median**	**Min/Max**
1	34.5	17/64	6.3	1.5/49	1.5	0.5/12
2	37.5	24/57	4.1	1/15	8	6/12
3	30.5	20/58	3	2/11	2.5	1/11
4	41.5	22/65	12.5	1/48	6	1/9
Total	**37**	**17/65**	**4.1**	**1/49**	**6**	**0.5/12**

Sites 1 and 2 were paired for control purposes, as were Sites 3 and 4. Potential threats to the homogeneity of the groups were the age and experience differences between Sites 3 and 4; and the variation of 'time on site' across all four sites. These are acknowledged as limitations. However, the gaps in age and experience are reduced when the sites are merged into their common groups (i.e. Sites 1&3: intervention A&B/Group 1; Sites 2&4: intervention C&D/Group 2).

Knowledge test scores: before and after

Table 4 shows mean test results before and after the interventions on themes A&B. ANOVA analysis found a very significant interaction effect between Group and Time ($p < 0.001$). This is important as it indicates a difference in group results over time. Figure 1 illustrates this difference as the intervention group gradually increases over time while the control group shows a gradual decrease.

Table 4 Knowledge test scores: Before & After Intervention on A&B

Group / Time	Before	After	Overall
Control (Group 2):			
Mean	11.75	11.55	11.65
s.d.	0.54	0.60	0.58
n	40	40	80
Intervention (Group 1):			
Mean	11.35	11.95	11.65
s.d.	1.08	0.22	0.83
n	40	40	80
Overall:			
Mean	11.55	11.75	11.65
s.d.	0.87	0.49	0.71
n	80	80	160

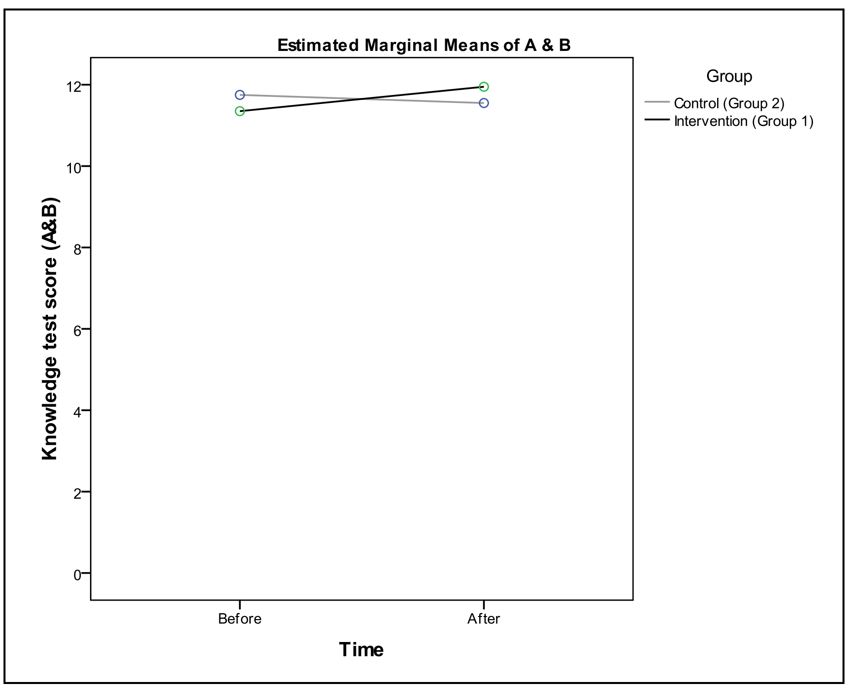

Figure 1 Knowledge test scores: Before & After Intervention on A&B

Table 5 shows mean test results before and after the interventions on themes C&D. ANOVA analysis found very significant effect for the interaction of Group and Time (p =

0.008). Separate results for Group and Time were also significant (p < 0.001); Time (p = 0.001). Figure 2 shows the intervention group increasing in mean test score over time. The control also shows a gradual increase, but not to the same extent.

Table 5 Knowledge test scores: Before & After Intervention on C&D

Group / **Time**	**Before**	**After**	**Overall**
Control (Group 1):			
Mean	10.07	10.20	10.14
s.d.	1.47	1.52	1.49
n	40	40	80
Intervention (Group 2):			
Mean	11.03	11.95	11.49
s.d.	0.86	0.22	0.78
n	40	40	80
Overall:			
Mean	10.55	11.08	11.65
s.d.	1.29	1.52	0.71
n	80	80	160

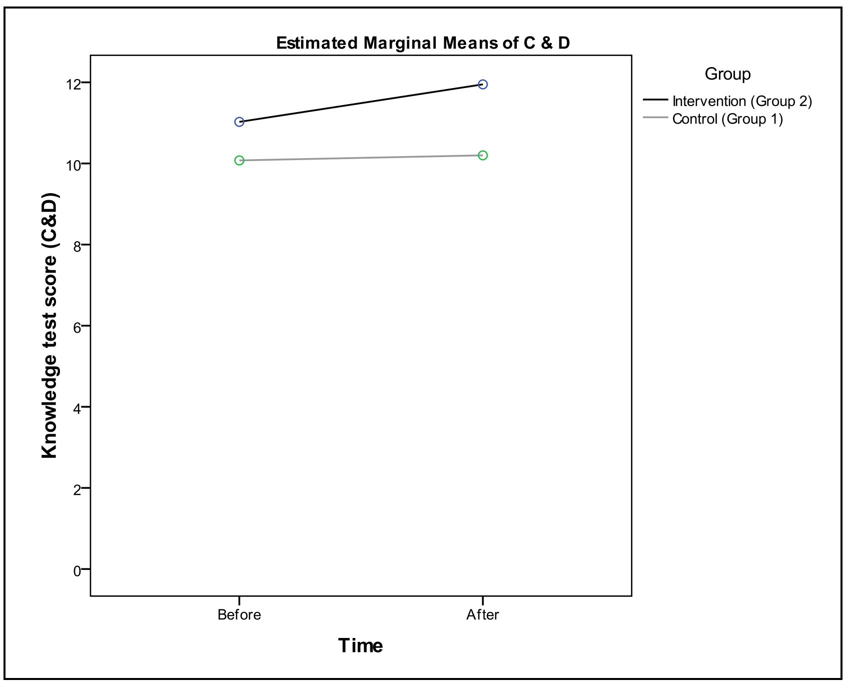

Figure 2 Knowledge test scores: Before & After Intervention on C&D

Knowledge test scores: Before, After & Later

Additional data was collected for Sites 1 and 2 one month after the original interventions. The following Tables (6 and 7) and Figures (3 and 4) incorporate the findings from the repeat visits for these sites.

Table 6 Knowledge test scores: Before/After/Later Intervention on A&B

Site / **Time**	**1**	**2**	**3**	**Overall**
Control (Site 2):				
Mean	11.75	11.40	11.33	11.51
s.d.	0.64	0.68	0.72	0.69
n	20	20	15	55
Intervention (Site 1):				
Mean	11.70	12.00	12.00	11.88
s.d.	0.47	0.00	0.00	0.32
n	20	20	12	52
Overall:				
Mean	11.73	11.70	11.63	11.69
s.d.	0.55	0.56	0.63	0.57
n	40	40	27	107

Table 6 shows the mean test results before, after and (one month) later for Site 1 (intervention) and Site 2 (control) on themes A&B. ANOVA analysis found very significant effects for the interaction of Site and Time ($p = 0.002$). Site was also significant ($p < 0.001$). Figure 3 shows that Site 1 follows the general trend of Group 1 (Figure 1) with a gradual increase post intervention. One month later, the mean test scores remain steady at 12.00. There has been a ceiling effect as 12 is the maximum score achievable (6 per theme). Site 2 drops slightly over the same period.

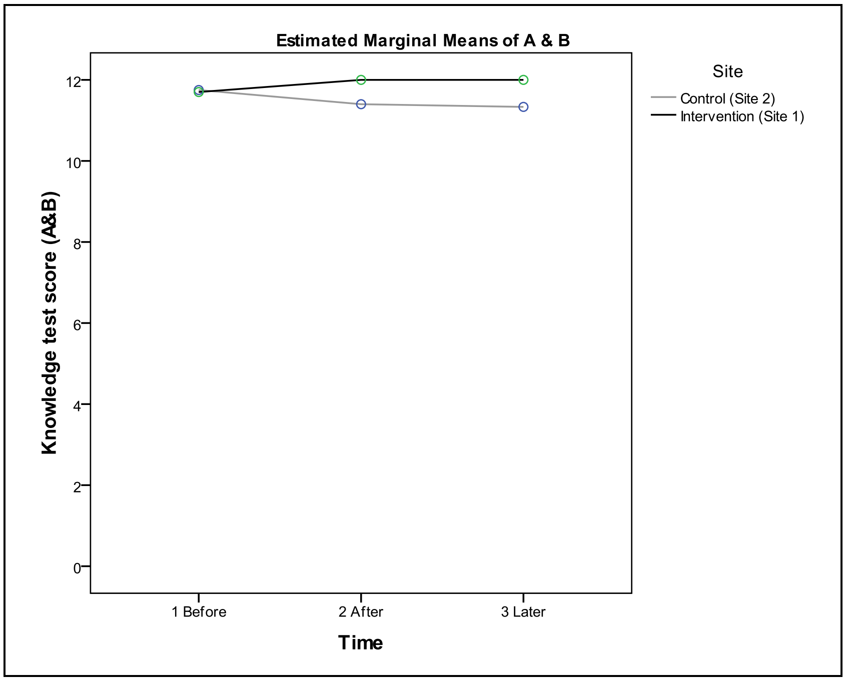

Figure 3 Knowledge test scores: Before/After/Later Intervention on A&B

Table 7 Knowledge test scores: Before/After/Later Intervention on C&D

Site / **Time**	**1**	**2**	**3**	**Overall**
Intervention (Site 2):				
Mean	10.90	12.00	12.00	11.60
s.d.	0.72	0.00	0.00	0.68
n	20	20	15	55
Control (Site 1):				
Mean	10.80	10.90	10.92	10.87
s.d.	0.83	0.85	0.90	0.84
n	20	20	12	52
Overall:				
Mean	10.85	11.45	11.52	11.24
s.d.	0.77	0.81	0.80	0.84
n	40	40	27	107

Table 7 shows the mean test results before, after and (one month) later for interventions on themes C&D. This time Site 1 is the control, whilst Site 2 is the intervention. ANOVA analysis found a very significant effect for the interaction of Site and Time ($p < 0.001$). Site and Time were also individually significant (Site $p < 0.001$; Time $p < 0.001$). Figure 4 shows that Site 2 follows the general trend of its Group (Figure 2) by climbing post intervention, then holds at 12.00 (ceiling effect) one month later. Site 1 remains virtually unchanged over the same period.

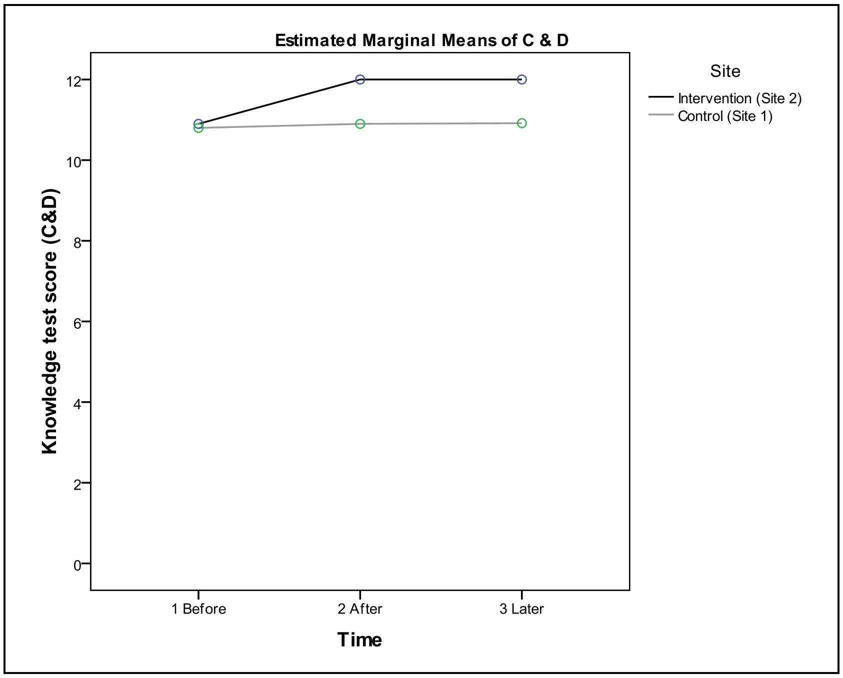

Figure 4 Knowledge test scores: Before/After/Later Intervention on C&D

7. Discussion and conclusions

The knowledge test findings all show a similar pattern in relation to the themes where pictorial aids where used. In all cases the scores increased. Whereas mean scores in relation to text-only themes showed random variation over time; increasing, decreasing or remaining static. ANOVA analysis found consistent interaction effects over all the sites. Whilst there was some variation between Group/Site and Time effects, the interaction results were the most important.

This confirms that the pictorial aids improve knowledge of targeted themes when compared with text-only tool-box-talks. Further, the knowledge has been retained one month later, whereas text-only training resulted in little change in knowledge scores.

The pictorial aids used were a combination of sketch drawings, pictograms and photographs. All followed a consistent format: hazards and consequences were shown as sketch drawings (which allowed specific injuries to be depicted without using real people); then controls were presented, first with pictograms to explain the concept, then photographs to demonstrate the context. This framework of hazard – consequences - controls is commonly used (HSE 2005) and, based on the findings, is effective and should continue to be used for communicating basic health and safety information to migrant constriction workers. It is also reasonable to assume that this would be true for all types of construction worker.

Many of the pictograms used in the knowledge test also featured in the corresponding tool-box-talks. Therefore, it could be argued that it was easier for the workers to improve their test scores purely as a result of recalling the images from their pictorial tool-box-talks. This would mean the test was merely measuring short-term memory recall rather than cognate understanding. In actual fact, the pictograms were variations of those used in the tool-box-talks. For example, in the tool-box-talks, the 'correct' stick man was always coloured black while the 'incorrect' stick man was always coloured red. Whereas, the test images were all black with multiple variations on the original theme, only one of which was correct. The sustained high scores one month later also reinforce the argument for understanding rather than that of short-term memory recall.

Having said this, other forms of testing, such as hazard spotting photos could have been used. This was not considered due to time and cost restraints (the pictogram tests had already been developed and validated). However, it is acknowledged that a more varied form of assessment could be considered for any future studies.

This paper sought to establish whether there was evidence that the delivery of hazard information and instruction, using pictorial aids, can be linked with improvement in targeted competences amongst second language (migrant) workers. Pictorial aids are merely a method of communication and do not ensure compliance. However, the beneficial impact of pictorial aids shown in this paper should be disseminated to the construction industry and beyond.

This paper has not considered the impact of pictorial aids on worker behaviour. However, this will be discussed in a later publication.

Acknowledgement

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ASSESSESSMENT OF MULTI-LEVEL SAFETY CLIMATES OF WORKING GROUPS TO DRIVE PERCEPTUAL UNIFICATION

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ABSTRACT

Poor safety performance has been attributed to most construction industries (due to hazardous conditions) of developing countries and Pakistan is not the exceptional with intensive human work force. In the absence of any legislative administration body for occupational health and safety the lagging indicator for safety performance i.e. safety records is inadequate and create a space for leading indicator i.e. safety climate. Safety climate as pivotal construct of safety culture shared common grounds as beliefs, values, attitudes etc for safety. The clear and positive perception about safety leads the positive safety climate to enhance safety culture in turn. Working groups (manager, supervisor and workers) based on organizational structure exhibit sub-cultures which create barriers for common safety climate. This papers aims to investigate the multi-level safety climate with two main streams as *Within Group Consensus* and *Between Group Differences*. A questionnaire has been developed comprise of 40 safety climate statements (using Likert scale), and survey done with major 21 companies (contractors) on 36 construction sites. 150 valid responses (73.33%) received through self interview and post mail. Collected data was analyzed by SPSS 17.0, in stance to assess multi level safety climates, evaluate aspects of agreement within groups by degree of cohesiveness ($rwg(j) \geq 0.75$) and differences among groups by one way ANOVA (sig. value < 0.05), relationships developed between differences aspects by Bi-variant analysis (sig. value < 0.05). The results found as; Managers agreed that they are capable of identify hazards, consider safety as prime priority, and accident reporting is important. Supervisors agreed upon Managers' role for implementation of safety is important. Workers perceived that they are also capable of identification of hazards. Differences between groups were Front line workers' suggestions were not considered by Managers, Managers do not involve Front Line workers for development/review of safety procedures/instructions/rules, Front Line workers have opinions that people are just unlucky to suffer an accident but supervisors opposed, Managers confirmed that every accident/near miss happened on site is reported but workers revealed that every accident/near miss is not reported. Differences between working groups were further investigated for correlation through bi-variant correlation analysis. Workers' participation showed a strong, positive relationship with Workers' engagement and Accident reporting. Workers' engagement also showed a strong, positive relationship with Accident reporting. No significant relationship found for Workers' bad luck to be suffered from accident to other variable. Construction companies can induct above findings to formalize the positive safety climate which helps to enhance safety culture with perceptual unification among workgroups.

Keywords: Safety Culture, Safety Culture, Multi-Level Safety Climate, Working groups, Pakistan

1. INTRODUCTION

Construction industry has attributed to economically and socially importance but also recognized as most hazardous (Suao and Jaselskis, 1993; Hinze 1997; Sawacha et al. 1999; Choudhry et al.2008). Generally, construction sites are one of the most dangerous workplaces because of high incidence or accidents (Teo et al, 2005; Ahmed et al., 2000). Construction work is typically performed by semi-autonomous, often contracted, work crews, engaged on a temporary basis to complete a package of work. This situation presents a management challenge with regard to creating a shared understanding of the importance of safety within organizations (Lingard & Rowlinson, 1994). Blockley (1995) advocates that the construction industry would be better characterized as one with a poor safety culture and that attempts to improve the safety record will not be fully effective until the safety culture is improved; progress over the last decade on defining and measuring the safety culture concept in construction appears to have been somewhat slow. Safety culture is becoming critically important to the safety of employees within the construction site environment (Choudhry and Fang, 2006). Arboleda and Abraham (2004) demonstrate a distinction between management attitudes and workers behaviors, advocating that, in order to be useful as a means of analyzing and categorizing safety culture, management activities and workers activities should be viewed as separate but related phenomena. Cooper and Philips (1994), safety climate is concerned with the shared perceptions and beliefs that managers and workers hold regarding safety in the workplace (i.e., safety climate is, to some degree, dependent on the prevalent safety culture). It can be, therefore, argued that safety climate is largely a product of safety culture, and the two terms should not be viewed as alternatives. Mohamed (2003) suggested that safety culture is concerned with the determinants for the ability to manage safety (top-down organizational attribute approach); whereas, safety climate is concerned with the workers' perceptions of the role safety plays in the workplace (bottom-up perceptual approach). Most studies seem to have focused on climate measurement issues, including factorial structure of measurement scales and its predictive validity with regard to a variety of safety outcomes (Zohar, 2010). Integrate both quantitative and qualitative approaches to measuring safety climate, and verified perceptions of safety climate shared by workers and the management groups to assist the organization to further advance its safety-related policies, procedures, and practices. The implementation of multi-level safety needs assessment surveys can identify major safety issues of concern (Gittleman et al. 2010).

2. PAKISTAN CONSTRUCTION INDUSTRY IN SAFETY PERSPECTIVE

Pakistan construction industry is contributing to national economy with 2.3% of GDP (Ahmad) and attributed as labor intensive comprising 15.5% of workforce with 10.77%

(Anonymous1) are from rural areas and 51.41% of them are illiterate (both civilian and non civilian labour force) (Anonymous2). According to General Labour Laws of Pakistan (Anonymous3), main emphasize has been given to industrial safety and there is no proper and legislative rules and regulations defined for construction sites. Implementation of a safety, health, and environmental management system is no widespread in developing countries (Koehn et al. 1995). In context of Pakistan construction industry attention can be raised over implementation of safety in construction site environment as gradual increase in percentage for occupational injuries and diseases (Survey of Pakistan, 2002 - 2009) has been observed from 12.54 (2002) to 14.54 (2009), evident the lacking safety culture. A mean value of Safety Performance Index of 0.52 indicates that even the basic practices required for safety are not present at most construction site. Also, the scattered safety performance levels of firms indicate lack of standard safety management system. (Farooqui et al. 2008). The most significant barriers towards implementing site safety have been found, descending order of significance as follows: lack of safety awareness, lack of familiarity with safety management techniques, worker cooperation/behavior, shortage of safety personnel, and schedule pressures (Saqib et al. 2010). In reference to research done earlier, there is significant need to enhance safety culture on construction projects through safety climate construct because there is no legislative administrative body in the country to put efforts for improvement in safety performance.

3. OBJECTIVES

This paper is an attempt to investigate the multi-level safety climate in working groups (position wise managers, supervisors and workers). There are two main research streams to be addressed as Within Group consensus and Between Group differences upon the safety climate dimensions/factors. Moreover the relationships among the evaluated differences are also of prime interest.

4. LITERATURE REVIEW

Safety Climate

Choudhry et al. (2007) provided the definition that *safety climate reflects employees' perceptions about the organizations'safety management system including policies, practices, and procedures that show how safety is implemented in construction sites environments*. It is regarded as a descriptive measure reflecting the workforce's perception of, and attitudes toward, safety within the organizational atmosphere at a given point in time (Gonzalez-Roma et al. 1999). The *safety climate* relies and focuses on current safety activities to establish the success of the safety management system rather than the system failure (Cooper and Phillips, 2004; Choudhry et al. 2009). O'Toole (2002) proposed that there is a connection between management's approach to safety and employees' perception of how important safety is to the management team. Mohamed (2002) presented a model of safety climate determinants and found that there was a significant relationship or positive association between perceptions of the safety climate and self-reported safe work behavior.

Safety Climate dimensions /factors

Dimensions of safety climate are the major features or levels of safety climate (Glendon and Stanton, 2000). Addressing safety climate dimensions specifically construction industry, Glendon and Litherland (2001) found six factors for safety climate in a road construction organization include communication and support, adequacy of procedures, work pressure, personal protective equipment, relationships, and safety rules. Mohamed (2002) has identified 10 dimensions of safety climate in construction site environments include management commitment, communication, safety rules and procedures, supportive environment, supervisory environment, workers' involvement, personal risk appreciation, appraisal of work hazards, work pressure, and competence. For Hong Kong construction industry, Fang et al. (2006) evaluated 10 dimensions as safety attitudes and management commitment, safety consultation and safety training, supervisor's role and workmates' role, risk taking behavior, safety resources, appraisal of safety procedure and work risk, improper safety procedure, worker's involvement, workmate's influence, and competence and Choudhry et al. (2009) reduced these factors to two as management commitment and employees involvement, and inappropriate safety procedures and work practices. The investigation for consensus and differences among safety climate dimensions among groups help to formalize the direction to enhance safety culture on construction sites.

Multi-Level Safety Climate

Studies identifying group differences in safety climate suggest groups do not share an overall view of safety (Collinson, 1999). Zohar (2000) proposed 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 (2000) 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. Glendon et.al (2001) reported differences in safety climate between construction and maintenance job categories within the road construction industry. Sub-climates for safety can exist within an organization which are differ on dimensions of safety climate (Glendon et al. 2001). Group differences in safety climate indicate the existence of multiple safety cultures that can negate the effectiveness of safety programs and communication (Findley et.al, 2007).

Modern organizations are large and complex and thus the notion of a single uniform safety climate seems overly simplistic (Lingard et al. 2005). Zohar(2000) suggests that group-level safety climate relate to patterns of supervisory safety practices, or ways in which organization level policies are implemented within each workgroup or sub-unit. This finding has significant implications for safety management because it suggests that the role played by supervisors in defining the workgroup safety climate is likely to be just as important as, if not more so, than the actions of top management in defining safety policy or of safety professionals in developing safety procedures. These dissimilarities in safety attitudes and perceptions among different groups within an organization were attributed to divergent management styles and levels of concern for safety issues. While these dissimilarities are not viewed as necessarily undesirable, neglect of these differences could result in failure to identify competing agendas and disparate risk perceptions (Findley et al. 2007). As opposed to behavior-based interventions targeted solely at the worker level, this leader-based approach recognizes that contributing factors to adverse events are multifaceted and complex, requiring conditions allowing for true company (multi-level) priority of safety (Kines et al. 2010). Workgroups within the same organization can have significantly different group safety climates, providing a good theoretical explanation for why some organizational sub-units consistently perform better in terms of safety than others (despite having very similar risk exposures) (Cooke et al 2006).

A comparison of organization-level and group-level consequences suggests that they differ in terms of two important behavioural parameters, that is, outcome frequency and immediacy (Zohar et al. 2005). Construction work is largely non-routine, necessitating the exercise of supervisory discretion in the interpretation of formal safety policies/procedures. In this context, the role of supervisors in shaping subordinates' safety behaviour is likely to be considerably greater than in work contexts with routine production processes. Thus, it is useful, in the construction context, to test whether group-level safety climates develop within construction organizations and, if so, what impact group-level climates have on safety performance (Cooke et al. 2006).

5. RESEARCH METHODOLOGY

Following are the main phases of the research study:

1. Initially in depth knowledge gained regarding the research stream through review of books, conference papers, journal papers, articles, internet browsing etc., which were sorted upon the degree of relevance to the study.
2. A questionnaire, developed by Choudhry et al. (2009) of 31 safety climate items, which has been formatted with required modification, inducting the pivotal research aspects derived from earlier studies for Pakistani construction industry (adding 9more safety items). The questionnaire in its final form consisted of 45 statements about safety issues at the organizational, group, and individual levels and consisted of four parts. The first part of the questionnaire related to the respondents' general information. The questions include respondent's project name, name of the company, department and working group. Further questions included the respondent's job information that is he/she a worker or, supervisor or a manager. The second part consisted of 40 safety climate items which asked the participants to endorse the statements using a five-point Likert - type (from 1 = "strongly disagree" to 5 = "strongly agree") scale.
3. In data collection phase, a questionnaire survey has been done on 36 construction projects (of different type as industrial, facility, housing, community buildings etc) located in different cities of Pakistan, moreover both lower and higher categories of contractors (as per P.E.C). Cumulative 150 valid responses (83.33% of distributed questionnaires) received and interview based questionnaire filled was about 73.33% of valid responses.
4. Collected data was fed in SPSS 17.0 for statistical analysis, in stance to assess multi level safety climates, evaluate aspects of agreement within groups by degree of cohesiveness ($r_{wg(j)} \geq 0.75$, derived by James et al, 1984) and differences among

groups by one way ANOVA (sig. value < 0.05), relationships developed between differences aspects by Bi-variant analysis (sig. value < 0.05).

5. The results of the data analysis provided thought provoking issues for development of safety culture and termed to be taken as valid addition to safety research in perspective of Pakistani construction industry. In the same tune both conference and journal papers will be published to validate the research work.

6. DATA ANALYSIS

Major research streams under this heading are within group consensus and between group differences which were measured statistically.

Within Group consensus

To determine the level of agreement between members of the same workgroup, indicating team cohesiveness in their perceptions of safety, the rwg(j) statistic was calculated using a formula developed by James et al (1984). Within-group agreement is deemed sufficient if rwg(j) ≥ 0.75. In table 1; cohesiveness score for each statement (with rwg(j) ≥ 0.75) of project organization positions as Managers, Supervisors and workers. There is consensus found among Managers' that substantial provision has been given to site safety and considered as prime priority for execution; Managers' considered themselves as knowledgeable and experienced to identify the hazardous situations; moreover considered regular reporting for safety performance helps to improve safety on site. Supervisor agreed upon the role of Managers are of extreme importance for safety implementation and to resolve safety issue without delays. Workers considered that, they capable to identify hazardous situations but related to knowledge and experience.

Position	Safety Climate statements	$r_{wg(j)}$
Manager	It is in my interest to maintain a safe workplace.	0.82
	I am aware that safety is the number one priority in my mind while working	0.81
	I am capable of identifying potentially hazardous situations	0.81
	My supervisor/safety manager welcomes reporting safety hazards/incidents	0.78
Supervisor	My supervisor/safety manager is a good resource for solving safety problems	0.77
	Management acts quickly to correct safety problems	0.75
Worker	I am capable of identifying potentially hazardous situations	0.79

TABLE 1: Within-group Inter-rater reliability for groups upon safety statements.

Between Group differences

A one-way between-groups analysis of variance was conducted to explore the perceptions of position against safety climate statements (40Nos). Subjects were divided into three groups according to position (Manager, Supervisor and Workers).

Initially test of homogeneity of variances has been done, according to Levene's test 07 items has violated the assumption (i.e sig. value > 0.05) as CQ2, CQ5, CQ6, CQ20, CQ30, CQ38 and CQ39. After that Robust Tests of Equality of Means has been performed to explore the valid items with differences (with sig. value < 0.05), which resulted items CQ2, CQ3, CQ4, CQ12, and Q40. According to ANOVA Table 2 items has been found with sig. value < 0.05 which were CQ2, CQ3, CQ11, CQ12, CQ34 and CQ40. Finally taking in account the criteria (i.e sig. value < 0.05) Welsh and Brown-Forsythe (for Robust Tests of equality of means) 4 items taken for further analysis and discussion, which are CQ2, CQ3, CQ12 and CQ40. Effect size of each difference is measured by eta square value to assess the impact of variance between groups, Cohen (1988) classifies 0.01 as a small effect, 0.06 as a medium effect and 0.14 as a large effect.

Working Groups	Safety Climate statements	Sig. value	eta squared score	Effect size
Front Line worker > Manager	(Q2) Suggestions to improve health and safety are seldom acted upon.	0.003	0.08	Medium
Manager > Front Line worker	(Q3) I feel involved when health and safety procedures / instructions / rules are developed or reviewed.	0.011	0.06	Medium
Front Line worker > Supervisor	(Q12) People are just unlucky to suffer an accident.	0.006	0.07	Medium
Manager > Front Line worker	(Q40) Accidents which happen here are always reported.	0.038	0.04	Small

Table 2: Differences between groups with effect size by One way ANOVA.

There was a statistically significant difference between workgroups (Front line worker and Manager) at the $p<0.05$ level workers' suggestions are not considered by Management to improve safety, have medium effect size ($F(2, 146) = 6.2, p = 0.003$). Managers do not involve Front Line workers for development/review of safety procedures/instructions/rules ($F (2, 147) = 4.6, p = 0.011$) with medium effect size. Front Line workers perceived that people are just unlucky to suffer an accident but supervisors deviated and considered personal mistake or unsafe site conditions ($F (2, 145) = 5.2, p=0.006$) with medium effect size. Managers confirmed that every accident/near miss happened on site is reported but workers revealed that every accident/near miss is not reported ($F (2, 147) = 3.3, p = 0.038$) with smaller effect size.

Bi-variant Correlation Analysis

In order to determine the nature and strength of linkages between variables measured, bivariate correlation analysis were conducted. The relationship between *Workers' participation, workers' engagement and Accident reporting* was explored using Pearson product-moment correlation coefficients. The results of this analysis are presented in Table 3.

Correlations

		CQ02	CQ03	CQ12	CQ40
CQ02	Pearson Correlation	1	.189*	.091	.185*
	Sig. (2-tailed)		.021	.275	.024
	N	149	149	147	149
CQ03	Pearson Correlation	.189*	1	-.002	.257**
	Sig. (2-tailed)	.021		.976	.001
	N	149	150	148	150
CQ12	Pearson Correlation	.091	-.002	1	-.051
	Sig. (2-tailed)	.275	.976		.540
	N	147	148	148	148
CQ40	Pearson Correlation	.185*	.257**	-.051	1
	Sig. (2-tailed)	.024	.001	.540	
	N	149	150	148	150

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3: Bi-variant Correlation Matrix

Workers' participation showed a strong, positive relationship with *Workers' engagement* (r =0.189, *p*=0.05) and *Accident reporting (*r=0.185, p=0.05). *Workers' engagement* also showed a strong, positive relationship with *Accident reporting (*r=0.257, p=0.01). No significant relationship found for *Workers' bad luck to be suffered from accident* to other variable.

7. CONCLUSION AND DISCUSSION

Within Group Consensus

There was prominent consensus found regarding safety dimensions within the group (organization position). The coherent pattern of managerial action and practice of supervisor and workers derived the significant aspects upon which each group agreed.

Mangers stated safety as prime priority which entails the safety policy of the company but the level of consideration need to be set. Manager interest in safety is related to the obligations according to contract or local law. Being responsible for safety on site Manager must have competency to scan for hazardous conditions. A focus on this perspective should lead to measures that would likely relate to such elements as management safety policy, commitment, accountability, and leadership (Mohamad, 2002). Managers need the participation of supervisor or worker through incident/near miss reporting enact the safety communication at refined channels. According to Sawacha et al (1999) management viability and participation require management involvement such as safety policy, relationship with workers, safety representative, talk on safety, etc., were all found to be linked safety performance.

Supervisors shift the major responsibility for safety to managers because of implementation of rules/procedures are enforced by them but the supervisor acceptance for safety is of great concern which influence the worker behavior for safe work. Zohar and Luria (2005) demonstrated that supervisory decisions in situations where they had to choose between safety and accomplishing the mission were predictive of employee perceptions of safety climate. Supervisor perceived quick response from managers regarding safety problems, help to develop trust and confidence upon management. In other words, top managers are concerned with policy-making and the establishment of procedures to facilitate policy implementation, while at lower organizational levels supervisors execute these procedures by turning them into predictable, situation-specific action directives (identified as supervisory practice) (Zohar, 2010).

Workers with competency and experience of safe work can identify hazardous conditions but new and untrained workers are not capable for the same. Job security and social relationships has deep influence over worker performance for safety which urge them to suppose as with adequate safety knowledge. Training for safety must be provided to all workers with practical approach encompassing all accidents as fall, shock, improper equipment etc. The essence of this construct is the workforce's perception of the general level of workers' qualifications, knowledge, and skills, with associated aspects related to selection and training (Mohammad, 2002). Personality disposition variables in relation to risk, such as fatalism and optimism are included. These may have a direct effect on risk taking or an indirect effect on safety behaviors, influencing a worker's predisposition to speak up about safety or to become involved in safety initiatives (Flin et al, 2000).

Between group differences

There are perception gaps (relating to health and safety in the workplace) between managers, supervisors and the workforce (HSE, 2002). In current study an attempt has been done to identify the key differences in the perception about safety climate.

There was conflict about the statement that workers suggestions to improve safety were not considered by Managers which refer the less weak participation of workers. Rules and procedures for safety are demonstrated safety policies which are company specific and no provision for amendment or modification conformance to site conditions. Mostly no representation of workers found in safety related meeting on construction site rather site reports are referred for safety audits. In the same line Managers not even involve workers for development or review of safety rules/procedures/instructions. Managers perceived that workers are not capable to address safety issues and help to improve safety, which is not the case for experience workers. Rules and procedures are the core component of safety management systems. A successful safety management system program is based upon the premise that safety is both a management responsibility and a line function (Mohammad, 2002). Although top management helps formulate safety policy, its actual success depends upon the ability of site management and supervisory personnel to insure that rules and policies are adhered to during daily operations (Agrilla, 1999). Senior managers reported they were always informed of the outcome of meetings that addressed health and safety. At the same time foremen and the workforce felt they were not always informed. (Findley et al, 2007)

Inadequate knowledge and lacking competency for safety helps to develop wrong perceptions. Uneducated and untrained workers are of opinion that the person suffered from accident only with God's will, and ignore the aspects as personal mistake or unsafe job site conditions. Safety knowledge is another influencing factor for safety climate and can be controlled and promoted through education and training in the company (Fang et al, 2006).

In stance to safety initiates accident reporting is effective and Managers also considered it significant. Managers have the opinion that all accidents/incidents/near misses are reported but contrary workers have opposite opinion. There may be hurdles in communication channels which cause this malfunction but the responsibility of foreman and supervisors cannot be ignored. Senior managers reported that accidents are always reported while foremen believed accidents were not always reported. (Findley et al, 2007). On individual level, if one has been suffered from near miss, incident, or accident due to his own fault and manage the mishap well, then he may not communicate this to higher level, under lies the job security aspect.

Relationship among differences

Positive relationship between workers' participation and workers' engagement and accident reporting exhibit that if workers' participation is needed to be high then they must be engage in safety related activities and motivation is required to report any accident/near miss/incident on site. Further, workers' engagement found to be more strongly related (Sig. value <0.01) with accident reporting. This result confirmed the vitality of safety communication especially addressing the accident reporting to high level (supervisor or manager). This help to avoid system failure and such events lead to improve safety with the concern of management dedication.

8. FUTURE RESEARCH

It is pertinent to further investigate the multi-level safety climate in respect to consensus within groups to evaluate the drivers for common safety climate. Appropriate measure has to be researched which resolve the conflict issues lies in the differences between groups.

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An Analysis of Construction Worker Safety during Building Decommissioning and Deconstruction

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An Analysis of Construction Worker Safety during Building Decommissioning and Deconstruction

Abstract:

This paper reports the initial findings from our pilot research on understanding construction worker safety issues in building end-of-lifecycle operations specifically decommissioning and deconstruction. Although deconstruction is more environmentally friendly than demolition, it is more labor intensive and it requires more careful planning for critical health and safety issues. The data for this study comes from four buildings surrounding the World Trade Center. The buildings were damaged after September 11 and needed to come down.

Keywords: building deconstruction, worker safety, building decommissioning

1. Introduction

A building's end-of-lifecycle operations include various activities from decommissioning and remodeling to deconstruction and demolition. According to the United States Energy Information Administration (US EIA) 74% of all commercial buildings in the US are built before 1990 and 17% built before 1945 (CBECS, 2003). Similarly, 76% of all the housing units are built before 1990 and 19% is built before 1950 (RECS, 2005). Since the US building stock is relatively old, demolition or deconstruction of buildings to open space for new construction or, building renovation for new purposes have a significant impact on the construction industry. For example, in 2006, residential and commercial building renovation activities cost 36% ($438 billion) of the all building construction activities ($1.22 trillion) (DOE, 2006).

Building end-of-lifecycle operations also cause the construction industry to produce one of the largest shares of waste in the US. In 1998, 136 million tons of construction and demolition (C&D) waste was produced in the US. 48 percent of the waste came from demolition and 44 percent was generated through renovations (Franklin Associates 1998). A preliminary estimate claims that more than 160 million tons of C&D waste was generated in 2003, of which nearly 42 percent came from demolition activities and 49 percent was produced by renovation activities (EPA 2008, EPA 2009). The Environmental Protection Agency (EPA) estimates that only 40 percent of C&D waste was reused, recycled, or sent to energy facilities, while the remaining 60 percent of the materials was sent to C&D landfills.

From environmental sustainability perspective, there is a growing interest to divert building materials away from landfill disposal and provide cost savings and avoidance of virgin material use through reuse and recycling (Kibert and Chini 2000, Chini 2001, Chini and Shultman 2002, Chini 2003, Chini 2005, Crowther 2001, Crowther 2002, Durmisevic 2006, Hurley et al. 2002, Guy and Shell 2002, Hinze 2002, Te Dorsthorst and Kowalczyk 2002, Dorsthorst and Durmisevic 2003). In comparison to demolition, deconstruction is an effective way for reducing raw material consumption and protecting embodied energy in building materials. When buildings reach the end of their useful life, they are decommissioned and either renovated for new purposes or demolished and hauled to landfills. Demolition of a building through explosives or wrecking-ball style is convenient and offers a quick way for clearing the site. However, this method creates a significant amount of C&D waste and landfill costs. Deconstruction is defined as the process of selectively dismantling a building or parts of a building in order to salvage the materials for reuse, recycling, or waste management (Guy and Gibeau 2003).

This paper reports the initial findings from our pilot research on understanding construction worker safety issues in building end-of-lifecycle operations specifically decommissioning and deconstruction. Although deconstruction is more environmentally friendly than demolition, it is more labor intensive and it requires more careful planning for critical health and safety issues. Early planning involves complex activities such as collecting and analyzing various information that is coming from different sources related to the existing structure. Deconstruction activities involve many of the safety hazards associated with the construction. On top of that, all building end-of-lifecycle operations have safety risks due to the unknown condition of the building. These might be caused by deviations from the original design and missing as-built information, unapproved updates, unknown state of construction materials, strength or weakness issues with the structure etc.

2. Significance

In simple terms, deconstruction is the reverse of the construction process, but it shows differences according to the condition and location of the building and building materials involved. In comparison to demolition, which generates waste for landfills, deconstruction produces materials that can be used again or remanufactured into higher-value goods. Two distinct types of deconstruction can take place on a project—non-structural and structural. Non-structural deconstruction is the removal for reuse of any building contents that do not affect the structural integrity. Materials such as cabinetry, windows/doors, and appliances can be salvaged relatively easily with minimum safety concerns. Structural deconstruction consists of more involved recovery activities that are harder to implement and contribute to the structural integrity of the building. Salvaged materials consist of roof systems, wood timbers and beams, brick and masonry elements, and framing (EPA 2001).

Increasing awareness of environmental safety and the need for properly disposing the potentially harmful waste, such as asbestos or other chemicals, requires buildings to be appropriately decommissioned at the end of their lifecycle. The environmental characteristics of building materials are an important issue that needs to be carefully tracked through the building lifecycle. In comparison to the construction processes, decommissioning and deconstruction deals with significantly different waste and debris that is more likely to be contaminated by potentially hazardous substances such as lead paints, stains, and adhesives. The physical and chemical composition of a material can be altered through the surface treatment and maintenance applications. For example, finished wood has a different composition from raw wood. The chipping or shredding of finished wood during recycling can expose people to the hazardous substances such as lead-based paint. (Dolan et al. 1999).

3. Methodology

One of the most critical building end-of-lifecycle operations are being done recently on the surrounding buildings of the World Trade Center (WTC) site after September 11. Five buildings on the immediate vicinity of WTC are decided to come down due to the structural damages: *130 Liberty Street, 4 Albany Street, 130 Cedar Street, 133-135 Greenwich Street, 30 West Broadway-Fiterman Hall*. Environmental Protection Agency (EPA) coordinated the federal, state and city agencies to ensure that the impacted buildings are decommissioned and deconstructed in a manner that protects the health of people who live and work in the area. Due to the nature of the event, all documentation related to these demolition and deconstruction events are publicly available from EPA's web site and collected for the purpose of this research.
Four of these buildings, *130 Liberty Street, 130 Cedar Street, 133-135 Greenwich Street, 30 West Broadway-Fiterman Hall*, have very detailed documentation of their operations. Although the nature of decommissioning and deconstruction was very different for all four buildings, the basic regulatory submittal included the following documents: work plan, environmental air monitoring plan, health and safety plan and waste management plan. In addition to these documents every project has building specific information such as quality assurance plans, façade characterization reports, environmental characterization reports, scaffold erection operations etc. In this research, we specifically focused on health and safety plans to learn from how construction worker safety issues are addressed in these cases.

4. Findings

The analysis of health and safety planning documents for all cases show that although they are prepared for different deconstruction projects they are more similar than different. The content of these documents is grouped under nine topics:

Site security, entrance to site, decontamination section describes the work zones in the site, entrance and exit procedures for containment areas, emergency access, and security protocol together with general building access and perimeter security. Equipment and personnel decontamination procedures are listed as well as contamination prevention methods.

Personnel training procedures are explained in detail in all four documents. This section covers basic site orientation, visitor orientation and safety meetings together with general health and safety awareness training, safe work permit, asbestos training and Hazardous Waste Operations and Emergency Response Standard (HAZWOPER) training.

Personal protective equipment (PPE) section describes the requirements of PPE for different tasks. Level D, Level C and Level B PPE work is expected in the site but Level A description is also provided as a precaution. Basic safety equipment descriptions involve respiratory protection and protective clothing.

Personnel responsibilities part lists key personnel for the project and their contact information

Hazard assessment, risk analysis is the most detailed topic in all four health and safety plans. This part of the document explains physical, chemical or biological hazards in the site and also gives a risk analysis for tasks involved in the work plan.

Air monitoring is part of the safety measures of these end-of-lifecycle operations since the project takes place in a very dense urban environment and all four buildings are heavily contaminated with the dust from the collapse of two towers. The monitoring involves total suspended particulate (TSP), asbestos, Polycyclic aromatic hydrocarbons (PAHs), Polychlorinated biphenyls (PCBs), mercury, lead, silica, cadmium and chromium.

Incident reporting, emergency reporting procedures differ in four cases with their scope. The basic emergency reporting involves the call to first responders through 911. In more detailed processes involve incident investigation, root cause analysis and incident record keeping with a copy of the OSHA 300 log.

Emergency planning is listed in all documents with possible emergency scenarios such as fire, explosion, power or structural failure together with evacuation plans and site logistics.

Communication section involves labeling and material safety data sheets together with general communication procedures, radio and telephone usage, emergency warning and hand signals.

In addition to these procedure descriptions, health and safety planning documents also give references to the various regulations that need to be followed during the decommissioning and deconstruction of buildings. In Table 1, 2 and 3 the regulations that are addressed in four documents are listed. The first group is the federal regulations that are identified by Occupational Safety and Health Administration (OSHA), the second group is local regulations of New York City and the third group of regulations is from other institutions which might not be directly related to the worker safety. The amount of regulations involved in these operations show the complexity of tasks as well as the depth of planning that is required before starting the deconstruction. In some cases such as asbestos regulations or hazardous materials there are more than one regulations at different levels and a careful planning is required to identify possible conflicting or overlapping specifications.

Table 1: *Combined list of OSHA regulations referenced in four cases*

Federal OSHA Regulations for General Industry (29 CFR 1910)	Federal OSHA Construction Regulations (29 CFR 1926)
- Subpart C (General Safety and Health Concerns) - Subpart D (Walking and Working Surfaces) - Subpart E (Means of Egress) Health and Safety Plan - Subpart G (Occupational Health and Environmental Control) - Subpart H _ 120 (Hazardous waste operations and emergency response) - Subpart I (Personal Protective Equipment) - Subpart J (General Environmental Controls) - Subpart K (Medical and First Aid) - Subpart L (Fire Protection) - Subpart P (Hand and Portable Power Tools) - Subpart S (Electrical) - Subpart Z (Toxic and Hazardous Substances)	- Subpart C (General Safety and Health Provisions) - Subpart CC (Cranes and Derricks) - Subpart D (Occupational Health and Environmental Control) - Subpart E (Personal Protective and Lifesaving Equipment) - Subpart F (Fire Protection and Prevention) - Subpart G (Signs, Signals, and Barricades) - Subpart H (Materials Handling, Storage, Use and Disposal) - Subpart I (Tools-Hand and Power) - Subpart J _ 354 (Welding/Cutting on surfaces covered by protective coatings) - Subpart K (Electrical) - Subpart L (Scaffolding) - Subpart M _ 500 and 502 (Personal Fall Arrest Systems) - Subpart N _ 502 (Materials Hoists, Personnel Hoists and Elevators) - Subpart P _ 650 (Excavation) - Subpart T (Demolition) - Subpart X (Stairways and Ladders) - Subpart Z _ 1101 (Asbestos) - Subpart Z _ 1127 (Cadmium)

Table 2: *Combined list of local regulations referenced in four cases*

Local Asbestos Licensing Regulations - The State of New York Department of Natural Resources and Environmental Control asbestos regulations. - The State of New York Department of Asbestos Licensing Regulation - City of New York Asbestos Licensing Authority - New York State Department of Labor Industrial Code Rule 56 (ICR-56) (proper identification, handling, removal, and disposal of ACM in public buildings)
New York City Local Law 45 of 198 (Designating a qualified specialist as a site-safety coordinator for all phases of construction)
New York City Building Code Subchapter 19 (Safety of Public and Property During Construction Operations)
City of New York Department of Licenses and Inspections (Building Permit and Contractor Licensing Regulations

Table 3: *Combined list of regulations from other institutions referenced in four cases*

U.S. Nuclear Regulatory Commission (10 CFR) (40-hour Radiation Protection Procedures and Investigative Methods (10 CFR 1912))
U.S. Environmental Protection Agency Regulations - 40 CFR Subchapter C - 40 CFR Part 61, Subpart A (General Provisions) - 40 CFR Part 61, Subpart M (National Emission Standard for Asbestos) - US EPA 40 CFR Subchapter 1 - 40 CFR Part 241, (Guidelines for the Land Disposal of Solid Wastes) - 40 CFR Part 257, (Criteria for Classification of Solid Waste Disposal Facilities and Practices) - US EPA 40 CFR Subchapter R Health and Safety Plan - 40 CFR Part 763, (Asbestos Hazard Emergency Response Act)
American National Standards Institute (ANSI) Publications - Z9.2, (Fundamentals Governing the Design and Operation of Local Exhaust Systems) - Z88.2, (Practices for Respiratory Protection)
Underwriters Laboratories, Inc. (UL) Publications 586 (Test Performance of High Efficiency, Particulate, Air Filters Units)
National Electric Code (Latest Edition)
American Society for Testing and Materials E 1368-99, (Standard Practice for Visual inspection of Asbestos Abatement Projects
National Fire Protection Association (NFPA) Standard 701, (Standard Methods of Fire Test for Flame-Resistant Textiles and Films)

5. Conclusion and Summary

In this paper we report from our initial study on the decommissioning and deconstruction of four buildings surrounding the WTC in New York City, which were damaged needed to come down after September 11. Our analysis shows that the health and safety planning for deconstruction of these buildings required detailed information about the buildings' condition and a careful preparation for expected or unexpected events. In comparison to construction, worker safety issues are different in the deconstruction operation because of various variables such as structural instability, hazardous materials and contamination problems.

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Towards a Fully Automated Equipment Blind Spot Detection, Equipment Operator Visibility Monitoring, and Ground Personnel Proximity Warning and Alert System

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Towards a Fully Automated Equipment Blind Spot Detection, Equipment Operator Visibility Monitoring, and Ground Personnel Proximity Warning and Alert System

Abstract

Over six hundred construction worker deaths occurred in the United States during the inclusive years of 2004 to 2006 that were related to construction equipment and contact collisions. On average, about 25% of all construction work-related fatalities are due to the involvement of equipment. The goal of the presented research is to reduce these numbers to zero. This paper first presents findings about safety statistics as they relate to heavy construction equipment and vision-related construction fatalities. A framework follows to integrate a fully-automated approach to detect blind spots of construction vehicles as they are used in the field; an equipment operator visibility monitoring system; and real-time pro-active technology to warn or alert ground workers of nearby equipment. The paper will present details to the developed safety technology and results to field trials.

Key words: Construction equipment, blind spots, operator visibility, proximity warning and alert technology, real-time pro-active safety, RFID, SmartHat.

1. Introduction

In the past fifteen years nearly 1,200 construction workers have died each year (BLS 2009, CFOI 2007). That equates to approximately five construction worker deaths every working day in the US. Of these fatalities, 25% involved heavy equipment, most being categorized as struck-by incidents. As these statistics indicate, safety in construction remains a big problem. Despite the implementation of better safety practices, further improvements can be gained in construction safety through the use of technology.

Advances in technology have made it possible to integrate and leverage their potential in construction industry applications. The ability to improve safety performance in construction has been proven; however, these efforts have focused primarily on behavioral safety management and policy changes. Despite improvements in construction safety, the safety record in the construction industry continues to lag behind other industries. For example, for the inclusive years of 2004 to 2006 an investigation of the construction worker deaths revealed that one-fourth of all construction deaths were related to construction equipment and contact collisions. Clearly, additional efforts are required to make further improvements in construction safety.

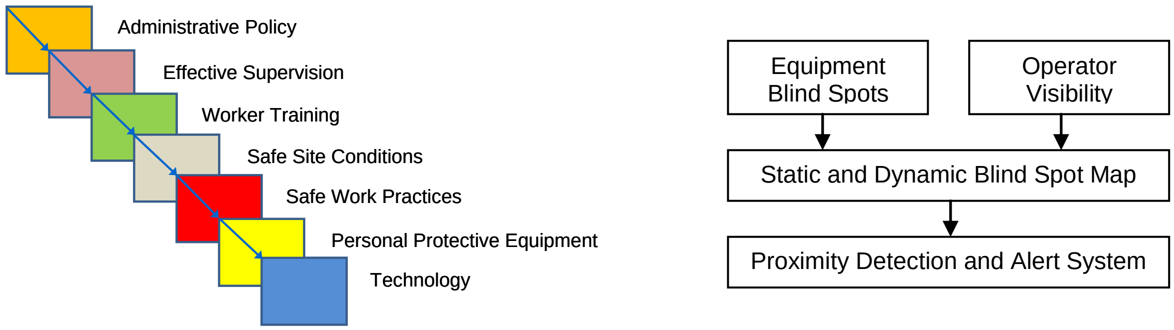


Figure 1: A real-time pro-active safety technology framework that forms an additional barrier to protect from equipment-ground worker-related hazards.

As illustrated in Figure 1, this study presents preliminary findings about applying technology as an additional layer of protection to enhance safety performance on construction projects.

Problem Statement: It is assumed that significant improvements can be gained in construction safety if technology is applied in addition to implementing safety management practices. Understanding how existing technology can be used to warn construction personnel of the presence of hazards in real-time and to monitor the location and movement of resources will help construction firms to integrate emerging technologies with work site safety.

Research Objectives: The primary objective of this research was to examine devices that warn construction personnel of the presence of potential hazards in real-time. Secondary objectives were to measure equipment blind spots and to use remote sensing technology that records accurate location, proximity, and trajectory data of construction resources (workers, equipment, and materials) in real-time.

The intent of the research was to select and evaluate a few promising and existing technologies through experimental field studies. These field tests could reveal how well the technology can be applied to construction operations. Field trials would include an assessment of the receptiveness of workers to the use of the technology.

Research Methodology: Past construction safety research has provided a solid base for making improvements in construction safety. A review of the literature revealed that most safety efforts have been focused on safety management issues. There has been a minimal emphasis on construction equipment operations. The research team reviewed existing research publications, occupational safety and health databases, and professional journals to evaluate the significance of worker/equipment interactions related to safety. The review focused on (OSHA 2002 and 2009):

1. The role played by construction equipment in 289 construction worker fatality cases between the years 1990 to 2007 where visibility was an issue.
2. The causes of fatalities related to more than 13,000 construction-related accidents.

3. The applicability of existing safety management and best practices in real-time construction site safety.
4. Relevant technology applicability to daily construction operations involving construction equipment.

The research team also employed opinion-based surveys to develop a real-time pro-active safety framework. The main focus of the real-time pro-active safety framework was to understand how and where technology is applied in an existing safety management system and which stakeholder of a construction project (owner, contractor) benefits from applying the technology.

To validate the developed real-time pro-active safety framework, the research team conducted field trials using warning and tracking devices. The research team developed a field trial methodology to cover a broad spectrum of job site application of technology. The research team selected 15 candidate sites in the Southeastern United States, ranging from small to large capital investments ($2 million to $1 billion). The construction sites ranged from having few to many construction workers (15 to 2,000) and varying numbers of pieces of equipment (5 to 250). The type and number of construction sites that were selected for field trials involved small to large building construction (5), small commercial construction (7), large industrial construction (2), and one union ironworker indoor training facility (1).

The field trials focused on the use of radio frequency based real-time proximity warning technology that warns workers and equipment operators when the worker/equipment proximity is too close. Tests in controlled construction environments were performed to measure warning distances of several pieces of equipment to construction workers. Surveys were conducted to record the opinions of workers and equipment operators who had used the devices. Field trials also included the testing of real-time resource location tracking technology. Data were retrieved on the real-time location of up to 50 workers close to several pieces of equipment. Proximity data of construction resources were processed and visualized to inform equipment operators of the presence of obstructions in the vicinity of their machines.

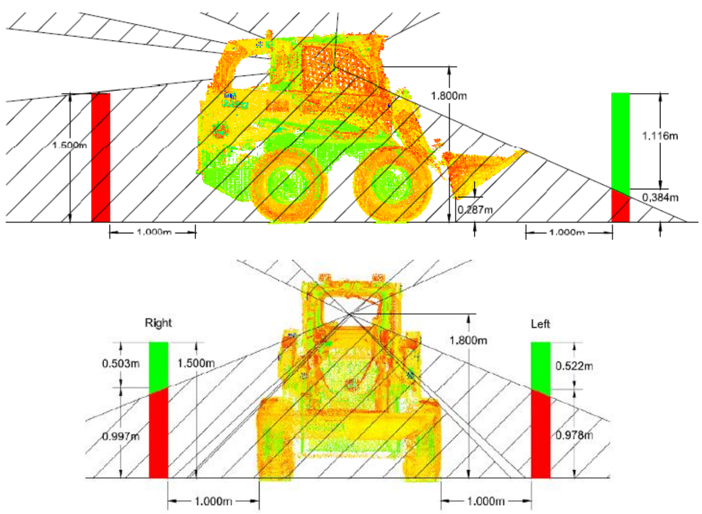
2. How Technology Can Impact Construction Safety

Construction sites are completed by coordinating multiple resources, including personnel, equipment, and materials. These resources are often in motion and can come in close proximity to each other. If not coordinated and organized properly through optimized work planning (schedule and resource leveling), spatial interference can lead to incidents between two or more objects (workforce, equipment, material). These incidents can be characterized as contact collisions that threaten the safety and health of construction personnel. It is further noted in the literature that information on the causation of construction accidents has yet to be thoroughly examined and recorded. Contact collisions between construction workers on the ground and construction equipment are attributed to:

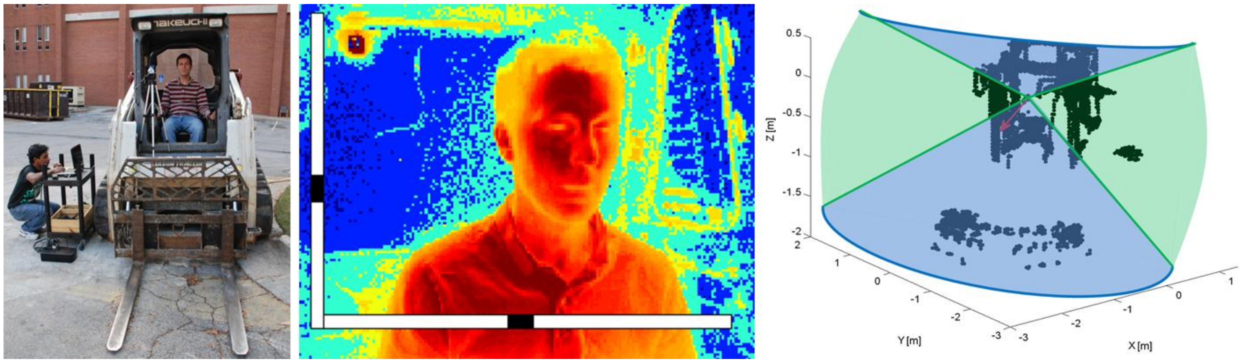
1. Lack of knowledge of existing specific risk factors,
2. A myriad of distracters on the construction site,
3. Lack of real-time data concerning incidents.

Construction companies are slow in adapting automated technologies that have proven to work in other industries. Railroad operations, freight transportation, and the mining industry, for example, have been testing various prototype safety technologies, while the construction industry has been slow in considering these technologies. If these were tested successfully in a construction environment, these emerging technologies could be adapted for application in construction. However, there has been a lack of (scientific) evaluation for new and existing automated safety technology for use in construction. Emerging safety technology needs to be thoroughly evaluated through research using current or newly developed methods, along with case studies and data analysis.

Injury Statistics Related to Workers and Construction Equipment: Findings by the Center for Disease Control (CDC) show that there has been little improvement in preventing workers from being killed through contact collisions with vehicles and/or equipment.



(a) Visibility of a 1.5 meter tall object in front (green: up to 83% visible), rear (red: 100% invisible), and side view (red: up to 65% invisible) (Teizer et al. 2010a, Hinze and Teizer 2011).



(b) Tracking the visibility of equipment operator's utilizing a 3D range camera (left: test bed; middle: automated head pose estimation; operator's range of field-of-view).

Figure 2: Visibility of heavy construction equipment operator and ground worker.

All information was based on after-the-fact data and was recorded after incidents had occurred. Fatality statistics from 1992 through 1998 show that out of the 465 vehicle-related construction fatalities, 318 of the victims were workers-on-foot. Vehicles involved in these struck-by incidents were most commonly a type of truck (60%), followed by large construction equipment (30%). The study reported that 110 of the 465 fatalities involved operators. Of these 110 operator-related fatalities, more than half were construction equipment operators (53%), followed by operators who were driving trucks. The remaining 37 fatality victims were supervisors and other personnel. Of the 465 fatality incidents, the majority of the fatalities (51%) occurred when a vehicle was operated in reverse; an operation that is exacerbated by blind spots that are prevalent on the backside of construction vehicles (Fosbroke 2004, Larue and Giguère 1992). This research conducted measurements of blind spots with a laser scanner (see Figure 2a) and estimated the equipment operator's head pose (see Figure 2b).

Table 1 presents data extracted from OSHA's (Occupational Safety and Health Administration) construction worker fatality database from 1990-2007. These statistics show that for forklifts, skid steer loaders, scrapers and backhoe loaders, 36% to 88% of the fatalities involved workers-on-foot. The most frequently noted causes are crushed-by, struck-by, pinned-by, run-over, and rollovers.

Table 1: Construction worker fatality data from OSHA (1990-2007): Fatality numbers by equipment type and specific incident cause*: Run over, rollover, collisions with another, caught-in/between vehicle, crushed-by, pinned-by, hit-by, and struck-by.

Equipment Type	**(A): Overall fatality number**	**(B): Fatality number related to ***	**(B)/(A) [in %]**	**Top 3 leading causes including ***
Forklifts (incl. ware-houses)	1,021	368	36%	Rollover (22%), Crushed-by 20%), Struck-by (16%)
Skid steer loaders	83	31	37%	Crushed (24%), Struck-by (11%), Pinned-by (2%)
Scrapers	60	37	62%	Run over (49%), Rollover (23%), Crushed-by (6%)
Backhoe loaders	198	175	88%	Crushed-by 34%), Pinned-by (28%),

				Struck-by (26%)

Existing Safety Best Practices and the Role of Technology: OSHA regulations help in establishing construction site safety, but are not sufficient to prevent the occurrence of contact collisions. For example, for applicable conditions OSHA mandates the use of personal protective equipment (PPE), such as hard hats, safety shoes, goggles, face shields, reflective clothing such as safety vests, heavy or thin (leather) gloves, hearing protection, wet weather gear, and respirators or filter masks. These types of PPE are passive safety devices, because they do not (pro-) actively warn or provide feedback to the wearer.

Safety training and education are to be conducted to increase worker/operator ability to recognize and avoid construction hazards. The behavior of individuals on the work-site; however, may change or may be affected by other factors including fatigue and other distractions. Safety training and education is another (important) form of pro-active safety. Nonetheless, it is up to the worker to also follow the rules, guidelines, and best safety practices.
Past research studies of the Construction Industry Institute (CII), e.g. RR101-11 and RR160-11, reported that better safety performances occurred when the behavior of the individuals on a job site was altered or site-specific safety programs were prepared early in the life of a project (CII 2010 and 2011). These studies involved work sampling techniques that require manual analysis and feedback and thus are quite limited in providing real-time feedback during the monitoring period.

The injury pyramid is a common analogy used to depict the relationship of serious injuries to all incidents. Many close calls occur for every minor injury and that many minor injuries occur for every serious injury. The actual numbers are usually estimates and they often vary from one study to the next, but they show why the focus should be on the causes of the less serious incidents. Most safety research has been focused on the upper part of the injury pyramid, but there is merit in focusing on the lower part of the pyramid representing the more numerous minor incidents. Currently, very few firms record statistical data on incidents that do not result in an injury and only a few will record first aid injuries. For example, collecting data on close-calls is a challenge because it requires workers to voluntarily acknowledge that a negative event occurred.

Automation may help to solve or simplify some of the aspects of identifying the potential for close calls. Technological devices that could provide real-time pro-active proximity alerts to warn workers-on-foot when they are too close to construction equipment could help to avoid close calls and accidents. Such information could also be easily stored and automatically retrieved.

Pro-active real-time safety: Pro-active real-time safety is necessary when organizational commitment, supervisory influence, and PPE fail. Providing workers-on-foot and equipment operators with real-time proximity alert devices can help avoid collision events through an early warning mechanism. Different accident causation theories help to explain accident occurrence. One theory is the “domino theory” or the “chain of events theory” that states that accidents are the result of a series of occurrence or actions. Every one of the actions must take place in order for an accident to occur. If one action is changed, the accident is avoided.

A related theory is the human error causation model that states that accidents occur when weaknesses in a series of levels take place. A number of safeguards may be in place to prevent accidents, but if each fails, an accident may still occur. Technology may be added as an additional safeguard to help ensure worker safety. Since zero incidents and zero collateral damage are the project safety objectives, technology-driven safety can assist (but not replace) existing safety best practices.

In summary, the above reasons support a modified human error causation model. Emerging safety technology can be applied at two levels. First, it can serve as a final barrier by giving workers an opportunity to escape serious harm through the use of real-time-proximity-warning devices. Second, the data retrieved from these devices can generate information from previously unrecorded events, such as close-calls. This new information can lead to significant changes in existing organizational safety practices. Effective implementation of technology can help to close up the "holes" in the human error causation model and further decrease the number of incidents on worksites.

Potential for Pro-Active Safety Technologies in Construction Safety: There is a distinct difference between re-active and pro-active safety technology. Re-active technology collects data in real-time, but consists of a post data collection processing effort to convert the data into information. Pro-active technology works in real-time to warn and alert personnel of the dangers occurring at that moment. Example: Almost all technologies have to work reliably in the harsh construction environment, and at the same time, solve constraints that equipment operators and workers-on-foot face during their work day.

Summary of Review

A report by the Center for Disease Control (1997) entitled "Recommendations for Evaluating and Implementing Proximity Warning Systems on Surface Mining Equipment" states that many proximity systems are available, but limitations for each technology exist. Criteria for selecting proximity warning and alert technology is presented in Table 2 along with some key technologies considered for application in the construction industry. Based on the literature search, this research recommends that a proximity warning system evaluation must be conducted on the actual equipment where technology will be installed before any conclusions can be made about reliable detection areas, false alarm rates, or alarm effectiveness. Because every piece of equipment is different, the NIOSH report further notes that "a system that works well on haul trucks may not be suitable for excavators", and the "detection range would [need to] automatically adjust to equipment travel speed".

3. Technology for Field Trials

The primary objective of the field trials was to test pro-active real-time safety technology that increases situational awareness and safety in construction equipment operations. The technology consisted of devices that autonomously provided wireless pro-active real-time warnings and alerts when two or more construction resources (workers and equipment) were in too close proximity (EV-Alert 2008, Motorola and 3D-P 2009, OrbitComs 2010, Protran1 2008, Pratt et al 2001, Ruff 2007 and 2010, Schiffbauer 2001, Schiffbauer and Mowrey 2008, Teizer et al. 2010b). Sensing technology can assist workers-on-foot and equipment operators in detecting the relative proximity to each other. When their proximity to each other is too close, visual, audio, and vibration alerts activate and warn both personnel on the ground and those operating the equipment. The devices, known as equipment and personal protection units (EPU and PPU, respectively) were deployed on workers and equipment and field tested on small, medium, and large jobsites.

The system employed in this research used a special secure wireless communication line of Very High Frequency (VHF) active Radio Frequency (RF) technology near 700 MHz. This consisted of an in-cab device and a personal device. The in-cab device was equipped with a single antenna, reader, and alarm; called the Equipment Protection Unit (EPU). The personal device consisted of a chip, battery, and alarm; called the Personal Protection Unit (PPU). The term “personal” was used because subsequent interviews revealed that workers like to identify themselves with the safety devices (they like to “own it”).

Although the user can define the signal strength of the EPU unit for each piece of equipment, the signal is typically transmitted in a radial manner, and loses strength with distance from the EPU. Setting the signal strength is carefully performed for each EPU prior to its use. The PPU then intercepts the signal at a user-adjustable distance and once this occurs the PPU automatically returns the signal such that both systems trigger their internal alarms. The operation of sending and receiving information is instantaneous; the whole process occurs in real-time. Figure 3 displays the EPU/PPU technology in field trial mode.

Table 2. Sample criteria for selecting proximity warning and alert technology.

Technology / Criteria		Radio Frequency		Optical		
	Ultrasound	**Ultra-High Frequency (UHF)**	**Very-High Frequency (VHF)**	**(Stereo) /Video**	**Eye-safe Laser (1D/2D/3D)**	**Infrared**
Objective	Distance	Proximity	Proximity	Proximity/Distance	Location	Proximity
Range [m]	0-10	0-40	0-500	0-500	0-50	0-30
Accuracy of data	Low	Medium	Low/Medium	Medium	Medium/High	Low
Signal bounce	High	Small	Medium/High	Small	Small	Medium
Data processing effort	Small	Small	Small	Small/High	Small/High	Small
Secure signal	Noise	Yes	Yes	No	No	No
Day vs. Night	Very Good	Very Good	Very Good	Poor	Very Good	Fair/Good
Signal update rate	High	High	High	High	High	High
Size and weight	Small	Small	Small	Small	Medium	Small
Installation/Maintenance	Small/Medium	Small/Medium	Small/Medium	Small/Medium	Small/Medium	Small/Medium
Purchase Cost	Small	Small	Small	Small	Medium	Small
Main barriers	Short range, noise	Proximity	Omni dir., proximity	Line-of-sight, segmentation	Line-of-sight, segmentation	Line-of-sight, noise

Main benefits	Inexpensive	Works in metal areas	Long range	Location, Range	Location	Inexpensive

Figure 3: Alert types for workers-on-foot and equipment operators: a vehicle approaching a motor grader issues alerts inside both equipment cabins.

Methodology of Field Trials: The warning and alert technology was scientifically evaluated through an experimental plan. Testing was performed with the proximity warning devices on different pieces of construction equipment including personnel movers, wheel loaders, forklifts, graders, forklifts, dozers, excavators, articulated dump trucks, and mobile cranes. Each piece of equipment was then directed to travel towards a simulated work crew. The operator was then asked to stop the machine once the audible or visual alert activated within the equipment cabin. The distance between work crew and equipment was measured, recorded, and analyzed. For each test, the worker-on-foot and equipment operator were interviewed. Testing was also performed over extended time periods and workers and operators were asked about the effectiveness of the devices over longer test periods.

The PPUs are durable and wearable since they come in different sizes. For a typical PPU, the casing is sturdy and can stand up to the daily weathering that occurs on construction sites. The devices are powered with conventional AA batteries and last for at least two months depending on the frequency of alerts. Light-emitting-diodes (LEDs) indicate when batteries are low on power and need to be recharged. The audible alarm that occurs on both the EPU and PPU is of sufficient strength to get the attention of workers and operators. The alarm emits a different sound than any other sound that is common on construction sites. The PPU also has a vibrating alarm so that workers can be notified even if wearing hearing protection or when working in an area with loud construction noises. Vibration alerts have the drawback of not working well when workers wear heavy coats in cold weather.

Field Trials and Results to Proximity Warning and Alert Device: Figure 3 shows a warning and alert system during a field trial involving two pieces of equipment. When the vehicles got in close proximity to each other, the visual and audible alarms alerted both. The EPU is compact and can fit into an equipment cab without creating any visual or mechanical obstruction. The PPU can be worn on the belt of the worker or around the arm with an arm band. Five PPUs of the same configuration were tested in the preliminary field trials. Since each equipment type may require its own unique signal strength, setting the warning and alert distances at a lower level reduces the number of nuisance alerts. The shortest empirical warning and alert distance from EPU to PPU was 2.80 m (see excavator, Table 3). Cranes, for example, are static, and alerts may only be needed when a lift is performed. The operator would be able to activate the EPU/PPU alert system only during lifts. In contrast, scrapers can travel with significant speeds (up to 60 km/h) and thus may require activate alerts earlier and at further distances to ensure the safety of workers close by. All distance measurements included the operator's reaction time and the distance required to stop the vehicle.

Table 3: Distance measurements on pro-active real-time proximity alert device with static (*) and dynamic construction equipment in realistic construction environments (with obstructions present).

Equipment Type	Number of Trials	Average Recorded Alert Distance [m]	Minimum Recorded Alert Distance [m]	Maximum Recorded Alert Distance [m]	σ [m]
Personnel Mover	4	11.9	10.6	13.6	1.4
Loader/Forklift	11	17.8	12.7	29.9	6.1
Grader and Scraper	10	31.5	25.5	50.2	7.6
Dozer*	8	24.5	7.8	43.0	8.5
Excavator*	8	23.4	2.8	38.0	10.6
Art. Dump Truck*	72	35.6	19.0	50.0	7.4
Mobile Crane*	80	34.0	8.9	62.5	16.0

The results of a machine in static position are illustrated in Figure 9. The jagged circular shape illustrates the alert zone around an articulated dump truck. The average alert distance was 35.6 meters. Table 3 lists the results to a total of 193 tests of other pieces of equipment at 15 different construction locations.

4. SmartHat: Self-Monitoring, Analysis, and Reporting Technology for Hazard Avoidance and Training

Radio frequency identification (RFID) technology was initially conceived around the notion of transferring only a unique ID (UID) or a small amount of on-chip memory from a tag to a reader. In particular, low-cost passive UHF "smart label" transponders, including those based on EPC Global's Generation 2 specification, need to derive all tag operating power from an incoming reader RF carrier. This results in a drive toward IC simplicity and low power CMOS design techniques. Minimizing tag IC complexity and on-chip clock frequencies results in lower tag operating power, which is crucial for maximizing read range in a power-limited passive UHF RFID system. At the same time, simplifying the tag design results in a smaller tag die, more tag die on a given wafer and improved yield, and thus lower overall tag cost.

As passive UHF RFID technology has matured, many new application scenarios have been proposed where a tag is expected to transmit ever-increasing amounts of data. These scenarios include tags with expanded on-chip memory of 128KB or more, tags including complex cryptographic security protocols, or tags that transfer stored sensor data in a semi-passive mode.

As seen in Figure 4, a new prototype SmartHat warning/alert device was designed. Testing of multiple SmartHat devices in harsh construction environments have resulted in warning and alert distances of up to 16 m. Further tests are pending and results are expected that ultimately demonstrate that a SmartHat device has the potential to work under harsh conditions, at highest reliability factor, and at low economical cost. Although not part of this research project, the goal is to transfer this technology into the field and make it become a best practice in construction safety.

Figure 4: SmartHat tag in field application.

5. Conclusions and Recommendations

Various applications areas for real-time pro-active safety technology exist that have the potential to significantly reduce hazards in high risk construction or maintenance work. The purpose of this research was to develop a framework that accounts for static (from equipment frame) and dynamic (from limited operator visibility) blind spots during equipment operation by implementing real-time wireless proximity detection and alert devices.

Real-time pro-active warning and alert devices proved to be effective in bolstering the safety environment on construction sites. Current safety practices are not sufficient in prevent every worker fatally, especially when workers are in close proximity to heavy equipment. The devices can detect the presence of tagged resources (workers, equipment, materials). The warning and alert devices were successfully tested in realistic construction environments on a wheel loader, forklift, scraper, dozer, excavator, motor grader, personnel mover, articulated dump truck, crane, and pick-up truck. When working in a construction environment, the personal protection unit (PPU) and equipment protection unit (EPU) were both effective at alerting personnel of the danger through auditory, visual, and vibrating alarms even when surrounded by other construction noise. These devices have the capability of recording safety data, making currently unrecorded data on close-calls (near misses) available. These data can then be analyzed and used to improve the positioning of workers and equipment and assist in the development of new safety concepts and training.

It is difficult to put a price tag on a person's life. Medical and insurance costs, time lost due to accidents, and lawsuits must be taken into consideration to justify any investment in safety. The key research findings are listed and require each detailed investigation:

- Project scope and complexity determine the level of technology use. Early decision making and involvement of all project stakeholders is of importance for successful implementation.
- A spectrum of choices rather than a single or all-or-nothing alternative exists. Proximity warning, alert, tracking and monitoring, remote real-time data visualization and other advanced are few of many useful technologies.
- The selection and use of real-time pro-active technology requires involvement of technology literate project participants. Personnel with safety and advanced technology expertise can link form and degree of real-time pro-active safety early on in the project.
- Worker involvement early in the process is a key factor in adopting technology. Companies must evaluate and implement the input of personnel into decision making for technology. Emphasis must be on explaining the purpose of technology. Workers are generally open to adapt technology.
- Successful implementation depends on overcoming a lack of industry awareness and knowledge of benefits and opportunities offered by real-time pro-active technologies. Demonstrations of providers to companies may be carefully evaluated on benefits, limitations, and promises.
- Adequate testing of technology in site environments plays a critical role for successful site implementation. Advanced technology may require initial analysis to optimize its field implementation. Extensive pre-planning and discussions are essential to meet optimal performance.
- Pro-active real-time safety technology advances multiple project levels: It primarily enhances existing safety management practices and other project goals. It provides warnings and alerts for workers/operators close to heavy equipment; it improves communication and recording of previously unreported incidents; it advances overall site safety and progress tracking methodologies; and/or it uses data visualization for advanced decision making and learning. Some technology that is used for safety can also be leveraged for multiple other project goals, such as productivity or site security control.

While field trials with the devices turned out to be successful, it is noted that several parameters can influence signal propagation in the construction environment. Some of these influencing factors include ambient temperature, relative humidity; mounting position and orientation of the devices on workers and equipment, obstacles (metal or wooden) in the construction field, multipath effects during signal transmission, reaction of workers, etc. These and other barriers require further investigation.

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Real-time Automated Construction Worker Location Tracking for Spatio-Temporal Safety Analysis and Feedback

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Abstract

Emerging sensing technologies offer significant potential to advance the construction safety by providing real-time access to the locations of workers, materials, and equipment. Unfortunately, little is known regarding the accuracy, reliability, and practical benefits of such emerging technology, effectively impeding widespread adoption. This paper evaluates a commercially-available Ultra Wideband (UWB) system for real-time, mobile resource location tracking in construction environments. A focus of this paper is to evaluate the performance of technology for tracking mobile resources in real-world construction settings. The paper provides case studies of resource tracking for analysis of safety worksite operations and demonstrates its applicability for the design of construction safety management support tools.

Keywords: 3D, location tracking, proximity, safety, sensing and safety technology, visualization, workers.

1. Introduction

The dynamic nature of construction activities, in comparison to the manufacturing industry and its mostly stationary fabrication plants and assembly environments, presents a significant challenge towards realizing the goal of understanding construction site activities. Hindering this understanding is the fact that production control protocols in the construction industry are labor intensive, manual, and error prone (Navon and Berkovich, 2006). Recent developments in remote sensing and automated data acquisition technology promise to improve upon existing material management strategies (Song, et al., 2006, 2007; Akinci et al., 2008; Grau, et al., 2009). Similar benefits are anticipated for process management strategies.

To date, many barriers exist that prevent owners and contractors from deploying data acquisition technology in construction. These include – but are not limited to – the risk of failure during the initial implementation phase and the high cost of implementation. When these risks are combined with the lack of demonstrated benefits, adoption of emerging technology can be non-existent. The penetration of emerging technology is thus limited to scattered implementations in various engineering subfields until more precise cost-benefit valuations are determined (Bohn et al., 2010). It is therefore highly imperative to understand the benefits of promising real-time location tracking technology so as to increase adoption and to advance production control procedures in the construction industry. Two key areas closely tied to the economics of construction projects are productivity and safety (Tuchman, 2009); lapses in both are responsible for significant losses in the construction industry.

With regards to productivity, one key area identified as a critical need is the localization and tracking of assets that are linked to work tasks, including workforce, equipment, and materials (Lundberg and Beliveau, 1989; Goodrum et al., 2010). For example, material handling and transport has been identified as a critical work task in construction (Nasir et al., 2010). Recent studies report significant amounts of time spent on materials searches in lay down yards (CII, 2010). The material flow for a steel erection process at industrial job sites may involve the delivery of the material component from the fabrication plant to a temporary lay down yard. A lay down yard is an important temporal space in the assembly process of material components, as it allows for storing and sorting the components in the correct order, and provides a healthy temporal buffer to ensure parts availability when needed. Prior research has shown that the current process of material handling on large industrial job sites is inefficient (Navon and Sacks, 2006).

Within the context of safety, significant time and economic resources are lost when workers are injured or killed by loads during work tasks (Teizer et al., 2010; Hinze and Teizer, 2011). Current construction best practices in material handling prescribe the foremen to blow a whistle or the equipment operator to activate the horn of a crane at the beginning of a material lift. Such manually activated signals are effective in alerting the surrounding workers to pay attention to where the load is swinging. Many workers or crane operators have difficulty, though, in relating their own location to the position of the load. Incorrect spatial awareness could lead to accidental injury. The importance of spatial awareness is emphasized by the fact that 25% of all construction fatalities relate to the unsafe proximity of ground workers and equipment (Teizer et al., 2009).

To more concretely understand worker behavior and activities for improving the understanding of construction site operations, it is necessary to analyze observations of construction work in progress. For example, one way of improving current work practices is by observing work tasks and generating manual evaluations. This practice is commonly known as ‘work sampling’ (Borcherding, 1976; Wang et al., 2009; and CII 2010). Any technology that can reliably, accurately, and automatically record the location of construction resources for work sampling could significantly simplify previously conducted manual assessments and improve confidence in the measurements. Likewise, technological systems that track project critical resources (e.g., people, equipment, material) and provide information on resource utilization can enhance current work practices. Such systems are popular in robotics and telecommunications by the name of *context aware systems*. The existence of a context aware system in construction that tracks the location of construction resources, and identifies and measures the status of work tasks, would improve project performance (Navon and Goldschmidt, 2003, and Eastman and Sacks, 2008).

Wireless, non-destructive, and reflector-less sensor technologies applied to construction have been identified as key breakthroughs (Nasir et al., 2010) for both construction practitioners and researchers in terms of reducing non-value-added activities, responding quickly to safety hazards, and automating and rapidly generating as-built and project documentation. In both cases, technological adoption is lagging due to uncertain benefits. Further investigation and control is needed to improve on these fronts.

This paper presents research findings on the evaluation of a commercially-available Ultra Wideband (UWB) system, which is a radio-frequency based real-time location tracking technology, in several harsh construction environments. The error rate of the real-time location tracking technology is measured and evaluated. Results of experimental field validation studies are presented in context to safety, along with technology application scenarios analyzing the field data.

2. Remote Construction Resource Location Tracking

Arguments in favor of using automated remote tracking technology in construction are to increase tracking efficiency, to reduce errors caused by human transcription, and to reduce labor costs. A variety of sensors and sensing technologies with automated tracking capabilities are available for use in construction and infrastructure projects (Akinci, 2008). Selection of one particular technology depends on the application, the line-of-sight (LOS) access between sensors and sensed objects, the required signal strength, the data provided, and the calibration requirements. Moreover, the prevailing legal framework regarding the permitted bandwidth and associated availability, and the implementation costs associated with each technology add further constraints (Teizer et al., 2007 and 2010; Cho et al., 2010). These characteristics must be weighed against the benefits provided.

Although any of the previously offered tracking principles and their associated data gathering devices could be selected to monitor the trajectories of construction resources, few studies have focused on evaluating technology that is capable of simultaneously monitoring multiple, mobile resources at high data collection rates. To be of interest to the construction industry, the tracking technology should meet as many of the criteria listed below:

- Cost and maintenance: Low implementation and maintenance cost, while rugged enough to withstand a harsh environment and project lengths of up to several years;
- Device form factor: Small enough to fit on any asset (as needed) without interrupting the completion of work objectives;
- Scalability: Robust in a variety of site layouts (open, closed, and/or cluttered space(s), and small to large spaces);
- Reliability: Capable of accurately and precisely recording the activities that are associated to monitored work tasks;
- Data update rate: High data frequency provided in real-time (greater or equal 1 Hz); and
- Social impact: Less invasive technology, but providing highest possible safety and security standards for all project stakeholders while at work (in particular

workers that face risks directly).

Existing UWB research in construction applications has focused on evaluating real-time resource location tracking of workers, equipment, and materials in outdoor and indoor environments (Teizer, 2007, 2010, Cho, et.al., 2010, Saidi, et al., 2010; Fontana et al., 2002) and first responder tracking applications (Khoury and Kamat, 2009). Recent research has shown the use of UWB in construction potentially offers a solution to the above requirements. Compared to other technologies like RFID or ultrasound, UWB has shown to possess unique advantages including: longer range, higher measurement rate, improved measurement accuracy, and immunity to interference from rain, fog, or clutter. This study focuses on the performance capabilities of UWB in real world settings while also demonstrating the operations analysis possible with UWB track signals from multiple project entities.

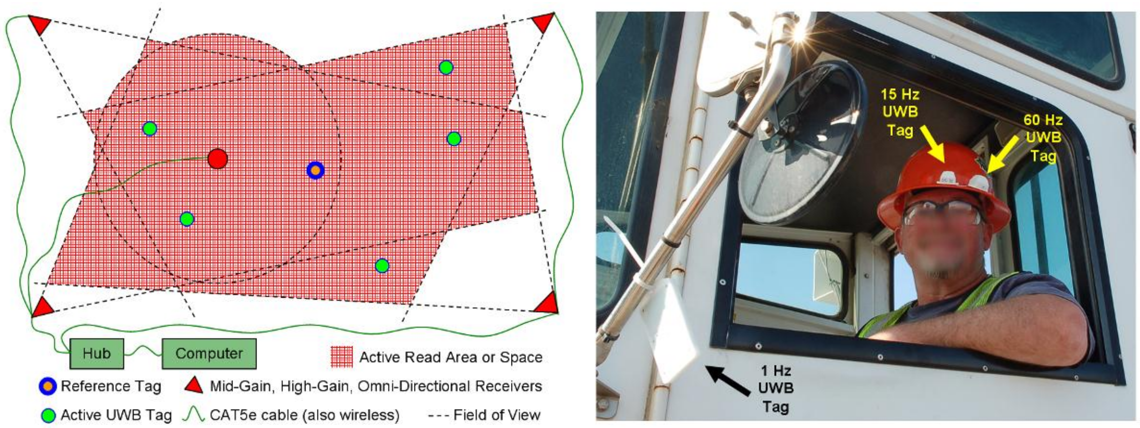


Figure 1: Triangulation of UWB tags using UWB receivers that overlap the coverage area/space and application to construction assets (yard dog and construction worker) inside a lay down yard.

3. Objectives and Scope

The goal of this research is to evaluate the performance of a commercially-available Ultra Wideband (UWB) system when used for assessing the safety aspect of work tasks that occur frequently on construction and infrastructure sites. The first objective is to measure the performance of the real-time tracking technology for mobile resources in realistic job sites. The second objective is to illustrate safety monitoring work tasks that would benefit from such real-time location data. Both research objectives include technology performance testing in live construction environments. The environments were a large and relatively flat lay down yard for handling large pieces of steel material and a construction pit that was classified as a confined space by construction safety professionals. Both had multiple workers, pieces of equipment, material, and other obstructions present at the time of the experiments. Typical scenarios that were observed included heavy construction equipment operating in close proximity to workers. This paper does not address the social, legal, or behavioral impacts on workers using UWB technology, the sensor node layout and its effect on measurements, nor the comparison of commercially-available UWB systems.

4. Methodology

This research utilized a commercially-available UWB localization system consisting of a central processing unit, called the hub, which triangulates the positions of incoming Time-Distance-of-Arrival (TDoA) streams from multiple UWB receivers deployed in the construction environment. The UWB signal receivers connect to the hub via shielded CAT5e cables. The TDoA streams originate from actively signaling UWB tags, which are attached to construction resources of interest (worker, equipment, material). In addition, the UWB system requires the placement of a static reference tag in the scene to improve the position measurements of UWB tags. A typical UWB setup and installation with tags on construction assets, including workers, equipment, and materials, is shown in Figure 1. More details to the experimental setup can be found in (Cheng et al., 2010). The methodology to evaluate the performance of UWB technology in live construction environments included the following tasks:

1. Coordinate field trial with field personnel and construction schedule prior to test day and identify test location.
2. Perform a laser scan of test site to capture existing as-built conditions.
3. Install UWB receivers to cover maximum observation space.
4. Utilize a total station to measure the receiver locations and register them.
5. Attach 1 Hz, 15 Hz, 30 Hz, or 60 Hz UWB tags on assets, e.g., workers, equipment, and materials.
6. Utilize Robotic Total Station (RTS) to measure the ground truth location of assets.
7. Gather real-time UWB and RTS location data.
8. Visualize the information in real-time using a 2D user interface.
9. Use data in post-processing analysis, e.g., for error and proximity analysis.

5. Evaluation of Ultra Wideband Data Error

This section describes the procedure followed to assess UWB tracking performance. The default data output stream provided by the UWB system consists of data packets of three types which are differentiated by their packet headers: position data associated to a sensed tag, status information regarding the receivers, and reference tag information. The data packet associated to tag position data is of the form:

<Data Header>,<TagID>,<X>,<Y>,<Z>,<Battery Power>,<Timestamp>,<Unit>,<DQI>

Each position data packet represents a triangulated position from an unique tag identification (ID). In addition to the tag identification number and the time-stamped spatial data (x, y, z, t) for the UWB tag, the UWB system (a Sapphire DART, Model H651) collects additional status information regarding the tag. Status information includes the battery power level, a message unit, and a Data Quality Indicator (DQI). Sample data and its corresponding path are illustrated in Figure 2. The data header "T" of each row means that two-dimensional data is collected. The time stamp is in the UNIX timestamp format. The tag, whose ID is 00005856, has variable X and Y coordinates, and a fixed Z coordinate. The battery level is 13 out of 14 (14 means full). In general, low DQI value means higher data quality.

Since the UWB signal are noisy with occasional outliers, the UWB signal was filtered with a Robust Kalman filter (Durovic and Kovacevic, 2009). In addition to signal smoothing, the robust Kalman filter rejects outlier measurements so that the outliers do not corrupt the filtered signal estimate. Further details to the method of signal synchronization and error analysis can be found in (Saidi et al., 2010).

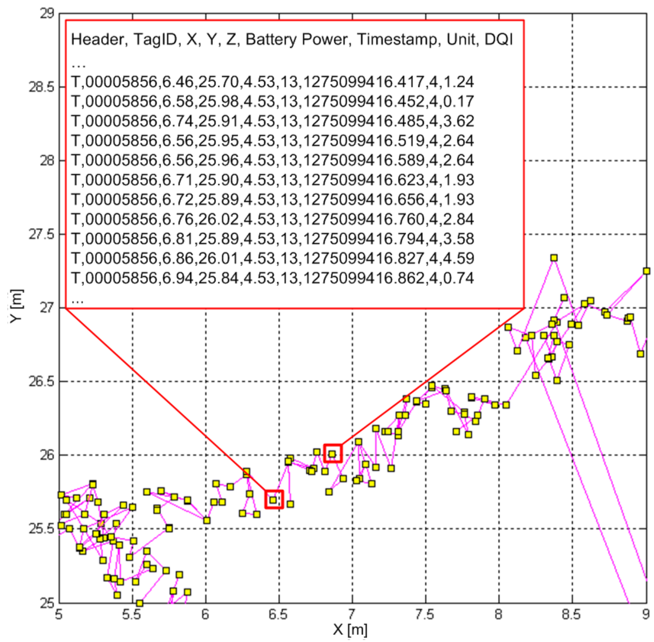


Figure 2: Sample and format of raw UWB data.

6. Experiments and Results

This section consists of four major subsections. The first details the experiments performed and their overall characteristics. The second collects the experimental data and examines the expected error rates of UWB when deployed for real-time tracking. The last two demonstrate practical benefits of having the real-time UWB track data for analysis. In particular, the coordinated activities of workers moving a load are assessed from a safety perspective.

Description of the Experimental Environments

There were a total of three experimental environments, one controlled and two real-world construction areas. The controlled area was an open field. The two construction areas were located on a large industrial job site (see Figure 3). They were a construction pit (classified as a confined space by construction safety professionals) and a lay down yard for temporarily placing steel materials. To understand resource flow visually and connect the trajectories to their surrounding environment, a commercially-available laser scanner gathered the three-dimensional (3D) point cloud and a camera documented the as-built conditions prior to the experiments. The focus of data capturing was on recording resource location from naturally occurring work tasks in harsh (i.e., resource rich, spatially challenging, object cluttered, metal) construction environments.

Figure 3: Layout of experiments: Construction pit (left), lay down yard (middle), and UWB tag and RTS prism on helmet (right).

Open Field. In order to provide a more complete picture of the tracking performance characteristics associated to UWB as a function of the site diameter, several controlled experiments were conducted in an open field. Four UWB receivers were placed in a square configuration. Within the primary sensing zone (where there were at least three receivers within the field-of-view), a person equipped with UWB tags and an RTS prism (all helmet mounted), was tasked to walk in a rectangular pattern. The same experiment was repeated for four UWB receiver diameters (20, 40, 60, and 70 meters). The trajectory of the person was scaled accordingly with the receiver configuration diameter (the *diameter* is the maximum pair wise distance between two installed receivers when considering all possible receiver pairings). Unlike industrial site environments, the open field provides the ideal environment for UWB sensing as there were no obstructions.

Construction Pit. This experiment was conducted in a confined work area of approximately 2400 m^2. The registered 3D point cloud of the as-built conditions at the time of the experiment can be seen in Figure 4. The red triangles represent the location and orientation of the UWB receivers (short edges indicate the direction), while the green circle represents the location of the static reference tag. UWB trajectory data for a few of the tracked resources are overlaid in the image. Of note, two access points (ramps for equipment and workers) allowed entry into the confined space. The south side of the pit was specified as a confined space (a 20 meter long, three meter wide, and five meter high space, with unstable walls and a repose angle of greater than 45°).

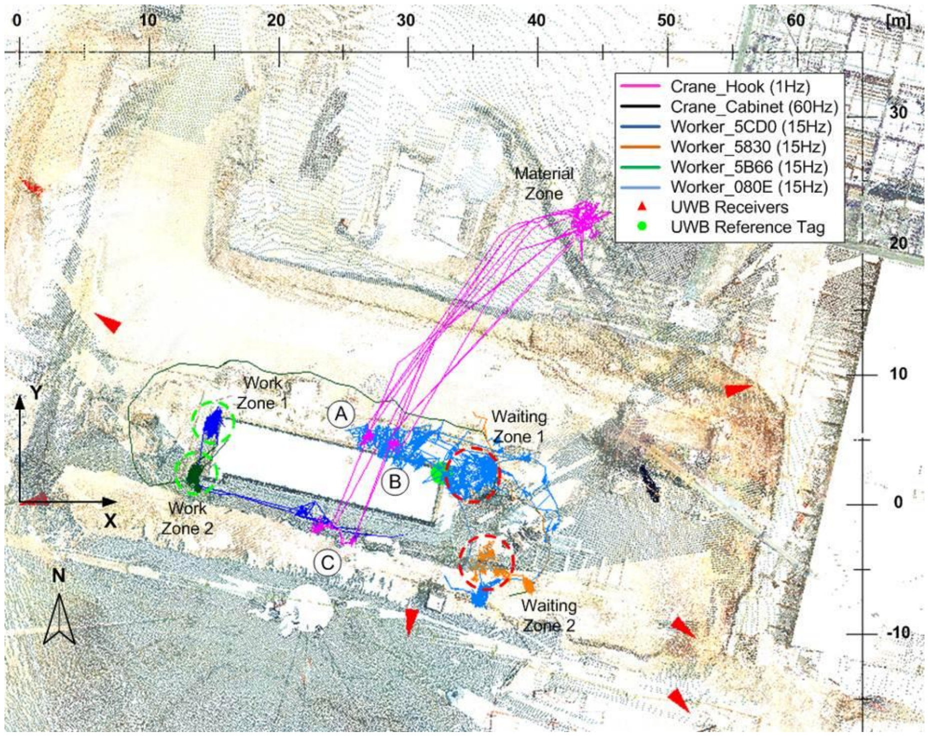


Figure 4: Plan view of construction pit: UWB resource trajectory data mapped on the registered range point cloud from a 3D laser scanner.

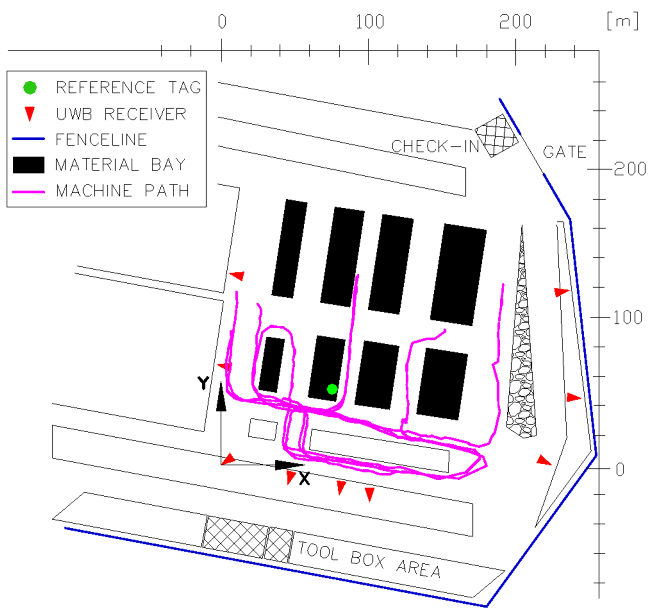
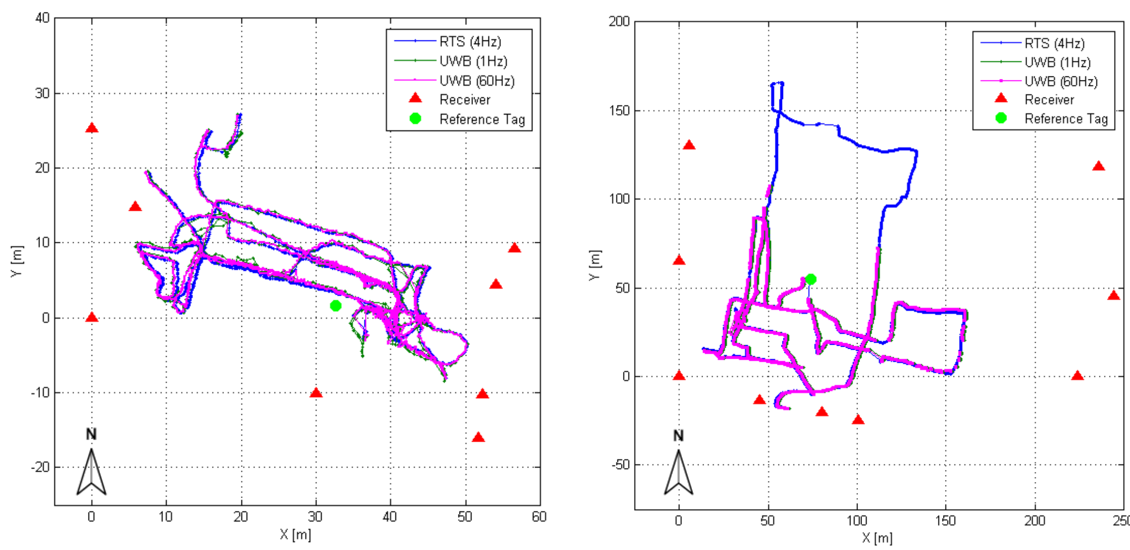


Figure 5: Lay down yard with overlaid sample of the UWB trajectory data of a yard dog (a construction vehicle to transport material).

The work crew consisted of several workers (six carpenters, ten rod busters, eight form workers, 2 foremen, and one crane operator) and equipment (one mobile crane, one tractor and two material hauling trailers). Although location data of the entire crew was collected, the following observations include (for illustration purposes) data to one carpenter erecting formwork, two rod busters tying rebar, one foreman supervising, and crane operator hoisting materials with the crane. The work task of the day was to erect formwork and rebar to all sides of a four meter tall rectangular reinforced concrete structure (close to the center of the excavated pit). Although the work activities and locations of resources were recorded for the entire work day, only a sample (43 minutes and 22 seconds) of the entire UWB data set will be analyzed. The data sample includes events linked to the crane unloading rebar into the pit.

Lay Down Yard. The second field trial environment included monitoring resource locations in a large lay down yard which had significant quantities of metal steel pipe and girder objects present. The size of the lay down yard and available UWB receivers limited the observation area to approximately 65000 m^2. The major material bays comprised mostly of custom fabricated steel pieces, which were well laid out for workers and equipment to move around. At the time of the experiment, equipment and ground workers had only one access point available to the yard and one tool and restroom area. Nine UWB receivers were set up at the boundaries (fences) of the lay down yard. A reference tag (green circle) in the line-of-sight of all receivers was placed on a 2.5 m high pole overlooking all steel materials. The location of important control points such as material bays, fence, road, and other installments in the lay down area were recorded using the RTS. These measurements were used to develop an approximated plan view of the lay down yard. The plan view of the lay down yard, access gate, work and tool box areas, and other facilities, including the UWB receiver locations (red triangles) are illustrated in Figure 5. The dark areas are the material bays where material was frequently placed or picked up. A 34 minute subset of the data was elected for analysis.



(a) Construction pit. (b) Lay down yard.

Figure 6. Synchronized UWB and RTS trajectories.

Tracking Performance Analysis of Ultra Wide Band

This section analyzes the error between the ground truth RTS signal and the UWB signal. We must first acknowledge that different tasks require different levels of accuracy. For the tasks being examined here, high fidelity (on the order of centimeters or millimeters) is not necessary. What is essential is that personnel utilizing the track data can effectively use it for analysis and operations purposes. With this in mind, an opinion based worker survey was taken. For materials discovery in large lay down yards, those surveyed identified the ability to “quickly locate materials within a two meter radii” would assist in the efficiency of their work. This is consistent with other research indicating that meter accuracy is sufficient for the majority of work tasks (Song et al., 2007; Grau et al., 2009).

Performance in the Construction Pit. The track signals of a worker fitted with a 60 Hz UWB tag and the RTS prism are plotted in Figure 6(a). The observation period collected 603 synchronized samples for the 1 Hz tag and 2654 synchronized samples for the 60 Hz tag. The average error of the 1 Hz tag was 0.48 m for raw data and 0.41 m for the filtered data. The average error of the 60 Hz tag was 0.36 m for raw data, and 0.34 m for the filtered data. The low average error coupled with a standard deviation of 0.35m/0.20 m for 1 Hz/60 Hz, respectively, means that real-time location tracking utilizing UWB technology in similar construction environments is feasible.

Performance in the Lay Down Yard. The track signals of a worker fitted with 1 Hz and 60 Hz tags, and he RTS prism are plotted in Figure 6(b). The observation period led to 1023 synchronized samples for the 1 Hz UWB tag and 4370 synchronized samples for the 60 Hz UWB tag. The average error of the 1 Hz tag was 1.82 m for raw data, and 1.26 m for the filtered data. The average error of the 60 Hz tag was 1.64 m for raw data, and 1.23 m for the filtered data. In this experiment, the larger covered area required to separate the UWB receiver distances to the upper limits of the suggested receiver configurations for some of the receiver pairings. Given that the error rates were within the suggested range for locating materials, and low standard deviations of 0.72 m/0.66 m for 1 Hz/60 Hz, respectively, UWB localization technology in large, open, outdoor areas is feasible.

Safety Analysis in the Construction Pit

Since 25% of all construction fatalities relate to too close proximity of pedestrian workers to equipment (Teizer et al., 2009, 2010), a particular emphasis in the experiment was to study the interaction of workers with equipment. To demonstrate how UWB tracking could assist, consider one of the hoisting operations. The last of the three hoists (“A”, “B”, and “C”) is associated with the drop-off zone labeled by a “C” in Figure 7. The rebar load was attached to the hook of the mobile crane at “C1”, in Figure 11. The crane and its attached load started swinging toward the drop location “C3” at timestamp 108 (seconds) and arrived at timestamp 267 (seconds). Detaching the load from the crane hook took the worker (5CD0) 224 seconds before the crane swung back to its original load location “C1”. This one material delivery cycle lasted approximately 10 minutes.

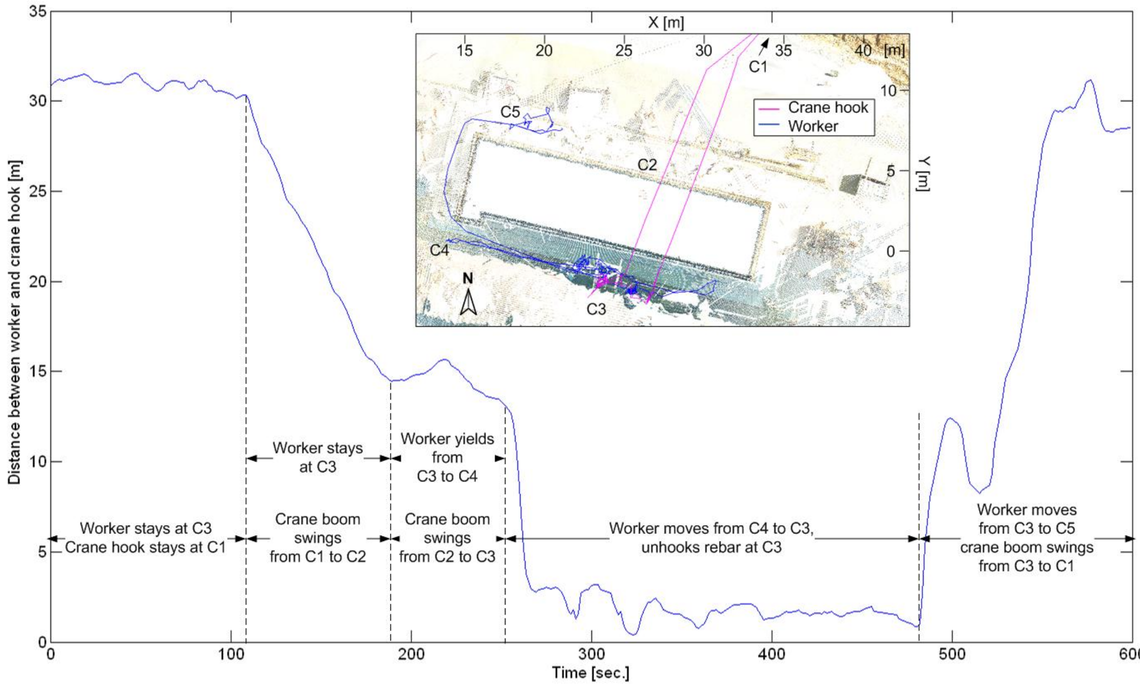


Figure 7: In-depth look at worker-crane interaction (distances) during a material hoist.

A spatio-temporal analysis of the worker assisting the process provides clues into the worker's behavior. For safety purposes, the worker should maintain a safe distance from the moving load until it has been safely lowered. While the crane boom was swinging, the worker (5CD0) originally occupied the drop location "C". As the crane was swinging toward him, the worker-to-crane hook distance decreased continuously from over 30 meters to 13.4 meters. Being warned by the horn of the crane and realizing the load was getting closer to the worker, he stepped outside the potential path of the crane load and moved temporarily to "C4". As shown in Figure 7, a safe distance of about 14 meters was maintained between the worker and the crane hook. As soon as the crane stopped swinging, the worker approached the load to unhook it from the crane. The worker-to-crane hook distance then dropped to less than three meters. After completion, the crane swung back using path "C2" and the worker moved to another work location "C5".

7. Conclusions

Rapid technological advances have made it possible to implement Ultra Wideband (UWB) real-time localization and tracking systems in construction applications. While possible, the capabilities and benefits of UWB deployment require further study, which is the aim of this investigation. This paper demonstrated in field trials, that a commercially-available location tracking system (UWB) is able to provide real-time location data of construction resources thereby resolving the capability question. Validation occurred through performance measurements utilizing a Robotic Total Station (RTS) for ground truth measurements.

Aside from being able to collect reliable spatio-temporal data from job sites, it is also highly imperative to understand the benefits of promising real-time location tracking technology so as to increase adoption and advance production control procedures in the construction industry. The safety application demonstrates the benefits of applying location tracking data for better documenting, analyzing, understanding, and correcting best safety practices as they are executed in the field. In this particular case, successfully computing the distance between two dynamic construction resources (worker and crane hook) allows analyzing for too-close proximity of resources, and eventually preventing struck-by incidents (Teizer, 2010).

In summary, UWB technology in large open space construction environments achieves sufficient accuracy as to be practical for many open environment construction application areas. Overall, the presented work showed that real-time location tracking has potential construction applications in assisting the safety management of job sites and other areas requiring monitoring and control.

Acknowledgements

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Integrating BIM and Safety: An Automated Rule-Based Checking System for Safety Planning and Simulation

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Integrating BIM and Safety: An Automated Rule-Based Checking System for Safety Planning and Simulation

Abstract

Safety planning in the construction industry is generally done separately from the project execution planning. This separation creates difficulties for safety engineers to analyze what, when, why and where safety measures are needed for preventing accidents. Lack of information and integration of available data (safety plan, project schedule, 2D project drawings) during the planning stage often results in scheduling work activities with overlapping space needs that then can create hazardous conditions, for example, work above other crew. These space requirements are time dependent and often neglected due to the manual effort that is required to handle the data. Representation of project-specific activity space requirements in 4D models hardly happen along with schedule and work break-down structure. Even with full cooperation of all related stakeholders, current safety planning and execution still largely depends on manual observation and past experiences. The traditional manual observation is inefficient, error-prone, and the observed result can be easily effected by subjective judgments. This paper will demonstrate the development of an automated safety code checking tool for Building Information Modeling (BIM), work breakdown structure, and project schedules in conjunction with safety criteria to reduce the potential for accidents on construction projects. The automated safety compliance rule checker code builds on existing applications for building code compliance checking, structural analysis, and constructability analysis etc. and also the advances in 4D simulations for scheduling. Preliminary results demonstrate a computer-based automated tool can assist in safety planning and execution of projects on a day to day basis.

Keywords: Building Information Modeling, Prevention through Design, Planning, Rule Checking, Safety, Simulation.

1. Introduction

Problems in Safety Planning, Design, and Execution

It is widely recognized that the construction industry is still different than most other industries in regards to customization, on-site fabrication or assembly, and number of trades present to execute work tasks. Some practitioners even claim that construction sites are often under resourced and under planned (Egan, 1998). The utilization of and collaboration among staff, for example, is often key in operating a site effectively. Any tool or practice that can make work tasks easier, will be helpful in reducing errors and waste (time, cost), and ultimately lead to better process and work flow efficiencies.

A key for successful projects in all industries is safety. As good safety practices and records can create a positive, pro-active, hazard free, and productive work environment, planning for safety at the front-end of a project is essential (Waly, 2002). However, construction remains at high rates of accidents and fatalities. Existing safety culture and management focus on planning for safety, applying best practices, and providing personal protective equipment (PPE). It is believed (Teizer et al. 2010) that technology can play a key role in reducing incident rates further once it positively influences current practices in safety planning, such as manual or experience-based decision making.

Current Methods

Although federal and state regulations and standards, and company best practices assist the decision making process of construction safety managers, research has shown that safety extends beyond just the application and adoption of rules. Creating a "safety culture" is needed (Hinze and Wiegan, 1992). It is further suggested that safety planning must also be conducted prior to a construction activity for determining the safety measures that are needed. Planning for safety is a first but fundamental step for managing safety. Construction site safety often remains the sole responsibility of the contractor. Failure or limited expertise of staff for good safety planning lead to increased safety risks, for example, exposing workers directly to hazards. In addition, limited attention is given to safety during design phase of a project. To date, the cooperation and communication among project stakeholders (owners, contractors, subcontractors, etc.) in regards to safety is quite limited at the front-end. Furthermore, safety planning in construction is generally performed separately from the project execution planning. Staging work tasks properly and safely often happens late in the process of getting a work site organized, and often is dependent on experience of safety engineers or staff involved. The separation of work task and safety planning creates an additional difficulty for safety engineers to analyze what, when, why, and where safety measures are needed for preventing accidents (Chantawit et al., 2005).

Issues during Design and Planning Stage

Major problems in current safety planning system are that design choices often determine construction methods and schedule. Often designers do not understand the impact their work has on construction methods, schedule, and most importantly on safety. Little knowledge and transparency exists during the design stage what the potential hazards could be once a project task is executed, and what prevention plans/methods may be applied to resolve the safety issue. Often, the relationship of planning for safety and work task execution is weak; for example, many contractors use two-dimensional drawings (2D) to determine hazard prevention techniques. Current practices cause difficulties in using and analyzing potential alternatives in safety planning. Even with full cooperation of all related stakeholders, current safety planning and execution still largely depends on manual observation and past experience. The traditional manual observation is labor-intensive, time-consuming, and thus inefficient and the observed result can be error-prone due to subjective judgments.

Reasons for an Automated Rule-based Safety Checking System

Other good reasons for assisting safety management in construction with automated safety tools have been stated in research: (1) The planning and design phases provide a vital opportunity to eliminate hazards before they appear on the site; (2) the ability to eliminate hazards diminishes as the project progresses (Gambatese et al., 2007).

Since safety rules, guidelines, and best practices already exist, they can be used in conjunction with existing three-dimensional (3D) design and schedule information to formulate an automated safety rule checking system to detect hazards automatically, visualize their location in a virtual 3D space, and provide solutions and visuals of protective systems to mitigate the identified hazards. Such a system can also function as a tool for simulating and visualization progress on project and safety over time. In particular the indication of safety measures will help safety managers planning for safety upfront during the design phase, but also during the construction stage, when preparing safety work tasks, controlling and monitoring for safety during the construction phase (Benjaoran and Bhokha, 2010).

2. Background on Information Modeling and Safety

BIM and VDC

Building Information Modeling (BIM) along with Virtual Design and Construction technology (VDC) have been highlighted by the Architecture, Engineering, and Construction (AEC) industry. BIM can provide a powerful new platform for developing and implementing “prevention through design” concepts that can facilitate both engineering and administrative safety planning and control tasks at the design and construction stage of a project.

Information modeling-enabled virtual safety controls can be used to detect potential safety hazards (“clashes”). Virtual design and construction can simulate various stages of the construction process to allow engineers, architects and contractors to identify potential safety and health hazards at an early stage in the project. Creating alerts and finding mitigation means and methods has the potential to resolve most if not all safety and health hazards up front.

Rule-based Checking Systems

Rule-based checking systems have been developed for building models as part of the new BIM technology (Eastman et al. 2009). They have been used to check fire exits and American Disabilities Act requirements, and are slowly growing to address other areas. The most widely used application in construction might be “clash detection” tools in BIM software (e.g., to detect design conflicts of structural components). Rule-based checking systems for construction safety applications have also received attention. Both Solibri and EPM (Engineering Planning Management) technologies, for example, have such capabilities in their software platforms. However, they are lacking one or more of the following capabilities:

1. Identification and machine-readable safety rules that can be checked in the context of a 4D safety simulation.
2. Definition and structure of safety information to allow different types of safety checks (e.g., from simple fall protection of slab edges to complex spatio-temporal work-space occupation analysis).
3. A rule checking language using predicate logic/types of rules that can easily be checked by a computerized tool.
4. An execution structure that can find all safe/unsafe conditions in a building.
5. An optimized reporting and visualization structure.

Information and Communication Technologies in Construction Safety

3D visualization and 4D simulations increase the ease and level of understanding of construction processes. They facilitate better communication among project stakeholders. These features are inherently embedded in BIM and thus can enable more effective safety planning before and during construction. Such technology can enhance safety through automated hazard identification early in the process, and propose inexpensive and easier ways to solve safety clashes. Utilization of BIM technology thus can bring safety more closely to the construction planning phase.

Previous work that has been developed offers a range of new safety tools to help contractors during the design and construction phase. Information and communication technology, such as BIM, virtual reality (VR), Geographic Information Systems (GIS), online database etc., are applied for site hazard prevention and safe project delivery.

Hadikusumo et al. (2004) adopted VR for construction safety by creating a design-for-safety-process (DFEP) database. The VR-based DFEP tool helped to identify safety hazards during the building design phase. The Virtual Construction Laboratory (VCL), developed by Li et al. (2003), is a knowledge-based VR system that enables a planner to conduct virtual experiments with innovative construction technologies and processes. Compared with other VR based real-field construction management systems, it provides more interactive capabilities to mock-up different construction scenarios rather than mere visualization and dynamic navigation of a construction site. Zaki (2006) developed the Patterns Execution and Critical Analysis of Site Space Organization (PECASO). It aims at developing a methodology and tool to assist planners with the assignment of activities' in the execution space, as well as the identification and visualization of workspace congestion. Benjaoran and Bhokha (2010) developed an integrated system for construction and safety management based on 4D CAD model and some rule-based algorithms (Hazard Explorer and Safety Measure Advisor). While the automated approach with hard-coded algorithms does not consider complex design parameters, reliance on human is still needed to check for safety rules. VTT Technical Research Centre of Finland (2010) developed a manual procedure of using BIM technology for safety planning, management, and communications. As part of the 4D-construction safety planning, VTT visualized BIM-based 4D safety railings for fall/edge protection in Tekla Structures.

Compared to other work related to BIM and safety, our research provides novel intelligent functionality of a fully-automated rule-based safety checking system for building information models (BIM).

3. Research Objectives

Collecting and analyzing construction resource location and project data (schedule, work breakdown structure, resource allocation) can be linked to a building information model (BIM) to generate a rule-based safety framework that enables safer design, planning, and execution of work tasks. At the same time, data fusion of safety rules and geometric project data can create information, that once applied will create knowledge that can improve safety education and training at the planning/design and construction stage. The objectives of this work are as follows:

1. Develop a framework that integrates safety rules with BIM.
2. Develop a rule-base consisting of object oriented/logic for safety evaluation.
3. Implement the rule-based framework and verify it on a selected case study.

To limit the scope of our work, we focused on fall protection. Falls in floor openings and from roof edge can result in serious injury and very often lead to death of workers. Falls to a lower level are the largest single source of fatal injuries for construction workers, and accounted for 33% of all construction fatalities in 2005. In OSHA's Handbook (29 CFR), fall protection is required in work spaces such as ramps, runways, and other walkways; excavations; hoist areas; holes; formwork; leading edge work; unprotected sides and edges; overhand bricklaying and related work; roofing; precast erection; wall openings; residential construction; and other walking/working surfaces. Deciding what fall protection system to apply, where, and when are an important task, and thus part of the research questions that is to be answered.

4. Framework and Methodology

Although the future might develop a more comprehensive open source repository for safety rules and regulations, an initial set of rules that is to work with any safety rule checker in BIM can be generated from OSHA guidelines and industry best practices (Sacks et al., 2009).

The proposed rule-based safety checking system is illustrated in Figure 1. The first step is to collect and analyze construction data to schedule, work breakdown structure, resource allocation. This data can then be linked to a Building Information Model (BIM) using an automated rule-based safety framework that enables safer design, planning, and execution of work tasks. As construction schedules change frequently, 4D simulation will be updated and re-run. Rules will be extracted and coded from the construction standards information identified in the Occupational Safety and Health Administration (OSHA) codebooks and any local construction safety best practice. The association between schedule and building model are one-to-many (e.g., sheet-rock finishing of multiple walls in a room), and many-to-one (e.g., formwork, reinforcement placing, concrete pouring to complete work on a reinforced concrete wall). Data fusion will create valuable safety information that once updated and applied frequently will become knowledge for all project stakeholders. Knowledge will ultimately lead to improvements in safety education and training at the planning, design, and construction stages.

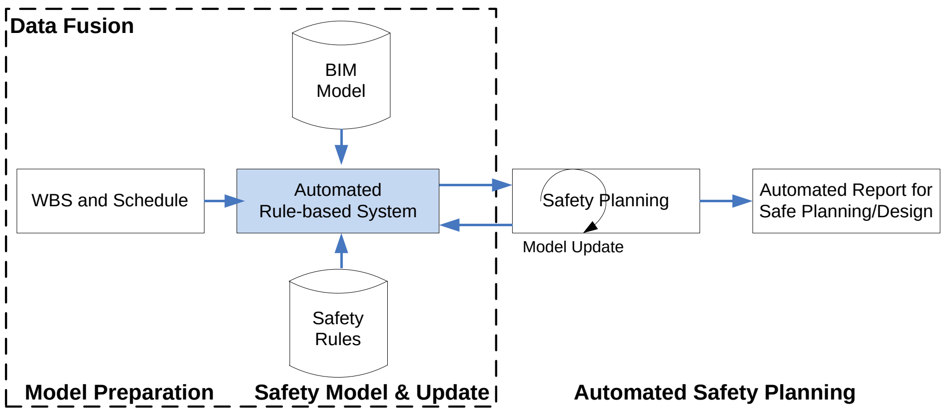


Figure 1: Framework for implementing an Automated Rule-based Safety System

5. Developing a Rule Base for Virtual Design and Construction

Object-oriented and Logic Repository of Safety Rules

According to OSHA regulations, fall protection rules can be classified into three parts: (1) Definition, (2) general requirement, and (3) prevention criteria. Definitions specify An extensible repository of rules has to be developed for the purpose. An initial set of rules was generated by using the OSHA guidelines. This set can be extended in the future into a comprehensive open source repository for organization-based safety rules and regulations. We implemented an automated rule engine based methodology to check the Building Information Models for compliance with such a repository. By making this extensible, we provided an opportunity to learn and train the rule engine model based on initial results. This can also include new sets of rules and object types in the database. Such a machine learning approach is commonly used in the industry, as computational programs tools are much more efficient than humans in applying a rule based checker. the unsafe area; general requirements show the protection methods which should be applied in a specific scenario; and prevention criteria relates to the detailed information of the prevention system to be used.

The preliminary research work concentrated on prevention falls from openings in slabs, edges on floor, and openings in walls. According to OSHA a “hole” means a gap or void of two inches (5.1 cm) or more in its least dimension, in a floor, roof, or other walking/working surface. Regardless of length, we implemented a default guardrail system for edges of slabs, floors, or for openings in walls, if they were elevated more than 1.8 meters (six feet). For holes measuring more than one meter (user-defined; 40 inches) in its least dimension in a floor, we applied also a guardrail system. Holes were “covered” if an opening measured less than one meter but more than five centimeters in its least dimension. Holes with less than five centimeters (two inches according to OSHA) in its least dimension were ignored (due to the small size of the hole). The default table-based safety rule translation for fall protection is shown in Table 1.

Table 1. Example of table-based rule translation for holes in concrete slabs.

Length (x) of a Floor Opening in its Least Dimension	*Prevention Method*
< 5 cm	*“Not considered”*
5 cm < x < 1 m	*“Cover with panel”*
> 1 m	*“Apply a guardrail system”*

Appropriate Software for Implementing Rule Engine and Model Checking

Tekla Structures, a BIM-based structural engineering and modeling software, provides construction management functions such as 4D simulation, site layout planning, quantity-take-off function and etc. Taking advantage of Tekla’s embedded functionality and its OpenAPI, we first developed our automated rule-based safety checking system in Tekla. In a second approach, we utilized our rule-based safety checking system in the Solibri Model Checker (SMC). SMC is an (industry foundation class) IFC-based model viewer that allows complex rule checking capabilities. We implemented a translator to convert syntax-based rules into machine-readable equations. To date, such safety code and parameters to check every building object in BIM for safety are not available in any commercially existing BIM software.

6. Case Study: Automated Rule-based Safety System for Fall Protection

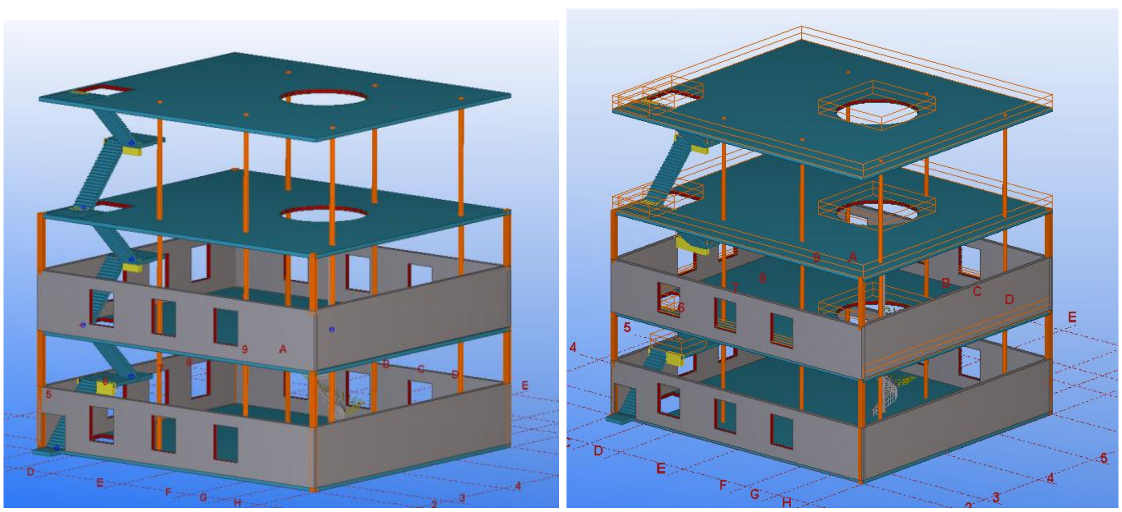
Implementation in Tekla

The OpenAPI in Tekla makes it possible to build a project with pre-fabricated model elements virtually. The object library contains parametric components that automate the tasks of creating the details and connections of the model. The OpenAPI makes it further possible to integrate further functionalities with the 3D model and continually enhance new features and attributes.

A 3D model was created in Tekla showing a construction site in progress. The building information model included different types of openings that could be a potential fall hazard. The identified openings had different sizes and geometric shapes (polygonal, rectangular, and circular). The holes were located on walls and floor slabs. The model (see Figures 2, 3 and 4) shows a four-story building with walls on the first two floors, spiral and emergency staircases, and pipework that are potential trip hazards.

Taking advantage of Tekla Structure and its OpenAPI, the rule-checking steps are listed as follows:

a. Automatically check the model and detect holes in slabs and exterior walls, and edges of slabs;
b. Differentiate the opening in slab from wall openings (including windows);
c. Install guardrail system at floor edges/wall openings and cover floor opening;
d. Take-off quantity and type (leading to an estimate) of the protection safety system to be installed;
e. Provide update in schedule of when and what safety protective system needs to be installed; and
f. Create a 4D visualization and 3D virtual environment to visualize the protective system and how it fits in the construction schedule/sequencing.



(a) Modeling w/o protective system (b) Modeling w protective system

Figure 2: Automated rule-based fall protection detection and installation in Tekla

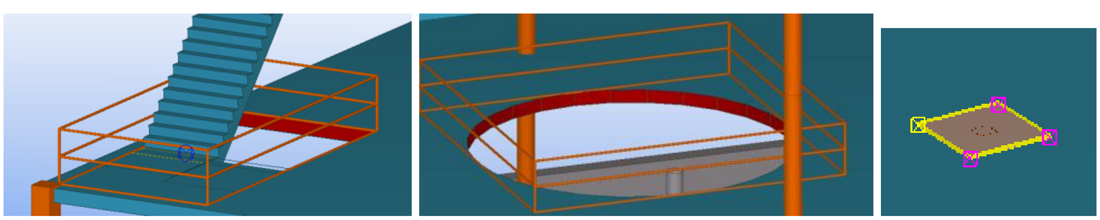


Figure 3: Examples of floor openings with different shapes/dimensions and protection.

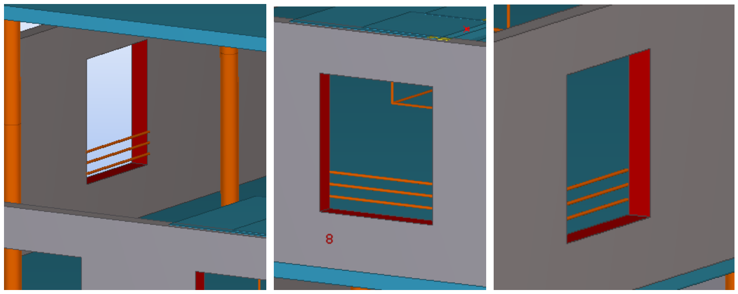


Figure 4: Examples of exterior wall openings and guardrail protection system in place.

Implementation in Solibri Model Checker

Similar implementation and results of opening and edge detection, quantity-take-off and 4D simulation were realized in the Solibri Model Checker (see Figure 5 and 6). Apart from that, rule customization is enabled and allows the user to select alternative protection systems. These individual prevention methods can be selected in a drop down menu (see Table 2). For example, the identified hazard #45 (a rectangular opening in a floor slab) was on the second floor level, had a width of five and four meters in length and width, respectively, with a height distance of three meters to the next floor, covering an area of 20 m^2, and having a circumference of 18 m. The system automatically applies user- or OSHA-defined best practices, in this case, proposes a "Guardrail system/safety fence". The user could still selected another protective system, thus the developed approach takes advantage of human knowledge and experience.

Table 2. Detailed information for each opening and its customized prevention method.

Hazard No.	**Floor Level**	**Max. Hole Length**	**Max. Hole Width**	**Dist. To Lower Level**	**Hole Area**	**Hole Perimeter**	**Selected Prevention Method***	**Check List √ / □**
45	Level 2	5 m	4 m	3 m	20 m^2	18 m	"Guardrail"	□

* Select in a drop-down menu from "Not applicable", "guardrail system", "cover", "personal fall arrest system", or user-input (e.g., "safety net").

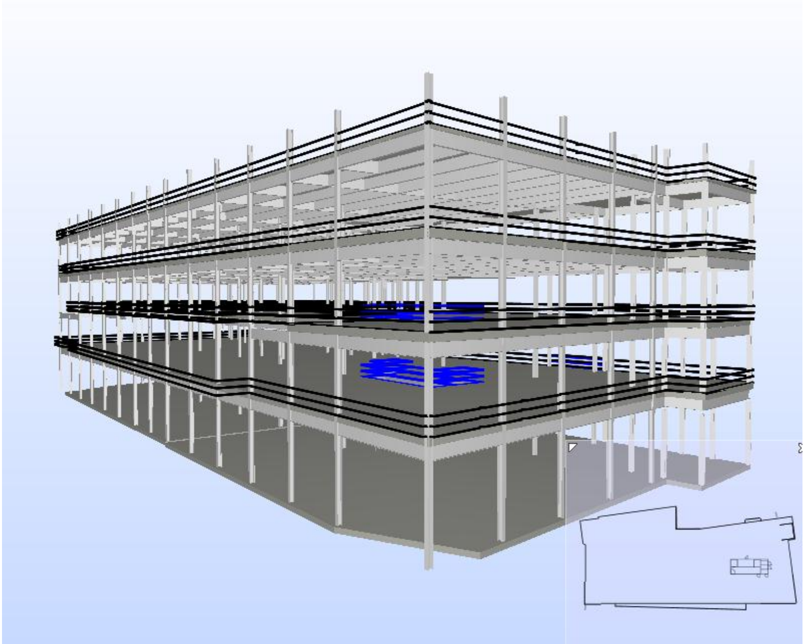


Figure 5: Fully-automated slab opening and edge detection with application and three-dimensional visualization of protective solutions.

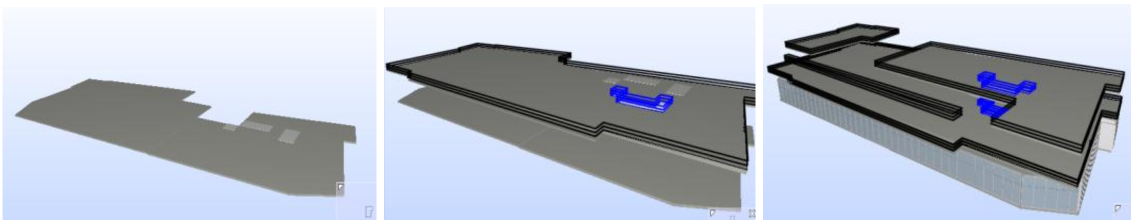


Figure 6: Schedule-based safety visualization and simulation (Phases 1, 2, and 3).

Results and Comparison

Preliminary results indicate that fall protection rules in OSHA can be translated into machine readable rules that then can be applied in the developed automated safety-rule checking tool. The automated rule-based safety checking system has been successfully implemented on a sample model for fall protection. The application of other (and more complex) rules might be considered in future research. This performed work illustrates that safety planning can be considered in the design stage for early detection and application of protective safety system, including identification of hazard location, quantity take-offs, and schedule for implementation of protective safety systems.

Implementation of the safety-rule checker in two software environments was conducted. The Tekla Structure software can easily add new (safety) objects (e.g., guardrails and covers). Tekla also possesses an OpenAPI that allows visualization, quantity-take-off and 4D simulation. Further advantages are envisioned once the developed safety-rule checker is embedded in the existing construction management tool. The Solibri Model Checker is an IFC-based model viewer and checker that offers easy-to-use visualization and virtual walk-through functionality.

7. Conclusions and Future Work

An automated table-based safety rule translation prototype was developed based on OSHA rules and construction safety best practices. The developed tool ran on two technology platforms: Tekla Structure and Solibri Model Checker (SMC). Preliminary results demonstrate the feasibility of the developed safety rule-checker in both software applications.

The developed automated safety-rule model checker shows good capability of practical applications in building information modeling and planning of work tasks. Once applied in construction design and execution phases, it may possess a large potential for reducing errors and waste in safety planning for construction site work sequences and activities. From a safety management perspective, time and effort of safety staff/engineers can be saved through an automated safety code checking and simulation tool that assists labor-intensive safety tasks. For example, hazardous work spaces can be identified and potential hazards can be prevented already at the design stage, before any field work is started.

Future work may focus on research that studies the applicability and performance of the safety-rule checker in simple to complex building information models. The analysis of parametric and complex rules customized to the specific type of project might also be explored. It is envisioned that the implementation of the safety prevention methods might need to be adapted to the scope of the project, type of firm, and the design process. Lessons and experiences can be learned to improve the tool further. Research will also need to focus on additional cases studies, scenarios, and machine-readable safety rules, guidelines, and best practices to convince practitioners of its usefulness.

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Informal Training in Construction Work: Attributes and Safety Implications

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Informal Training in Construction Work: Attributes and Safety Implications

Abstract

In contrast to formal training, informal training is unplanned, hands-on, and unstructured. The prevalence of informal training is well-documented, but no systematic analysis has been conducted on its effectiveness. Informal training was investigated with construction workers to describe and identify attributes or descriptors. A total of nine construction company owners and workers completed a questionnaire to elicit experiences with informal training, and the barriers and facilitators as attributes to informal training were identified. Content analyses were conducted. Sixty-one attributes were identified and categorized into 11 response themes. The most frequently-mentioned attributes of informal training were: learner-centered approach, explanation, and demonstration. Workers may employ both an action method and a supportive approach when conducting informal training. Participants also identified more attributes performed by those who were experienced instructors compared to less-experienced trainees. Findings suggest that effective informal training is relied upon more by workers as a teaching tool rather than as a learning tool for recipients or trainees. Additionally, a gap seems to exist between instructors' perceptions of informal training effectiveness and trainees' perspectives of effectiveness. This study established ground work to further operationalize and measure informal training in construction work systems.

Keywords

Informal training, hands-on training, construction workers, experienced workers, instructors, trainees

1. Introduction

The construction industry continues to have one of the highest rates of fatal occupational injuries per year since the current industry sector recording system was used in 2000 [Bureau of Labor Statistics (BLS), August 2010], and the second highest incident rates of nonfatal injuries and illness since 2007 (BLS, October 2010). Fatalities or injuries may not be reduced in the near future, as the skilled workers in the baby-boomer generation (those born between 1946 and 1964) are retiring while a large number of young Hispanic workers are entering the workplace (CPWR, 2007; page 12). Occupational and safety training will be in high demand and necessary to resolve shortages triggered by the large numbers of experienced workers who are retiring and the equally-large numbers of less-experienced young workers in need of training (CPWR, 2007; page 30).

Occupational training is routinely conducted in formal classroom settings as well as in informal settings. Informal training is defined as a situated and informal process where one person transfers knowledge and skills to another person, often between coworkers or peers (Terry, Burneo, Martinez, Riofrio**,** & Smith-Jackson, 2008). Informal training has been considered to be beneficial for transferring safe work practices and efficient work methods among healthcare workers (Ramanadhan, Wiecha, Gortmaker, Emmons, & Viswanath, 2010). In a recent study with chemical factory workers (Hambach et al., 2011), focus group participants reported that they considered their colleagues' opinions and experiences as important and of high value when considering safety. The trust and reliance on peers (colleagues) over safety professionals or supervisors emphasizes the importance and potential effectiveness of informal training among construction workers.

Most adult learning in the workplaces occurs informally. Likewise, informal training has been a major source of construction training (Glover, Long, Haas, & Alemany, 1999; Wang, Goodrum, Haas, & Glover, 2008). In one study, the percentage of time devoted to informal training ranged from 70% for electricians to 78% for civil-site workers among five major trades (Wang et al., 2008); and in another study, 100% of participants from eight focus groups considered informal training as a significant contributor to knowledge of worksite safety and health (Tackett, Goodrum, & Meloney, 2006). Interviews of construction personnel revealed that informal training is beneficial (i) for equipment operation (Tackett et al., 2006), (ii) when delivered by someone who knows the subject, has experience on the job, and is familiar with the job-specific risks (Tackett et al., 2006), and (iii) if conducted by one-on-one, on-site, and peer atmosphere at a level where workers feel comfortable to ask questions (Terry et al., 2008). Although it should not be considered a substitute for formal training, informal training is generally recognized as a useful training method (Terry et al., 2008; Wang et al., 2008).

However, no systematic analysis has been conducted of the process and effectiveness of informal training (Tackett et al., 2006; Terry et al., 2008). This could be due to difficulty with identifying metrics or indicators of informal training effectiveness or because the process has not yet been described or operationalized to the degree necessary for systematic study and analysis. Adding to this complexity is the extent to which the mechanism of informal training is closely interdependent and mutually reinforcing to formal training (Glover et al., 1999), and there is no consensus about how to define training effectiveness by extracting formal components as well as including component that are situated, unplanned, and unstructured(Tackett et al., 2006).

The main goal of this preliminary study was to investigate how informal training is conducted among construction workers at the actual worksite. Facilitating factors were defined as those factors that supported transfer of knowledge and skills based on self-report of participants. Barriers were defined as practices that did not support knowledge and skills transfer. Both descriptive and process knowledge of informal training will support ongoing research and development by helping researchers to operationalize different attributes of informal training as measurement variables in simulation and field studies. Practitioners may use the descriptive information to enhance their use and application of informal training.

2. Method

Research Design

This research was reviewed and approved by the Virginia Tech Office for Research Compliance and the Institutional Review Board. An open-ended questionnaire was used to obtain information about experiences and opinions of informal training from construction company owners and workers. Upon consent, participants were asked to complete the questionnaire online or by having the questionnaire read aloud to them and recording the responses. Once participants completed the questionnaire, their names were entered into a raffle for a chance to win a gift certificate from a local restaurant.

Participants

Nine construction personnel (six construction company owners and three workers) participated in the study. Companies represented in the sample were in plumbing, drywall, roofing, and electrical construction trades. All participants were Caucasian male, and the mean age in years was 49.2 (SD = 12.8). The mean years worked in the construction industry was 30.8 (SD = 14.2) for owners, 16.7 (SD = 11.5) for workers, and 26.1 (SD =14.5) for overall. Two of the participants completed a technical school, one received an associate degree, four had Bachelor's degrees and the remaining two received further advanced degrees.

Questionnaire

The questionnaire elicited information about workers' experiences with informal training as it related to their on-site construction jobs. The 19-item questionnaire consisted of questions from two different perspectives; one from the learner or trainee, and the other from the instructor. The questions elicited information such as (1) What helped or hurt in learning about new skills or knowledge; (2) How they would conduct training differently if they were the instructor; and (3) What they do as an instructor to teach confusing tasks. A definition of informal training was provided at the beginning of the questionnaire.

Procedure

The construction companies were identified via a database consisting of companies classified under the North American Industry Classification System (NAICS) and a local Better Business Bureau Accredited Directory. The owners who were recruited were selected based on a parameter search using size (20 or fewer companies), location (within a 20-mile radius of the research institution), and operating for at least 10 years. Owners who agreed to participate were given options of completing the questionnaire online or by an interview format. When the former was selected, the link to the online questionnaire was emailed to the owners. When the latter was selected, the interviewer typed the answers to the online questionnaire afterward. Once the owners finished the questionnaire, they were asked if they had employees who may also like to participate in the study. One owner provided two of his employees' email addresses and another introduced the interviewer to an employee at the worksite. The remaining owners either did not have any employees or did not have employees who had time to participate in the study. Among the nine participants, four completed the questionnaire online, and the remaining five completed the questionnaire by interviews.

3. Results

Content analyses were performed on the verbal responses to questionnaire items. The responses were categorized into 11 response themes (Table 1). Note that participants made multiple responses across the themes. The responses were categorized into groups and assigned the labels for the associated themes. Three researchers then reviewed and verified the categories and labels for the responses.

Table 1. Operational Definitions and Examples of Response Themes

Response theme	Definition	Example
Explanation	Explaining materials but not demonstrating or illustrating	The instructor explains to trainees how and why things work.
Illustration	Explaining materials with drawing (e.g., diagrams)	The instructor sketches out a diagram or writes down a step-by-step procedure.
Demonstration	Performing the process of the task	The instructor shows trainees how to specifically handle a tool.
Return demonstration	Actions that someone demonstrates what they were taught or what was demonstrated to them	The instructor shows trainees how to do the task, and lets them do it while Instructor is watching them.
Learner-centered	Approach that considers the learner's knowledge, capabilities, or preferences more important than other factors	• The instructor does not assume what trainees already know. • The instructor teaches tasks in the morning when trainees are more receptive to learn, rather than later in the day.
Coaching	Generic term for providing instructions or guidance	The instructor intentionally sets the machine/tool in a wrong way so that he/she can show trainees how to set it up properly.
Instructor visibility	Instructor's availability to trainees	The instructor is more available and/or stays on the job site while trainees perform new tasks.
Repetition	Repeating to perform the task	Trainees repeat the assembly or functions.
Communication	Communication between the instructor and trainee	Trainees try to have a good interpersonal relationship with the instructor and other workers.
Knowledge	Type and amount of knowledge the instructor or trainee has on the material	Trainees have good abstract and theoretical knowledge.
Collaboration	Conducting the task with other worker(s)	The instructor asks trainees what the problem is, then they take some measurements of the

		devices. The instructor then calls another worker to resolve the problems.

Participants reported either positive or negative attributes of informal training, which were then classified into either a facilitator or barrier, respectively. An attribute that was a facilitator was defined as beneficial to the effectiveness of informal training (e.g., the instructor does not assume what trainees already know), whereas a barrier was an attribute that undermined informal training (e.g., the instructor assumes that trainees knew something that they did not know).

Facilitators vs. Barriers

A total of 61 qualitative attributes were extracted for effective informal training. Figure 1 shows the distributions of those 61 attributes by the type (facilitator or barrier) and response themes. Most of the attributes (52 responses, 85%) were facilitators, whereas the remaining nine (15%) were barriers. Approximately 20% (12) of the attributes were classified in the *Learner-centered* category, followed by *Explanation* (16%) and *Demonstration* (15%). These top three categories included 50% of the total attributes.

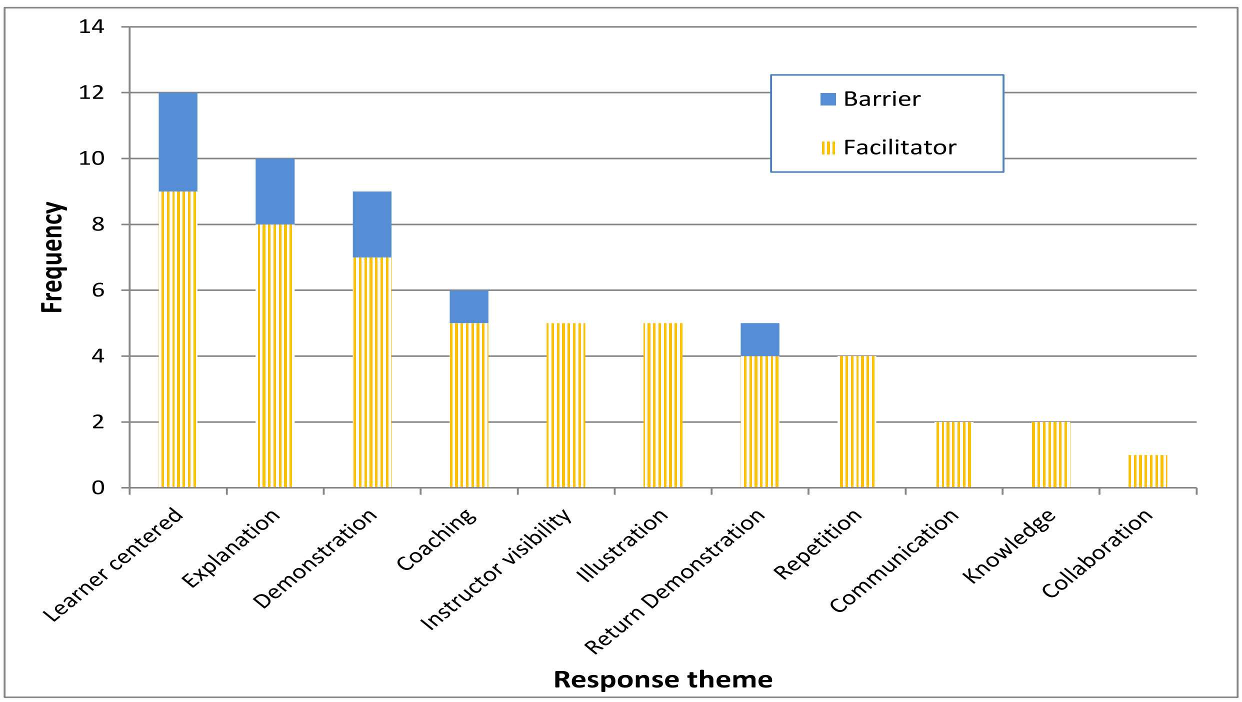

Figure 1. Attributes of informal training by type and response theme.

Instructor vs. Trainee

The attributes were also classified by roles (instructor or trainee). The instructor is defined as a person who teaches materials to other workers, whereas the trainee is a person who receives the training. Figure 2 shows the distributions of e the attributes by response themes and by role (instructor, trainee). Most of the attributes (51 responses, 84%) reflected actions or strategies that instructors used, whereas the remaining 10 attributes (16%) were used by trainees. All attributes derived from trainee perspectives were facilitators.

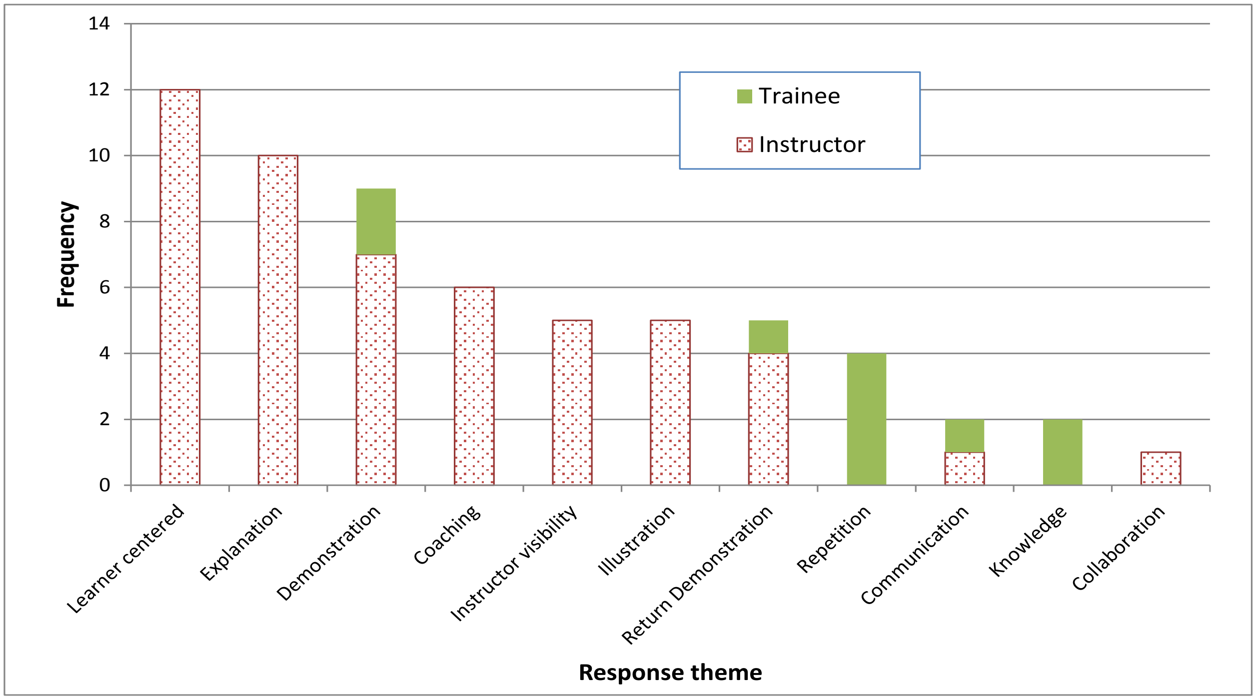

Figure 2. Attributes associated with informal training by role and response theme.

Factors Describing Instructors' Actions or Strategies Influence

Fifty-one of the 61 attributes were classified as instructor-focused behaviors performed during informal training. These 51 attributes were also classified as facilitators or barrier, and were also classified by role. *Instructor's perspective* refers to those made by the participants when they were asked to answer the questions from the instructor's perspective, rather than the trainee's perspective. The *trainee's perspective* refers to those made by the participants from the trainee's perspective on answering the questions.

Figure 3 shows the distributions of the 51 attributes by response themes reflecting the instructors' perspective. Most of the attributes (42 out of 51, 82%) were facilitators and the remaining nine were barriers. The majority of the barriers (8 out of 9) were from the trainee's perspective, and most of them (7 out of 9) fell into the top three response themes (*Learner-centered*, *Explanation*, *Demonstration*). Approximately 67% (34 out of 51) of the attributes were brought by the trainee's perspective, which covered nine out of 11 response themes. Many of the attributes from the trainee's perspective (26 out of 34) were facilitators. Seventeen of the 51 attributes for instructors were brought by the instructor's perspective, and almost all of them (16 out of 17) were facilitators.
In contrast to the attributes reflecting the trainee's perspective, only 33% fell into the top three or dominant content themes.

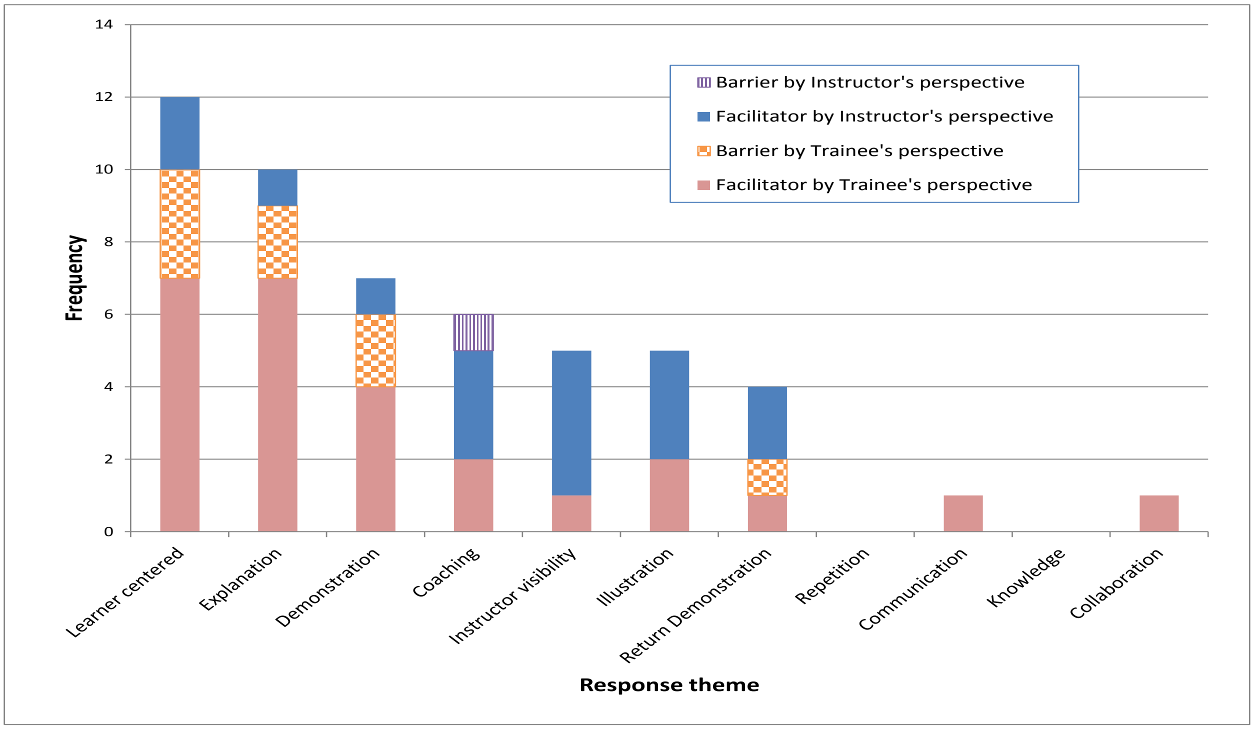

Figure 3. Instructors' actions or strategies by attribute type, role, and response theme.

Attributes that Trainees Can Conduct

There were 10 attributes reflecting the trainee actions or conditions. All of them were facilitators. As Figure 4 shows, three were made from the instructors' perspective, with these being classified to the *Repetition* response theme. The remaining seven attributes were made from the trainees' perspective, with each being classified into five different response themes.

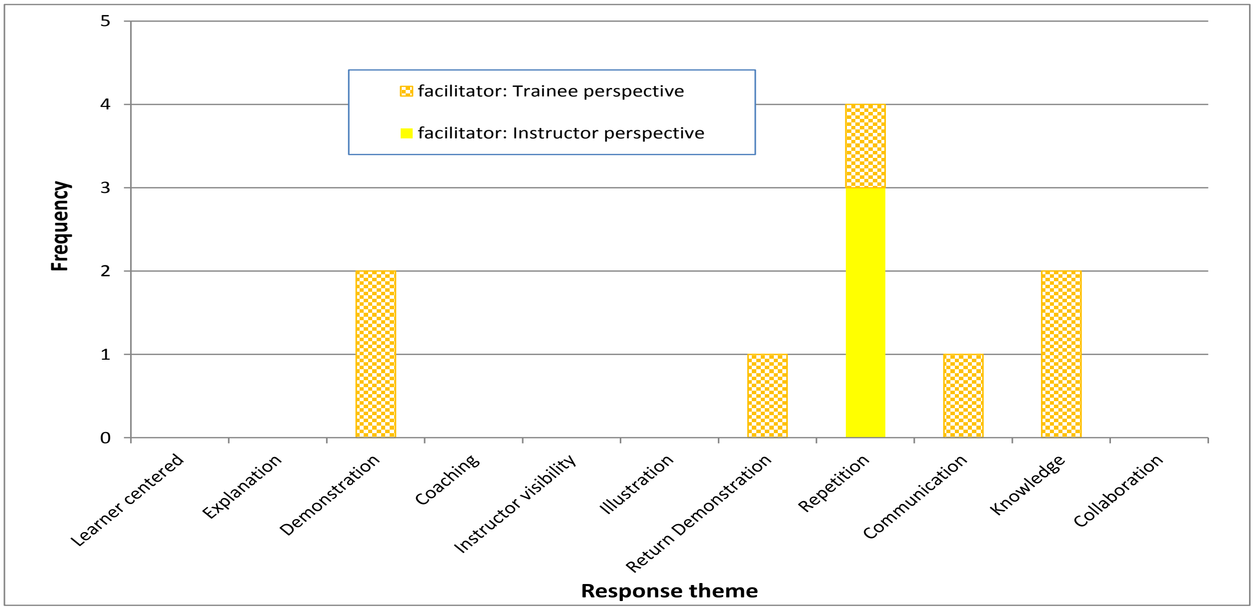

Figure 4. Attributes to trainees' actions by role and response theme.

Attributes Believed to Enhance Training for Difficult or Confusing Work Tasks

Participants were asked, from the instructor's perspective, to describe extra steps they would take to explain more confusing tasks to less-experienced workers on informal training. Interestingly, half of the responses (5 of 10) were *Repetition*, followed by *Demonstration* and *Illustration*, respectively, and the least frequent response was to be *Learner-centered*.

Difficult Topics and Challenging Learning Processes

Participants were asked, from the instructor's perspective, to report what they thought was most difficult for less-experienced workers to understand during informal training. Some of the responses were specific topics (e.g., electricity, wiring a building), and others were challenges during the learning process (e.g., visualizing the end result, moving from just getting the task done to getting the task done in a neat way).

4. Discussion

This study revealed that practices that were learner-centered and involved explanation and demonstration are practiced frequently and considered valuable for informal training among construction workers, as over 50% of the participants' statements were categorized into these three themes. Learner-centered training is more accurately reflective of an approach or attitude, as opposed to concrete actions that would occur during informal training, such as explanation and demonstration. Along with the fourth most-frequent response theme *Coaching*, workers may employ specific actions (e.g., explanation, demonstration) and a supportive approach when conducting informal training.

One of the topics ("the instructor assumes/not assume what trainees already knew") in the *Learner-Centered* theme included the highest number of attributes (3) among the entire 61 statements made by the participants. This "assumption by instructor" was also found in a previous study on informal training in construction work systems by Terry et al., (2008).

It was not surprising that the majority of statements participants made were considered as facilitating factors to informal training. It was interesting that majority of the statements were about the actions and/or approach that the instructors can conduct at informal training, rather than what trainees can do to improve informal training. This finding suggests that effective informal training is relied upon by workers who teach the tasks or methods to their colleagues, more than those who receive informal training.

As illustrated in Figure 3, approximately 67% (34) of the attributes to the instructors' actions or strategies reflected opinions about the trainee's perspective and remaining 33% (17) attributes were from the instructor's perspective. Only one topic was shared by both trainee and instructor perspectives -- "the instructor exercises more patience to trainees". Thus, there may be gap between what instructors can contribute to facilitate informal training and what trainees can contribute.

As is common with qualitative research, a large amount of useful information about informal training was obtained from a small number of participants. Individual workers seem to have different ideas about how to conduct and support informal training. This phenomenon was relatively easy to isolate through self-report, given the salience of the practice in everyday work experiences among workers.

5. Conclusions

This study investigated how construction workers conduct informal training at the worksite. A unique aspect of this study was to talk about informal training both from the experienced instructor as well as less-experienced, trainee perspectives. The dual perspectives were possible because participants had 10 or more years of experience in construction, and consequently brought significant knowledge regarding informal training.

However, more controlled field studies that support objective observation and measurement of informal training practices are needed. Researchers do not yet know the extent to which workers' actions or performance reflected in participants' self-reports actually occur during informal training. This qualitative study did not test or verify whether the facilitators or barriers actually influence informal training. Participants provided self-reports of their own experiences, which provides a useful starting point for research but requires expansion to more comprehensive research design and analysis. Beginning this endeavor by asking those who practice informal training day-to-day in the situated construction work context has uncovered some interesting descriptors to support continued exploration of informal training.

As recommendations, it would be beneficial for construction workers to have the opportunities (e.g., a short meeting, part of weekly employee meeting) to learn about other workers' ideas for informal training. More comprehensive descriptors of informal training will be applicable not only to teach new occupational skills but also to inform safety issues. Further understanding will also be useful to identify the topics that challenge less-experienced construction workers.

Future studies include developing a method of measuring the effectiveness of informal training. Another study will investigate the gaps between what workers perceive as effective for informal training when teaching and learning, and what actually influences teaching and learning when measured objectively. Additional studies should also focus on cultural or other differences in informal training effectiveness among the diverse groups who comprise construction work systems.

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Safety Climate Among Immigrant Latino Residential Construction Workers.

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Safety Climate Among Immigrant Latino Residential Construction Workers.

Abstract:

It is estimated that approximately 2-3 million Latinos make up approximately 30% of the US construction workforce (Burdette, 2004). Historically, the rate of construction related fatalities for Latino workers exceeds the non-Latino workers and is particularly concentrated in small, less than 10 employee companies (Dong, et.al. 2010). By the nature of the industry and firm size a large portion of this workforce is concentrated in the residential workforce and many times perform work in multiple trades, e.g., drywall and framing, or concrete and masonry. A study was conducted gather data on the safety and health climate from a large group of Latino construction workers situated in western North Carolina to determine a sampling of the climate that affects the health and safety of this workforce. Cross-sectional (N=119) baseline demographic data, a physical demands inventory, safety climate data, workplace PP&E, and abusive supervision data was collected and compiled representing a variety of trades, including framing, masonry, roofing, and general labor.

Additional sampling was done through a real-time 21 day phone diary of workers with one or more work-day diary entries (N=90). The work environment reflects a physically demanding and stressful work environment with frequently less than adequate employer provided PP&E and a risk free day being a rare event. Results from the work climate and supervisor relationship reveal that although workers perceive a concern by management for worker safety this is not borne out by actual management actions and the discouraging belief by 90% of the sample population that sometime over the next 12 months they will be injured.

Keywords: Latino construction worker safety, safety climate

1. Introduction

Construction workers have some of the highest occupational injury rates of all U.S. industries. Although construction has dipped below 1000 in the past three years it remains the industry with has the highest number of fatalities of any US industry, over the past decade there were approximatly1200 fatalities per year, and in 2007 the industry had over 135,000 nonfatal recordable occupational injuries and illnesses with an incident rate of 5.4, second highest among all US industries (BLS, 2007). Further, the illness and injury rates reported in the construction industry are likely vast underestimates (Azaroff et al., 2002), especially in the segment represented by non-fatal, immigrant incidents.

This study focuses on Latino workers in residential construction because first, they constitute a sizable percentage of an increasingly ethnic minority, and foreign born construction workforce, e.g., during 1995 and 1996 Latinos represented 10% of all workers in the construction industry; in 2001 the percentage reached 18% or 1.3 million, and in 2007 it reached 30% or 2.85 million. This represents an increase of more than 300% for the last 12 years (Brunette, 2004). The second reason for this study is that Latinos have been documented as experiencing a higher rates of fatality, injury and illness within the industry (Dong et al., 2010).

There is considerable research directed at determining the reasons for such a large number of fatalities and injuries. The safe management of this workforce is clearly a challenge to all construction professionals, as indicated by a recent report from the Associated General Contractors of America (2008, p. 1) stating, "…nearly ¼ of current construction workforce is Latino … and the number is expected to increase. Latino immigrants are often illegal, illiterate and do not speak English." One line of research that is being pursued is identifying safety climate over a short time period, in the instance of this work 21 days, and compare that to workers perception of safety climate, and management's alignment in support of a safe work environment.

2. Objectives:

This research identified in this paper uses a nine-question modified Safety Climate Measure for Construction Sites instrument in a baseline survey to assess workers perceptions of safety climate and is followed up by daily surveying practices that contribute to safe work climate. Minor instrument modifications were done to allow for ease of language translation and response by participants. To accomplish the goals of the research longitudinal data was obtained from a community-based sample of Latino residential construction workers (n=119) in selected trades, particularly framers, roofers, and general trades, that: 1) delineate work organization characteristics of immigrant Latino residential construction workers, including variation job in structure (i.e., work hours, precariousness), job design (i.e., skill variety, control, psychological demands, hazards exposure), supervisory practices (i.e., power, retaliation, ability to communicate) and safety climate experiences (baseline survey); and 2) documented reporting over of work over a 21 day time period to record well-being, activities, behaviors, and practices.

3. Safety Climate:

The goal of safety climate analysis is to identify the current safety climate with the intent of determining if safety perception has an impact in job site safety (i.e., is reality matching perception), and is it also reflected in safe practices instituted by the collective organization or employer. There is evidence that safety climate can be positively related to safety performance and negatively associated with accidents (Neal and Griffin, 2002), in total there are over 200 publications that have been done on safety climate, over the last 30 years, demonstrating the predictive validity of safety climate as a leading safety indicator (Zohar, 2010). Collective aspects of a desirable safety climate are evidenced by management's commitment to maintaining a safe site, eliminating unsafe conditions, and mitigating unsafe behaviors by continuous safety and health training. The concept of worker safety climate and how workers perceive the safety climate of their workplace is an ongoing research effort and is frequently measured using this reliable nine question instrument first developed by Dedobbeleer and Beland (1991) who adapted an earlier safety climate instrument developed by Zohar (1980) that focused on management concern, management actions, and risks as components of safety climate. This 'Safety Climate Measure for Construction Sites' instrument was used by Gillan et.al, (2002) to survey the safety climate among 255 construction workers that resulted in a positive assess that union workers perceived and participated in a safer work climate than non-union workers.

Although there is some literature on safety climate among unionized construction workforces little work has been done on the safety climate of Latino construction workers. Therefore this study aims to through the use of a similar nine question component of a larger baseline instrument to assess safety climate and individual and collective (organizational) practices of immigrant Latino workers employed predominantly as roofers, framers, and general laborers within the US residential construction industry.

4. Methodology:

The data for this study are partial results of much broader NIOSH funded research project designed to determine the feasibility of using Computer-Assisted Telephone Survey (CATS) technology to collected daily diary data from Latino residential construction workers (OH009761-01, subproject #647). The project consisted of four distinct data collection components: 1) a baseline interviewer administered survey, 2) a 21-day self-reported daily diary period using CATS technology, 3) a debriefing interview at the end of the 21-day diary period, and 4) a follow-up interview conducted 3 months after completing the 21-day diary period. The current paper uses data from the baseline and the 21-day daily diary entry.

Sample Population

Baseline data were obtained from a non-probability sample of residential construction workers who self-identified as Latino (N=119). The participants were recruited in partnership with Wake Forest University School of Medicine and HOLA of Wilkes County, a 501c3 non-profit organization that serves the Latino communities of Wilkes and surrounding counties in western NC. HOLA staff used a combination of techniques to recruit residential construction workers, including identifying known individuals within existing social networks, snowball, and referral. Criterion for inclusion within the study were; age 18 years or older, Latino (self or parents born in a Latin American country, or self-identified as "Latino" or "Hispanic"), and employment for 35 or more hours per week in construction. There were no exclusion criteria.

Ninety (90) or 75.6% of the one hundred and nineteen (119) study participants completed one or more work-day diary entries (n=90).

Data Collection: The baseline interview assessed stable attributes of the individual (e.g., age, country of origin), occupational characteristics (e.g., years in construction, primary tasks performed in construction), health history (e.g., presence of chronic conditions), and multiple aspects reflecting the organization of work. It took, on average 48 minutes to complete a baseline interview and participants were paid a $15 incentive. The 21-day daily diary focused on daily well-being, job tasks, injury/accidents, general safety climate, general safety behavior, psychological workload, abusive supervision, and the use of personal protection equipment. The duration of the call-ins varied based on the individual responses and subsequent as-needed follow-up questions. Participants received between $50-$100 incentives for their levels of completing the 21 day call-in cycle. The follow-up interview focused primarily on experiences of injury and changes in health during the preceding 3 month period. The follow-up interview took 24 minutes, on average, to complete, and participants received a $25 incentive. All recruitment and data collection activities were approved by a federally authorized Institutional Review Board (FWA #00001435).

Baseline content and follow-up interviewer-administered survey questionnaires underwent thorough translation and back-translation procedures. Content from validated Spanish instruments was used without modification where they were available. English-only instruments and items developed for this project were translated into Spanish by a native Spanish-speaker. All items were then back translated into English by a fluent Spanish-speaker. Discrepancies identified in the back translation were corrected through consensus and incorporated into both the Spanish and English versions of questionnaires (Behling & Law, 2000).

Baseline survey questionnaire data were collected by trained native Spanish-speaking interviewers. Training consisted of a thorough review of study purpose, screening and recruitment procedures, line-by-line review of the interviewer-administered questionnaires, and progressively more realistic practice interviews. The daily dairy data was collected using the CATS technology over a 21-day period following rolling acceptance into the program. All analyses were performed using SAS v9.2 (SAS Institute, Cary, NC), and used a Type I error rate of 0.05.

5. Results:

In general the median age of a residential Latino construction worker in western NC is 32 (31.7 SD=7.6), years old, and has a relatively staple residency approaching 10 (9.7 (SD=6.0) years, is married or living as married (63.3%), yet is living away from their spouse (90%). Nearly one-quarter of the sample (22.4%) reported having completed an apprenticeship and worked an average of 38.3 weeks (SD=16.9) in construction in the previous year, averaging of 42 hours per week (SD=8.6). The work environment reflects a physically demanding and stressful work environment with frequently less than adequate PP&E provided by the employer and a risk free day being a rare event.

As evidenced by the data in Table 1, Latino residential construction workers' perception of their employers' commitment to safety, in many ways, are quite favorable. Approximately 70% of workers report "Workers' safety practices are very important to management" and that "Proper safety equipment is always available" Over 70% of workers report "Workers are regularly made aware of dangerous work practices or conditions" and almost 80% state that "Workers have almost total control over personal safety."

However, in several other ways the results from Table 1 identify a contradiction between reality and worker perceptions, One-third or less of workers reported "Workers are regularly praised for safe conduct," or "Workers receive instructions on safety when hired," and "Workers attend regular safety meetings." An even more telling statistic and a startling prediction of safety reality is that less than one half (40.3%) of workers reported that their boss or supervisor does "… as much as possible to make my job safe" and the vast majority (84%) agree or strongly agree that "the possibility of being injured at work in the next 12 months is very likely." This dichotomy may lead one to believe that either the Latino workforce has a low expectation for an employer's responsibility to provide a safe worksite or that there is a high level of organizational loyalty from Latino workers.

Table 2 identifies substantial variation in adherence to safety principals: being risk free is a rare event for some work practices, e.g., Ladder Safety Risks where, on average, only 2.6% of the observed work days were "risk free," while it occurs regularly for others, e.g., Attended a Daily Safety Meeting which was reported on 45% of observed work days. Overall, the majority of the observed work days were not "risk free," in fact there were no days reported without a carry related safety risk for any participant. In general, the patterns of "risk free" days follow what you would expect from self-reported scores on the safety climate.

Specifically identifiable from the study is that roofers have the lowest perceptions of supervisor's commitment to safety, both on several individual items and on the total score. In most cases, the trend is that individuals in the low tertile of safety climate scores have the lowest percentage of "risk free" days, while those in the middle and upper tertile have generally higher scores. However, in most cases these differences were not statistically significant, probably because of low power. In two cases, the comparison was statistically significant, and in one case the comparison approached statistical significance. Overall, the pattern of results suggests that the workers appraisals of the safety climate on the job site are predictive of subsequent observed safety behavior at the individual and collective level.

6. Discussion:

Collectively, the pattern of responses seems to suggest that workers generally agree that their employers are conscientious when it comes to safety, i.e., they seem to respond favorably to overall appraisals, BUT the behavioral translation of these appraisals doesn't seem to happen, e.g., things like recognizing safe behavior or providing safety instruction (either upon hire or regular safety meetings). Put differently, the results indicate that workers believe their supervisors are committed to safety, but behaviors suggesting actual commitment to safety are lacking. The contributions of this study must be considered in light of its limitations. First, the patterns that are evident are predictive although they may not be statistically significant indicating that any larger generalizability of the study findings cannot be ascertained because the sample population was small, localized, and recruited using non-probability methods.

More research with larger Latino population sampling is needed. According to Zohar (2010) high level of analysis is also needed that can lead to recognizing patterns that identify relationships among priorities, e.g., production or field leadership vs. safety, and as a result once individuals recognize these patterns the opportunity for safer behaviors will likely be supported, and rewarded thereby improving safety climate and reducing overall injuries and fatalities. One research strategy may be to place particular emphasis on the trades with the lowest safety climate and high Latino representation with the intent to effect an essential reduction in occupational health and safety disparities experienced by immigrant Latino workers. In perspective it's not unexpected and one can go so far as to predict that the trade (roofing) with the lowest safety climate score from the study, is the trade with the highest number of fatalities (34.7/100,000 full-time workers) of all the construction trades (BLS 2010).

7. Acknowledgements:

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Table 1. Responses (‡) to safety climate items, and summary total, by type of construction worker.

	Sample (n=119)	Framers (n=26)	Roofers (n=35)	General Laborers (n=58)	p-value
	N (%)	N (%)	N (%)	N (%)	
Workers' safety practices are very important to management	83(69.7)	23(88.5)	18(51.4)	42(72.4)	0.0036
Workers are regularly made aware of dangerous work practices or conditions	85(71.4)	20(76.9)	20(57.1)	45(77.6)	0.0837
Workers are regularly praised for safe conduct	35(29.4)	6(23.1)	2(5.7)	27(46.6)	0.0001
Workers receive instructions on safety when hired	37(31.1)	9(34.6)	4(11.4)	24(41.4)	0.0094
Workers attend regular safety meetings	30(25.2)	7(26.9)	3(8.6)	20(34.5)	0.0200
Proper safety equipment is always available	82(68.9)	19(73.1)	21(60.0)	42(72.4)	0.5095
Workers have almost total control over personal safety	93(78.2)	24(92.3)	22(62.9)	47(81.0)	0.0172
Taking risks is not a part of my job	74(62.2)	21(80.8)	9(25.7)	44(75.9)	<0.0001
The possibility of being injured at work in the next 12 months is very likely.	100(84.0)	23(88.5)	29(82.9)	48(82.8)	0.4115
They do as much as possible to make my job safe (†)	48(40.3)	11(42.3)	14(40.0)	23(39.7)	0.9430
	M(SD)	M(SD)	M(SD)	M(SD)	p-value
Summary Score	23.0 (5.3)	24.3(4.8)	19.9(5.6)	24.3(4.7)	0.0001

(‡) individuals who responded "strongly agree" or "agree" versus "disagree" or "strongly disagree". (†) individuals who responded to the question "How much do supervisors seem to care about your safety" with the reported answer over "they could do more to make my job safe" or "they are only interested in doing the job fast and cheaply"

Table 2. Variation in the percentage of observed work days during the diary period that individual and collective safety practices were reported among Latino construction workers.

		Summary Safety Climate Score			
	Sample‡	Low Tertile	Medium Tertile	High Tertile	p-value
	M (SD)	M(SD)	M (SD)	M (SD)	
Individual Safety Practices					
No Ladder Safety Risks	2.6(9.3)	2.0(6.0)	1.3(3.5)	5.2(15.8)	0.2473
No Lift-Related Safety Risks	2.1(6.9)	2.3(7.5)	2.0(7.3)	2.0(5.5)	0.9732
No Carrying-Related Safety Risks**	0(0)				
No Scaffolding-Related Safety Risks	3.6(12.3)	3.7(7.7)	2.0(7.3)	5.6(20.0)	0.5448
No Glove-Related Safety Risks	33.1(26.8)	26.6(28.1)	37.0(23.8)	36.5(28.1)	0.2253
Did Not Do Something Known to be Unsafe	42.2(27.6)	32.8(30.8)	49.6(24.9)	44.5(24.2)	0.0418
Collective Safety Practices					
Attended a Daily Safety Meeting	45.2(28.3)	36.9(31.2)	52.5(25.2)	46.2(26.3)	0.0822
Reported a Safe & Orderly Worksite	10.8(17.9)	11.6(20.3)	13.0(18.5)	6.8(13.3)	0.4138
Had all Necessary Safety Equipment	11.8(21.5)	12.7(22.9)	14.1(23.3)	7.5(16.9)	0.4918
Did Not Need to Use Damaged Equipment	43.7(28.3)	33.1(28.8)	51.7(26.5)	46.7(26.6)	0.0227
Did Not See a Coworker Create an Unsafe Situation	43.6(27.0)	36.5(31.1)	49.0(25.3)	45.5(22.1)	0.1600

‡ Sample consists of participants with one or more work-day diary entries (n=90).
**No days reported without a carry-related safety risk for any participant

Safety Initiative Effectiveness in Hong Kong – One Size Does Not Fit All

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Safety Initiative Effectiveness in Hong Kong – One Size Does Not Fit All

ABSTRACT

Hong Kong is experiencing a massive increase in construction output. However, the cost of work-related accidents and ill-health in the construction industry account for as much as 8.5% of project costs when social, direct and indirect costs are included. The industry in general is receptive to change and becoming more OHS conscious but the forces driving change in the industry are opposing. The research found that institutional barriers exist to a concerted improvement effort and the best performing contractors, clients, consultants and subcontractors attain standards of excellence comparable with the best in the world but there is a wide range of organizational maturity, and so performance, throughout the industry. In this research study the following issues have been identified where new initiatives need to be developed:

- Developer attitude: a culture change is required:
- Client insurance;
- “Can do” attitude;
- Use of data;
- Maturity of Organisations;
- Health issues

KEYWORDS: Safety initiatives, effectiveness, Hong Kong, action research, organizational maturity

1. CONTEXT

An underlying theme running throughout the research has been the need for empowerment of the industry to manage itself effectively. In order to do this many industry participants have recognized the need for capability development within individual firms and development of a sustainable industry. As far as safety is concerned initiatives have been, in the main, very successful on larger, public projects but a plateau in the improvement trend has now been reached. In order to further reduce accident rates a different approach needs to be adopted and the industry as a whole needs to examine the skills required industry wide for further successful accident rate reduction.

More importantly there is a serious problem in relation to the expected increase in output within the next two years with the onset of the 10 major infrastructure projects and the West Kowloon Cultural Development. Accident rates can be seen to mirror output in the construction industry (see Figure 1) and, hence, we should anticipate a significant increase in the accident rate with the increase in output. Thus, this study was undertaken to informing planning, now, for the expected.

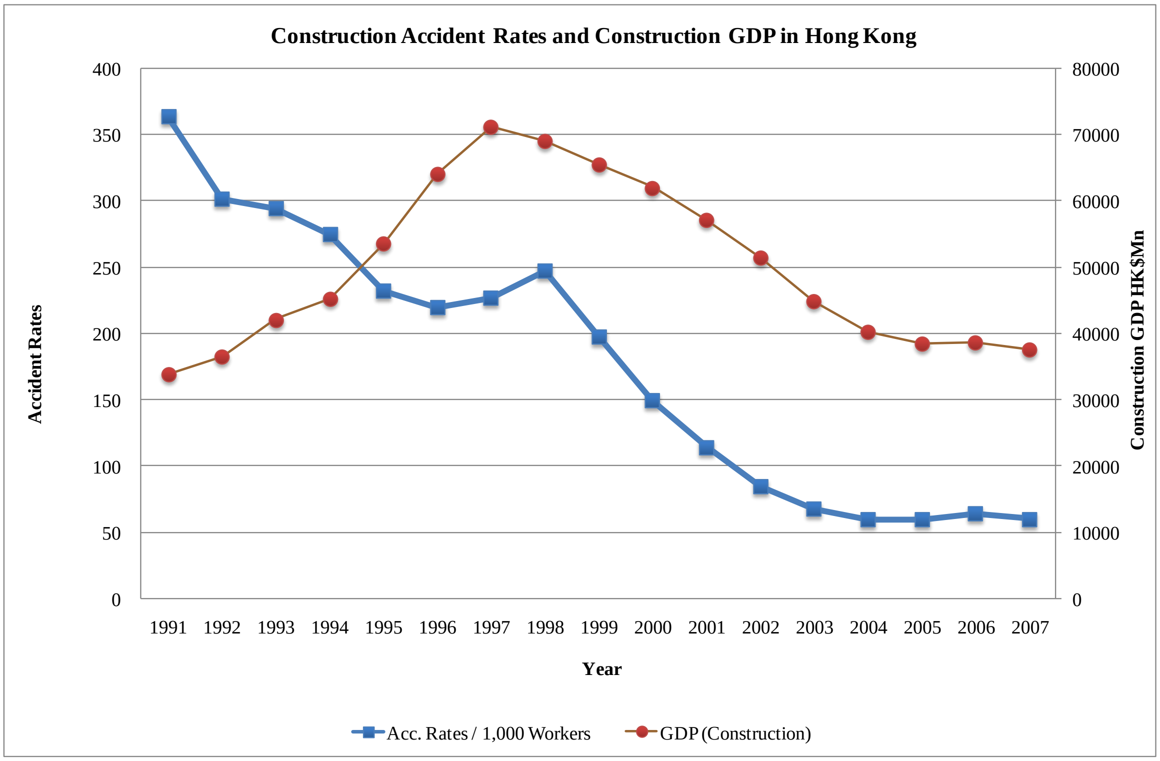


Figure 1 - Construction Accident Rates and Construction GDP in Hong Kong
Source: Census and Statistics Department & Labour Department, Hong Kong.

Approach

The objectives of this study wee to assess what are effective strategies for all sectors and sizes within the industry. In order to consider these strategies the following needed to be addressed:

- an audit of the current situation, with problems identified and targeted, the current issues study reported here;
- capabilities and costs identified and change focused on effectiveness, the cost effectiveness study and cost calculator, reported elsewhere;
- in order to see improvement change needs to be implemented at all levels and in all sectors of the real estate and construction industry.

Background to the research

Hong Kong has moved away from prescriptive safety legislation towards performance based management of safety and health over the past decades (Lingard and Rowlinson 1994). This move has obviously met with some success as the accident rate in the construction industry has continued to fall over this period. Figure 2 indicates how a series of initiatives, commencing with the promulgation of the safety management system approach, has led to a steady and consistent decline in accident rate. The decline has been such that the accident rate in Hong Kong's construction industry is now apparently less than that in the United States (see endnote), and is also now lower than that of the catering industry in Hong Kong. Hence, at least in parts of the industry, something has been done effectively and performance has improved. In order, to maintain this downward trend it is necessary to review existing initiatives as well as develop new ones.

The Hong Kong context

One of the issues to bear in mind in this research is that organisations are all different. What works effectively in one organisation may not be as effective in another organisation. Hence, it has been important to widely survey different sectors of the industry and different levels within organisations in order to draw together a report that provides a good understanding of what makes initiatives effective. Examples of good practice have been drawn from work in the United Kingdom whereby workers are empowered to improve safety performance through worker engagement groups. Such an initiative, which may perhaps be started through the site safety work cycle, could well be effective in Hong Kong and should be investigated. Also, culture is an important issue. Not just the national culture but the culture within the organisation. All countries and organisations exhibit different cultures and in order to make use of these cultural traits there is a need to focus on the partnership between worker and company and between company and industry and to develop the concept of relationship management and the sharing of common goals in order to improve safety performance. Additionally, the multi-layered sub-contracting system adopted in Hong Kong has been seen to be an impediment to safety. This was indicated in the Tang report and is being addressed by the Construction Industry Council. Hence, these structural and cultural issues must be included in the safety management process in order for effectiveness to be properly gauged.

The issue of 'Design for Safety' has been regularly raised as an important concern. The fact that risk assessments related to method statements are now commonplace on Hong Kong projects has undoubtedly contributed to improvements in safety. However, the process of involving the client and consultants in the early stages of the project in considering safety is fraught with difficulty, as the UK has found out (and to a greater extent the EC with its model) in attempting to implement the UK Construction Design and Management Regulations. Recent reports have indicated that this approach is flawed and needs to be remodelled in order to become effective. Work in progress in Australia (by Lingard et al, 2008, Federal Safety Commissioner , 2006 & 2007) that investigates why simplistic design OHS provisions are unworkable in the complex, socio-technical process of construction design has informed this research. This is one area that needs to be carefully considered and an industry consensus derived so that such an approach can be effectively implemented. A whole life cycle view may well be the answer.

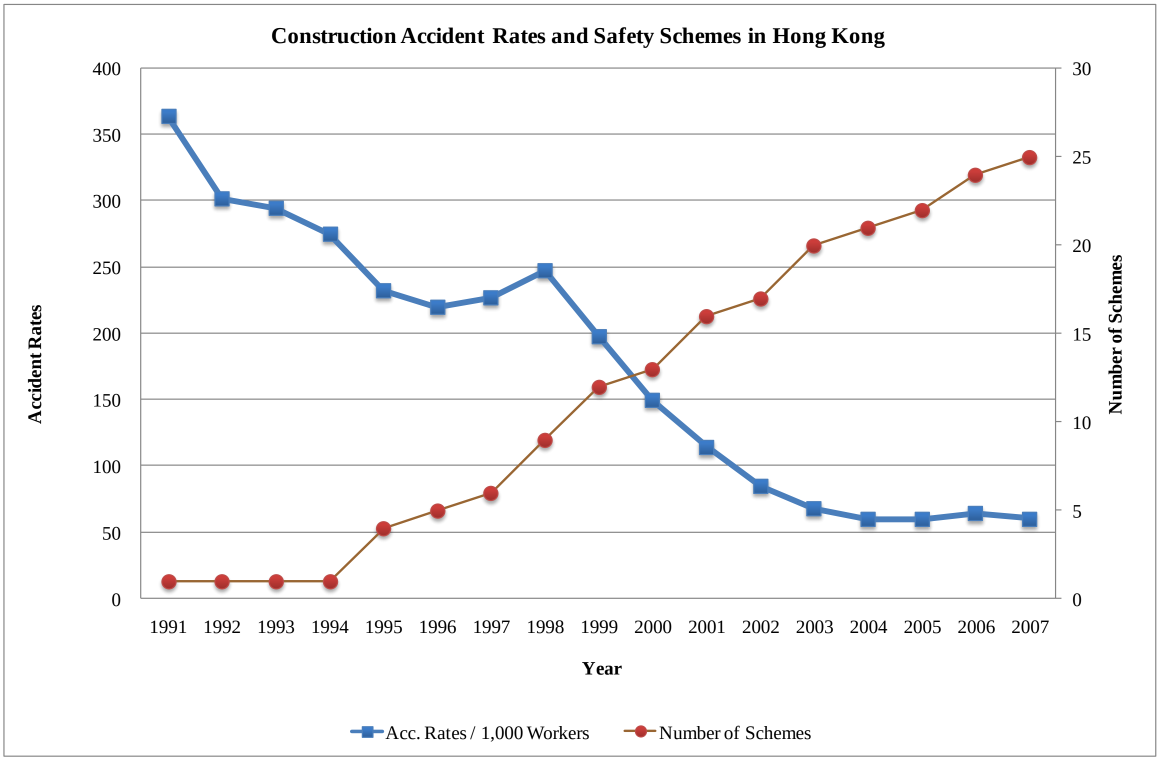


Figure 2 - Construction Accident Rates and Safety Schemes in Hong Kong
Source: Labour Department and HKU research team

Existing initiatives

Of the initiatives which have been undertaken in order to improve construction site safety one might categorise these into four types. These are:

Statutory, based on the Hong Kong Ordinances with the Occupational Safety and Health Ordinance being an example which introduced safety management systems to the industry;

Financial, which are to do with providing incentives to safe performance such as the 'Pay for Safety Scheme' introduced by Works Bureau contracts in 1994**;**

Procedural, these initiatives are based around processes that are included in the construction contract and these might include the Housing Authority PAS Scheme, the Safety Work Cycle and other similar initiatives;

Punitive-administrative, examples of this would be the Works Bureau's approach to safety performance, whereby contractors who experience serious injuries on their sites are brought before a committee, who can advise voluntary suspension from tendering. The Housing Authority's Superleague might fall into this category.

These initiatives have been assessed in order to form the framework within which the findings of this research are explained and presented: things that have worked well; things that need improvement; things which have been ignored but need to be addressed.

2. Work Undertaken

Potential issues that can be used as drivers for improvements were identified. The research approach used to do this is discussed below.

Research Programme

The research adopted a participative approach in which the results of the surveys were fed back to managers and the effects of the safety initiatives and the perceptions of managers on the safety performance perceived by employees and other stakeholders were explored in participating organisations. This provided a valuable benchmarking exercise for the participating organisations and provided them with an opportunity to explore new directions in order to improve their performance. It also provided the researchers with the opportunity to compare and contrast these effects in different industry sectors and, through collaboration with Australian and UK researchers, highlighted significant differences that may be brought about by different cultures.

Safety Effectiveness Qualitative Study

A series of face to face interviews were conducted among 30 different stakeholders in the construction industry to collect their opinions on the effectiveness of different safety initiatives. The participants were strategically selected to include but not limit to developers, main contractors of Groups A, B and C, sub-contractors, suppliers and insurers. The positions of the interviewees mainly include directors, project managers and safety management. During the interviews, the interviewees were asked to share their experience and express their opinions on the current safety initiatives; as well as suggest new initiatives or areas for future improvement. The interviews were conducted continuously until the interview contents were saturated.

The map that appears here in Figure 3 indicates the range of issues which surfaced during the detailed study of perceptions of safety initiatives and safety management in Hong Kong. The map was derived from a series of interviews with a wide range of professionals, managers, workers and administrators in the industry (contracting, consulting, developer and insurance sectors) and the questioning was informed from a detailed analysis of accident statistics. Each of these issues will be dealt with briefly here but two underlying issues need to be highlighted in order to put the issues into context.

3. Results

Maturity is an important issue

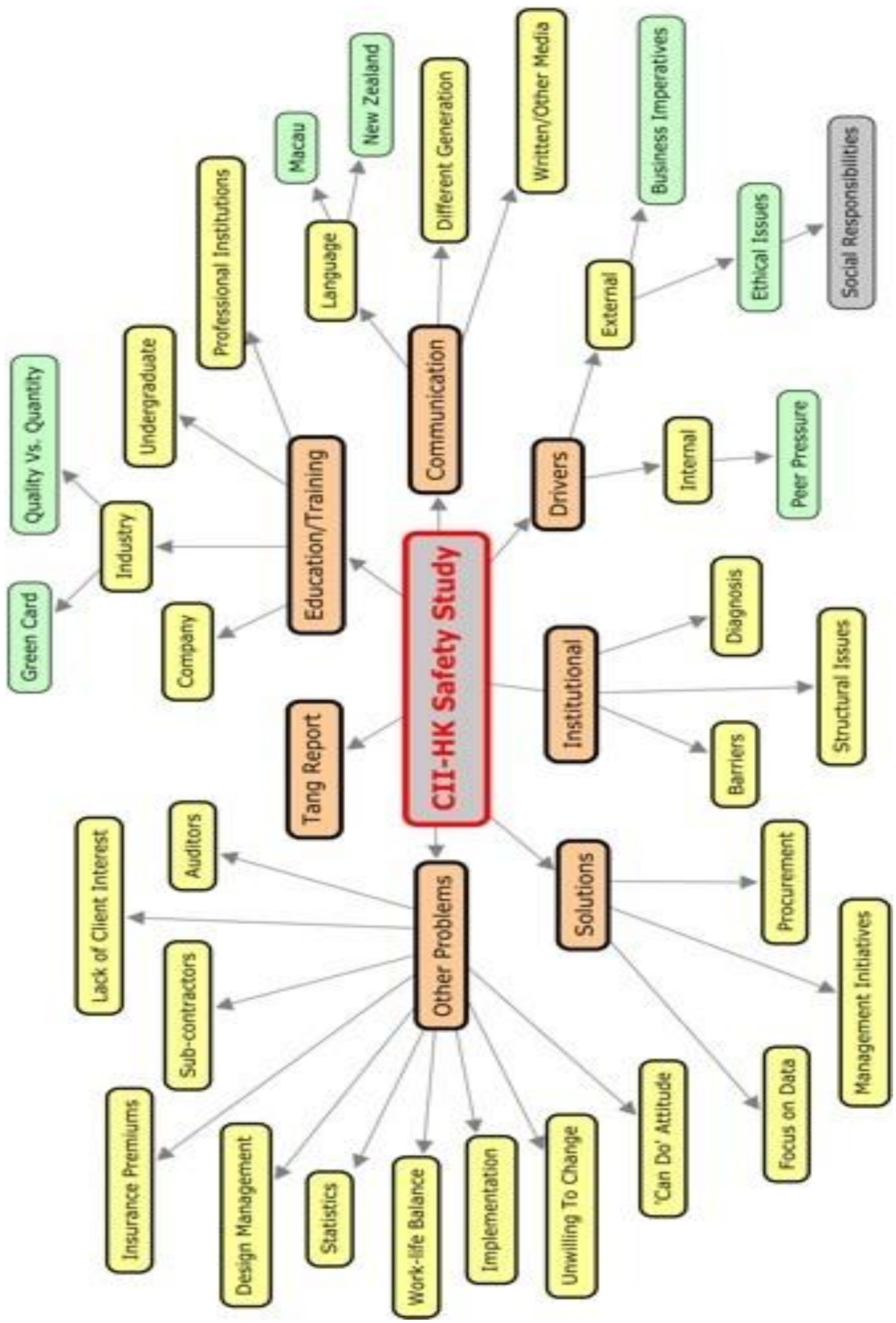
It became apparent during the study that a major issue for the industry was the maturity of organisations. If we were to take a five level maturity system then one might argue that only the top ten contractors could be classed as level five maturity. Indeed, much of the industry is seen to be at a maturity level one or two whereby their main focus in terms of safety management is compliance as opposed to the continuous improvement philosophy of the top contractors. Such a view could also be applied to the private developers, in that perhaps less than ten of these can be seen to be adopting a mature attitude to safety management on their projects. Hence, in terms of future strategy this leads us to the situation whereby a three-pronged approach to improving accident rates is necessary. Briefly, this means that three different foci of attention should be provided for those contractors, and developers, falling into the three categories of immature, maturing and mature. This approach is illustrated in Table 1 and points to the need to develop quite separate strategies for the "three levels" of participants in the industry; one size does not fit all.

Table 1 - Maturity of Organisations

Level	Nature	Commitment	Focus
Level 1 - Initial	Immature	Compliance	Compliance
Level 2 - Repeatable Managed Level 3 - Defined	Maturing	Continuance Normative	Norm
Level 4 - Quantitatively Managed Level 5 - Optimizing	Mature	Affective	Continuous Improvement

(Source: adapted from the Capability Maturity Model: http://valuebasedmanagement.net/methods_cmm.html)

Figure 3 - Current issues in safety management in Hong Kong



Education and training

The current green card system could usefully be revamped but is not the cause of the problem addressed here – the green card system sits at the bottom of the whole range of training needs of the industry. There is an urgent need, as noted above, to develop an OH&S competence framework for the industry as a whole in order that management may exercise effective leadership. This view was reported from a number of sources. The basic problem for the green card is twofold, and at one level reflects similar criticism of the Construction Skills Certification Scheme in the UK too (http://www.cscs.uk.com). Firstly, the syllabus of the green card scheme needs to be reviewed so that it may be more carefully structured and address ***skill and safety*** issues at a more detailed level, particularly focussing on hazard identification rather than knowledge of legislation; the former being essential for the front line worker. Secondly, there appears to be an over provision of underperforming providers of accreditation courses and this issue needs to be addressed by the industry as a whole..

Whilst recognising that it is important to reach consensus on this an important issue to bear in mind here is that the green card system was devised in order to provide only a basic, introductory course which is to be supplemented by contractors' own in-house training system. However, in comparison with the UK, the Hong Kong course emphasises regulations and knowledge of their implementation as opposed to hazard recognition; a very different focus. Hence, any review of the system should focus on the effectiveness of and need for teaching regulations as opposed to hazard recognition and action. A more practical focus of the course content might lead to a significant improvement.

Education and training at tertiary and professional levels

The coverage of occupational health and safety issues at tertiary institutions can be improved quite considerably. A whole series of professions are educated in Hong Kong's tertiary institutions, such as civil engineers, builders, facility managers, building services engineers, structural engineers, architects, etc. and there is no common syllabus in terms of occupational health and safety and there are no courses designed at integrating the design and management of construction projects, excepting MIDIM at Hong Kong University. This is an issue that should be addressed by both the universities and the professions. It is now a cause for failure in Institution of Civil Engineers (UK) professional assessments if the candidate does not show adequate knowledge of occupational health and safety. Such an approach could be mandated for all of the professions within Hong Kong.

People issues

Communication is a problem in safety improvement. It was reported by a number of respondents that communicating safety management ideas, procedures and instructions is often a difficult task. A major issue here is the overwhelming of middle management with documentation and systems whereas at the worker level it is the problem of maintaining a consistently focused message to the workers. Technologies such as visualisation, video on phone, sms, etc are now all readily available and provide simple, functional and effective means of promoting safety messages and explaining safe practice. Many expressed the view that language wasn't so much a barrier as the means of communication. A different view that addresses this issue is presented in Hare and Cameron's (2007) paper.

Ageing workforce

In a related point, there was also a belief that the ageing workforce and ingrained ideas and attitudes were difficult to change because of this demography. In their reports, Leaviss, Gibb and Bust (2008a; 2008b; 2008c) highlight the issue of older workers in the construction industry and list the following key issues in relation to their "value", which have also been raised by contractors' directors in Hong Kong (see Table 2). Given the likely upsurge in output in the near future leveraging the positive values in "inducting" new staff and addressing the negative values through training and job re-design are essential new initiatives.

In addition Leaviss et al. (2008a) point out the financial benefits of reducing work-related ill-health in the construction industry. A UK study estimated the cost of work-related accidents and ill-health in the construction industry to account for 8.5% of project costs (HSE 1997). This includes the costs of delays, absenteeism, health and insurance charges. Quite worryingly, there appears to be a worldwide trend for construction workers to retire early due to health issues: this both deprives the industry of skills developed and knowledge gained over many years and also adds to the social cost that the industry generates for society at large.

Table 2 – Value: Older Workers in Construction

Positive Value	**Negative Value**
Trade skills and knowledge	Lack of fitness
Experience	Lack of safety behaviour
Work ethic	Resistance to change
Workmanship	Cost to project

Potential Issues which can be used as Drivers for Improvements

Developer attitude. Following on from the previous point, it is important to recognize that developers as well as contractors exhibit different levels of maturity. Such a problem needs to be addressed at an institutional level in that the organizations representing developers and government departments interacting with them need to lay down basic principles and procedures they are expected to follow.

Client insurance. The insurance industry plays an important role in the real estate and construction industries. However, the Insurance Industry Ordinance does not allow for the active and comprehensive sharing of information on construction industry performance. Hence, an experience rating modification system is difficult to implement in Hong Kong at the present time. This is an institutional barrier to progress which would allow better performing contractors to experience lower premiums and so higher competitiveness. Indeed, one mechanism for addressing this might be to put the insurance in the hands of the clients and so focus clients' attention on occupational health and safety management.

"Can do" attitude. One of Hong Kong construction industry's distinctive competences is its "can do" attitude. The ability to construct high-rise buildings on four day floor cycles cannot be matched in many places worldwide. However, this "can do" attitude comes at the cost of flooding sites with plant and equipment and a focus on long working hours in arduous conditions leading to stress all round. This is an issue which needs to be reviewed and the industry needs to be educated to take a more mature attitude to this problem. The ability to say no to unreasonable client demands for speed needs to be developed and the Housing Authority's initiatives in the 1990s in this area are an excellent, successful example.

Use of data. The industry as a whole and the Labour Department in particular collect a massive amount of data on construction site accidents and their effects. A program should be put in place to make better use of this data in order to inform contractors and developers of trends in accident causation. This work could be let competitively to an organisation outside of the Labour Department in order to ensure an unbiased opinion. Examples of issues which have been identified but not so far addressed are the occurrence of high rate of accidents in the summer months and the existence of two peaks in accident occurrence at different times of the day. Evidence from the UK indicates that interventions in terms of workers diet can be effective in this respect.

Frank auditing. Independent auditors are placed in an ambiguous position in that they strive to provide frank audits and yet are under pressure to ensure that their auditees actually achieve a passing grade. Hence, there is a tendency to underplay faults in audited safety management systems in order to address this ambiguity. However, the mature contractors and developers expect to be given feedback from audits which will allow continuous improvement within their organizations. Thus, there needs to be a careful review of the existing system to protect the integrity of the auditors and provide best value for the auditees.

4. Conclusions

The industry in general is receptive to change and becoming more OHS conscious but the forces driving change in the industry are opposing. Currently, institutional barriers exist to a concerted improvement effort and these need to be addressed and removed. The best performing contractors, clients, consultants and subcontractors attain standards of excellence comparable with the best in the world but there is a wide range of maturity, and so performance, throughout the industry. In this research study the following issues have been identified where new initiatives need to be developed.

- Developer attitude: a culture change is required and a move towards open disclosure of OHS performance

- Client insurance: a move to a territory wide insurance modification system where the best performing contractors and developers are rewarded

- “Can do” attitude: one of Hong Kong’s strengths is also one of its weaknesses – we drive ourselves and our co-workers beyond the limit of what can be reasonably expected.

- Use of data: the data collected on accidents and incidents should be reviewed for its content and its use – more can be made of the data

- Frank auditing – focus on improvement: a mechanism has to be developed to allow independent auditors to be freed from the commercial pressure they feel to bowdlerise their audit reports.

- Maturity of Organisations: the best contractors in Hong Kong are world leaders in OHS management and performance. A concerted effort is required to enable the less mature organizations to develop and grow despite their limited resources;

- Health issues: these are not dealt with adequately in Hong Kong at the moment. One third of construction workers suffer from health issues.

Endnote

Incident rate is calculated as number of accidents multiplied by 200,000 and divided by the number of employees’ hours worked. This is intended to be equivalent to the accident rate per 100 workers assuming a 40 hour week for 50 weeks in a year. In Hong Kong the average working week in the construction industry is 48 hours, six days per week, over 50 weeks. Hence, taking the 2007 figures for both jurisdictions (the most readily available and reliable figures) the US rate of 5.4 (http://www.bls.gov/iif/oshwc/osh/os/ostb1921.pdf, accessed June 1, 2011) would compare with a Hong Kong rate of 4.3 (*op cit*). However, such comparisons are fraught with difficulty due to, in addition to the calculation regime, different reporting protocols and mechanisms and the worldwide phenomenon of under-reporting, the scale of which is difficult to assess in any jurisdiction. Suffice it to say that the ten year improvement from 1997-2006 in Hong Kong has been substantial and brought accident rates back in line with western nations. Figures show over 1000 fatalities in total in the US industry in 2007 compared with 40 in Hong Kong; note, these are not rates.

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A Collaborative Examination of the Metro Indiana Coalition for Construction Safety as a Possible Model for a Safety Regulatory NGO

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Abstract

The utilization of a Non-Governmental Organization (NGO) similar to ISO is one approach for overcoming barriers to the globalization of standardized workplace safety rules and regulations. The Metro Indianapolis Coalition for Construction Safety headquartered in Indianapolis, Indiana is a non-governmental organization which has served to promote workplace safety for the construction industry. A study of this organization is proposed to determine if it presents both the form and scalability of a type of NGO that might one day be utilized to successfully implement globally enforced workplace safety principles and processes.

1. INTRODUCTION

Global conditions may or may not be considered when countries craft regulatory processes to govern internal activities. At times, this poses contradictions as nations attempt to conduct activities and interactions with the entire world and yet, govern their actions only by internally recognized rules.

When an organization operates by its own rules exclusively and without regard for the greater community, it loses the ability and opportunity to build consensus with others. A "common order" is necessary to bring about consistency and understanding with other organizations which have no previous knowledge of one another. As an example, the directives of the International Standards organization (ISO) are utilized to bring about a global consistency in the documentation of the manufacturing process in order to yield quality manufactured goods. The ISO process is accepted globally.

As safety professionals we realize that the protection of human life and welfare in work activities is necessary in order to preserve human capital. The enactment and enforcement of workplace safety rules and regulations can be influenced by particular cultures, political systems and various moral/ethical persuasions, all of which may or may not be acceptable to another organizational system or culture.

The compliance behavior of contractors engaged in a wide spectrum of construction trades has been observed for a number of years in the Indianapolis, Indiana market area. Several safety performance indicators of these contractors including the TCIR and DART Rates have noted a decrease in the total number of recordable injuries. The individual data bases of some local owners who regularly purchase construction services have also recorded lower rates of reported accidents and injuries on construction projects they have managed. These affects appear to be associated with membership and active participation in a local organization locally known as MICCS, Metro Indianapolis Coalition for Construction Safety. The intent of this paper is to examine this phenomena in an attempt to determine the founding precepts and principles of this organization, gain some insight as to why it may have motivated contractors towards safe behaviors and any distinguishing factors that might begin to explain why this organization seems to have much more influence in motivating safe work behavior than does the statuary regulators of the State of Indiana's OSHA plan.

The process of this inquiry takes the following steps. First the inquiry of why do anything beyond the OSHA statutory requirements for work place safety management. Once decided that actions beyond OSHA compliance would be taken the follow on inquiry is what those actions should be, then how to accomplish these actions and finally some inquiry as to sustaining the forms and processes which deliver the desired outcomes.

2. BACKGROUND

First Inquiry – why surpass OSHA regulatory compliance requirements

A first question of this inquiry was to determine the foundational motivator for justifying the activity of developing an organizational structure in the first place.
MICCS beginnings why change in the first place, was a question of motivation. A Fortune 500 . pharmaceutical company experienced a fatality event where a contractor on one of its projects was killed. The corporate construction management team asked the question as to how they could gain more control of the construction process to enhance safety. A methodology was needed to establish control and provide a motivation for all contractors to accept and execute improved safety process.

It was widely thought that the contractors had taken a "this is our turf" attitude about managing work site safety practices. And, while no contractor wants any of its employees to be intentionally hurt, there was no aggressive management of safety as a formally practiced means and/or method of construction management.

Concurrent with the examination of managing construction safety this same company instituted an Owner Controlled type of insurance program whereby a form of a master policy is underwritten by a carrier to insure all worker compensation risk during a given project. The motivation of this approach is the financial incentive of not having injury claims and a direct refund to the policy holder. This approach created a direct monetary incentive to eliminate injuries at project work sites.

Different motivations were discovered which gave a direct incentive to the outcome of zero accidents. Rather than a simple regulatory avoidance there was an active outcome defined to provide motivation. However, this outcome required the active participation of the construction contractors and trades personnel themselves. The issue of motivations quickly evolved into how could these motivations could be shared and manifested in others whose participation is necessary to implement safety at construction sites.

A focus on defined change

This particular Fortune 500 Company was spending more than 500million/year in construction of capital projects. It was reasoned by this company to be a significant critical amount of spending to entice construction contractors to cooperate in exchange for the opportunity of gaining this amount of work. However, if efforts to affect more control of the construction process and to be able to influence the safety behavior and resulting safety performance at construction sites was to be profoundly changed. Then a time span for influence and a managing presence was needed to sustain the change process. There was not a good model for integrating government, meaning OSHA, into this process as a managing presence over time. OSHA's primary mission was perceived to be that of enforcement, a perspective not conducive to fostering transparency, consensus or cooperation at that time.

The initiative to integrate more involvement with contractors for the planning and execution of more extensive safety and risk management principles required a strategy aimed at embracing as wide an audience of interested owners and contractors as possible. The focus of "industry wide" was adopted in order to steer the perception of participants away from the thinking that this effort was singularly self serving. The plan for implementation settled on the technique of creating a free standing independent organization charged with a broad, universally acceptable mission. This organization could then facilitate the process of safety improvement change using coordinative techniques appropriate to the affected participants.

3. EXPLANATION

A mechanism to make and sustain change

The construct or using a unique organization lead to the formation of the Metro Indianapolis Coalition for Construction Safety, Inc. (MICCS) in 1992 ; a nonprofit organization dedicated to achieving zero injury on construction job sites. It attempts to accomplish this by promoting the adoption of safety-related industry standards that are different from and/or more stringent than, for example, rules and regulations implemented by OSHA.

Members include construction companies, users of construction services ("owners"), design professionals, suppliers, and construction-affiliated organizations. All members pay dues each year.

The MICCS Board of Directors was deliberately selected to represent every segment of the construction industry, from general to subcontractors, owners (construction consumers), union and nonunion contractors, and companies affiliated with the industry. This broad based board membership was adopted in order to promote an understanding within the membership that when the Board endorses an industry standard, the industry can be assured that this group has thoroughly considered the standard and recommended its adoption. These standards are then implemented when owners and/or contractors adopt the standards for use on their construction sites.

All construction sites are encouraged to implement and enforce these standards, though MICCS cannot and does not require them. Below are listed a number of key organizational principles which the MICCS leadership publicly presented. These attributes were stated to be the key reasons for the success of the organization.

1.MICCS is led By Owners which increases the likelihood of all-industry support (union and nonunion).

Owner leadership puts "teeth" into the "Council's" "suggestions…they become mandatory by implication.

ALL owners – even one-time, benefit

2.MICCS is funded by voluntary dues, which increases the likelihood of

efficient use of resources.

3.MICCS encourages genuine involvement – and care – in the organization and the cause of safety

MICCS leadership also offered a number of specific actions taken in the organizational process stated as "Things to Be Sure and Do":

In early stages, communicate every stepping stone of progress, adding credibility.

Don't settle for lower management on the Board: contractors will see the importance you place on the organization.

Involve the entire industry when major programs are considered: conduct "open hearings".

Provide seed money for early development: dues come with credibility.

Invite all major owners to participate…personally.

Choose Committee Chairs carefully…especially the first ones!

Create a "steering committee" that all committee chairs are on…with owner chair.

In 1996 MICCS introduced a certification program. The goal of the MICCS Certification Program was stated as being the following:

The program is a web-based database that is used by construction consumers ("owners") as well as by contractors to pre-qualify their subcontractors by providing them with important safety-related information in an easily-accessible, standard format. This allows system users to, in mere seconds, view validated safety statistics and information from the exhaustive safety audits MICCS conducts on each participating company.

To become a "MICCS Certified Company" means that a company safety performance is among the top 20% of construction companies in the nation.

The program is an evaluation tool for companies when it comes to their safety program each year. From the very first time a company enters the program through each annual renewal in the program, MICCS provides an extensive review of a company's safety program and validates that the statistics in the program's database are what was also reported to OSHA.

4. IMPLEMENTATION

Changes Made - A process implemented, First steps and beyond

FIRST steps of change. Once the motivation was developed, a first fruits campaign was developed whereby the organization considered what could be done first and quickly and successfully. A study of construction accidents showed that in a very high percentage, illegal drugs and alcohol were a common element .that caused impaired behavior. Therefore, the first efforts were focused on developing a consensus using a difficult to object to universal condition. Dissention or non-cooperative would then have little or no opportunity to gain any traction against a principle based on such unquestionable common good.
Change SYSTEM - process. Next the drug free workplace issue took the form of creating a process for the determination, frequency and tolerances of detection. The issue here was one of standards of measure and more importantly a date system for recording and publicizing results to parties in need of this information. The tensions created by the exposure of results became a significant enforcement motivator to change substance use behavior and conform to a social norm. When business opportunities are facilitated or denied based on conformance to norms, companies quickly comply. The implementation of safety within MICCS organizations is indicated in Table 1, IDOL-MICCS “Certified Partners” Total Recordable Incident Rate.

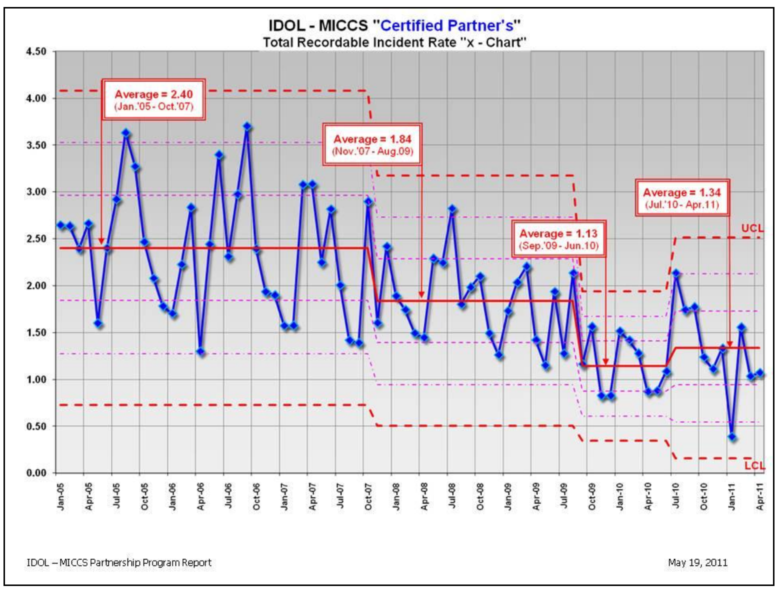

Table 1: Total Recordable Incident Rate

Change system celebration. Demonstration of having acceptable behaviors such that one can join the business community. Big systems that create big exposures, particularly negative exposures are a liability to participants. Therefore there must be some motivation in order to want to belong. Simply having the necessary safety parameters was not enough if all effort is done out of sight. The aspect of pressure from a community of “balancers” is important in order to maintain conformity. The MICCS annual Dinner Gala served as a joining and celebratory event which created the opportunity for members to be exposed to each other, compete with each other in public, and generally create a situation where the community could come together and recognize it’s community “bigness’ and thus feel empowered and encouraged by the size of the

group and numbers of people. The impact of the pressured socialization has proven to be one of the most enduring and sustaining aspects of the organization. A contest is an integral part of the celebration process whereby individual members via with each other in the presence of their potential customers for who is the best…an easy continuation of the inherent competitiveness of construction pricing and marketing.
The MICCS Dinner event creates a social and interactive business environment where accidents are simply unacceptable. Couple this with a clear and direct economic incentive to enhance safety and the process of cultural change is made.

In addition to the MICCS dinner acceptable behaviors are demonstrated in Table 2, IDOL-MICCS "Certified Partners" Days Away Restrictions and Transfers (DART) Rate. Continuous improvement is DART over the indicated period shows behavioral improvements in MICCS member organizations.

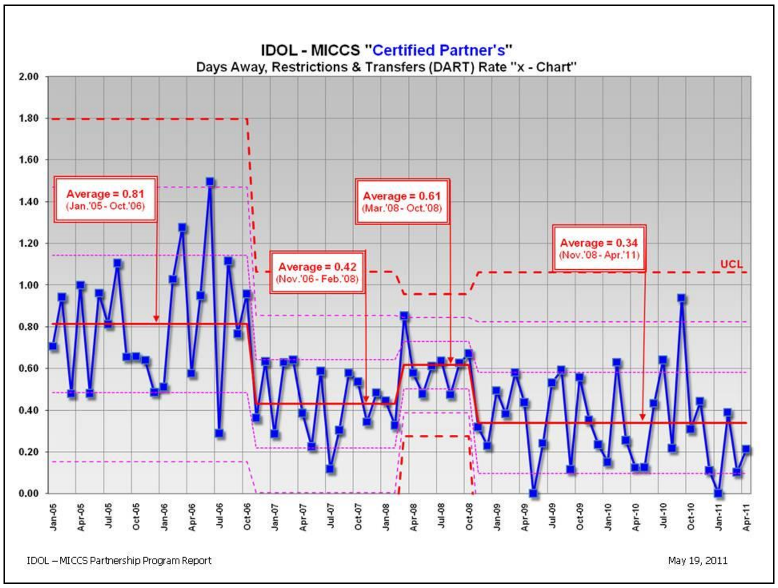

Table 2: Days Away, Restrictions, and Transfers (DART) Rate

Sustaining Change, creating newness and aspiration. The efforts and resources of some companies are far above that of others. If a level of consistence conformity is established then a layer can be identified that allows the consistent conformity to be easily recognized. This creates differences which can be recognized and rewarded. It is this reward area where the greatest challenge of sustainability presents itself. Client exposure is considered critical to building relationships and subsequent business opportunities. So one is forced to live at the level one attains, good or bad for the sake of staying within the "system" and maintaining this client exposure. . With layering comes the possibility of using inter layer movement as a motivator. Achieving a new layer is motivating based on attaining the notoriety of the top most levels. Table 3, IDOL-MICCS "Certified Partners" 12 Month Moving Average Total Recordable Incident Rate (TRIR) shows constant improvement and is much better than national and Indian averages. In addition Table 4, IDOL-MICCS "Certified Partners" 12 Month Moving Average Away Restrictions and Transfers (DART) Case Rate shows constant improvement and is better than national and Indiana averages.

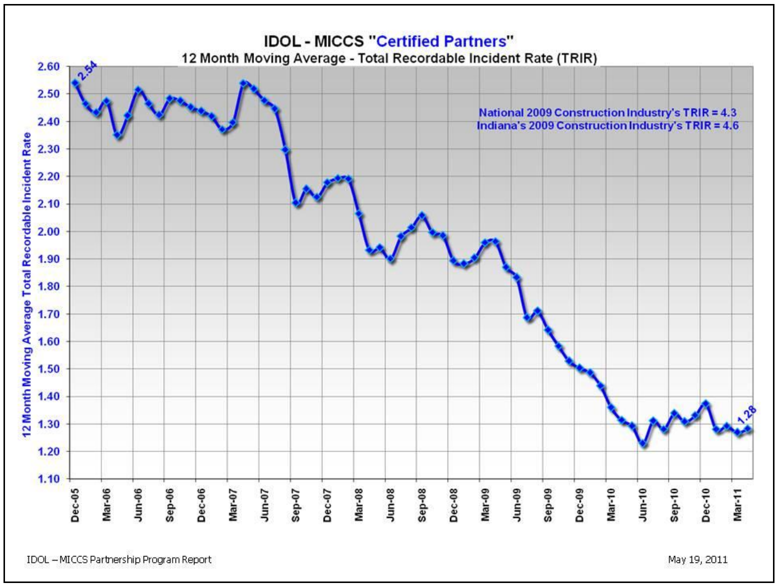

Table 3: 12 Month Moving Average – Total Recordable Incident Rate (TRIR)

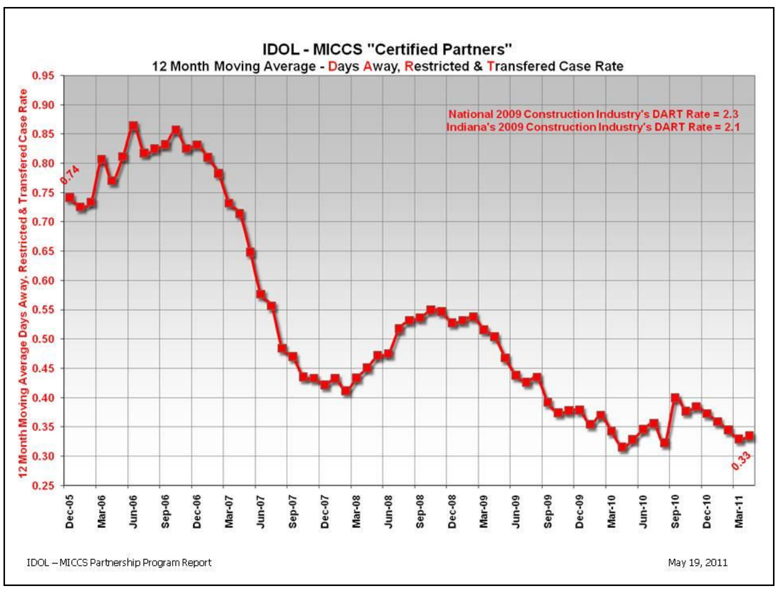

Table 4: 12 Month Moving Average: DART Case Rate

Leading Change. The initial organization steps seems to have been extremely business motivated however, the evolution into a dues paying membership with striving to have new and original activities embracing issues relating in importance to members seems to have been brought about by the personality of the leader. Personality seems to have one of the single largest energies in the maturation of the MICCS organization to become more than a single issue group. Therefore the question of the translation of the MICCS organization to another local begs this question of leadership.

Flamboyant Leadership …especially when the motivations are apparently member focused can yield surprising outcomes.

5. RESULTS

Understanding and Translation

Observing the aforementioned characteristics consistently over a number of years leads to the conclusion that a totally new and contrived social system was instituted. A new culture was created in which those living within this culture were required to conform to it. As the perception of business gain and relationship with owners was embraced, members of the new culture needed no encouragement to engage in safety improvement activities in attempts to outperform each other. This led to an empowerment of the construction buyer where previously the buyer had been somewhat beholding to the actual construction service groups who by virtue of their knowledge of means and methods had held control of the processes of delivering capital projects. Here to forth, owners were to a degree reliant upon a construction company's own internal means of being communicative, participative and transparent. The new culture engineered by the MICCS organization now provides models of behavior, communication and transparency within an inclusive staunchly supported social system. Table 5 clearly shows the benefits of implementing site safety in MICCS organizations. The indicated results in Table 5, IDOL-MICCS "Certified Partners" Injuries Prevented, are show as injuries prevented, or 66% better than average.

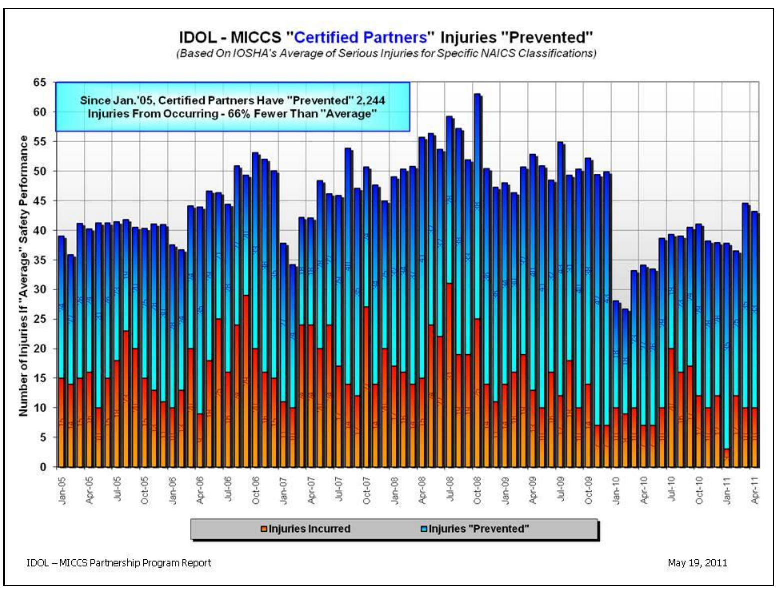

Table 5: IDOL – MICCS "Certified Partners" Injuries "Prevented"

6. THE Promise Unfulfilled

It is sometimes expressed that disappointment with the MICCS organization comes from the fact that membership and participation even on very in-depth levels does not guarantee any advantage with the cadre of MICCS Owner members. This expectation was an initial motivator of membership and participation has given rise to some relative deprivation within the group of long time members who see others getting business opportunities without the investment of time and energy and with little to no commitment to alter their safety culture.

There is no place in this study to discuss the outcome dynamics of this expression. The point here is to understand possible translation and scalability and to understand whether or not unmet expectations will limit replication of the MICCS organization.

In comparison, a difference with the ISO model type is consistency of individual member relativity with the scheme of the program. There is an equality within ISO contained within membership one either is or is not…the lack of “alternative” criteria preserves the integrity of the progress and intent.

7. Conclusion

This observational study falls considerably short of providing the in-depth analysis necessary to provide a basis for any sort of definitive conclusions. However, the success of this effort suggests that improvements in construction safety will focus not on deriving more safety tools but on the effective use of the ones we have. The MICCS Model suggests that motivating this use will focus on developing and sustaining safety defined relationship systems.

The Evolution of Legislation on Health and Safety on Construction Sites in Italy

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ABSTRACT

Starting in 2007, with the approval of law 123, the Italian government has proceeded to reorganize the law summary in the matter of health and safety in the workplace, highlighting important observations in respect to previous regulatory framework.The first concerns the reunification of set standards, ending the existing distinction between the construction site and other workplaces.

The second concerns the complete abandonment of logic on which the norm in the 1950's was based on, which are *obligations* and *prohibitions*, in favor of evaluative logic introduced in the EU Directives in the 1990's.

The paper examines in detail the path taken by Italy starting from the first legislation in the end of the 19th century until today highlighting the following stages:

- Damage preventions
- Risk preventions
- Safety planning
- Safety management

The differences found in the law summary highlight the difficulties of this route that is due to the particular situation that the construction industry is experiencing in Italy.

An element of no lesser importance, for example, is given by the excessive fragmentation of productive infrastructure of construction sector.

Keywords: Legislation, Health and Safety, Coordination, Construction site

1. **The socio-cultural Italian context**

Italy was among the first countries in the world to adopt specific legislation on the protection of workers' safety. The aspects of health and social work, in fact, have always been studied and analyzed carefully by the Italian medical and scientific world. It is no accident that, historically, the Italian, Bernardino Ramazzini was recognized as the founder of occupational medicine, who at the beginning of the eighteenth century inserted a new question into the Hippocratic anamnesis: "et quam artem exerceas? – What is your occupation?" Author of "De morbis artificum diatribe" (Padua, 1700), Ramazzini identified through an analysis of sixty categories of workers, the harmful effects of work and "the nature of harmful utilized substances."

Another Italian record is the development of occupational medicine as an independent clinic branch. In 1902 the "The Labour Clinic" was founded, the first institution in the world dedicated to this discipline, which was completed in 1910. In 1906, in Milan, the first international congress of occupational medicine took place and the International Commission on Occupational Health (ICOH) was founded.

In this cultural and scientific climate, the Italian regulations to protect workers, were developed. At the end of the nineteenth century in the middle of the Italian industrial revolution, theconcept of work was profoundly different from today. Environmental resources and human labor-power itself were seen as unlimited resources and inexhaustible assets to the industry that could exploit them at will, without any concern for their protection. The worker's protection, prevention of injuries and work related illness issues were not taken into consideration. Unlike the artisan, in fact, the worker was more often than not qualified, because the tasks carried out in the factories were often characterized by a low level of qualification. The worker, therefore, was interchangeable and his state of health was not a concern for the employer, who could easily be replaced. With the birth and the organization of the first unions, specific norms to protect workers came about. After the Crispi Pagliani Law of 1888 a system based on worker's insurance began to develop in Italy. A few years later, in 1899, the first laws dedicated to a specific work activity, work in mines and quarries, were enacted.

The health insurance system has gradually extended to new categories of workers. In the fascist period, within a social model based on corporations, health care coverage shifted from a voluntary to a mandatory regime, first for individual categories and individual illness, and later in a generalized form with the creation of the "The Workers Health Care Institute". During the same period, with the enactment of the Civil Code (1942) and the Penal Code (1930), the concept of "corporate responsibility" on the civil and criminal matters, recognizing that "the employer is required to adopt the necessary measures to protect the physical health and mental health of workers", began to develop. This concept was reinforced a few years later giving it constitutional value. In fact in 1948, in Article 35 of the Constitution work protection in all its forms was laid down.

The socio-economic change in Italy in the following years led to the need of developing a legal system to protect workers based on imposing company restrictions and constraints.

The companies did not apply, therefore, the regulations in accordance with a real interest in the health of its workers, but rather to avoid fines and penalties resulting from their breach. Between 1955 and 1956, with full industrial development of post-war reconstruction, a series of measures (the Act No. 547/55, 164/56 and 303/56) were issued, aimed at identifying the hierarchy responsible for safety to provide specific sanctions and to supervise their implementation. The legislation of the fifties still had many limitations within.
No information/formation activities for workers were provided, as a preventative intervention; the identification of specific exposure limit values lacked; identified remedies were too generic and, finally, the workers and their representatives were still poorly involved in prevention. The recognition of the necessity for direct participation of workers in the process of protecting their own health happened at the end of 1969, when the working population realized, that only direct experience of those who worked daily in hazardous environments would be efficient for assessing working conditions and the impact on the health of the workers. The "Workers' Statute" then introduced the rights of workers to control, through their union representatives, the implementation of standards for the prevention of accidents and occupational illness.

At the same time the claim to pay full wages and maintenance of the workplace in case of injury, occupational disease, maternity and sickness in general until complete healing was made. With the creation of the National Health System (Act No. 833/78), specific "environmental health services and occupational medicine" were set up, organized within each of the local health units to which the powers of the department of Health and Safety were progressively transferred in terms of injury prevention and safety at work. A personal health record to be distributed to all citizens, including possible exposure to risk in the conditions of life and work was also established. Moreover, within the same regulation, a consolidated safety and hygiene rule should have been included by the end of 1979, however, it was not added until 2008.
Since the early nineties health issues began to become intrinsic and strategic aspects of production processes as an indicator of quality. After the inception of the European Union (Treaty of Maastricht, 1992), Italy began to implement the EU directives in the field of health protection at work. The Act No. 626/94 was issued after a long process, preceded a few years earlier, by Act No. 277/91 on protection against risks of exposure to chemical, physical and biological (specifically lead, asbestos and noise).

The Act No. 626/94, in applying "to all public and private sectors," accepted seven EU Directives (workplace, use of work equipment, DPI use, cargo handling, use of display screens, safety to carcinogens and biological agents). This legislation introduced new provisions on risk assessment, information, complete and regular training of workers and their health inspection.

Specifically, in the construction sector, European law is applied in the Act No. 494/96, in which, for the first time, a system of analysis, design and safety planning was constructed within a specific safety management on construction sites document

2. **Development of Italian health and safety regulation**

Developments in Italian legislation and regulations on health and safety covered four basic stages, which are summarized as follows;

- Damage prevention
- Risk prevention
- Safety planning
- Safety management

Period 1865-1942: damage prevention

The first important provision in Italy in health and safety at work, laying the groundwork for future legislation, is that established art. 2087 of the Civil Code which provides: "The entrepreneur has the duty to adopt measures in the performance of the company, according to the particularities of the work, experience and techniques are necessary to protect the physical integrity and moral personality of the employee."

The diagram below illustrates the results obtained, namely:

- compulsory insurance for workers against the contractor
- the obligation of prevention and protection for workers
- the burden of proving possible negligence of the worker
- the compensation for damage suffered by the worker

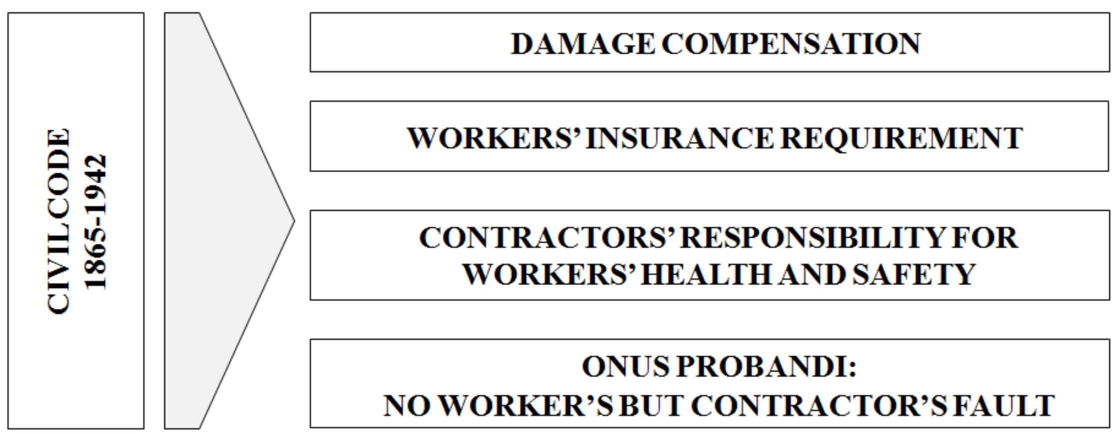

Fig. 1 – Summary diagram of the damage recognition in the Civil Code

Period 1955-1978: risk prevention

The subsequent provisions date back to the 1950's with the legislation concerning the prevention of accidents at work or the Act No. 547/55 and hygiene of work, the Act No. 303/56. Such laws are the pillars of accident prevention in Italy, along with the Act No. 164/56 on construction and emphasize the prevention of intrinsically safe mechanical systems and dictating prevention rules specific to each individual machine, or for any single working environment, allowing limited freedom of choice to the employer who is obliged to comply, for detailed and specific penalties for each breach, in fact, "Employers, managers and those responsible for carrying on, manage or supervise the activities of the company, within their respective functions and responsibilities are:

- take the safety measures provided in the relevant acts;
- warn employees of specific risks they face and make them aware of the ways to prevent damage due to such risks;
- provide workers with the necessary means of prevention;
- require those who have individual workers follow the rules of hygiene and safety and apply the protections available to them."

Such detailed and specific regulations to define specific rules do not allow room for interpretation and discretion to the employer who, within the enterprise, is not free to choose and adopt a preventative system but is obliged to comply with specific rules; A repressive system whose judgment is therefore delegated to the monitoring party that must ensure compliance to the obligations of the legal system. Only with the enactment of the Workers' Statute (1970) a new policy is established, compared to the above provisions, giving workers the right to "monitor the implementation of standards for the prevention of accidents and occupational illnesses and to promote research, development and implementation of all measures to safeguard their health and physical fitness."

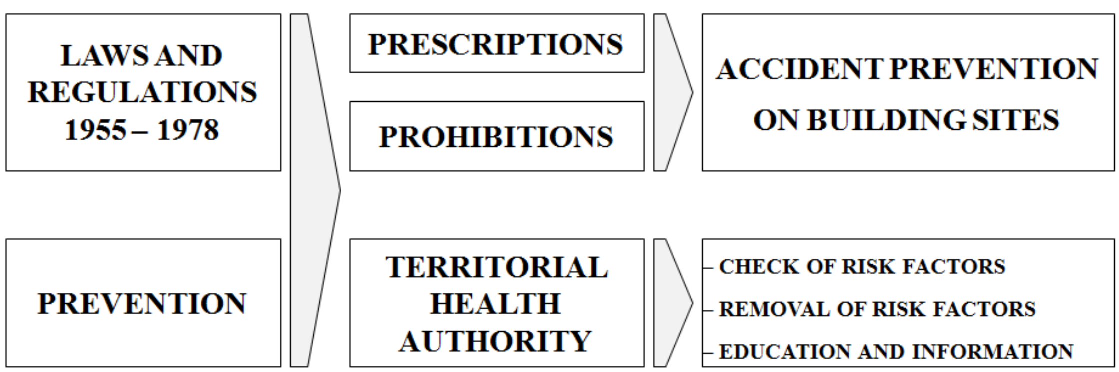

Fig. 2 – Summary diagram of the risk prevention in Acts from 1955 to 1978

Period 1980-1992: safety planning

In the 1980's a gradual change of the original setting of the 1950's was recorded, with the introduction of the laws on protection of the worker from chemical and physical agents in the workplace with the issue of Directives 80/1107/EEC, 82/605/EEC, 83/477/EEC, 86/188/EEC, 88/642/EEC, in which a prevention system is imposed to all the involved subjects and not just the workers and criteria for risk evaluation and prevention and protection measures are defined.

The Act No. 277/91, which establishes requirements on risks related to chemical, biological and physical agents and is the first norm that reverses the previous of the above requirements, indicating among the prevention measures, training for workers, health surveillance, the exposure limit values, the emergency measures and consultation of workers through their representatives. With Act No. 13/82 of the Ministry of Labour is introducing the concept of accident prevention plans for the assembly of heavy prefabricated structures:

"Before beginning assembly the following technical documentation must be made available to those responsible for the work, the workers and controllers:

- work plan that clearly describes the execution assembly operations and their order;
- safety procedures to be adopted in the various phases of work;
- in the case of more companies working in the worksite, a specific scheduling regarding the various companies involved.

In the absence of this documentation it is forbidden to perform assembly operations."

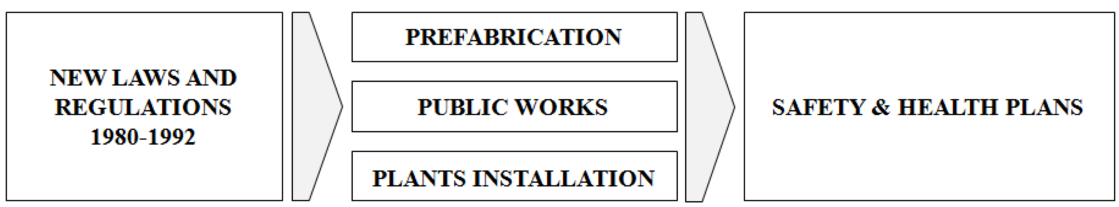

Fig. 3 – Summary diagram of the safety planning in Acts from 1980 to 1992

Period 1994-2009: safety planning and management

The most important revelation in health and safety at work in Italy came with the enactment of Act No. 626/94 which gave effect to EU Directive 89/391/EEC and other seven EU Directives details such as 89/654/EEC, 89/655/EEC, 89/656/EEC, 90/269/EEC, 90/270/EEC, 90/394/EEC and 90/679/EEC.

In the Act No. 626/94 the institution of the *Prevention and Risk Protection Service* is a novelty compared to the Italian legislative landscape prior to the 1990's. The most important Italian reference regulations, the Acts No. 547/55, 164/56 and 303/56 do not cite the *Prevention and Risk Protection Service*. With this Act Health & Safety is not more a technical issue. From technical prescriptions we passed to a new concept of prevention through risk assessment and involving all actors (client, contractor, workers, controllers, unions, etc.) of construction process.

The Act No. 494/96 gave effect to EU Directive 92/57/EEC (Temporary or mobile construction sites). This Act has introduced the obligation to draft a Safety & Coordination Plan for the client and the nomination, by client, of two Coordinators of Health & Safety: one during the design phase, the other for the execution phase.

The Act No. 222/03 clarifies in detail the minimum contents of the Safety & Coordination Plan (drafted by Coordinator) and the Safety Operating Plan (drafted by contractor or subcontractor).

The *Prevention and Risk Protection Service* could be or inside the structure of the company, either managed by professional consultant's experts in Health & Safety.

The Act No. 123/07 had founded the base for the reunification of the entire legislation corpus regarding Health & Safety.

This Act had consolidated a couple of principles: the first concerns the risk assessment approach; the second principle underlines the important of involving all actors of construction process during the various phases.

It was confirmed that Health & Safety must be treated and designed from first steps of all process.

In Act No. 123/07, an important aspect is the amendments to art. 7 of Act No. 626/94, with the introduction of a requirement for the client, in case of contract, the drafting of a single document relating to the evaluation of the risks of interference. This document must contain both the risks of the activities of the client in respect of subcontractors, both of the latter towards the client and those generated by the overlap and interference of the activities of the contractors themselves. This document must be drafted not only in the presence of contracts characterized by many overlapping businesses or self-employed workers, but also and especially in the work site environment.

In reality, however, the obligation was already expressed in Act No. 494/96, which said that the Safety & Coordination Plan was intended to assess and prevent risk interference between contractor, subcontractors and one-man companies.

On April 30, 2008, was published the Act No. 81/08, based on principles of Act No. 123/07, setting the following three objectives:

1. The revised laws and regulations regarding Health & Safety in the workplace, through the reorganization and coordination of the same in a single piece of legislation on Health & Safety in a single text;
2. Simplifying compliance for smaller companies: the Act introduces some simplifications for the self-employed and family businesses and other simplifications in the risk assessment;
3. More effective implementation: the legislature has suggested to achieve this objective through the establishment of coordination committees, the introduction of trade unions in a strong figure of the representative of the workers' safety, the organization of a retrieval system and management of information on the matter from the health information written by physicians for each company and, ultimately, through the reorganization and strengthening of control institutions.

The Act No. 106/09 modifies some detail elements regarding responsibilities and sanctions.

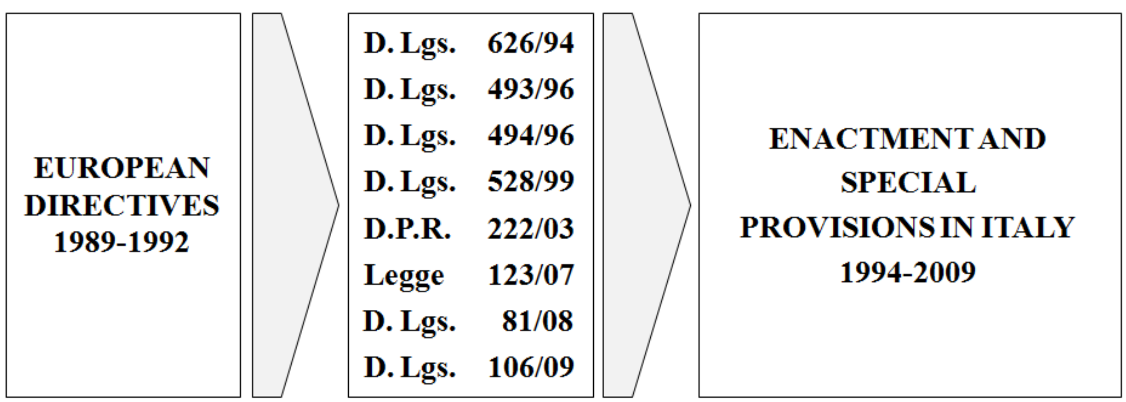

Fig. 4 – Enactment of EU Directives in Acts from 1994 to 2009

3. The management of safety on construction sites

In the first implementation of Directive 92/57/EEC (Act. No. 494/96), the Italian legislation has in fact kept contractors out of the safety process. Contractors were bound to implement the Safety & Coordination Plan (S.C.P.) through a deed of acceptance.

The Act 528/99 has introduced the Safety Operating Plan (S.O.P.) to be drafted by the contractor and subcontractors.

This plan gives a factual response to the requirements expressed by the Safety Coordinator at the design phase in the Safety & Coordination Plan.

Through the enactment of Act No. 222/03 and Act No. 81/08, the legislator meant to complete the reference grid for drawing up the Safety & Coordination Plan and the Safety Operating Plan.

The Act No. 222/03 further highlights the need to develop real interaction between the Safety Coordinator at the design phase and the contractor.
The Safety Coordinator at the design phase is actually asked to specify the detailed procedures in connection with the Safety & Coordination Plan. From the other side the contractor's own choices have to be detailed in the Safety Operating Plan.

Another issue that has turned out to be essential in safety management is determining the costs involved in its implementation; the latter regulation has made all the difference between the costs implied in each process and the costs for the safety procedures to be carried out on each site.

For the first time, the Italian legislator acknowledged that the working conditions of the construction sites had to be recognized at the very start of the design process, thus bringing together the earlier two Acts: Act No. 494/96 and the following amendment Act No. 528/99.

The regulations define, as "design and organizational choices" all of the choices made by the work designer in close co-operation with the safety engineer in order to ensure that the risks associated with each process are removed or minimized. To this effect, the Safety & Coordination Plan cannot but be site-specific and so it cannot help refer to the site features, the site organization and the processes that are to be carried out there.

The regulations recognize that it is essential for safety management that the design of the work and the Safety & Coordination Plan evolve together, in close connection, so as to highlight the preventative choices integrated by the designer in different phases: the design and the spatial, temporal and economic planning of the work.

The Safety & Coordination Plan might solve those problems that cannot be managed at the design phase, or cannot be tackled before the execution of the work.

The Safety & Coordination Plan must be drafted to reflect the peculiar features of the construction site, the layout and organization and the processes carried out during the productive cycle of the site.

The Safety Coordinator at the design phase should divide each process in specific parts (a kind of W.B.S.).
For each hazard/risk associated with the specific construction project, the Safety & Coordination Plan must contain:

- design and organizational choices, procedures, preventative and protective measures required to remove or minimize work-related risks;
- coordination measures required to implement the foregoing with special reference to the common usage of systems, equipment, facilities, joint safety equipment.

Another important step regards the spatial and temporal planning of the execution phases and the management of any interference during the construction. The introduction of the requirement to specify the operating prescriptions also in graphic design terms and time schedules make the Safety & Coordination Plan more integrated in the process and more legible by the site operators.

The principle underlying the site design should be Coordination, and this is why the site design must be broken down into several steps, so that the information can be adjusted to the development of the site phases.

The level of detail of site design should be fit for facilitate coordination so as to remove or minimize any interference between the various workers present on site.

At the design phase, the Safety Coordinator is responsible for describing an appropriate scenario so that site activities can be carried out, while the contractor is responsible for the site organization and the management of the Safety Operating Plans.

The primary goal of the Safety & Coordination Plan is to prevent accidents associated with interfering and/or overlapping process steps.

To prevent interfering and overlapping process steps from increasing the risk level, the Coordinator should plan works at the design phase through a time schedule, citing the duration of processes, divided into steps and any process priority.

The entire legislation corpus is involving in one main direction: prevention of Safety & Health risks through a better education, information, better organization and management. The *person* is to be considered before any technical or economical reason.

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Safety Climate and Use of Fall Arrest Systems

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Safety Climate and Use of Fall Arrest Systems

Abstract:

Falls in the construction industry continue to be challenging in terms of prevention of injuries and fatalities in the construction industry, especially in residential and post-frame roofing. In 2010, OSHA issued a directive requiring residential builders to use fall protection unless it places workers at a greater risk of harm. However, small contractors face a number of challenges within the context-of-use that interfere with compliance and consistent use of fall arrest harnesses. In this study, we explored the role of safety climate and fall arrest motivators and barriers to develop a more detailed understanding of the constraints experienced by small roofing contractors. Fourteen small post-frame and residential roofing companies (total of 52 workers) were administered a safety climate scale and subsequently interviewed regarding fall arrest harness usage. Some significant differences in safety climate related to supervisors pressuring workers to work faster at the expense of safety were found. We also identified several motivators and barriers to the use of fall arrest harnesses as well as new design features to improve usability.

Key Words: Fall arrest systems, fall arrest harnesses, safety climate, personal protective technology, roofing hazards, construction falls

1. Introduction

Preliminary data for 2009 from the Bureau of Labor Statistics (2010) indicates that 617 fatalities occurred because of falls in construction. In residential roofing, requirements are only just beginning to be understood. On December 16, 2010, OSHA issued a directive (STD-03-002) with the intent to end confusion about the 1995 directive, which only required a fall protection plan to be instituted by the company. By June 16, 2011, workers in residential building who work 6 feet or higher must use fall protection unless the builders/owners can show that fall protection places the worker at greater risk of harm. But, small residential builders face a number of barriers that interact to constrain the use of fall protection. These factors can be classified collectively as safety climate.

Safety climate continues to be highlighted as a key factor in workers' use of personal protective technology as well as the likelihood for practicing safe behavior. In fact, safety climate may be a more powerful predictor of safe work practices compared to legislation, such as OSHA directives. Lehtola et al. (2008) conducted a meta-analysis of studies that evaluated the effects of interventions on fatal and non-fatal injuries in the construction industry, with a focus on slips, trips, and falls in the workplace. Multifaceted safety campaigns were found to more effectively reduce fatal and non-fatal injuries compared to legislation.

Not surprisingly, safety climate influences the collective workers and supervisors on site. Zohar and Luria (2004) referred to this effect as social-cognitive, because safety climate is a manifestation of ideas reinforced, modeled, and communicated in the workplace.

Consequently, perceived safety climate indicates given priorities in the workplace during task performance; for instance, any apparent tradeoffs between task completion time and safety are made on the basis of what workers perceived to be the priorities of the organization. The evidence for safety climate as a social-cognitive construct distributed across a work environment was also supported by longitudinal studies that found significant relationships between the percent of safe behaviors, reduced number of accidents, and the level of safety climate (Cooper and Phillips, 2004; Guldenmund, 2000; Hofmann and Stetzer, 1996). Random factors are, of course, present in these relationships, but a lower risk of injuries and fatalities was associated with strong safety climates. Although safety climate and safety culture may be used interchangeably by some researchers, we refer to safety climate as the perceptions held by employees about safety in the workplace (Schneider, 1975; Zohar, 1980).

Given the relationship between safety climate and practice of safety-related behaviors, this paper explored the association of fall arrest system usage and safety climate. Aalso, the influence of usability of fall arrest systems as an additional determinant of fall arrest system was explored. Several studies have explored the relationship between personal protective technology (PPT) and usability (Goggins et al., 2003; Lahiri et al., , 2005), but have not focused on fall arrest systems specifically. OSHA 1926.502 does not address usability or ease-of-use in selection and/or design of fall arrest systems, in spite of well-supported guidelines related to usability that are applicable to PPT.

One such standard is ISO 9241-11 (ISO 1998), which has been expanded to apply to any products that require human-system interaction. This standard was recommended for use as a consequence of a National Academy of Sciences/Institute of Medicine committee review of the NIOSH PPT program. The goal is to ensure manufacturers evaluate the usability of PPT, and that potential distributors and users are aware of PPT usability. The recommendation ensured PPTs were designed effectively, efficiently, and comfortably (satisfaction) within the context of use to achieve the specified purposes. Complex designs have been shown to lead to non-use because of the high cost of compliance, which is reflected in some workers' assumptions that it is easier to avoid using the equipment rather than struggle to use complex equipment.

Research by Sa (2009, Figure 1) explored the use of fall protection systems in the roofing industry. Roofing workers reported reasons for non-compliance with the use of fall protection. Causes included the inordinate amount of time required to don and doff the equipment, the need to constantly adjust and re-adjust the equipment, the level of discomfort while wearing the equipment, and the lack of enforcement at worksites or negative peer pressure (machismo effects). Regardless of commercial or residential focus, Sa found the causes of falls in roofing related to incomplete connections, improper use of fall protection, and having old and outdated equipment that was unreliable.

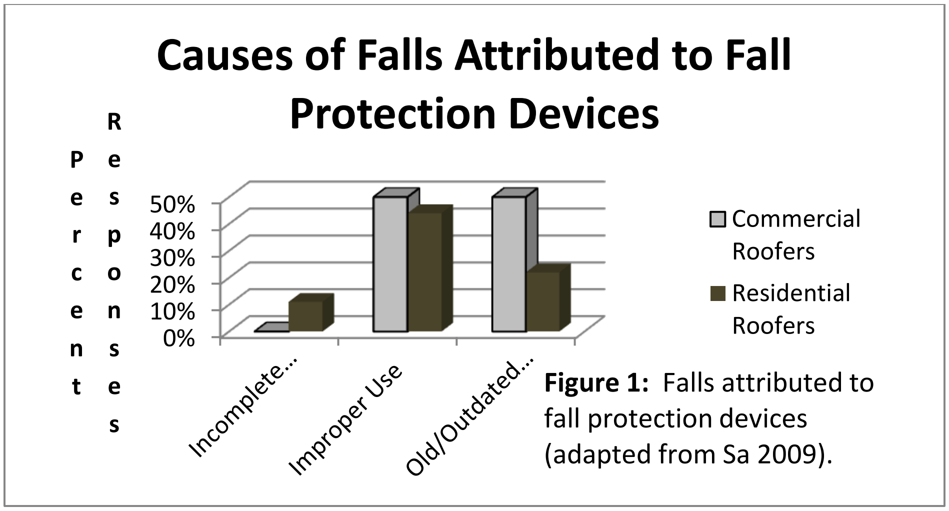

Figure 1. Falls attributed to fall protection devices (adapted from Sa 2009).

In summary, it is clear that safety climate and usability are key factors in the use of fall arrest systems. Although directives exist, it is important to understand the organizational context as potential contributors to the effectiveness of directives to use fall protections. The purpose of this NIOSH-funded study is to explore factors associated with use of fall arrest systems (FAS) among small builders, with a focus on safety climate and usability.

2. Method

Preliminary data on the first part of a 3-part study to examine usability and safety climate among small roofing contractors, and subsequently, to use that data to design and test a fall arrest system is reported. The focus of this paper is the use of fall arrest harnesses as the primary personal protective technology for this context.

Participants

Fourteen construction companies specializing in residential or commercial (post frame) roofing were randomly selected for the study using NAICS codes and other parameters from a national database of companies in the USA. Criteria to participate included: (1) residential or post-frame; (2) residing in the states of Virginia, West Virginia, or North Carolina; (3) operational for at least 10 years; and (3) experienced no fatalities related to roofing in recent years.

Upon selection, companies were contacted by phone and were given the purpose of the study, and further screening questions were asked. Upon agreement to participate, a site visit time and date were agreed upon by the researchers and company owners.

Procedure

Workers and owners were interviewed either onsite or in mutually agreed upon locations. Two to six employees from 14 companies (n = 52 participants; 24 residential, 28 post-frame) were administered Zohar's (2000) Group Safety Climate questionnaire and were interviewed to discuss fall protection usage and usability. All companies had 50 or fewer employees, with the exception of one post-frame roofing company with 70 employees. Mean company size was 20 employees (SD = 19.96). Mean age of workers was 43.08 (SD = 12.57).
Safety climate items were read aloud to workers upon request. Interviews were audio-recorded and were conducted in either English or Spanish, based on the first language of the workers.

3. Results

Cronbach's reliability values for the Group Safety Climate scale were $r_{alpha} = .82$, indicated a high level of reliability of the instrument (Nunnally, 1977). Mann-Whitney-U tests of total safety climate ratings revealed no significant differences between post-frame and residential roofing.

To characterize discrepancies in safety climate, a deviation score for each company was calculated using the absolute value of the difference between the owners' and workers' safety climate ratings. The distribution of deviation scores was non-Gaussian, with a median of 0 and means ranging from .02 to .63. A significant difference between deviation values was found for one safety climate item (supervisor pressuring workers to work faster rather than by the rules), $X^2 (1) = 7.09$. $p < .01$, with residential builders showing a higher deviation between workers and owners compared to post-frame workers. Other results revealed significant correlations (Spearman rho) between age, years of experience, and the extent to which owners reward workers for good safety practices. Older workers and those with more years of experience showed higher discrepancies or deviations for this safety climate item (rewarding workers); r_s values were .32 and .33, $p < .05$.

Qualitative data from interview transcripts on usability and fall arrest harness usage was derived from audio recordings of the interviews. Participants were asked to report their use of fall arrest harnesses and any factors that motivated or prevented their use of fall arrest harnesses. The audio recordings were transcribed and subsequently analyzed using HyperResearch™ qualitative coding software. Axial coding with predetermined codes derived from the interview questions, and coded utterances was used. Thus, the frequency or reporting may be higher than the sample size of participants.

The most frequently uttered motivators of fall arrest harness usage were workers' personal motivation to use the equipment and whether the company provided the equipment. Additional motivators included mandatory instruction from supervisors, working at dangerous heights (fear of falls), and workers having a strong awareness of safety and hazards associated with falls from roofs. Figure 2 illustrates the frequency of codes resulting from the qualitative analysis.

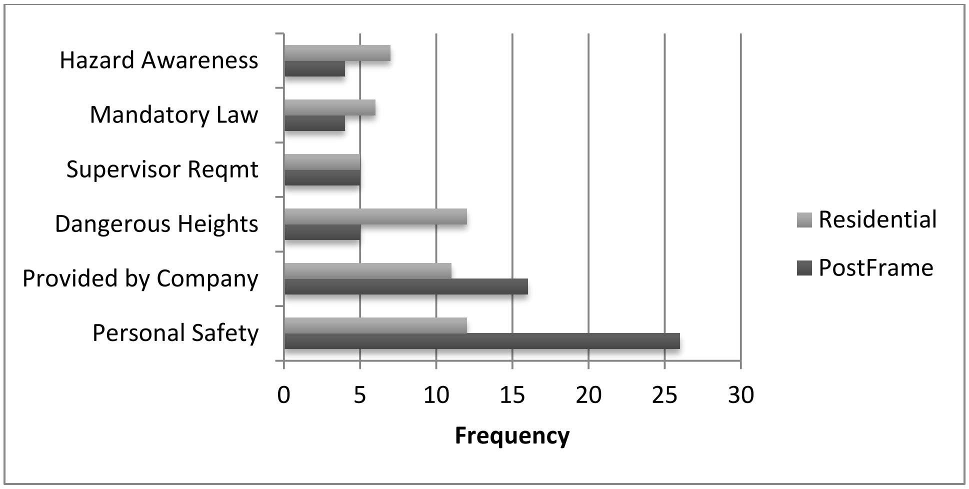

Figure 2. Frequency of codes or themes identified from the interviews.

Emergent codes that might increase the likelihood that workers will use fall arrest systems were also explored. The emergent codes illustrated a number of modifications to the design of fall arrest systems, and these modifications were perceived by workers to enhance usability and motivation to use the harnesses. These included:

- Designing fall arrest harnesses to be more similar to climbing gear;
- Using yoyo and lanyard designs;
- Developing a one-button features to release the entire harness from the body in one step;
- Personally fitting each harness to each workers' anthropometry;
- Improving the design to reduce neck and back discomfort.

Workers were also asked to report factors that prevented their use of fall arrest harnesses, and these are shown in Figure 3. The most frequent barriers were related to fear of rope entanglement, discomfort when wearing the harnesses, and tendency of harnesses to restrict movement.

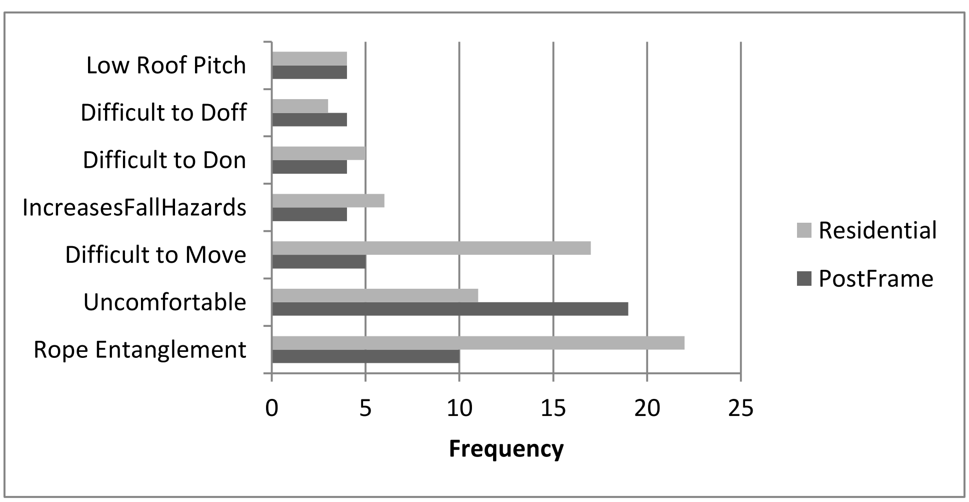

Figure 3. Barriers related to design and usability of fall arrest systems.

4. Discussion and Conclusions

There were a few differences between safety climate among residential and post-frame workers, but not at the level expected as shown in the quantitative analyses. There was a significant difference in the extent to which supervisors pressure workers to work faster rather than comply with safety practices; where residential roofing contractors showed a higher deviation in ratings than post-frame contractors. Workers in residential roofing indicated that they were pressured to skip the rules and take short cuts at the expense of safety, but residential contractor supervisors did not report an equivalent perception. This deviation warrants more attention, especially given the findings of previous researchers on the impact supervisors' expectations, role modeling, and communications on the likelihood that workers will practice safe behaviors (Hung et al., 2011). This particular safety climate item did not show a high deviation among post-frame contractors. Given the regulations that direct the use of fall arrest harnesses among post-frame contractors, supervisors may be more consistent in encouraging and enforcing use of harnesses.

The qualitative data provided more detailed information on the underlying factors contributing to or preventing the consistent use of fall arrest harnesses. Personal safety and hazard awareness were important factors that motivated the use of fall arrest harnesses. Workers were also more likely to use fall arrest harnesses if they were provided by the company. Cost and knowledge of appropriate harnesses for the context of use may be a concern of workers, thus contractors should assist workers to select and purchase proper fall arrest harnesses. Most prominent codes/themes in the qualitative data were the usability challenges and other barriers to use of fall arrest harnesses. In particular, workers perceived harnesses to add to the hazardousness of roofing tasks because of the possibility of entanglement and difficulty moving when wearing harnesses. Additionally, workers provided suggestions on how to improve harness design and highlighted important features that could be transferred from climbing gear to fall arrest design. Most importantly, a better fit of harnesses was critical to usability and consistent use.

Only preliminary data are reported here, and this study continues with an expanded sample and additional analyses of the data. However, the preliminary data provide some confirmation of previous studies on the importance of usability of PPT and the need to modify the design of fall arrest harnesses. However, a better harness design will not guarantee more consistent use among workers. Hofmann & Stetzer (1996), in an analysis of 222 employees, found a negative correlation between safety climate and such factors as use of PPT, prevalence of unsafe behaviors, and number of actual accidents. The safety climate issues arising from the overall organization and supervisors' expectations will serve as the context in which PPT will or will not be used. How employees are rewarded for safe practices and enforcement are also critical mediators between the design of harnesses and actual use.

5. Acknowledgments

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How Do Project Manager's View Construction Safety in Australia versus the United States?

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Abstract:

This paper investigates differences between the safety cultures in the United States and Australia from the viewpoint of constructor project managers. The authors conducted interviews with the project managers on three large construction projects in both countries to qualitatively examine differences of how safety is considered throughout the construction project lifecycle. The results indicate that while constructability reviews during the design phase occur in both countries, safety is considered as an explicit factor in constructability reviews in Australia, while in the United States safety is considered after this review is completed. It is contended that this difference has a major impact on safety culture.

Keywords: construction safety, safety culture, occupational safety and health

1. Introduction

Australia is generally considered to perform better in regard to occupational safety and health in the construction industry than the United States as evidenced by fatalities per 100,000 workers and other indices (Safe Work Australia 2010; BLS 2010). There are a variety of factors that differ in the two countries, such as greater project involvement by unions and more stringent legislation concerning safety procedures in Australia than in the United States. This has led to differences in the safety attitudes within the construction industries of the two countries. Exploration of these differences could lead to a better understanding of why these differences exist, and generate knowledge that can be used to improve occupational safety and health (OSH) performance in the United States.

An active concern for worker safety during the design phase of a project and management's commitment to safety have both been described as major influences on construction site safety (Mohamed 2002; Hecker and Gambatese 2003; Behm 2005). The project manager on a construction project is in a unique position, as he or she is many times involved during the design phase of a project and is often the top level of management on site during a project. This paper compares the initial perceptions of construction safety between Australia and the United States project managers (PM's). Three project managers were interviewed in each country to collect viewpoints on how safety was considered during the design phase of a project and the impact of decisions on safety during the lifecycle of the project.

Safety in Design

Safety consideration in the design of a construction project is a growing concept in the construction safety field, and can have a significant effect on the hazards that are present on a construction site. Prevention through design is a major component of the National Occupational Research Agenda (NORA) in the U.S. One project found that 42% of fatalities in a study were linked to decisions made during the design phase (Behm 2005). Research collecting data from designers and contractors has detailed numerous examples of decisions made during the design phase of a project that positively impacted construction worker safety through site layout, access points for work, design changes, stairways, location of material, walkways, fall protection, guardrail height and locations, and utility locations (Hinze and Wiegand 1992; Gambatese, Behm et al. 2005; Weinstein, Gambatese et al. 2005). Implementing these design modifications and tools through education, training, and legislation can increase safety visibility throughout the entire supply chain of a project, and ultimately lead to safer working environments for construction workers (Hecker and Gambatese 2003).

Time/Safety Influence Curve

The time/safety influence curve is shown in Figure 1, and illustrates the impact that design can have on safety compared to other supply chain phases (Szymberski 1997). In the U.S., construction worker safety is primarily left to the constructor. The primary consideration for this position is to avoid the liability that can be associated with dictating the "means and methods" of construction as currently assigned to the constructor by contract (Hecker and Gambatese 2003). While architects are hesitant to address these issues, identification of hazards earlier in the construction lifecycle can have a greater impact, because the hazards can possibly be eliminated or controlled more effectively than using PPE and other methods that are usually utilized during the construction phase (Behm 2005). Significant safety improvements gained from focusing on safety earlier in the lifecycle will not only increase the perception of safety in these stages, but also in the construction phase with the partnerships that these initiatives create (Hecker and Gambatese 2003).

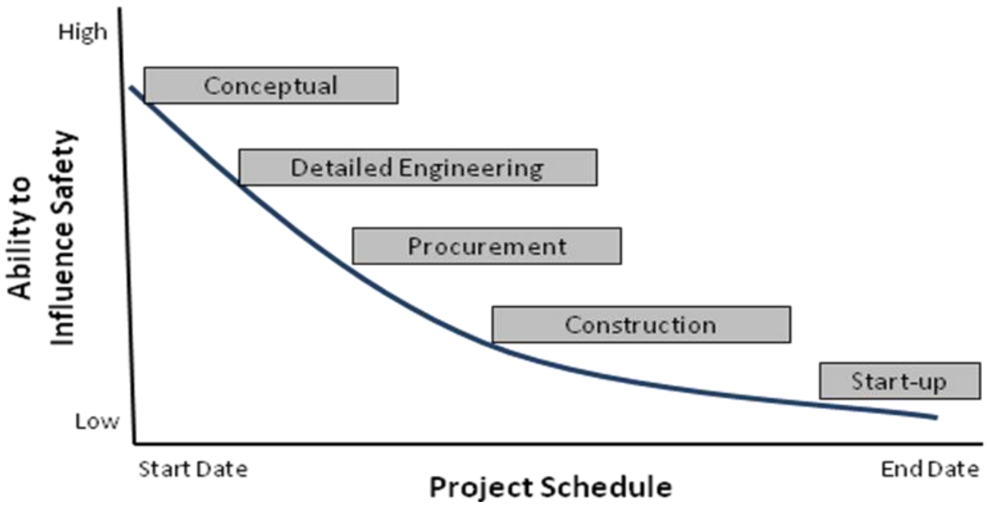

Figure 1 Time/Safety Influence Curve (Szymberski 1997)

Hierarchy of Safety Controls

The hierarchy of safety controls is another framework that illustrates how hazard controls are more effective in earlier versus later stages of a construction project. A depiction of the hierarchy is shown in Figure 1.2 (adapted from SA 2007), and the main concept behind the hierarchy is that control methods are potentially more effective, protective, and cost-effective from top to bottom of the hierarchy (NIOSH 2010). The controls at the top of the pyramid are normally associated with design aspects earlier in the delivery of a construction project. Therefore using this approach can lead to more emphasis and procedures for focusing on construction worker safety during the design and engineering stages of a project by eliminating potential hazards (engineering controls) versus trying to control them with administrative controls (Gambatese and Hinze 1999; Behm 2005; Gambatese, Behm et al. 2005).

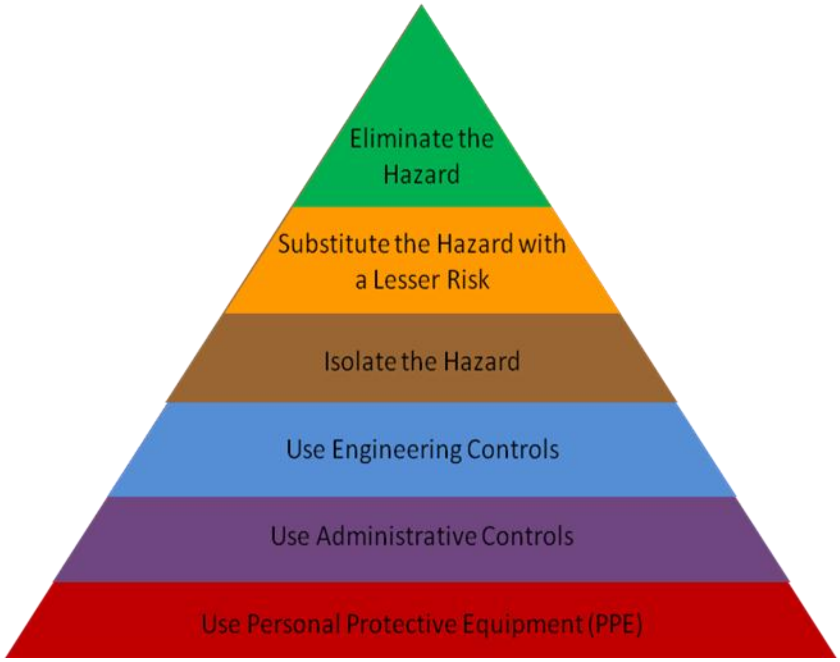

Figure 1 Hierarchy of Safety Controls (adapted from SA 2007)

Management Commitment to Safety

Several studies have found that management's commitment to a safety is one of the most important factors affecting the success of an organization's OSH program (Zohar 1980; Jeselskis, Anderson et al. 1996; Flin, Mearns et al. 2000), and that workers also view management positions as the most safety critical (Dingsdag, Biggs et al. 2008). Other work has shown that construction site safety initiatives that have more management support and commitment are more effectively implemented than ones with less management engagement (Duff, Robertson et al. 1994; Lingard and Rowlinson 1998). The most important initiative that management can be committed to in order to improve the success of safety programs is increased communication in regards to OSH (Marsh, Davies et al. 1998). This communication allows management to learn what factors workers perceived to be the most important blockages to increased safety performance. Taking action on removing these blockages on a consistent basis has also been shown as a factor on the level of commitment that workers perceive (Hinze 1996; Gittleman, Gardner et al. 2010). Taking action shows that management is committed to improving OSH, and workers are more willing to support OSH programs when they perceive that management listens to their concerns and is genuinely concerned about their personal safety (Langford, Rowlinson et al. 1993).

2. Projects Overview, Data Collection and Research Methods

Australia Projects

The project managers that were interviewed in Australia were all involved on urban projects in the state of Victoria that were $100+ million (AU) in cost. The constructors on these projects were all major commercial builders with extensive experience with large construction projects. The projects and their procurement methods are as follows:

Table 1: Australia Projects

Project Number	Industrial Sector	Delivery Type	Size
1	Commercial (residential high-rise)	Traditional (design-bid-build with CM @ risk with preconstruction services contract)	Large (48-story residential tower with 412 units)
2	Commercial (academic low-rise)	Design-Build	Large (10-story, 370,000 square foot building)
3	Commercial (civic low-rise)	Alliance (Collaborative)	Large (2300+ seating capacity theatre)

United States Projects

The project managers interviewed in the United States were also all involved on large projects in excess of $20 million (US), and were all located in the Southeastern United States. These constructors are all comparable to the constructors in Australia in size and experience managing large construction projects. The projects and their procurement methods are as follows:

Table 2: United States Projects

Project Number	Industrial Sector	Delivery Type	Size
1	Heavy Construction	Traditional (design-bid-build with CM @ risk with preconstruction services contract)	Large (6 million gallon wastewater overflow tank)
2	Commercial (mixed-use low-rise)	Traditional (design-bid-build with CM @ risk contract)	Medium (5 story, 91,000 square foot building)
3	Commercial (civic low-rise)	Accelerated (Fast Track with guaranteed maximum price)	Large (25,000 seat football stadium expansion)

The projects were chosen for the Australian case studies based on opportunity samples while the primary American researchers were located in Australia. The United States projects are all participating on a larger research project funded by NIOSH, and were chosen because they were the most similar to the Australian ones in terms of industrial sector, delivery type, and size. The construction management organizations on all of the projects are large firms with extensive experience on large projects, and all have established safety management programs in place. All of these organizations are also corporations, and thus the authority structure above the project managers is somewhat similar.

Data Collection and Research Methods

Yin (2009) promoted the case-study methodology as the best approach to investigating how or why phenomena occurred and relationships among these phenomena. Accordingly, the research team used case studies to discover key relationships within the context of safety during the design phase of a construction project. The team began by collecting interview data through participant-observers, those individuals from firms who have knowledge of project delivery decisions and actions from concept to the current state of construction (Yin 2009). The team identified appropriate individuals for interviewing as those in the role of project manager of the construction phase. These PM's were also involved in early decisions of the project design and could attest to the influence of such decisions early on the project lifecycle. The team used criterion-based sampling processes (LeCompte and Preissle 1993) to solicit knowledge of safety decisions that were made during the project lifecycle that could not be obtained from other subjects (Maxwell 2005).

3. Findings

Australia

- Unions are very prevalent in Australia, and drive many safety initiatives because the general labor position is not to work unless the job is considered safe. Safety us generally very strong from the bottom up according to all three PM's.
    - PM on Project 1stated he tries to remove hazards as an excuse for not doing certain tasks so the focus on safety is high when determining construction methods during the design phase of the project.
    - Safety committees were present on all three projects, and were involved in ensuring the job can be done safely. These committees include management and workers, and at least 50 percent of the members must be employees. These committees are required by employers in Victoria if the required Health and Safety Representative for employees requests their establishment, and their goal is to create a healthy environment between management and employees (WorkSafe Victoria 2006). All three PM's said that the safety committee discussed important safety issues on the

project such as using fencing to surround exposed edges at heights and construction of the building core.

    - Union workers cannot work in the rain or above 35 degrees Celsius (95 degrees Fahrenheit), so all three project manager's said that they took care to provide cover for these working conditions as soon as possible in the schedule. The Project 2 project manager said that they had spent almost $100,000 (AU) for covers at the site, but that this cost was more than offset by losing $50,000 (AU) for every day of lost work.
- All three project managers mentioned design phase workshops for safety in which the design documents were reviewed specifically for safety issues.
    - The scheduling of demolition was changed on Project 3 in order to allow large ducts to be removed using a different removal method than originally planned due to safety concerns.
    - Cages were used on Project 1 to allow the windows to be installed from the outside, but in a manner that allowed the workers to not be tied off to improve productivity. The cages surrounded the building and were self-pumping to rise up the building with the core, and used a wooden platform to allow workers to stand on the outside surrounded by the cage structure. This method was reviewed by the safety committee, and was developed during the design phase by a temporary structure engineer. This type of cage structure was also used on Project 2 instead of barriers at the edge of the building.
    - All three project managers were familiar with and discussed the hierarchy of controls from the safety literature (Behm 2005). The goal of eliminating or substituting a hazard versus mitigating risk with administrative controls was a central part of the safety workshops.
- Safety for maintenance after completion of the project was mentioned as part of the safety review during the design phase. The owner partner for Project 3 approved a design change to ensure that food shipments and delivery of sets for performances were separated so that they were not "running on top of each other".
- Laws in Victoria require all constructors and sub-contractors to develop job safety analysis (JSA) documents, have safety management plans, perform safety meetings, and have appropriate PPE.
    - Project managers all said one of their job responsibilities was ensuring that safety procedures were followed, but that subcontractors are all used to following these procedures due to regulations.
    - All three project managers felt that administrative controls such as PPE and JSA's were just part of the business, and did not see them as a practice within their safety programs that set them apart from others.
    - If an accident occurs there is the risk of liability if the hazard that should have been known was not identified on the JSA, and so all three project managers said focus should be taken to these are not completed casually.
- Constructability was cited as a large concern by all three project managers, but they all also said they consider the ability to construct safely when determining construction methods. Cost and schedule were mentioned by all three project managers as a major concern, but safety was considered as another factor prior to making decisions.

- Additional cost due to safety controls was present at all three sites. The PM on Project 1 said that this cost is basically reflected in the final price of each unit, and was included in the cost of the contract. He said that cost is a primary factor in all decisions, but that at times cost, quality, and safety can be improved together if construction methods are developed early that require less labor and eliminate potential hazards. (Note: Jointly "optimizing" multiple factors is a tenet of socio-technical approaches (Hendrick and Kleiner 2001))
- The reinforced concrete core of Project 1 was an example (this type of core was also used on Project 2) of this concept. The constructor was pushed by the safety committee to find a safer way to construct the core and stay within budget.
- The pre-cast floor sections of Project 2 were poured on top of the existing concrete slab on each floor then lifted out to the edge of the building to avoid workers pouring at the edge of the structure.
- Drawings for the facility were 5-10% completed when the constructor became involved on Project 2 and 3, and 60% on Project 1.

United States

- All three projects involved constructability reviews with the constructor during the design phase of the project.
    - Cost and schedule were the primary factors in these discussions according to all three project managers, but constructing safely was considered to be the responsibility of the construction management firm.
    - A design change on Project 1 was made to the excavation methods due to safety concerns. This design change was made outside of the design review process however, and was initiated by the subcontractor once they were brought onto the project.
    - The Project 3 project manager said that they considered safety during these reviews as to whether they could safely construct a design, but that this was not a formal part of the review. The roof type of the elevator shaft and the type of panels used on the outside of the stadium were changed during the constructability reviews due in part to safety concerns of the construction manager.
- The Project 2 PM said that the owner made it clear that the constructor was responsible for safety "inside the fence" and that safety was not discussed during the design phase. The owner was however concerned with the safety of the interaction between the site and general public users, and that was the focus of most safety related discussions.
- The Project 3 project manager stated that safety was left up to their firm. An example was that their firm took the lead in determining how the excavation for the largest set of seats would be undertaken because they knew the architect would only be concerned that it met the appropriate depth.
- The project manager for Project 1 was primarily responsible for the scheduling and cost, and there was a superintendent on the project that was at the same level organizationally that was responsible for construction issues.

- Dictating the means and methods to subcontractors and the associated liability was mentioned by the Project 1 and 2 PM's as an issue in determining construction methods to subcontractors.
- All project managers said that they included administrative controls such as PPE and JSA's requirements in their subcontracts because their safety management programs almost always exceeded those of subcontractors. Project 2 stated that if they did not make JSA's a subcontract requirement that the subcontractors would in most cases not provide them.

4. Conclusions and Next Steps

Collecting data from three project managers on large projects in Australia and the United States highlights differences in the safety attitudes and practices within the construction industries of the two countries. The Australian construction industry is exemplified by government regulations and unions that create a driving force to review safety at all stages of a project (including design). While factors such as cost and schedule are primary decision drivers in both countries, the data gathered for this paper suggests that safety is more of a decision factor during the design stages in Australia as compared to the United States. Can this be a major driver for fatality rate difference between the two countries? Constructability reviews are evident in both countries, but safety seems to be more of a lagging practice in the United States once the design and associated construction methods have been identified. The attitude that once the design is finalized then the constructor can figure out how to build it was much more evident in the United States than in Australia where the safety of building a proposed design seemed to be a factor on all three projects.

One small detail that the authors felt was indicative of the different safety cultures in the two countries was that Worksafe Victoria (a government agency) ran commercials on major TV stations that discuss that it is law to work safely and inspections are in work places every 12 minutes. This was not just for the construction industry, but highlights the importance placed on occupational safety and health in Australia. The projects at which data was collected were all large commercial projects, and all three project managers said that the measures in place would not be as strong in smaller projects with small subcontractors or in the residential market. This is also true in the United States, but the comparison between the sample projects still displays some potential differences in occupational safety and health attitudes and practices between the two countries.
The main conclusion from the data that was collected for this paper is that the focus on safety in the design phase is more prevalent in Australia versus the United States. The focus on technological controls such as elimination and substitution was higher in Australia in the projects that were studied. In the United States, the project managers interviewed indicated that constructability was the main focus in design, and that the focus was on cost and meeting the schedule. All U.S. project managers interviewed felt that OSH concerns were left up to the constructor to figure out how to build the project safely once the design was completed. The next steps to better support the conclusions above is to expand the sample and collect quantitative data using methods such as

surveys to collect data on potential differences between the construction industries in the two countries.

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Investigating Causality on the Construction Project as a Homicide Scene

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ABSTRACT

In response public concerns about perceived laxity in the law on holding companies responsible for deaths from their activities, new legislation was passed creating a new corporate manslaughter offence. One of the requirements for a conviction is that the death must be caused by the way the company's activities are organised or managed. This paper has been developed from research aimed at assessing the likely operation of this new law in the construction industry. It critically examines the causation requirement in the light of construction health and safety management practice and construction accident causation research. The principal finding is that the reported construction accident causation models can contribute to the task of establishing causation by providing a framework for not only demonstrating multi-organisational contribution to accident causation to lay juries but also designing methodologies for post-accident investigations by state enforcement agencies and expert witnesses.

KEY WORDS: Health and safety, construction, accidents, corporate manslaughter

I INTRODUCTION

In English law, an individual human person whose direct act or omission causes a fatality may be prosecuted under the common law for gross negligence manslaughter if: (i) the defendant owed the victim a duty of care; (ii) the defendant's act or omission amounts to a breach of that duty; and (iii) the relevant act or omission amounts to gross negligence: *R v. Adomako* [1990] 1 AC 171. In theory, a manager or supervisor of a construction operation may therefore be convicted of this crime depending upon the degree of incompetence with which the relevant operation was managed and the nature of the causal link between individual management failure and the death.

A company could also be prosecuted for common law gross negligence manslaughter although it was notoriously difficult to convict companies other than very small entities. The difficulty in achieving conviction of large companies was attributed to the operation of the identification doctrine in the law on gross negligence manslaughter by corporate identities. This doctrine required proof that a "directing mind and will" of the company, and who could therefore be treated as the embodiment of the company, was responsible for the gross negligence act or omission. This meant that there must be evidence to convict, of gross negligence manslaughter, a person stationed so high in the management structure of the organisation to constitute its "directing mind and will". This requirement of derivative liability acted as a great barrier to convicting companies of manslaughter because, with the exception of very small companies, it was difficult to find an individual who was causally linked with the death and was also so high up in the corporate hierarchy as to be considered the company's "directing mind and will".

A related development was that decades of government intervention by way of legislation and other initiatives aimed at improving health and safety at the workplace were not meeting the expected degree of success in the construction industry (HSE 2002; House of Commons

2004; Donaghy 2009). Concerns were expressed that, in the lax legal regime applicable to companies and their senior managers, health and safety issues was not being taken seriously enough in boardrooms. In response, Parliament passed the Corporate Manslaughter and Corporate Homicide Act 2007 (COMCHA), which came into force on 6 April 2008. Section 20 COMCHA abolishes the common law crime of gross negligence manslaughter in so far as it applies to corporate bodies and other unincorporated entities covered by the legislation. In its place, it creates the new offence of corporate manslaughter in England, Wales and Northern Ireland and corporate homicide in Scotland. The labels apart, there is no difference between the two offences. For simplicity, the "corporate manslaughter" label will be used hereafter.

The sanctions that may be imposed on an organisation convicted of corporate manslaughter are an unlimited fine, a remedial order and a publicity order. From guidelines on the levels of fines, an organisation convicted should expect to be ordered to pay sums in the hundreds of thousands of pounds or even millions. The total of the costs of the prosecution, for which the company would also be liable, and the cost of compliance with the remedial and publicity could exceed the amount of the fine. Furthermore, the financial consequences of a conviction could pale into insignificance in comparison with the inevitable reputational damage.

An implication of the construction industry's poor record on health and safety in comparison to other industries is that construction companies and firms need to treat the risk of corporate manslaughter prosecution as a serious possibility even for very well managed organisations. Indeed, the only conviction under the new legislation so far has been that of an engineering organisation. In *R v. Cotswold Geotechnical (Holdings) Ltd*. Cotswolds Geotechnical Holdings (CGH) was on 15th February 2011 found guilty of corporate manslaughter and fined £385,000. A 27-year junior geotechnical engineer employed by the company was carrying out investigations down a 3.8 metre deep trench on a development site when it collapsed and killed him (Simpson, 2011). The jury found that CGH, in breach of its duty of care, had failed to take practicable steps to protect the deceased.

This paper presents part of research undertaken with the aim of assessing the likely operation of the new legislation in the light of construction industy health and safety management practice. It focuses on how causation, one of the requirements for a conviction. It is organised as follows. To provide a holistic understanding of the new offence, the next section sketches out the requirements that must be satisfied before an organisation can be convicted of corporate manslaughter. An outline of construction causation studies is then provided, followed by discussion of the likely application of the general principles of causation in the light of these studies and construction industry practice. Conclusions are drawn up in the last section.

II THE INGREDIENTS OF CORPORATE MANSLAUGHTER

From the definition of the offence in subsections 1(1) and 1(3) of COMCHA, its elements are: (i) the organisation charged with it is one to which the legislation applies (organisation test); (ii) the organisation owed the victim a relevant duty of care (duty of care test); (iii) the way the organisation's activities were managed or organised caused the death of the victim (causation test); (iv) the way in which the activities are managed or organised amounts to "a gross breach of that duty of care (gross breach of duty test); and (v) "the way in which the organisation's activities are managed or organised by its *senior management* is a *substantial element*" in the gross breach of duty (senior management test). Each of these tests presents a hurdle that must be overcome by the prosecution before an organisation can be convicted of the crime. Should the prosecution fail at any of these hurdles, the organisation should be acquitted.

Organisation Test

The types of organisations covered by the legislation are defined in subsection 1(2) of COMCHA so widely that, with the exception of the sole trader, any business form adopted for offering any of the services of the construction industry would be covered.

The Duty of Care Test

From the definition of the offence in subsection 1(1), it is an essential element of the crime that the way in which the organisation's activities are managed or organised causes the death of a person to whom it owes a "relevant duty of care". The meaning of the "relevant duty of care" is defined in subsection 2(1) in such terms that the duties owed by a construction industry organisation under the law of negligence as an employer, an occupier of premises or a commercial enterprise are covered.

The Gross Breach Test

Whilst an ordinary breach of duty at common law is sufficient for the purpose of determining the liability of the defendant to compensate a claimant for the injury caused by the breach of duty, to reflect the gravity of a criminal conviction, the requirement under the Act is a "gross breach" of duty.

The Causation Test

An organisation cannot be convicted of the offence unless the death was caused by the way its activities were organised or managed. This issue is discussed in more detail in the light of general construction accident causation models produced by researchers.

The Senior Management Test

For an organisation to be guilty, the way the activities were managed and organised by its "senior management" must be a "substantial element" in the breach. This requirement raises issues concerning who in an organisation qualifies as a member of its senior management and what amounts to a "substantial element" of a breach of duty.

III CONSTRUCTION ACCIDENT CAUSATION RESEARCH

The causal factors of industrial accidents have been studied by researchers in ergonomics, engineering, sociology and management. These studies paint an image of the industrial accident as the result of a combination of a multitude of factors forming causal chains. For example, Reason (1990) developed a model of accident causation that visualises the causal path of an accident as a ray of light and the impact of safety systems as barriers across the causal path. A perfect barrier is completely impenetrable but, in practice, there are holes in it allowing the ray to pass through to the next barrier. These holes represent weaknesses and shortcomings in the safety systems implemented and maintained on the project. Where holes in the barriers line up the ray is able to pass through them all, thus completing the causal path and the accident therefore occurs.

The Occupational Safety and Health Administration (OSHA) in the US collect data on causes of construction fatalities. In the period between 1971 and 1998 every recorded fatality had to be coded into one of five classifications referred to as causation categories: falls, struck-by, caught/in between, electric shock and others (Hinze *et al*, 1998). Analysis of the database developed thereby could therefore provide, on an annual basis or other period of interest, a breakdown of fatalities within the period by these categories. This five-point codification system had the deficiency that the codes were too generic to provide helpful information on what remedial steps were needed to prevent accidents. To overcome this deficiency Hinze *et al* (1998) carried out research that recommended expansion of the five codes into twenty codes. Its purpose was to identify necessary modifications to health and safety regulations and to direct the attention of managers of construction organisations and projects to the specific risks of serious accidents. This was achieved by developing and testing the expanded coding system which had huge potential as a tool for shedding light on the relative occurrence of death from the identified risks.

Abdelhamid and Everett (2000) developed an accident root causes tracing model (ARCTM) for the construction industry that recognised three generic root causes of accidents in construction: (i) failure to identify an existing unsafe condition before starting the activity from which the accident arose; (ii) deciding to proceed with the works in the knowledge of an existing unsafe condition; (iii) a worker deciding to act unsafely regardless of the initial condition. Underlying the model were four causes of accidents recognised in the literature: (i) management actions/inactions; (ii) worker unsafe acts; (iii) non-human-related events; and (iv) an unsafe condition that is a natural part of the initial construction site conditions. Presumably, the model was proffered to companies directly carrying out construction works for use in investigating accidents for three types of remedial action towards accident prevention: (i) worker training; (ii) change of worker attitudes; (iii) revision of management procedures. Whilst it is fair to say that the article throws some light on courses of action available to such an organisation, the model has been criticised for insufficient recognition of the contribution of project owners and designers to accident causation (Gibb *et al*, 2001; Suraji and Duff, 2001).

Suraji *et al* (2001) developed a conceptual constraint-response model of construction accident causation that classified the factors underlying such accidents into “distal” and "proximal" factors. The proximal factors are those that contributed directly to the occurrence of the events constituting the accident scene and comprise inappropriate construction planning, inappropriate construction control, inappropriate site conditions, inappropriate operative action and inappropriate construction operation. Each of these factors is a collective label for specific types of inappropriate responses to identified constraints affecting the project. The distal factors are those that can, if not recognised and dealt with properly, lead to the creation of the proximal factors as follows. The distal factors reflect inappropriate responses by the project owner and its professional advisers to project conception constraints such as challenges in the physical, economic, social and political environments in which the project must be realised. The project owner's response to these constraints creates project management and project design constraints to which the owner's design and project management team must also respond. Their response in turn leads to construction management and sub-contractor constraints to which the construction team on site must respond, thus triggering off the proximal factors identified above.

The work reported by Haslam *et al* (2005) and Gibb *et al* (2006)) entailed the application of Reason's model to produce a complete construction accident causality model with three barriers across the accident causation path referred to as "immediate accident circumstances", "shaping factors" and "originating influences". The immediate accident circumstances reflect risk factors introduced by the accident site (layout, space, lighting, noise, weather), materials and equipment used (suitability and conditions) and operatives (actions, behaviour, capabilities communications). The immediate accident circumstances are influenced by the shaping factors, which concern risks from the work team's attitudes/motivations, knowledge, skills, health, fatigue and supervision provided and the quality of the workplace (e.g., housekeeping, work schedules and physical constraints). The shaping factors are in turn impacted by the originating influences, which represent influences on health and safety flowing from factors such as client requirements, economic climate, construction education, design of the permanent works, project management, construction processes, safety culture and risk management.

IV RESPONSIBILITY FOR DESIGN & CONSTRUCTION ACTIVITIES

The traditional allocation responsibilities for project activities has been one whereby the architect/engineer undertakes design and contract administration and the contractor carries out construction to the design. However, members of the construction project supply chains are increasingly undertaking modified or even new responsibilities to respond to new legislation and innovation in project delivery systems. A consequence of development is diffusion in supply chain responsibility for activities on projects that may be the cause of a fatality. To aid understanding of the nature of this diffusion and its impact on the difficulty of identifying the particular organisations to prosecute, an indicative taxonomy of the generic project activity elements that have to be undertaken in order to deliver a project has been produced. It is shown in Figure 1.

SUPPLY CHAIN MEMBER	PROJECT ACTIVITY ELEMENTS																
		Ownership	Selection of Project Participants	Advice to Owner	CDM Statutory Duties	Project Management	Site Investigation	Design	Design Coordination	Construction	Site Control & Facilities	Contract Administration	Supply of Materials	Manufacture	Plant Hire	Statutory Certification/lincensing/approval	Post-construction Survey
Project Owner/Client/Employer		x	x		x	x		x					x				
Architect/Engineer			x	x	x	x	x	x	x			x					
CDM Coordiinator				x	x				x								
Demolition contractors				x	x												
Main Contractor			x	x	x			x	x	x							
Principal Contractor				x	x				x								
Project Manager				x		x											
Construction Manager			x	x		x			x								
Management Contractor			x	x		x			x								
Specialist Design Consultant				x	x		x	x	x								
Sub-contractor			x	x	x			x		x							
Supplier of Materials				x									x				
Manafacturer				x										x			
Plant Hirer															x		
Licensing/Testing Organisation																x	
Statutory Undertakers										x							
Building control authority																x	
Building Surveyor/Inspector																	x

Figure 1: An Indicative Taxonomy of Project Activity Elements and Supply Chain Member Responsibility for Them

V DISCUSSION

The starting point of any analysis of causation generally involves application of the “but for” test. This exercise requires examination of whether or not, absent the conduct for which the organisation is to be charged with corporate manslaughter, the death would still have occurred in the same way. Where the death would have not have occurred, the conduct under consideration is treated as “causation in fact” of the death. However, the test must be used with two caveats in mind. First, the test operates only as a filter for sieving out events that could not have caused the outcome; it is not enough as proof that the defendant caused the death. If satisfaction of the “but for” test alone were sufficient to prove liability, not only the persons who created the organisation but also the persons who took the decision to tender for the project could be convicted for causing the death, which would be contrary to common sense.

The “but for” test must be followed by a process of identifying which of the events satisfying it should be treated by the law as the actual cause or causes of the death for the purpose of punishment. This cause is referred to as “causation in law” whilst the label “legal cause” is used for the result of the analysis. Secondly, it should not be applied where the exercise yields an absurd answer. An example is where parties A and B simultaneously inflict mortal wounds on the victim any of which alone would have caused the death. Application of the test would let off both parties, which is an affront to common sense.

Most of the factors in causation chain models flow from the actions or omissions of one or other of the construction project supply chain members. In most cases, reflecting the logic of the Reason's model and its derivatives that a hole in any individual barrier cannot lead to accidents without coinciding holes in the others, more than one organisation can be said to have caused the death. Multiple causal factors raise two main types of issues in civil proceedings. Firstly, there is the question whether another event eclipsed the defendant's breach of duty to such an extent that that other event should be treated as the sole cause of the damage complained of and not the defendant's act. This issue is referred to by the Latin term *novus actus interveniens*. Sometimes the causal argument is about whether another event for which a third party or even the claimant himself was responsible added to the damage caused by the defendant. If the court determines that the chain of causation was not broken but there was material contribution from the third party, the liability can be shared between the two actors. In the case where the claimant was to some extent the author of its own damage, the court may reduce the compensation it is entitled to by a fraction representing the claimant's responsibility. In criminal law each of the parties is charged separately and the task is for the court to determine, for each defendant, whether it contributed to the death beyond the *de minimis* level. Multiple organisations could therefore be convicted for the accident although different levels of contribution attract different sentences.

The question whether a death was caused by the way the organisation's activities were organised or managed is one for the jury to answer. In view of the complexity already outlined this must be a challenging task for a lay jury. The construction accident causation models provide a very useful empirically based framework to educate lay juries on multiple organisational responsibilities for accidents and the role of organisational culture in accident causation. Also, use of the models in conjunction with the "but for" test should quickly eliminate those organisations for which no causal link with the accident exists.

The diffusion in supply chain members' responsibilities for the performance of activities on a construction project and the high probability of multiple organisational contribution to accident causation implied by models mean that when a fatality occurs it will often be necessary to carry out extensive investigations to identify all the parties who may be charged with corporate manslaughter. Such investigations may involve examination of the chain of contracts within the supply chain, physical inspection of the accident scene and interviewing of witnesses. To preserve evidence, the construction site may have to be closed down for a period, which would give rise to production and disruption losses to be incurred by some of the supply chain members. The financial consequences of attempts to pass the liability down to the parties ultimately responsible could be as financially damaging as the criminal proceedings.

Use of the causation models is likely to expose issues on which there is a dearth of precedents on the existence of a duty of care. For example, consider the role of the project owner. At the one extreme, there is the owner highly motivated to procure a highly complex facility to an extremely challenging budget within an impossibly short period. The supply chain is put under pressure to compromise on health and safety to meet the client requirements. At the other extreme is an enlightened and highly health safety conscious client who puts in sufficient time and other resources for proactively managing health and safety right from project inception, through completion, use and maintenance, to final demolition. Clients, as a collective, may exert influence at an industry-wide level through the extent to which their corporate procurement practices incentivise effective health and safety management by all members of the supply chain. Although the causal chain models produced from empirical research put beyond any doubt the causal link between the owner's procurement decisions and accidents, there is no clear legal authority supporting the proposition that project owners owe duties of care to avoid endangering the lives of site workers in formulating their procurement decisions.

It is already common practice to engage different specialists as expert witnesses to assist the court with causation issues in relation money and time claims and responsibility for defects and failure of the products of the industry. The complexity of the causation issues likely to arise in corporate manslaughter prosecution and the greater seriousness of a criminal conviction point towards use of expert witnesses to a much greater degree. Such experts would find the accident causation models very useful although further work would be necessary to translate them into methodologies for identifying those organisations whose activities can rightly considered to have produced the legal cause of a fatality. Analysis of the other ingredients for liability, which has not be presented in this paper, also show that expert witnesses are also likely to be retained for a host of other issues such as the foreseeability of the accident and whether the organisation's conduct was far below what was reasonably expected. Considering the complexity of these issues and the fact that they span civil and criminal law, large teams of lawyers from different areas of practice are likely to be involved in corporate manslaughter investigations and proceedings. Taking together the cost of this level of involvement of legal representation and expert witnesses and the gravity of the sanctions that may be imposed after conviction, the survival of a convicted organisation other than the larger concerns is likely to be seriously imperilled.

VI CONCLUSIONS

Under this legislation, an organisation may be convicted of the crime of corporate manslaughter where, subject to a number of qualifications, a person is killed by its operations. One of the qualifications is that the death must be caused by the way its activities are organised or managed. The issue of causation is likely to be very controversial considering the gravity of a corporate manslaughter conviction. Factors likely to compound the controversy include multiplicity of project participants, diffusion in supply chain responsibility for the tasks that must be performed to achieve project completion and the requirements to prove causation beyond reasonable doubt to a lay jury. Although none of the reported accident causation studies had been undertaken with proof of causation for the purposes of punishment as part of their research aims, they are nonetheless capable of being used to support corporate manslaughter prosecutions in several ways.

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Development of a Knowledge-Based Energy Damage Model to Assess Occupational Health and Safety (OHS) Construction Risks in Malaysia

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Development of a Knowledge-Based Energy Damage Model to Assess Occupational Health and Safety (OHS) Construction Risks in Malaysia

Abstract

Malaysia's construction industry has been long described as a dangerous industry, indicated by its poor health and safety performance. One of the Malaysian government's initiatives to address OHS in construction is through the widespread adoption of Industrialised Building Systems (IBS). An IBS approach is believed to affect the significance of a particular safety risk because it changes the nature of the construction process. This study proposes to examine the extent of IBS impact upon OHS in contrast with traditional construction in Malaysia, by developing a knowledge-based energy damage model that assesses the OHS risks of different construction approaches. The proposed model will provide best-practice reasoning support for designers in construction.

Introduction

The construction industry is renowned as a high-risk industry which involves complex, time consuming design and construction processes characterized by unforeseen circumstances. As a result, the construction industry has been plagued with accidents for a long time (Ren, 1994). Major causes of accidents are related to various factors such as the nature of the industry, human behaviour, difficult work-site conditions and poor safety management and culture. This has resulted in unsafe work methods, equipment and procedures and has made occupational safety and health (OSH) management an important element in the construction industry.

In Malaysia, safety performance in the construction industry has lagged behind most other industries as evidenced by its disproportionally high rate of accidents and this is proven by annual report produced by the Social Security Organization (SOCSO). Statistics reveal between 4,500 and 5,000 cases of construction site accidents every year, with an average of 80 to 90 fatalities per year (Foo, 2005). According to the SOCSO (2000), the case fatality rate in the construction industry in Malaysia was more than 3 times that of all other workplaces, 3.3% in the construction sector compared to all other workplaces of 1.1% (SOCSO, 2000 as cited in Foo, 2005). The latest statistics in 2009 indicate that among the 4108 accidents reported in the Malaysian construction industry, 116 cases resulted in a fatality while 977 in permanent disabilities (SOCSO, 2009). This high accident and fatality rate has caused concern among the industry players and government.

It is proposed that one of the ways to improve safety and health in the construction industry is through the implementation of off-site production (OSP), commonly termed "Industrialised Building Systems (IBS)" in Malaysia (CIDB, 2004). The implementation of IBS changes the nature of activities, which are different from traditional processes. In IBS, the process is industrialised by which components of a building are conceived, planned, fabricated, transported to and then erected on site (Junid, 1986). Even though there are several studies indicating IBS can significantly reduce OHS risks in traditional construction (McKay, 2010 and Gangolelles et al., 2010), the extent of IBS impact upon safety and health in construction is still unclear as there is no current system to assess OHS risk in the construction process.

In order to address this, a study at RMIT University seeks to apply the concept of an "argumentation theory model" (Toulmin, 1958; as cited in Yearwood and Stranieri, 2006) by building on a tool developed by Cooke et al. (2008) to help construction designers integrate the management of occupational health and safety risk into the design process. It was developed from structured knowledge in the context of uncertainty and discretionary decision making, by involving expert reasoning regarding design impacts upon OHS risk represented by "argument trees" (Cooke et al, 2008). This paper presents the development of a model which consists of a series of "argument trees" for best practice reasoning that can be used by designers or decision makers when examining the OHS risks posed in the construction of their designs. In addition to the existing model, an "energy damage model" (Viner, 1991) will be used as an underpinning framework for developing the model. The development of this model contributes by suggesting options for the decisions that can be made by product and process designers, in such a way as to assess the extent to which their design decisions mitigate the OHS risk in construction, and thereby offering a more rigorous relative comparison of OHS risks between IBS and traditional approaches.

This paper serves to outline the development of a knowledge-based energy damage model to assess OHS risk in construction processes at the design stage. Initially the paper will provide an overview of the Malaysian construction industry and its OHS record, followed by its government's desire to improve OHS performance through IBS. The paper provides some further OHS risk background before discussing the concept of the model.

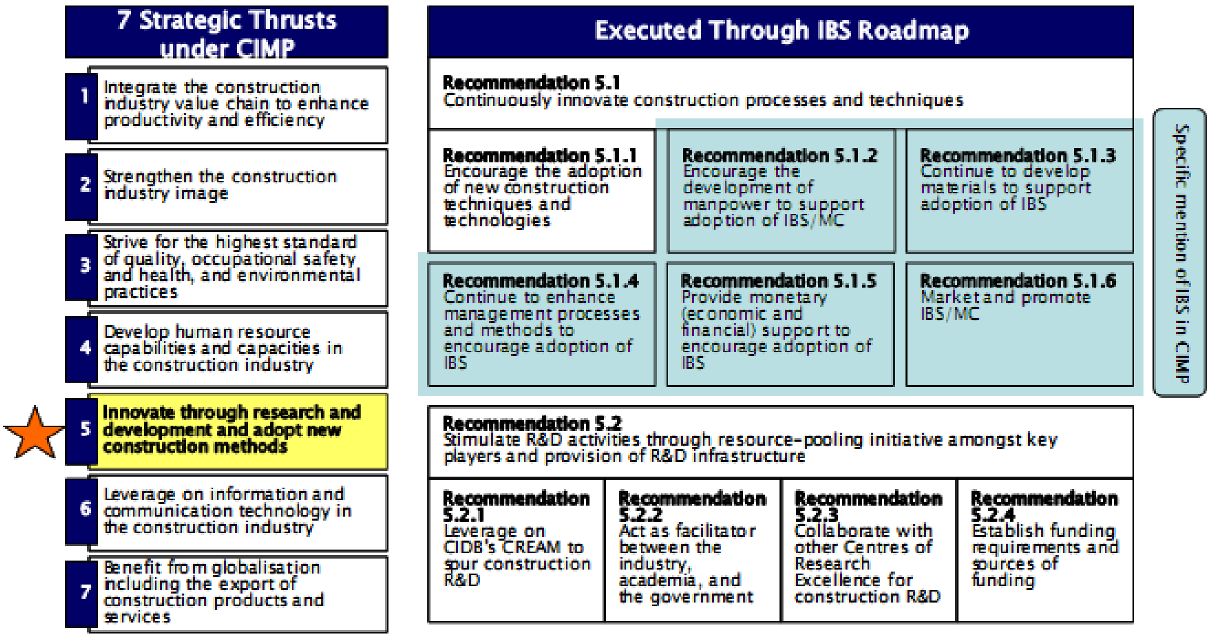
Overview of Malaysia Construction Industry

The construction industry in Malaysia is generally divided into two sectors, namely general construction and civil engineering construction. In 2009 during the slowing global economy, the construction sector was the only sector that plotted a positive growth during every quarter of that year in Malaysia. The Construction Sector registered a strong growth of 5.8% in 2009, and subsequently 8.7% for the first quarter of 2010 as against the overall GDP growth of 10.1% during the first quarter of this year (Mansor, 2010).

Prosperity and high economic growth in Malaysia have both created a high demand for construction activities. As a consequence, a large number of foreign workers have been attracted into the country to take up employment on site as unskilled labour doing manual jobs (Hamid *et. al*, 2008). According to the Construction Industry Development Board (CIDB) of Malaysia, 69% (552,000) out of a total of 800,000 registered workers (as at June 2007) are foreign workers (CIDB, 2007a). Regardless of the over dependence on foreign labour, the industry is still saddled with serious problems such as low quality, low productivity, poor image, economic volatility, bureaucratic delays, lack of ethics, shortage of skilled manpower and lack of data and information (CIDB, 2004). Moreover, the OHS performance of Malaysian construction industry is poor as evidenced by its high accident and injury rates.

Additionally, the huge demand for construction projects, especially building construction has fostered interest in Industrialised Building Systems (IBS), which could save on labour, cost and construction time, and confer quality and durability (Ismail, 2001 and Hamid *et al.*, 2008). The implementation of IBS is also seen as one of the initiatives to improve the industry's OHS performance (CIDB, 2004).

The importance of IBS implementation is highlighted in the *Construction Industry Master Plan* (CIMP 2006-2015), under the *Strategic Thrust 5* (CIDB, 2007b), as shown in Figure 1. The Government of Malaysia has emphasized the full utilization of IBS for government projects by the inclusion of not less than a 70% IBS component (CIDB, 2003). Further to this, the IBS Roadmap 2011-2015 aims to raise the existing IBS score from 70% to 80% by 2015 for government projects above the value of RM10 million (CIDB, 2010). Furthermore, this Roadmap is predicted to impact the private sector through "public-private-partnership" (PPP), with an average 50% IBS uptake for private projects being achieved by 2015.



Source : Construction Industry Master Plan, 2006-2015

Figure 1: IBS Thrust in the CIMP 2006-2015

The context of Industrialised Building Systems (IBS) and health and safety

The Master Plan for Occupational Safety and Health in the Construction Industry 2005-2010 recommends that to improve the performance of OHS, implementation of mechanization and new methods for construction that will optimise labour utilization in the industry are needed (CIDB, 2004). It is proposed that by using an IBS approach, the hazards inherent in traditional construction activities change when the process is moved offsite, and in some cases the hazards on site are completely removed, or are easier to reduce and control in a factory.

Some researchers suggest that IBS is safer than the traditional process in a way that the work location can be shifted to a lower hazard environment (Toole and Gambatese, 2008) and from the field to the factory which allows better control of the hazards (Gibb, 1999; Toole and Gambatese, 2008). This is supported by McKay

(2010) who studied the OHS risks associated with offsite and found that offsite can significantly reduce OHS risk in traditional construction in the UK. However, that study did not present a mechanism by which a particular design could be assessed and compared to an alternative. He only suggested the ways to mitigate the residual OHS risk, but overall he did not precisely address how the risks in both offsite and traditional can be treated effectively. Therefore, there is a gap in the research to effectively address the designers' role in making decisions in their designs and further understand the level of OHS risk their designs pose.

Gibb (1999) proposes that developing a project-wide strategy at an early stage would be essential and consideration of off-site fabrication should be done from an overall project perspective rather than on an element by element basis. This strategy is essential in achieving health and safety benefits from IBS where the project could organise the whole project to minimise risk and maximise efficiency (McKay, 2010).

The Concept of Designing for Construction Safety

The potential benefits of IBS can be better understood if viewed as a 'design change' from traditional construction products and processes. "Designing for construction safety" is a perspective that has been gaining attention among researchers for the past decade to reduce and eventually eliminate construction accidents. IBS as an alternative approach offers potential to realise significant safty gains through product and process design. Cooke (1997) and Gambatese, et al. (2008) suggest that the poor safety performance of construction can be improved through preventing accidents and reducing uncertainty before it happens. In addition, Szymberski (1997) postulated that by incorporating safety earlier in the project schedule, greater influence could be exerted (Figure 2). It can be seen that by including construction site safety as a consideration (along with production, quality, project scope, etc) early in the project's life cycle, one has a greater ability to positively influence construction site safety. The evidence of the effectiveness of this strategy is confirmed by several authors such as Jeffrey and Douglas (1994); Furst (2010); Gibb et al. (2004) and Behm (2006).

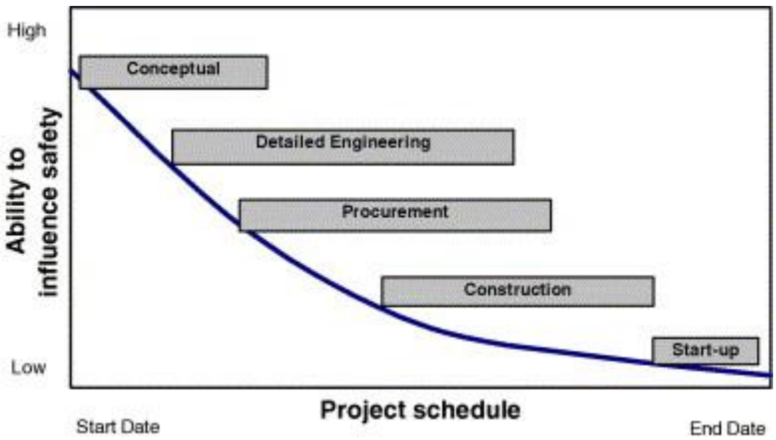


Figure 2: Time/safety influence curve (Szymberski, 1997)

Despite the awareness among designers of this concept, Toole and Gambatese (2008) argue that there is still a lack of technical principles to help designers better perform Construction Hazard Prevention through Design (CHPtD) and that there is a need to facilitate the development of additional CHPtD tools. According to Gangolelles *et al.*

(2010), most publications on this subject only offer solutions that can be directly implemented and checklists for the subsequent monitoring of the design. For example, the Health and Safety Executive (HSE) has documented and illustrated how designers could significantly improve construction safety and reduce costs or programme time using several case studies (HSE, 2003). Similar documents have been published by the Guide to Best Practice for Safety Consrtuction: Design Stage (2009) for the Australian context. Other examples include Gambatese and Heinze (1999) who accumulated design suggestions for improving construction worker safety while in the design phase.

Other tools developed by researchers to help the design decision process include "Design for Construction Safety Toolbox", a computer design tool which is built upon 400 design practices that could be used by designers to minimize or eliminate hazards in their design (Gambatese et. al, 1997); and Construction Hazard Assessment Implication Review (CHAIR), a safety in design tool in Australia developed by WorkCover, a body responsible for regulating OHS in the State of New South Wales (NSW), in 2001. CHAIR was developed to identify risk in a design of the whole project life cycle including construction, operation and maintenance, where the stakeholders are required to review the design in a prescribed manner and ensure that their OHS issues are considered in the design phase of the project (WorkCover, 2001).

In Malaysia, initiatives for addressing safety in the design phase are defined in the Construction Industry Management Plan (CIMP) 2006-2015. Some of the positive recommended actions addressing OHS are related to "designing for construction safety" which include education in OHS concepts; and providing guidelines for clients to have safety and health design checks put in place before construction; (CIDB, 2007a). However, it is doubtful that Malaysian construction designers adequately understand how to identify, assess and control OHS risks in their designs.

Designing the construction process for OHS performance can play a role in evaluating the effectiveness of IBS construction over traditional approach. This is because moving from traditional construction methods to IBS changes the process, and the changing design decisions may affect the significance of a particular safety risk. In addition, by considering safety during the design process, hazards can be eliminated or reduced during construction, thus improving the safety performance (Behm, 2005). In this "Designing for Construction Safety" concept, the designers assess the risk of their designs created for construction, and consequently attempt to eliminate or reduce these risks within their designs.

OHS Risk Management

Inherent within the Designing for Safety Concept is the analysis of safety risk. Safety risk analysis is a foundation upon which safety management is built and risk assessment becomes a critical task which forms a part of safety management systems (Fung *et al.* (2010); Langford et al. (2000); Low and Sua (2000); Cheng *et al.* (2004); and Jung *et al.* (2008). According to Gangolelles *et al.* (2010), authors like Carter and Smith (2004), Cheung *et al.* (2004a), Cheung *et al.* (2004b), Imriyas (2009) and Seo and Choi (2008) had addressed the methods of how health and safety aspects can be integrated during the design and preparation phase, however, subjective judgements often influence the accuracy of their methods.

When the risks assessed are regarded as high, they should ideally be controlled by implementing measures to reduce the risk associated with a hazard in the order portrayed by the hierarchy of controls. The hierarchy of controls is based on the principle that control measures that target hazards at source and act on the work environment are more effective than controls that aim to change the behaviour of exposed workers (Matthews, 1993). Therefore, designing-out OHS risks is a better approach than controlling the risks using measures that are dependant on administrative controls and PPE. This is supported by Manuele (1997) and Andres (2002) who specify design as the primary method to reduce risk.

Gangolelles et al (2010) established an assessment tool providing the basis and criteria to quantitatively measure safety performance of construction projects by mitigating construction risks during the design stage. The limitations of the study are that it uses a simple quantitative methodology where there is no thorough scoring system for evaluating significance rating of the risks; and the risk exposure rating was only based on the information contained in construction documents. The outcome is doubtful due to the methodology used, as the health and safety risk indicators are based on the product, not the process. The tool would be more worthwhile if the methodology is robust and the risks indicators are built upon the construction process.

ToolSHED (Cooke *et al*., 2008) was developed to help construction designers integrate the management of occupational health and safety risk into the design process in Australia. It was developed from structured knowledge in the context of uncertainty and discretionary decision making, by involving expert reasoning regarding design impacts upon OHS risk represented by "argument trees". However, the example presented is only on the design-related risks of falls from heights for the maintenance of roof plant, which is post-construction. Therefore, there is a gap in the research to expand the tool into the other construction processes and phases.

Addressing the issue of safety and health in IBS construction is vital because it will affect Malaysia's construction industry as a whole. However, it is believed that there is a lack of designated IBS risk assessment methodologies addressing occupational safety and health. Even though there is one recent study which quantitatively addresses safety and health assessments, it is only based on the present safety performance of IBS construction and does not seek to design the IBS process for OHS performance (Ahmad, 2010). Therefore, it would be ideal to apply the concept of ToolSHED into the construction process and include other areas of OHS risk. The outcome would be a model that presents construction process knowledge delineated by argument trees showing the inference procedure.

Argumentation theory

ToolSHED uses "argumentation theory" to represent the modelled design OHS knowledge to support human decision making in a complex situation. The use of argument trees to model expert reasoning in solving problems in such situations represents the "open textured" concepts which are suitable for the vagueness characteristics of real world problems. Open texture concept has been adopted by many countries in their OHS legislation, in which they have reformed the legislation from detailed and prescriptive requirements to performance-based requirements, following the UK legislation shift in mid-1970s (Cooke, et al, 2008). These countries have addressed "general duties" for employers, employees, suppliers of plant and materials and others.

The "general duties" provisions are not absolute and often limited by words such as "so far as is practicable" or "reasonably practicable". For instance in Malaysia, Section 20 of Act 514 Occupational Safety and Health Act 1994, Part V General Duties of Designers, Manufacturers and Suppliers requires that:

(1) It shall be the duty of a person who designs, manufactures, imports or supplies any plant for use at work -

> *(a)* to ensure, so far as is practicable, that the plant is so designed and constructed as to be safe and without risks to health when properly used;
>
> *(b)* to carry out or arrange for the carrying out of such testing and examination as may be necessary for the performance of the duty imposed on him by paragraph (*a*); and
>
> *(c)* to take such steps as are necessary to secure that there will be available in connection with the use of the plant at work adequate information about the use for which it is designed and has been tested, and about any condition necessary to ensure that, when put to that use, it will be safe and without risks to health.

Open texture is useful for representing expert reasoning in deciding how to comply with performance-based OHS requirements due to the large number of inter-related and heterogeneous factors that revolve around the requirements. In executing their duties, duty holders would surely need to balance OHS risk against cost and technical possibility, and the phrase "how safe is safe enough" would be their dilemma in making decisions (Cooke et al., 2008). Therefore, Cooke et al. (2008) suggest the use of "argument trees" for modelling expert reasoning as better suited to solving problems in such situations.

Argument trees

Argument trees can represent the reasoning process, enacting on presenting or defending, in seeking a rational or reasonable standpoint or decision. Using argument trees as an approach to represent the knowledge of design OHS is useful because design OHS is subjective and interconnected to other issues that require concurrent considerations.

The idea of representing knowledge from argumentation was initiated by Toulmin (1958; as cited in Cooke et al., 2008), however, he loosely specifies how arguments relate to other arguments and provides no guidance as to how to evaluate the best argument (Yearwood and Stranieri, 2006). Therefore, Yearwood and Stranieri (2006) use "argument trees" graphically to clarify the hierarchical ordering of factors pertinent in decision making processes.

In argument trees, all arguments consist of one conclusion represented by a single "root" node that are proven or supported by "child" and "parent" nodes. The nodes are connected by lines that represent the relevance relations in an argument structure.

The values on “children” nodes will conclude the linguistic variable value on the “parent” node using the pre-determined inference procedures, which ultimately give the value of the “root” node. The inference process depicts a template for reasoning in complex situations (Cooke *et al*., 2006).

Knowledge-based energy damage model to assess OHS risks designed

In developing a model that represents the reasoning for decisions around the construction processes, the same method of modelling as the expert reasoning system in ToolSHED, in the form of a series “argument trees”, will be used. However, the argument trees developed in this study will be underpinned by a knowledge-based energy damage model in construction processes to assess OHS risks in the design.

The energy damage model, created by Viner (1991), suggests the identification and control of potentially harmful energy to eliminate or reduce the latent conditions of the unsafe person while operating in an unsafe place. This is underpinned by, “when an unwanted and harmful energy source is transferred unexpectedly (in type, time, speed or force) or to an unwilling or unwitting person, the problem may arises even though the energy itself is not dangerous”. Identifying such damaging energies enables a designer to provide technological control of elimination or reduction.

Figure 3 depicts the Energy Damage Model which is adapted from Viner’s original model. In order to cause damage, energy has to penetrate the barrier and transfer to the recipient. The extent of damage depends on the amount of energy that exceeds the energy threshold of the recipient. The types of damaging energies (hazards) include gravitational; noise and vibration; chemical; electrical; mechanical; thermal; pressure; radiation; microbiological; biomechanical; and psychosocial (Safetyline Institute, 2005). As the high amount of damaging energies to penetrate the shield could determine the level of injury to the recipient, reducing the amount of these energies will become increasingly important.

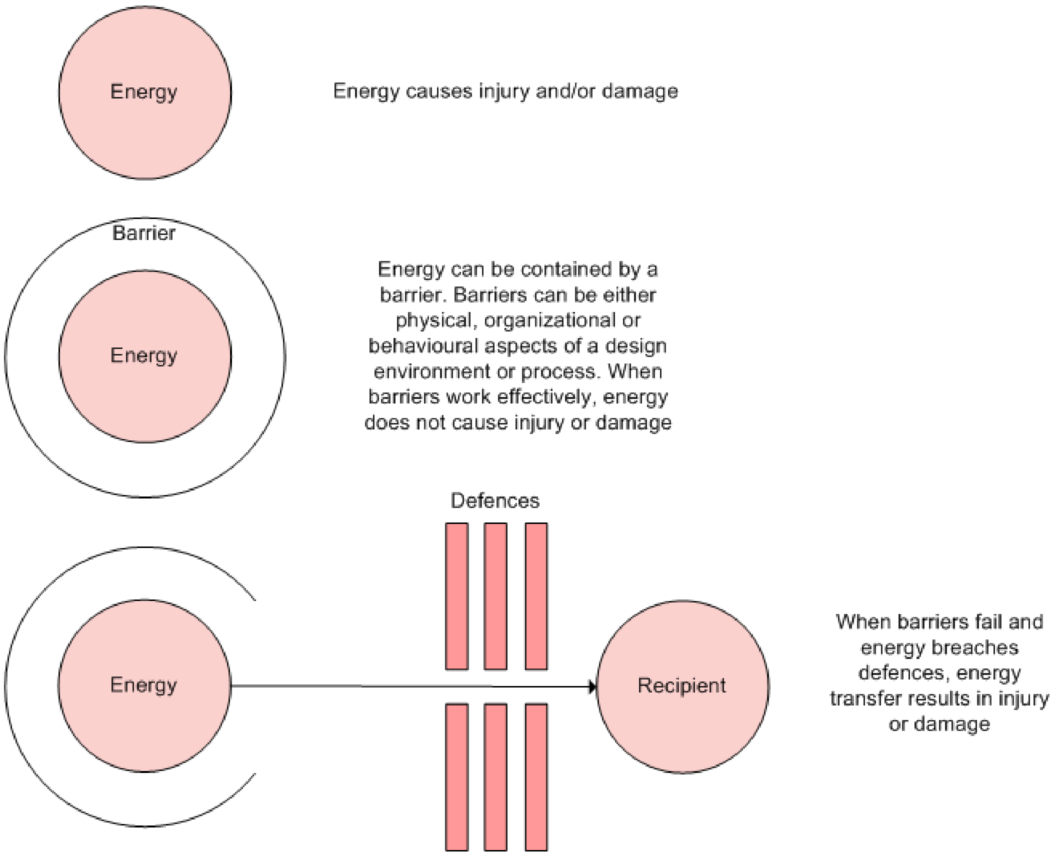


Figure 3: Energy Damage Model (Source: Guide to Best Practice for Safer Construction (2009); Adapted from Viner (1998))

The development process

Integrating the damage energy model with argument trees provides a powerful tool for assessing construction process risk. The development process of the model is depicted in Figure 4. It consists of two stages initiated with knowledge acquisition, followed by knowledge processing.

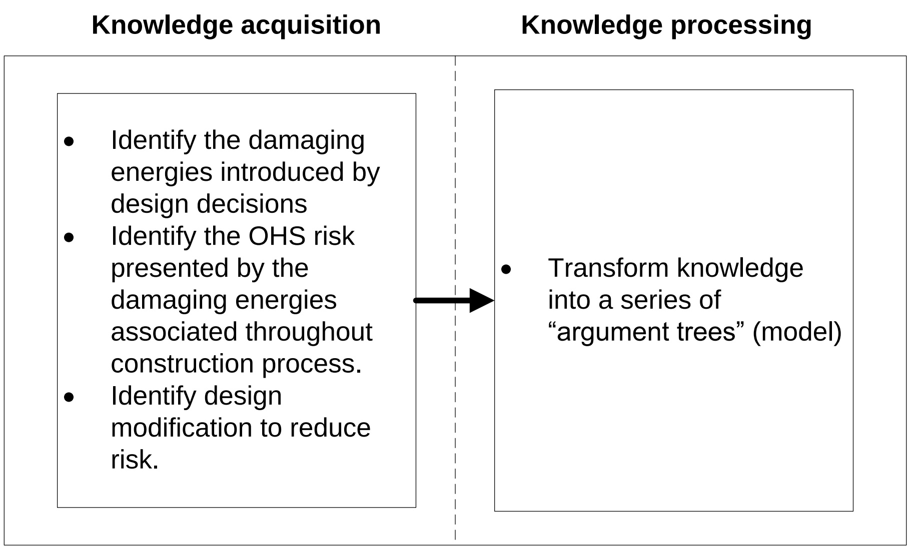


Figure 4: Model development process

Knowledge acquisition involves collecting the data that will underpin the model. To assess the construction OHS risks within a design, knowledge energy transfers (hazards) associated with the construction processes are needed. Further the identification of barriers to prevent such energies from injury or damage together in energy transfers can then be transformed into argument trees. The extent of damage depends on the amount the energy deflected by the “barriers”. The use of “argument trees” for modeling expert reasoning is better suited to represent the level of “how safe is safe enough” of the designer’s decision on the “barriers” to be used to counter the damaging energies during the construction process. This level of decision will determine the value of a risk rating at the “root” node of an argument trees.

The risk rating is determined by the value of risk magnitude at the “root” node expressed by the linguistic variables “extreme”, “high”, “moderate” and “low”. The final risk rating is calculated using the common “risk management” function of 1) likelihood that an injury or illness will occur; 2) the severity of the consequence of that injury or illness should it occur; and 3) frequency with which a person is exposed to the hazard. The magnitude of the likelihood, consequence and frequency are determined by expert panels from the relevant factors, inferred from a series of child nodes.

Figure 5 is an example of a design OHS argument tree for the likelihood of risk for concrete panels. A set of linguistic values with numerical values are assigned to each node of the argument tree, regardless of its position. These values are relevant to the design options available to a designer when making judgement upon aspects of design, pertinent to the risk of wall cladding construction. It can be seen that the tree has linguistic values with corresponding numerical values in the child nodes inferring values of parent nodes. This inference procedure, denoted by A, B, C, and D, continues until ultimately inferred at the root node, the final risk rating. The risk rating at the root node indicates either “extreme”, “high”, “medium” or “low”. It is measured by calculating the likelihood, consequence and exposure which are contingent upon the values decided by the designer at every child nodes. One may notice that the inference process in structured argument trees apparently mimic the risk assessment process.

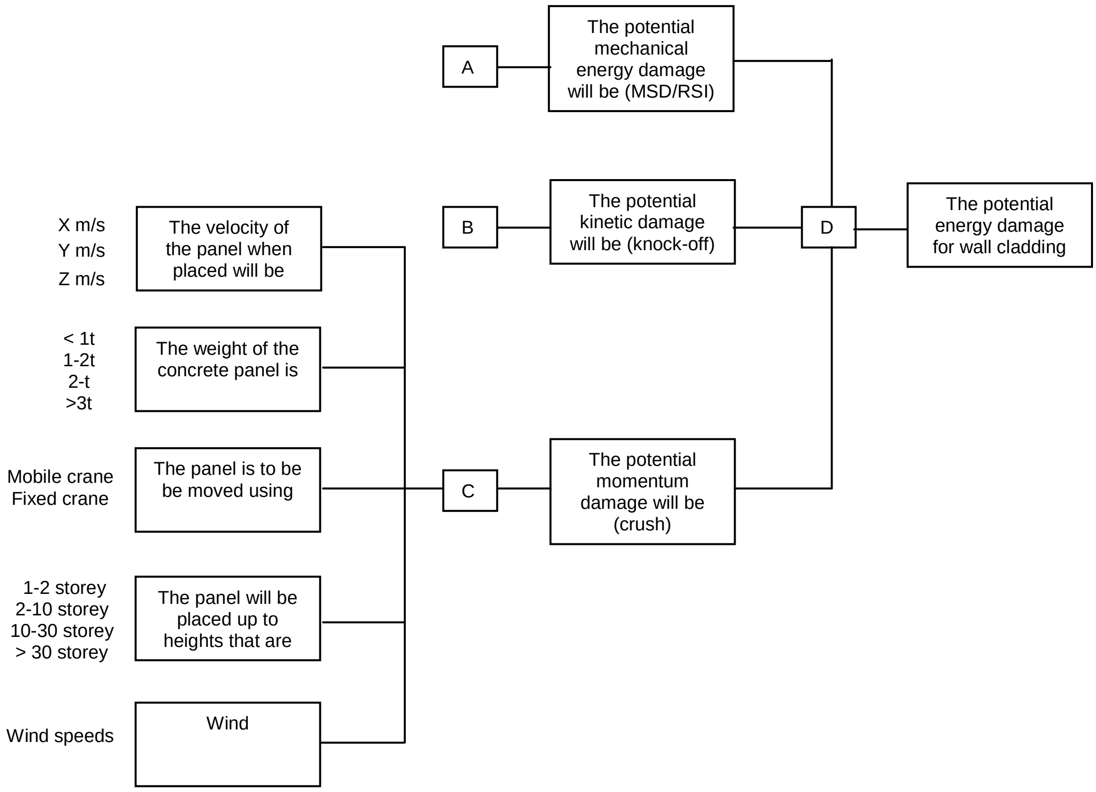


Figure 5: Example of argument tree showing the inference procedure

Scope and limitation

The scope of the project currently underway is focused on occupational health and safety risks (OHS) of IBS and traditional projects for residential building construction. The reason for focusing on residential projects is to discount the possible variation due to irregular structural layout plan if other types of projects such as hostels, universities and schools are considered. Moreover, residential projects have typical structural layout plans and are repetitive, even though minimal or variation might occur. This makes direct comparison between building systems more representative and unbiased (M.R. Abdul Kadir *et al.,* 2006).

This project will only cover the major hazards (damaging energies) involved in building construction using both IBS and traditional approaches which represent the hazards in building construction as a whole. The determination of the major hazards will be justified from the data analysis of safety performance of building construction in Malaysia. The case study will be undertaken for three construction projects that represent both IBS and traditional approaches and cover the structure and envelope of the building.

Conclusion

This paper presents the development of a knowledge-based energy damage model to assess OHS risks designed in construction processes. The model used a combination of the “argumentation theory” and “energy damage model”, building on a risk assessment tool named ToolSHED. The outcome of this study will be a model for best practice reasoning used by designers or decision makers when examining the OHS risks posed by their designs. This requires integrating construction process knowledge into design to eliminate or reduce hazards during construction in both IBS and traditional approaches. Whether the option is an IBS or traditional approach, the fundamental idea of the model will initiate construction designers or decision-makers to address safety in the design process and encourage them to examine carefully the probable OHS risk variables surrounding an action; thus preventing accidents in construction.

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An Investigation into Safety Culture of Chinese Construction Supervision Organizations

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An Investigation into Safety Culture of Chinese Construction Supervision Organizations

Abstract:

To prevent casualties from happening and reduce injures, the State Council of China issued Production Safety Regulation on Construction Projects (PSRCP), which set out safety responsibilities of each party in construction project. On-site supervising engineers (who have similar roles to the Engineer in FIDIC Conditions of Contract for Construction), had also been assigned legal responsibility in regard to safety performance according to that regulation. Safety culture is proposed as an effective way to improve safety management performance. However, safety culture needs to be understood, evaluated, developed and fostered. The paper firstly developed a safety culture framework, then, 15 construction sites were surveyed based on the questionnaire designed from the framework. The survey results were analyzed using Factor Analysis with SPSS software. The analysis results show that individual safety consciousness of supervising engineers is good and Construction Supervision Organizations also pays great attention to the safety supervision. The main implications of the research findings are supervising engineers should improve their professional knowledge, the communication skill and apply risk management into their safety management practice. In the meantime, negative influences from the clients and contractors should be paid attention because it is a serious obstacle which deters the effective safety management of supervising engineers.

Key words: safety culture; Construction Supervision Organizations; safety culture model; Factor analysis; safety culture evaluation

1. Introduction

Construction industry has played a great role in Chinese economic development. The economic output of construction industry increased from RMB 2.77 trillion Yuan in 2004 to RMB 7.68 trillion Yuan in 2009, the average increasing rate being 21% each year. However, construction industry always bears the bad reputation of high rate of casualties and injures. Construction is the second risky industry next to mining industry in China (Zou et al, 2009). Table 1 shows the statistics of accidents and casualties from 2001to 2009. From Table 1, it can be seen that there were nearly 1000 people killed every year. Accidents also result in big financial loss, for example, the financial loss of all accidents was RMB 250 billion Yuan, accounting for 2% of GDP that year in 2004 in China (Sina, 2005).

Table 1: Construction accidents and casualties in China

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
Accidents	1004	1208	1278	1144	1010	888	859	778	684
Casualties	1045	1297	1512	1324	1195	1048	1012	964	802

Source: Ministry of housing and urban rural development (2001-2009)

To prevent accidents and injuries from happening, Chinese authorities have made a lot of efforts to strengthen safety responsibilities and to constrain unsafe behaviors in construction projects by setting up safety specifications on specific dangerous construction work items and issuing laws and regulations on safety production. For example, Construction Law was issued in 1998 and Production Safety Law of the People's Republic of China in 2002. However, from the data, there was little change in terms of the quantities of accidents and casualties. To be more effective and specific, Production Safety Regulation on Construction Projects (PSRCP) was issued by the State Council to set out safety responsibility of each party in construction project in 2004. In PSRCP, supervisor engineers, one of the parties on site, are assigned the legal responsibilities to supervise safety performance of contractors.

After PSRCP took effect in 2004, many supervising engineers were involved in accidents suitcases, for example, supervising engineers of almost all accidents with 3 deaths and above has been sentenced in prison (MOHURD, 2010). The main reason behind the high duty crime rate of supervising engineers is the lack of safety culture. This can be supported by the following two facts. Wang (2006) states for a long time, great efforts were put on quality, time and cost control of the construction project by participates of construction projects. Though safety responsibilities are required by laws, the participants including supervising engineers still haven't paid enough attention to the safety issues. Secondly, many practitioners of construction industry equaltysafety culture to safety songs, signs and slogans, instead of connecting safety with safety consciousness/actions (Huang et al, 2006). So in many cases, safety management is very ineffective because it is done very superficially.

The Advisory Committee on the Safety of Nuclear Installations defined safety culture as the product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior that determines the commitment to, and proficiency of, an organization's health and safety management. (cited in Health and Safety Commission 1993). From this definition, it can be seen that safety culture is not only about the "soft thing", such as perception, but also about some "solid action" such as behaviors. Health & Safety Executive (2005) defined safety culture based on the work of Cooper (2000), safety culture as a product of three interrelated aspects, (1) Psychological Aspects or 'safety climate' (individual and group attitudes, perceptions and values), (2) Behavioral Aspects (safety-related actions and behaviors) (3) Situational Aspects (policies, procedures, organizational structures and management systems. This definition further added the importance of situational aspects to safety culture.

Safety management practice develops with the concept of safety culture's evolving. Zou (2011) provided brief summary of the historical development of construction safety management by reviewing literature including Hinze and Harrison (1981), Holmes et al. (1998), Reese (2003), Biggs et al.(2005), Zou et al. (2008), Garavan and O'Brien (2001), Sawacha et al. (1999), Zou and Sunindijo (2010). Current safety management research is focusing on foresting the safety culture within most organizations and industry-wide to improve the safety consciousness and safety performance, (Fung et al. 2005; Lingard and Rowlinson, 2005; Zou,2009). Zhou and Fang (2009) also states that improved safety culture can reduced accidents and injure rate and construction of safety culture which include not only policy making and supervising, but also safety consciousness of climate.

In China, supervising engineer is the party who manages and supervises construction work for clients. To improve their safety management performance, one of the ways should also be to foster a good safety culture in Construction Supervision Organizations (CSO). However, safety culture needs to be understood, evaluated before it is fostered. This paper aims to evaluate safety culture in CSOs to provide the basis for making meaningful safety culture construction measures. Based on the literature review and case studies, the paper firstly present a safety culture model for CSOs, then, a questionnaire survey based on the model was conducted, at last, Factor Analysis with SPSS is employed to analyze the survey results and evaluation of the safety culture is given.

2. The Proposed Safety Culture Model

When evaluating the safety culture of construction supervision organisations, the biggest problem is it is immeasurable. Lee and Harrison (2000) explained that safety culture has many manifestations, complex, and even intangible. Consequently, they argued that measuring safety culture is beyond the scope of any single method. Gellor (2001) investigated a safety triad theory in which he thought that a "Totally Safety Culture" should maintain a continue monitoring process to three domains which are environment, person factors and behavior factors. Lingard and Rowlinson (2005) developed a model that shows how occupational health and safety attitudes might shape related behaviour in construction. Zou (2011) depicts a conceptual model for fostering a strong construction safety culture in which the art balances the science of construction safety management.

This paper proposes a layer model of safety culture for Construction Supervision Organizations (SCMCSO). From inner to outer, the layers are personnel, organization and environment, the outer one being the environment of the inner one. The arrangement is based on the premise that persons are the core of safety culture. They are the receiver of the organizational safety values, police and perform the safety culture by their actions. Persons are also the members of organizations in which they are organized and influenced by organization's value, policy, rules etc., thus, the outer layer of person layer is the organization layer. Organization is an open system, which interacts with its environment as it takes in inputs and distributes outputs. The external environment which consists of forces and institutions outside the organization potentially affects the organization's performance (Robbins et al, 2006). To describe the influences of external environment on organization, the third layer is defined as environment layer.

Personnel

To understand why supervising engineers have been frequently sentenced to be in prison, 50 accident cases which involve at least 3 deaths were analysed (unpublished undergraduate student's thesis by Gu D. Y., 2010). The top 10 criminal evidences are:

(1) not stopping unsafe behaviours of on-site workers

(2) not checking the construction plan or specific construction plan for dangerous sections

(3) not finding/instructing to remove accident hazards

(4) not instructing to suspend part works/ work when serious hazards are not rectified as required

(5) not checking the certificates of the workers who do dangerous works

(6) not supervising and stopping the law-breaking actions of contractors (such as illegal resume of suspended work)

(7) not doing standing-by supervision and touring inspection on the site

(8) not checking the safety protective measures of dangerous works

(9) not reporting construction hazards to competent governmental authorities

(10) not checking the qualification of construction corporations

These top ten evidences are all about supervising engineers' unsafe behaviours. According to Robbins et al (2006), persons' behaviour mainly includes psychological things as attitudes, personality, perception, learning and motivation. Compare these components to the top ten evidences, it can be found that the most serious problems of supervising engineers are the poor safety attitude. As we introduce in the first section, safety has been ignored for a long time, thus, many supervising engineers do safety management superficially. This situation becomes worse especially when safety conflicts with other objectives, such as, cost, time, etc., in those cases, safety is directly put aside. In the cases involves criminal evidence 1, 2, 4, 6, 7, 8, 9, 10, almost all projects had cost/time constrains. Lacking professional knowledge is the problem supervising engineers have, which contributes to the evidence1, 2, 3, 8. Lingard and Rowlinson (2005) developed a safety behaviour model consists of four elements: " belief about job, job attitudes, behavioural intentions, and the actual behaviour towards safety". Referring to the behaviour theory, case analysis and the literature, this paper measure supervising engineers' safety performance from three aspects, safety attitude, safety behaviour and professional/safety knowledge.

Organization

In terms of organization layer, HSE (2005) described the corporate dimension as what the organisation has, which is reflected in the organisation's policies, operating procedures, management systems, control systems, communication flows, and workflow systems. The three aspects are interrelated and not mutually exclusive. Zou and Sunindijo (2010) classified safety climate of organization into six dimensions, top management's commitment, supervisor's involvement, trainings, communication, employee's involvement and safety policy, rules and guidelines. Referring to the literature on the definition of safety culture and the organization, this paper describe the organization from similar dimensions, safety value, safety policy, rules and guidelines, top management's commitment, employee's involvement, communication and safety Training.

Environment

According to Robbins (2006), the external environment is made up of two components, the specific environment and the general environment. The specific environment directly relevant to the achievement of the organization's goal and is unique and changes with conditions. In terms of safety culture, stakeholders, site environment are all very unique and have direct influence to the safety culture. The general environment includes the broad economic, political/legal, sociocultural, demographic, technological and global conditions that may affect the organization. As for safety culture, the most obvious components should be broad economic, legal, sociocultural, technological according to the characteristic of safety management practice.

It should be noted that the three layers interact, such as, persons are not the passive receiver of organizations, the experience and lessons learned from the practice will inversely influence the organizational safety policies and rule. Another example is though supervising engineers are responsible for supervising contractors' safety management, contractors also influence supervising engineers actions which will be explain later.

The framework of safety culture model for Construction Supervision Organization (SCMCSO) is shown in Fig. 1.

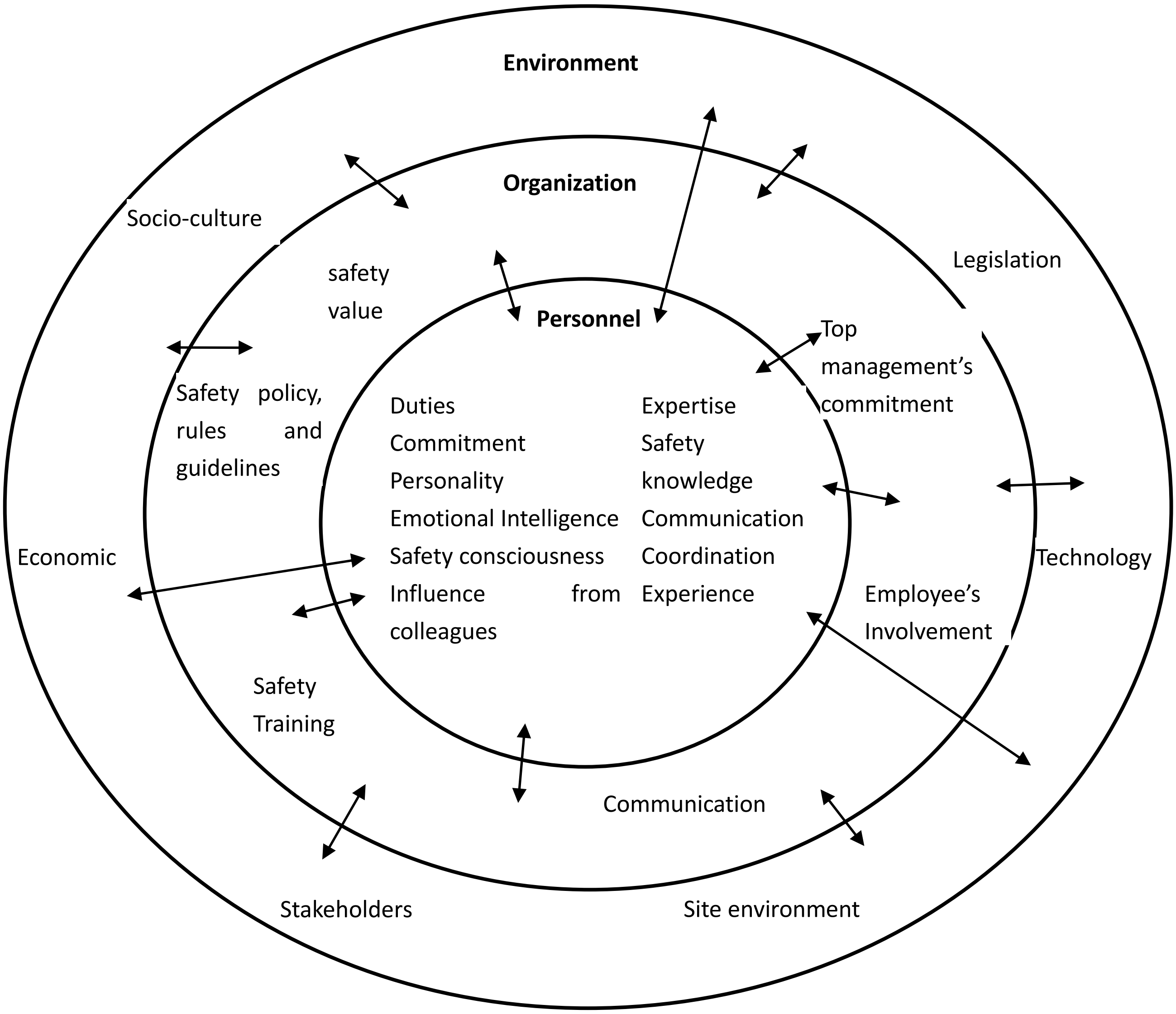

Figure 1: Safety Culture Model for Construction Supervision Organizations (SCFCSO)

3. Data Collection and Analysis

Questionnaire Design

Questionnaire survey is employed to collect data to evaluate the level of safety culture of Construction Supervision Organizations. The questionnaire is designed based on SCFCSO in section 2. It consists of 3 groups of questions to cover the factors in the three layers. The question list under the three groups is shown in Table 2. For each question, 5 options were given (strongly agree, agree, neutrality, disagree or strongly disagree). White spaces were provided for the respondents to provide qualitative comments. There are total 38 questions in the questionnaire. Among the 38 questions, the first 23 questions are positive and the scores for each option are 5, 4, 3, 2, 1. The last 15 are negative and the scores the other way round, namely, 1, 2,3,4,5. Given that participants may tend to choose neutral, reminder is given trying not to choose neutrality as much as possible. To prevent the respondents from following the authors thinking pattern, the order of the questions are arranged in random to some degree.

Table 2: questions included in the questionnaire

1 Person	
1.1 Supervision behavioral	
Q1	I know clearly about the responsibility of my job and I will fulfill it.
Q 2	I will ask workers to amend defects immediately if I find them when checking.
Q 3	We will re-examine the amendments after they are finished.
Q 4	If workers do not respond to the instructions, I will report to the corporation to do further actions.
Q 29	When other supervisors turn blind eyes to safety problems, I will follow them, even though I don't think I should do so.
Q 30	I often fail to report some safety violations to governmental authorities which are supposed to be to avoid conflicts with clients.
Q 31	I fail to report some safety violations to governmental authorities/clients which are supposed to be to avoid conflicts with contractors.
1.2 Safety attitude	
Q 5	I think safety is the top issue in the construction work.
Q 6	It is the important work to stress on safety in my work.
Q 7	I think most accidents could be avoided upon proper risk management.
Q 32	I become aware of the importance of safety only after accidents happen.
Q 33	I do not think big accidents would happen in the work I supervise.
Q 34	Sometimes I put safety rules aside to speed the work.
Q 35	I would not interfere with or report unsafe behaviors/work procedures if I

	think they have little negative effect on work.
Q 36	I think it is the head of supervisors who should be responsible for the safety supervision, which have little business with other supervising engineers.
1.3 Professional knowledge and safety knowledge	
Q 8	I am have enough professional knowledge to be a competent supervision engineer .
Q 9	I know clearly what measures we should take to ensure safety at each stage of a project.
Q 10	I know laws and regulations on construction works well.
Q 11	I know how to deal with safety problems well.
Q 12	I know clearly the hazards which cause construction accidents well.
Q 38	Poor communications between workers and I have negative effect on safety supervisions.
Organization	
Q 13	We often discuss construction hazards and pre-active measures with clients.
Q 14	We often discuss construction hazards and pre-active measures contractors.
Q 15	We often discuss construction hazards and pre-active measures in-house.
Q 16	We can settle the disputes between clients and contractors well.
Q 17	The head of our corporation place great importance to safety supervisions.
Q 18	Our corporation often holds safety training classes for us.
Q 19	Safety supervision trainings are very helpful for us.
Q 20	We know safety value and policies of our corporation well, which have been conveyed to us in various ways.
Q 21	We learn lessons from accidents happened in the works we supervise.
Q 22	We have well-structured safety supervision system in our corporation.
Q 23	I am satisfied with my present job.
Q 37	We often discuss pre-actions to accidents after they happen.
Environment	
Q 24	High turnover of staff in the corporation brings negative effect on safety

	supervision.
Q 25	The lack of the sense of stability of my job makes me feel uneasy.
Q 26	I feel irritated when accidents happen.
Q 27	Sometimes the depression outside of my job projects negative effect on my work.
Q 28	Sometimes the poor site conditions make me feel irritated when I am working.
Q 30	I often fail to report some safety violations to governmental authorities which are supposed to be to avoid conflicts with clients.
Q 31	I fail to report some safety violations to governmental authorities/clients which are supposed to be to avoid conflicts with contractors.

Survey

To improve the quality and the suitability of the questionnaire, pilot survey is conducted before formal survey. The respondents of pilot survey were supervising engineers and supervisors came from 4 different construction projects in Nanjing area. After pilot survey, the structure of the questionnaire is adjusted and 7 questions are deleted. The final questionnaire consists of 38 questions as seen in Table 2. In formal survey, 15 construction projects were chosen from Nanjing area because of the convenience of collecting data. There are 97 supervision engineers and supervisors got the questionnaire, 77 came back and 70 valid. The return rate is 79% and validity rate 72%, which are acceptable.

The respondents' information is shown in Table 3.

Table 3: Basic Information of respondents

Age				Education			Work experience in current Corporations				Work experience in construction industry			
< 30	31-40	41-50	> 51	J. high	S. high	Ba. and above	1-5	6-10	11-15	> 16	<3	3-10	11-15	> 16
26	25	11	8	2	21	47	36	24	8	2	10	30	15	1

From above information, it can be seen that the age of the respondents span from less 30 to more than 50, which means the survey results represent the opinions of staff at all ages. More than 60 respondents have more than 3 years' work experience in construction industry and half of them have more than 5 years' work experience in current corporations. Therefore, their opinions can reflect the real situation of Construction supervision organizations. The majority of the respondents are well educated from the data of their education background, which is very helpful to improve the reliability of the data.

Safety Culture Factor Analysis

Factor analysis (FA) is employed to analyze the survey data. FA is a statistical method used to describe variability among observed variables in terms of a potentially lower number of unobserved variables called factors. In other words, it is possible, for example, that variations in three or four observed variables mainly reflect the variations in a single unobserved variable, or in a reduced number of unobserved variables. Factor analysis searches for such joint variations in response to unobserved latent variables. (Bryant and Yarnold, 1994). The procedures of factor analysis are: (1) Fitness test of the data; (2) Establishment of factor Model and determination of the number of factors; (3) Factor rotation; (4) Interpretation of factors structure; (5) Construction of factor scores (DeCoster, 1998).

4. Results

Fitness tests

The reliability of the survey data is tested by the Cronbach's Alpha. The computed result is 0.896, which reflects the survey is highly reliable.

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) is 0.692, which is close to 0.7 and means the survey data is appropriate to do factor analysis.

Bartlett's Test of Sphericity is 1525.219, $p<0.001$. This result shows the correlation matrix is not an identity matrix, the survey date appropriate for factor analysis.

Factor extraction

Principal components are chosen as the method to extract factors and Varimax as the method of performing factor rotation. The rotation results are shown in Table 4. Five factors are extracted from 38 questions whose eigenvalue are all above 1. The cumulative percentage of five factors is 52.740%, which though is not very high, but is good enough considering that these 5 factors explain the original 38 questions. The average communalities between each question and the corresponding factor is above 0.5, which present the high reliability of the explanation of the factors.

Table 4 Results of Factor Analysis

1	2	3	4	5	6	7
Factors / Variables	Factor 1 The importance of safety in corporation's management	Factor 2 Negative influence from the third person and environment	Factor 3 Professional knowledge and safety knowledge	Factor 4 Individual safety consciousne-ss	Factor 5	Commu-nalities
Q 20	0.860					0.784
Q 18	0.776					0.639
Q 13	0.755					0.602
Q 22	0.744					0.583
Q 17	0.700					0.643
Q 23	0.690					0.530
Q 21	0.646					0.666
Q 16	0.643					0.512
Q 15	0.640				0.400	0.593
Q 19	0.501					0.335
Q 14	0.485					0.414
Q 8	0.478					0.422
Q 3	0.468		0.435			0.548
Q 30		0.684				0.504
Q 34		0.671				0.697
Q 29		0.656				0.605
Q 32		0.653				0.464
Q 26		0.617				0.572
Q 31		0.610				0.487
Q 38		0.585				0.500
Q 25		0.584	-0.486			0.621
Q 28		0.577				0.458

Q 27		0.543				0.388
Q 24		0.522				0.418
Q 35		0.514				0.602
Q 10			0.663			0.500
Q 12			0.598			0.405
Q 9			0.538			0.461
Q 11	0.553		0.433			0.567
Q 6				0.776		0.617
Q 7				0.739		0.664
Q 5				0.602		0.440
Q 2			0.463	0.455		0.425
Q 36		0.533		0.434		0.530
Q 4					-0.551	0.514
Q 33					0.537	0.357
Q 37		0.453			0.508	0.585
Q 1						0.394
Total	6.902	5.172	3.021	2.844	2.102	20.041
% of variance	18.16%	13.61%	7.95%	7.49%	5.53%	
Cumulative %	18.16%	31.77%	39.72%	47.21%	52.74%	

It should be noted that though factor 5 could explain question 4, 33 and 37, it couldn’t be named because the variations between the questions are too big. Thus, this factor will not be considered in following analysis. In addition to that, question 1 couldn’t be explained by any factor because any factor loading on which 1 is lower than 0.4, so it will not be considered as well.

For understanding purpose, question 11 is adjusted from factor 1 to factor 3. This is acceptable because its factor loading to factor 1 and factor 3 is close. This slight adjustment is permitted due to the random errors appearing in the survey. Same adjustment also happens to question 2, which is adjusted from factor 3 to 4.

Evaluation of safety culture

Factor scores After doing FA, the 38 questions have been reduced to the 4 factors which could then be used to evaluate safety culture in an efficient way. To do the quantitative evaluation, each factor must be set value. The method used to score the factors in this paper is to calculate the average score of the questions in a specific factor. Each question's score is shown in Table 5 which is the average value of 70 respondents' scoring, as well as the score of each factor.

Table 5: The average score of the survey question

Factor 1 The importance of safety in corporation's management													
Q20	Q18	Q13	Q22	Q17	Q23	Q21	Q16	Q15	Q19	Q14	Q8	Q3	**Ave.**
4.31	4.11	3.78	4.36	4.63	3.83	4.5	4.17	4.31	4.41	4.3	4.11	4.49	**4.25**
Factor 2 Negative influence of the third person and environment													
Q30	Q34	Q29	Q32	Q26	Q31	Q38	Q25	Q28	Q27	Q24	Q35	**Ave.**	
3.07	3.81	3.6	4.13	2.51	3.81	3.69	2.83	2.59	2.96	2.59	3.83	**3.28**	
Factor 3 Professional knowledge and safety knowledge													
Q10	Q12	Q9	Q11	**Ave.**									
4.04	4.07	4.21	3.79	**4.03**									
Factor 4 Individual safety consciousness													
Q5	Q6	Q7	Q2	Q36	**Ave.**								
4.83	4.57	4.09	4.74	3.89	**4.42**								

The evaluation of safety culture of construction supervision corporations
The overall level of safety culture can be graphically shown in a safety culture radar

plot based on Table 5, see Figure 3.

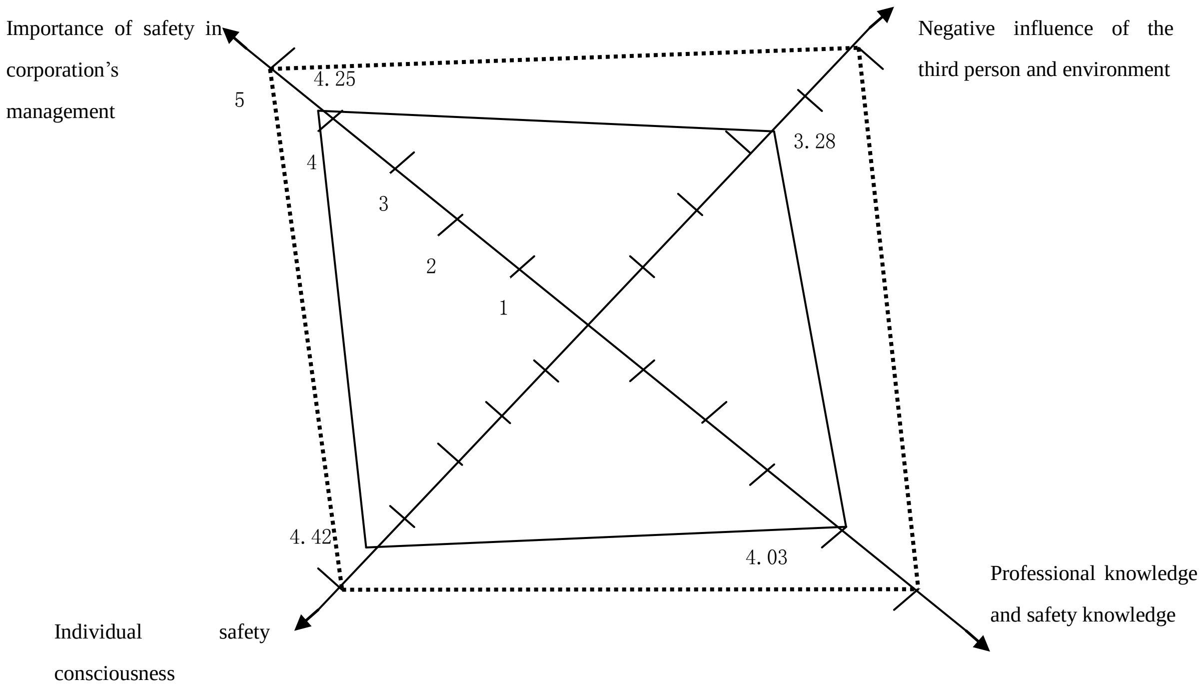

Fig.3: Radar Plot of safety culture of Construction Supervision Corporation

The area bounded with dotted line represents the highest level of safety culture. Correspondently, the area bounded by the solid line represents the level of safety culture of Construction Supervision Organizations in China. From the area comparisons, the overall level of safety culture is not bad. To know more details of the safety culture, each factor is analyzed in the following.

Individual safety consciousness (factor 4) ranks the top. This is a good phenomenon because individual safety consciousness is the key to improve safety management performance. This seems conflicted with the top ten criminal evidences, but is reasonable because most supervising engineers still pay a great attention to safety issues except the ones who commit the duty crime.

The importance of safety in corporation's management (factor 1) ranks the second. Q17, Q21, Q3, Q22, Q15 and Q19 are all positive questions and scored high. They represent that top managements' commitment, group behavior, internal communication and safety training are paid great attentions in organizations. This is beneficial to improve organizational safety performance.

Professional knowledge and safety knowledge (Factor 3) ranks the third. It only includes 4 questions, only Q9, "I know clearly what measures we should take to ensure safety at each stage of a project", scored relatively high. Q12 "I know laws and regulations on construction works well" and Q10 "I know clearly the hazards which cause construction accidents well", just got middle scores. These represent that supervising engineers lack confidence to the laws and risk management knowledge in terms of safety management. Question “I know how to deal with safety problems well” scored lowest. This seems a little conflicted with Q9. However, it is reasonable if we know that many supervising engineers simply equal the “measures” to technical measures. For safety management, only technical knowledge is not enough. The 50 accident cases (mentioned in the second section) show most accidents were caused not by techniques, but poor safety behaviors. Therefore, how to help contractors improve the safety consciousness is the key improve safety management on site. To reach this objective, communication is very important. So the problem behind this question is poor communication skill with contractors.

Negative influence of the third person and environment ranks the last. The influence sometimes come from colleagues (see Q29, Q34), sometimes from the stakeholders (see Q31, Q30). Questions 31 and 30 reveal the negative influence from the contractors and the clients. This reflects the awkward satiation of supervising engineers in China. There are some owners who don’t want supervising engineers to do management of the project, but have to according to the laws, thus they don’t authorize enough rights to supervising engineers. The insufficient authorities put supervising engineers in another awkward situation, that is, some contractors don’t follow the supervising engineers’ instructions if supervising engineers don’t get along well with them. The obstacles from the contractors and clients seem the worst problems which deter the effective safety management considering that supervising engineers have high safety consciousness and supervision organizations pay great attention to safety management. Q32 “I become aware of the importance of safety only after accidents happen” scored the highest under the factor. This can be explained on the one hand that safety had been ignored for a long time. On the other hand, considering the high safety consciousness of supervising engineers, this can be explained that they didn’t identify the hazard in advance. To solve this problem, risk management should be introduced into safety management.

5. Conclusions

The paper aims to evaluate the current safety culture of construction supervision organizations (CSO). The layer safety culture model proposed in the paper try to express such kind of assumption that persons are the core element of an organizational safety culture, they are influenced and interact with organization and in turn the organization is influenced and interact with external environment. The three layers are dynamic and interacted.

After doing FA to the data collected from the questionnaire survey based on the safety culture model, four factors were extracted to evaluate the level of safety culture of CSO. They are, according to the positive order from top to down, individual safety consciousness, the importance of safety in corporation’s management, professional knowledge and safety knowledge and negative influence of the third person and environment. The overall level of safety culture of CSO is good. After doing detailed analysis of each factor, it is found that individual safety consciousness of supervising engineers is good and SCOs also pays great attention to the safety supervision. The main problems are supervising engineers need improve their professional/safety knowledge, the communication skill and should apply risk management into their safety management practice. In the meantime, negative influences from the clients and contractors should be pay more attention because it is a serious obstacle which deter the effective safety management of supervising engineers.

The findings of the paper could provide useful information for CSO in terms of how to improve their safety management. It also provides a good basis to do further study, such as, the scheme of construct good safety culture.

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Assessment of Health and Safety Risk Perception of Site Managers, Supervisors and Workers in Tanzania Urban Construction Sites

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ABSTRACT

Risk perceptions play a prominent role in the decisions people make, that is, differences in risk perception lie at the heart of disagreements about the best course of action between the individual and their context. In the construction industry risk perception holds a central position in health and safety risk management through risk assessment and risk communication. Construction site managers and supervisors, as individuals, are regarded as having greater impact on project performance in relation to health and safety risk. Their assessment and communication of risk depends largely on their perception of risk. This paper is part of an ongoing research to develop a conceptual framework for health and safety risk assessment and communication in Tanzanian urban construction workplaces. It presents preliminary fieldwork results of which 20 construction site managers, 10 gang supervisors and 50 workers were interviewed on how they characterize and rank risk in different activities in construction projects under two trades namely concrete casting and block laying trades. Twenty large construction sites were purposively selected. The findings are based on site managers' perception of health and safety risk, and factors influencing such perception(s) of risk.

Key words: Risk perception, health and safety risk, site managers, supervisors, workers and construction sites

Assessment of Health and Safety Risk Perception of Site Managers, Supervisors and Workers in Tanzania Urban Construction Sites

1. Introduction

Construction industry is an important part of the economy in Tanzania, often seen as a driver of economic growth. Typically, the Tanzania construction industry accounts for more than 50% of capital formation, and constitutes 5.7% of the Gross Domestic Product. Owing to its relatively labour-intensive nature, construction work provides opportunities for employment for wide ranges of people who are skilled, and the urban poor who do not have much skill (Well, 2007). Employment created by construction workplaces has a significant impact on urban poverty alleviation (Laurence et al 2008). Despite its importance, the construction industry is considered risky, with frequent and high accident rates, health problems of workers, practitioners and end users (Mombeki, 2005; Kikwasi 2010). Currently, construction sites are ranked as the second most dangerous place to work, after mining workplaces (Mbuya and Lema, 2004; ILO, 2005). The concern globally and particularly in Tanzania is how to make construction workplaces a safe and healthy place to work in.

A lot of efforts have been made to change the health and safety situation in the Tanzania construction industry. Such efforts include the formation of different regulations such as the Occupational Health and Safety Act, 2004; the Contractors Registration Board (CRB) Act No. 17/1997; and the Employment and Labour Relations Act (EALRA) No. 6/2004. Risk assessment and communication has been the cornerstone of these regulations, and all employers are required to assess the health and safety risks to workers and any other person who may be affected by their undertaking. However, in risk assessment and communication much depends on how people involved in the process perceive risk. People make varied decisions depending on their perception of risk. Such perceptions lie at the heart of disagreements about the best course of action and control measures. In the construction sites, site managers and gang supervisors play an important role in ensuring safety in the workplace, and employees conform to safety rules and procedures when they find fairness in their supervisor’s action (Yule, Flin & Murdy, 2007). This paper will share some insights obtained from an investigation study on how site managers, gang supervisors and workers characterize and rank risk in concrete casting and brick laying activities in urban construction sites in Tanzania.

2.0 Risk and Risk Perception

Risk perception

Risk is a multi-facet concept and there is no single definition on what risk is. According to Fischhoff et. al (1987), for example, risk is the existence of threats to life or health. Risk is also regarded as exposure to the chance of injury or loss (Hertz and Thomas, 1983), and the likelihood that harm will occur (Health and Safety Commission, 1995). On the one hand, risk is closely connected to uncertainty and is a commonly used term in all kinds of contexts, but it is more often related to the negative outcome of an event (Ward and Chapman, 2003).

Numerous studies of risk perception have been carried out with regard to the psychology of risk perception and risk assessment for individuals (Irizarry and Abraham, 2007; Rohrmann, 2007; Loushine, 2010). Accordingly, risk perception is based on people's judgments and evaluations of hazards they are or might be exposed to. On the other hand, risk perceptions are interpretations of the world, based on experiences and/or beliefs. They are embedded in the norms, value systems and cultural idiosyncrasies of societies (Finucane & Holup, 2006; French et al., 2006). When risks are misinterpreted workers can have inappropriate risk behaviours.

Weber (2001) reviews three approaches by which risk perception has been studied: the axiomatic measurement paradigm, the socio-cultural paradigm, and the psychometric paradigm. Studies within the axiomatic measurement paradigm have focused on the way in which people subjectively transform objective risk information, i.e., possible consequences of risky choice options such as mortality rates or financial losses and their likelihood of occurrence, in ways that reflect the impact that these events have on their lives. Studies within the socio-cultural paradigm have examined the effect of group- and culture-level variables on risk perception. Research within the psychometric paradigm has identified people’s emotional reactions to risky situations that affect judgments of the riskiness of physical, environmental, and material risks in ways that go beyond their objective consequences. Wilde (1982) developed the risk homeostasis theory which states that an individual’s behavior in risky situations is determined by a desire for cost minimization, which explains how behavior can be in accordance with risks, even subjectively perceived risks, without an ever-repeated process of conscious risk evaluation.

Factors influencing risk perception

The experience of construction workers and their knowledge of safety are important factors to consider in the evaluation of their risk perception. An evaluation of the relationships between workers’ attitude towards safety and the incidence of injuries on high rise building projects in Jakarta Indonesia found that ‘safety performance [was] primarily affected by individuals’ attitudes towards safety’ (Koesmargono, 1998: 32). Once an individual has an attitude to an object, things related to the object are seen in a selective way. He found that workers’ attitudes to safety were affected by age, work experience, level of education, and safety training experience. The same findings were revealed on a study done by Rohrmann (2007) in which workers’ experience, age and background of safety training were found to be related to the tendency of reporting any accidents or near misses on the site. Their perception on the need to report accidents and near misses was high due to their awareness of the importance of safety on the construction site. This awareness rose in line with an increase in experience, age and background of safety training.

A study with previously injured oil workers working on offshore installations found that the experience of an injury influenced their overall perception of the work environment. Worker behavior regarding safety may be influenced by the worker's perception of what is safe or unsafe. Based on this perception, decisions are made when to adopt or not adopt required safety precautions. This relationship was observed by Huang and Hinze (2003), who found that approximately 33.3% of all accidents are caused by a misjudgment of hazardous situations. Figure 1 summarizes factors affecting risk perception of the individuals.

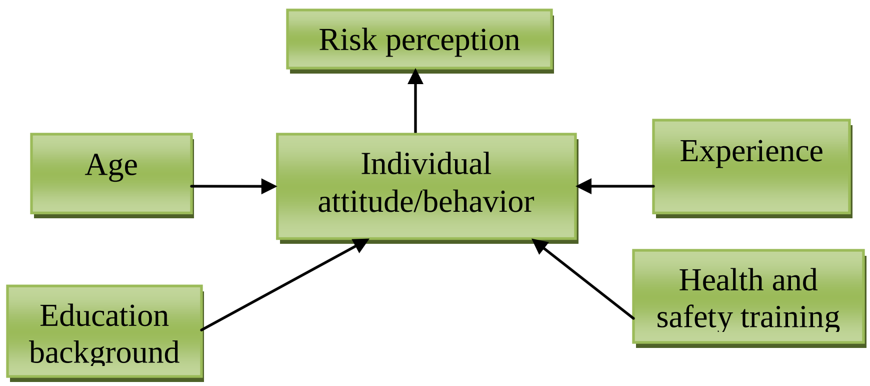

Figure 1: Risk perception factors

Figure 1 (above) indicates that risk perception is based on individual attitude or behavior of accepting risk. However, attitude and behavior are affected by an individual's education background, age, working experience, and training in health and safety.

Health and safety risk on block layers (masonry) and concrete casting

Block layers are engaged in building and renovating houses, offices, and industrial complexes using blocks and mortar. The most demanding activity in concreting is moving /transporting concrete, cement and sand to the required areas. Concrete are manually transported and compacted in repetitive ways for more than eight hours a day. For block layers the most demanding task in terms of physical work is the one handed repetitive lifting of blocks with a bended lower back for more than six hours a day. At the work site, the most demanding task for both concreters and block layers in terms of physical work is the manual transportation of bricks, blocks, concrete and mortar. This involves the manual lifting and carrying of materials and pushing/pulling wheelbarrows for more than six hours every working day. Block layers and concreters are exposed to dust when sawing bricks/blocks or when mixing cement/glue. Mortar contains cement. Cement is alkaline, and regular prolonged skin contact can result in skin complaints. Again, block layers and concreters are exposed to noise caused by equipment such as the concrete mixer present in their environment, to impulse noise when positioning bricks and when chipping blocks to size, to noise caused by cutting bricks/blocks, and by work involving power tools (drilling, sawing, grinding) or when compacting concrete.

Both concreters and block layers are at high risk of occupational accidents. Injuries can be a result of bumping into something, tripping or slipping, being trapped by a swinging load, being hit by falling material or equipment, or by a load falling from a crane, being hit by falling or collapsing scaffolding, or being trapped by a falling pile of stones or a toppling wheelbarrow. There is the risk of falling from floors or scaffolding, caused by missing railings or floor jambs not being closed up or sealed off, or as a result of slipping off a ladder. Inadequate lighting hampers work and increases the likelihood of accidents. Figures 2 and 3 show workers in block laying and concrete casting in one of construction sites in Tanzania.

Figure 2. Block layers and a concrete casting gang at a construction site

Figure 3. Concrete transportation and compacting in a construction site

Figure 2 and Figure 3 show the typical practice of concrete casting and block laying in a risk situation without proper protection. Workers are subject to manual handling, chemicals (cement), dust, too much bending and twisting while laying blocks and compacting concrete, and falling from height. The main question which this study sought to answer was how workers and their supervisors perceive risk in their workplaces.

3. Methodology

Twenty ongoing large construction sites were selected as a survey through purposive sampling. All the construction sites were multi-storey buildings with more than 10 storeys. A questionnaire was used to collect information. From the construction sites twenty site managers, ten gang leaders and fifty workers were asked to rank their perception of different risks in concrete casting and block laying process, especially in wall construction. Eight health and safety risks were identified from literature on concrete casting and block lying. Site managers, supervisors and workers were asked to rank in a 1-5 Likert scale. 1= very likely to occur, 2= likely to occur, 3= moderate, 4= not very likely to occur, and 5= not likely to occur (i.e., no chances of occurrence). Other parts of the questionnaire were designed to profile the participants in terms of their level of involvement in construction, gender, employment status, level of education, construction-related qualifications and experience, exposure to injury and illness, exposure to construction H&S training and information. The data were analyzed using SPSS.

4. Discussion of Findings

Demographic characteristics of the respondents

All 80 respondents were men as most activities in concrete casting and block lying are done by men in Tanzania. Respondents' ages ranged between 20 and 45 years where the majority (50 or 63%) fell within the range of 25 years to 35 years, followed by 30 (37%) respondents ranging between 36 and 45 years of age. There were no respondents of the age above 46. The finding contradicts the study done by Irizarry and Abraham (2006) on risk perception among iron workers, and found that the majority of their respondents were over 40 years of age. In the current study the majority (63%) ranged between 25 and 35 years of age. This study brings out the opinion that since concrete casting and block laying activities require one to be physically strong, they are not activities that the aged would prefer. The respondents' level of education and their experiences are as presented in Figure 4 below.

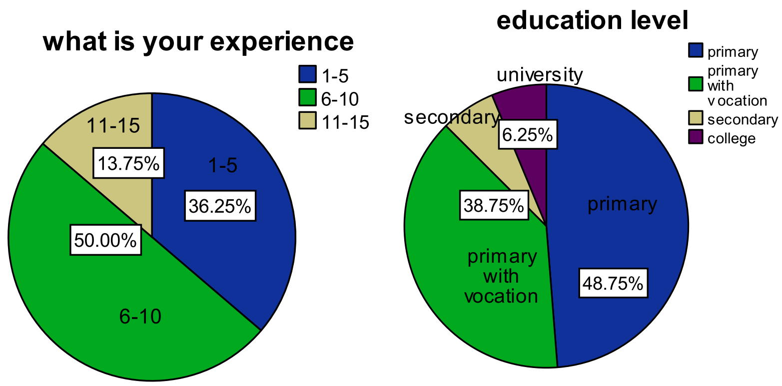

Figure 4: Education and working experience (in years) of the respondents

Figure 4 indicates that almost half of the respondents (48.7%) had only primary education; followed by 38.7% who had primary education with vocation training. 6.3% each has lower secondary education and university education. In terms of experience, half of the respondents (50%) reported 6 to 10 years of experience in construction, followed by 36% with experience of 1 to 5 years. Only 14% have experience for more than ten years. From the data it can be observed that there is a large variability in the level of experience of the respondents.

Knowledge on construction health and safety

Site managers/ gang supervisors and workers were asked to respond to whether or not they had been to any training on health and safety. The responses are indicated on Table 1.

Table 1: Knowledge on health and safety risk of the respondents

A	**workers**		Frequency of respondents	
		Nr	Yes	No
1	Have you ever received any training related to health and safety in construction sites?	50	20 (40%)	30(60%)
2	Have you been trained in proper use of Personal Protective Equipment?	50	25 (50%)	25 (50%)
3	Have you ever been involved in an accident while performing your task?	50	17 (34%)	33(66%)
4	Have you ever been injured while performing your tasks?	50	32 (64%)	18 (36%)
5	Do you think that Personal Protective Equipment affects the productivity?	50	18 (36%)	32 (64%)
B	**Site managers/gang supervisors**			
1	Have you ever received any training related to health and safety in construction sites?	30	30 (100%)	0
2	Have you ever been trained in proper use of the Personal Protective Equipment?	30	30(100 %)	0
3	Have you ever seen one of your workers being involved in an accident while performing his/her task?	30	30(100 %)	0

4	Have you ever seen one of your workers being injured while performing his/her tasks?	30	30(100 %)	0
5	Do you think that Personal Protective Equipment affects the productivity?	30	5(17%)	25(83%)

Table 1 show that the majority of the workers (60 %) do not receive any formal health and safety training. However half of the respondents (50%) have received training on how to use the Personal Protective Equipment (PPE). On the other side, 34% of the respondents have been involved in accidents while performing their tasks. 64% have been injured while performing concrete casting works and block laying without being involved in accidents. This finding suggests that although majority of the workers had no formal health and safety training, but to some extent they have been subjected to either accidents or injury. The experience of accident or injury changed the way these workers perceived risk. On the other side one third (36%) of the workers believe that PPE affects their productivity. This is interesting because the same workers would not make use of the PPE to minimize accidents. This affects construction projects, especially when time is pressing. The findings tally with those in the study done by Mombeki, (2005) on compliance on Tanzania construction sites. On the other side all supervisors have received health and safety training, and they have witnessed their workers getting accidents, sustaining injuries. 17% of the supervisors believe that the PPE affects productivity of their workers.

Risk perception

Site managers, gang supervisors and workers were asked to indicate qualitatively their probability of occurrence when working on a situation of hazards. The Likert scale was used where 1 = very likely to occur, 2 likely to occur, 3= moderate, 4= not very likely to occur, and 5, Not likely to occur at all (i.e., no chances of occurrence). The results are as indicated in Table 2 and Table 3. The mean score for the results is 3.0.

Table2: Descriptive Statistics of the risk perception of workers

	N	Minimum	Maximum	Mean	Std. Deviation
workers					
falling from height	50	1	5	2.92	1.047
falling object	50	2	5	3.04	.989
neck, arm pain due to manual handling	50	1	4	2.86	.969
crushed by moving object	50	2	5	3.60	1.195
hearing loss due to noise	50	1	4	2.66	1.081
respiratory illness due to dust on site	50	1	5	2.62	1.193
musculatory disorder due to bending and twisting.	50	2	5	3.04	.856

Table 3: Descriptive statistics of the risk perception of and site managers/supervisor

	N	Minimum	Maximum	Mean	Std. Deviation
falling from height	30	1	4	2.57	.898
falling object	30	1	4	2.00	1.017
neck, arm pain	30	2	3	2.43	.504
crushed by moving object	30	2	4	3.00	.587
hearing loss	30	2	4	2.60	.770
respiratory illness due to dust on site	30	1	4	2.83	1.085
musculatory disorder	30	2	3	2.77	.430
Valid N (list-wise)	30				

It may be clearly seen in Table 2 and Table 3 that both groups (workers and supervisors) completely indicate that the probability of falling from height, arm and neck pain, hearing loss and respiratory illness from dust are moderate in their occurrence. However, being hit by falling objects was perceived differently between workers and supervisors. While supervisors said that being hit by a falling object was *likely to occur*, workers said that there were no chances at all of being hit by falling objects. Workers also felt that musculatory disorders and being crushed by moving objects in the sites were not likely to occur. In such a situation where differences exist in the perception of risk, it is suggested that more communication be done to bridge such a gap between supervisors and workers.

Factors affecting risk perception

To ascertain factors affecting risk perception, cross tabulation was performed on risk and demographic characteristics of the respondents. One risk was selected based on common perception of both supervisors and workers. The risk selected was *falling from height.* Again demographic characteristics such as level of education, experience, age and knowledge on health and safety were selected. The results are presented in Table 4.

Table 4: Cross tabulation of the falling from height with age, education level, experience, and health and safety training

falling from height			very likely to occur	likely to occur	moderate	not very likely to occur	not likely to occur at all	Total
	Age	20-35 years old	0 (0%)	12(24%)	23 (46%)	7(14%)	8(16%)	50(100%)
		36-45 years old	5(17%)	12(40%)	9(30%)	4(13%)	0(0%)	30(100%)
		Total	5(6%)	24(30%)	32(40%)	11(14%)	8(10%)	80(100%)
	education level	Primary education	6(15%)	5(15%)	16(41%)	7(18%)	5(15%)	39(100%)

		primary with vocation	0(0%)	20(64%)	6(19%)	5(16%)	0(0%)	31(100%)
		secondary	0(0%)	2(40%)	3(60%)	0(0%)	0(0%)	5(100%)
		university/college	0(0%)	0(0%)	5(100%)	0(0%)	0(0%)	5(100%)
		total						80(100%)
	experience	1-5 years	3(10%)	5(17%)	11(38%)	8 (28%)	2(7%)	29(100%)
		6-10 years	3(8%)	18(46%)	13(33%)	4(10%)	1(2%)	39(100%)
		11-15years	5(42%)	7(58%)	0(0%)	0(0%)	0(0%)	12 (100%)
		total						80(100%)
	Training health and safety							
		yes	3(6%)	21(42%)	19(38%)	5(10%)	2(4%)	50(100%)
		n o	310%)	6(20%)	11(37%)	7(23%)	3(10%)	30(100%)
		total						80(100%)

Table 4 indicates a strong correlation between the age of the respondent and the perception of likelihood of falling from height. As the age of the respondents increased, the perception on health and safety risk also increased. A higher percentage of respondents of the age between 36 and 45 indicated that falling from height was either very likely to occur (17%), likely to occur (40%) or moderate (30%). Only 13% indicated that falling from height was not likely to occur. This finding suggests that elders are more cautious of risk due to their experience or exposure to different risk situations.

Table 4 also shows that there is a strong correlation between experience and the ranking of health and safety risk. One third of the respondents with 1 to 5 years of experience indicate that falling from height while performing a task was either not very likely to occur (28), or no chances of occurring at all (7%). As the experience increased from 6 to 10 years, the number of respondents indicating that falling from height was likely to occur or very likely to occur increased too. At the same time, the number of respondents indicating that falling from height was not likely to occur decreased. As the experience increased from 10 to 15, all respondents in this group indicated that falling from height was likely to occur or that chances of occurrence were moderate. This finding is contrary with the study done by Che Hassan et al, (2007), where respondents with more experience rated risk *low* due to the fact that they had developed confidence, having worked long in risk situations. This indicates that with more experience workers are likely to be exposed to different health and safety training or being involved in accidents/ injury which shape their risk perception.

Table 4 also indicates that there is a strong correlation between education level and ranking health and safety risks. The majority of the respondents with primary education ranked *falling from height* as moderate while few of them indicated that falling was either not very likely to occur or not likely to occur at all. As the education level increased the number of respondents indicating that falling from height would not occur decreased. Table 4 also indicates that there is no correlation between training in health and safety and the ranking of health and safety risks. Although a significant number of the respondents had received some type of safety training, its effectiveness in reducing accidents could not be determined from the data. This mismatch could be attributed to the contents of the training programme.

5. Conclusions

Risk perception by site managers, supervisors, and workers on a concreting and block lying reveal that both supervisors and workers perceive that the possibility of arm and neck pain, hearing loss, respiratory illness due to dust, and falling from height was moderate in occurrence. While supervisors acknowledge cases of musculatory disorder and being hit by falling objects on concrete casting and block lying, workers have different views. They perceive that there is no musculatory disorder and being hit by falling objects in the concreting and block laying process. With regard to the health and safety training, the findings reveal that the majority of the workers do not have formal training on health and safety issues. All supervisors have had health and safety training at some point. However there is no strong correlation between training and risk perception. The findings also reveal a strong correlation between one's experience and risk perception. As the experience increased there was more consciousness on health and risk. Additionally, there is a correlation between the level of education and risk perception. Respondents with higher education perceive risk more compared to those with lower education. Age also has a strong correlation with the perception of risk. As age increases, the perception of risk gets changed. It is recommended that when carrying out health and safety programmes in construction sites, the workers' age, experience and education level should be considered.

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Training as First Step Toward Prevention: Our Experiences in Training Workers Employed in Road Constructions in South Italy

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Training as First Step Toward Prevention: Our Experiences in Training Workers Employed in Road Constructions in South Italy

Abstract

Training is the main area in which we invest all available resources to improve site safety and achieving the goal of zero incidents: all Italian bodies dealing with prevention at work (INAIL, ASL, etc.) agree on this solution to bring the high recurrence of on-the-job injuries down.
Apart from Universities, which train engineers, Building Craftsmen Schools play an important role. These schools, supported by prime contractors and unions of building trade workers, train the new generations of workers to be employed in local companies.

A few years ago Ente Bilaterale per l'Edilizia, a bilateral board for building trades, now ESEFS, Ente Scuola Edile per la Formazione e la Sicurezza, the building craftsmen school of Reggio Calabria and its provincial area, kicked off a strong cooperation with Università degli Studi Mediterranea in Reggio Calabria, focusing on the best way to use the subsidies allotted by Fondimpresa (a joint interprofessional fund gathering over 77,000 companies aiming at financing life-long learning program) to provide training for local companies.

During the last year, in cooperation with Formedil (Italian national board for vocational qualification in building trade) we began a specific life-long learning program in order to give workers suffering from economic crisis proactive solutions. As a matter of fact, 48% of the courses we offer are dedicated to re training of temporarily laid-off workers who live in Calabria.

Our paper summarizes our work carried out over the last few years with those companies building the final stretch of Salerno - Reggio Calabria highway. We also took an inventory of the past experiences in building sites for on-site training of Safety Managers and workers' representatives where we focused particular attention on work at height, tunneling and the use of machineries.

Keywords: education, health and safety, training

1. Ente Scuola Edile: A Board Providing Training and Safety Standards

ESEFS - "Ente Scuola Edile per la Formazione e la Sicurezza della Provincia di Reggio Calabria" is a bilateral non-profit board created by the will of industrialists and Construction Trade Union Federation of Workers of the same province. Its economic resources come from the funds allocated obtained through contributions paid by developers as set forth in the National labor contract, and allocations from local authorities.

Vocational qualification and the popularization of safety rules in workplaces in the construction trades is carried out by Scuole Edili and Local Joint Committees, regulated by Articles 87 and 92 of the Sectoral Collective Agreement for employees of building companies and related services, signed by ANCE - National Building Contractors' Association - and trade unions such as FILLEA-CGIL, FILCA-CISL, as well as UIL Feneal.

ESEFS belongs to a national network of organizations, characterized by financial and organizational autonomy, coordinated by central bodies such as FORMEDIL - Italian national board for vocational qualification in building trade - and CNCPT - National Committee for Injury Prevention, Hygiene and Labor Environment - in charge of safety-related campaigns.

Within the frame work of safety, ESEFS represents the joint body as set forth in the Consolidated Law on Safety (Legislative Decree n.106/2009 and Legislative Decree n.81/2008).
In dealing with training, ESEFS must to promote, organize and implement in its territorial area orientation and training initiatives aimed to :

- unemployed people, including foreign workers, who want to enter the job market in this field;
- people already employed in building companies, workers included in redeployment schemes;
- female labour force in order to ease their entry into this field;
- young and/or workers who are entering or already active in the field.

It also organizes some initiative of lifelong learning, vocational qualification, retraining, specialization and refresher courses for workers, clerks, technicians, managers and entrepreneurs, according to needs of the labor market. As for safety, ESEFS has multiple tasks ranging from the study of general and specific issues related to injury prevention and healthy working conditions to the promotion of appropriate initiatives such as diffusing in workplaces leaflets and popularization materials about safety & health, the adoption of appropriate measures to foster law implementation on public works and preventative measures providing consultancy for and assisting businesses and experts.
In December 2000, ESEFS, having already joined several initiatives about Health & safety in construction trades, signed an agreement with the Faculty of Architecture of the local university setting up collaboration for safety-related training activities.

2. Information and Training: The Tools for Accident Prevention

From the very beginning, ESEFS was committed to make training and information not just simple aids for prevention but key elements in the struggle against occupational accidents and industrial diseases. It considers the prevention of occupational accidents as a "social problem"; it aims at making health and safety an integral part of corporate culture.

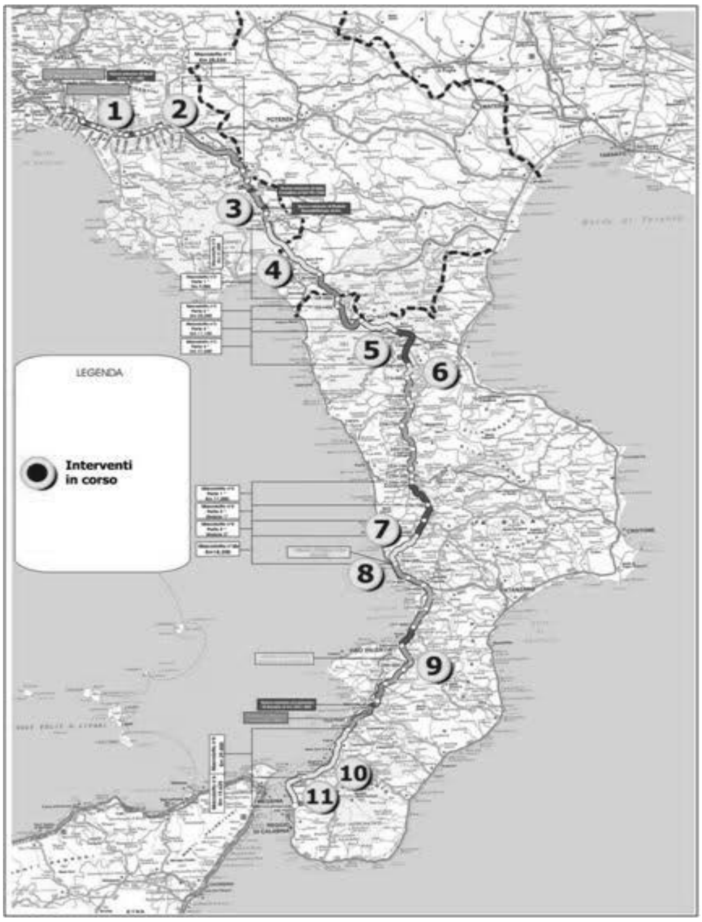
In this prospective, health and safety must be considered before, during and after the execution stage. As a matter of fact, managing the risks faced by people working in this sector less expensive and easier if it’s carried out before starting work on site.

It must start in the conception phase of work in an organization that cares about health and safety as an integral part of their corporate culture. However, it’s know that, for the prevention purposes, it is important that all stakeholders, including managers, are aware of the dangers, informed about risks and measures to avoid, and able to operate safety for themselves and all others. It is essential that the need to perceive the risks, their consequences and precautions to be taken to act safety since this is the role of information and training.

Workplace health and safety should not be seen as a succession of mere bureaucracy, often identified as an additional cost to the company, but should be considered as factors which, if implemented, could affect the business performance. In fact, one can observe that: the company output grows if the workers are in good health; decreasing absenteeism, reducing costs and organizational disruption. The reduction in accidents and occupational diseases; productivity increases, quality improvements and the risks to health and safety decrease if the equipment and working environment are optimal with respect to the needs of the workforce. In addition proper maintenance decreases the damage and the risks of liability from injuries and diseases..

3. The Highway Sites in Southern Italy

A3 Salerno – Reggio Calabria motorway is the main arterial road connecting Sicily and extreme southern Tyrrhenian regions to the large European motorway network, inserting in the corridor 1 Palermo - Berlin.
The project for the modernization of this motorway, built in the 1970s, consists in 61 interventions split into 12 macro lots and 49 lots. In April 2011 the highway work was approximately 86% complete, ongoing on about 385 km of the total project. After completion of the modernization the project will cover a length about 433 km.



Source ANAS

Figure 1: Map of Southern Italy

The stretch between Gioia Tauro and Reggio Calabria (section 10 in illustration), all in the Reggio Calabria province, 50 km long (pk393,500 – pk442,920), consist in 48 viaduct and 24 tunnels for 1.699.000,00 € investment. It is divided into two macro lots : the 5thof 29,8 km from Gioia Tauro to Scilla and the 6^{th} of 19,62 km from Scilla to Reggio Santa Caterina junction, the current highway termination point.

In the 5th macro lot work modernization began in April 2007 and runs along 70% on the old path. Among the major works are 12 natural tunnels and 3 artificial ones, for a total about 15 km to 29,8 km.

The works were assigned to ANAS - Autonomous National Roads Company - the General Contractor, Society Project Salerno – Reggio Calabria, a joint venture consisting in Impregilo and Condotte with the requirement to entrust about 85% of works to other companies. The remainder share is responsibility to General Contractor which delegated to Scilla Consortium (always made by Impregilo and Condotte).

In May 2005 Scilla Consortium signed an agreement protocol with the construction workers unions that gave ample space to safety and prevention issues for which was defined a relations network, articulated in a peripheral and national level with the following chronology:

- Quarterly checks to review injuries status, diseases, pest's assessments, health investigations and inspections. Evaluation of measures taken or to be taken and the orders given by the construction management and or safety coordinator to ensure that foster and or sub contractors, provide for the necessary adjustments to safety standards (Decree Law n.626/94, n.494/96 and n.528/99 than in force).

- Semestral review at national level between the ANAS Directorate General on the provisions on the state of safety in each contract and evasion detected on all construction sites.

It gave a mandate to the General Contractor through the Construction Management and Security Coordinator to verify that each site had prepared all the steps and measures as defined in the design documents and laws on safety and hygiene in the workplace. Where non-compliance would be determined and/or discrepancies by any company found then all necessary measures to ensure that workers were able to operate safely and were made aware of steps to perform work safely were taken. It stipulated that the training programs concerning workers representatives' and those individuals under the provisions of the national labor contract in the construction sector had to be agreed upon at the local level and conducted in collaboration with the Territorial Joint authority.

4. Operator Training

In 2006, during the phase of construction of the site that preceded the start of work as defined on the basis of the Memorandum of Understanding, was started at the headquarters of the Consortium Scilla. This was in compliance with regulatory provisions then in force (Legislative Decree n.626/1994 now merged in the Consolidated Security - Legislative Decree No 81/2008, as amended and supplemented). A course for representatives of the Workers Safety and a course for Managers / Employees of the Prevention and Protection.(modules A, B, C) was initiated

The first professional as indicated initially by the European Directive 89/391/EC, which is the representative is elected by a three-year mandate to protect farm workers' rights to safety. Its contribution is promoting the improvement of working conditions. In companies with more than 15 employees safety representative participates in periodicals meetings where has examined the document on risks assessments and are identified and planned measures for risks prevention and protection. The company is required to provide adequate training to Rls, that must be conducted during working hours with training modules lasting for at least 32 hours and whose costs are paid by the Employer.

Training must be provided in the following cases:

> **a)** in the constitution of the employment relationship or the beginning of the use when this is a business administration;
> **b)** in the transfer or change of duties;
> **c)** in the introduction of new work equipment or new technologies, new substances and dangerous materials.

The courses, managed by ESEFS of Reggio Calabria, were instituted under the initiative of Fondimpresa (Notice No. 3 / 2005 - Occupational safety and

Interculturalism) that is the most important interbank funds for continuous training through the training Account, makes available for the company the provisions made at the National Institute of Social Security -INPS.

Themes tackled cover the following areas:

- risks assessment and identification of the prevention and protection measure;
- Personal protective equipment for specific activities;
- safety in working in a tunnel and road construction.

The workers who participated in the course appeared very interested in the concepts provided by the instructors and actively participated in exercises on the use of personal protective equipment in relation to the types of risks that characterize the specific processes for road work.

Themes tackled concern:

- risks assessment and identification of the prevention and protection measure;
- Personal protective equipment for specific activities;
- mentions to safety in working in a tunnel and road construction.

The workers who participated in the course appeared very interested in the concepts provided by the instructors and actively participated in exercises on the use of personal protective equipment in relation to the types of risks that characterize the specific processes for road works and galleries.
The second professional carry out their duties within the Prevention and Protection company service with specific tasks directed to:

- identification of risk factors in the working environmental production processes, to predispose the appropriate security measures to be taken to eliminate or reduce them;
- programming information and general and specific training of workers;
- all problems related to occupational safety in the company.

Specific task of the Service is improving the safety of places of work to be implemented through:

- predisposition of preventive measures;
- identify the most effective personal protective equipment;
- elaboration of security procedures which combines the company's operational needs with those of prevention and protection of workers;
- introduction of control systems to monitor implementation of the measures taken;
- continuous adaptation of programs and information activities and training of workers.

Training activity, conducted through module A (28 hours for new operators) and B (60 hours for the building sector) corresponding to two levels. The first is general information and the second is devoted to problems of specific work activities. Training was divided into frontal lessons and seminars sessions that have introduced , (after the information regarding the legislative developments in the sector) a comparison of work experience already made with the specific activities of executing works and road infrastructure related with difficulties of different types risk (falls from height, cargo handling, mechanical risk, electrical risk, workplace confined outdoors risks).

A specific *course of basic training for their first entry to the tunnel operators*, under the project Fondimpresa (year 2005 av3/40/05 code) "Safety at Work and intercultural" was held at the base camp of the site of Barritteri on behalf of the company Cossi Costruzioni SpA, finalized for workers who would work in different galleries of the highway tract (over 50% of the new path).

Themes concern:

- legal and legislative aspects, the duties and responsibilities;
- risks of building site and in particular the risks and safety measures to be implemented in the work in the gallery;
- work equipment;
- electrical risk;
- falls from height;
- manual handling of cargo;
- operating machines and lifting tackle;
- provision of safety;
- noise;
- dust;
- Personal protective equipment.

Training activities carried out by ESEFS with the contribution of qualified university professor and specialists was particularly attentive to those who are about to undertake specific activities of work in the tunnel. An important activity in which it was possible to learn from the testimonies of some students who attended the course for a change of duties, was a comparison between codes of practice and actual experience in production processes at the work sites.

5. Highway Sites Complex Management

As previously mentioned the General Contractor work are conducted through direct involvement in working with the Scilla Consortium and a control activities on the work entrusted to a large part of other companies.

It was found that a subcontracts chain which in turn subcontracted to other firms that made it impractical to program an agreement that was initially signed since it was thrown into crisis due to the provisions for regular review.

For major companies, it was possible to run training activities with good and effective results for site management. But for small subcontractors who often don’t have full security and procedures required for training results were not effective. Other management difficulties had been for the severe environmental problems linked to the “ndrangheta” presence, a criminal organization which, with its constant threats, conditioned the work regularity at the highway sites.

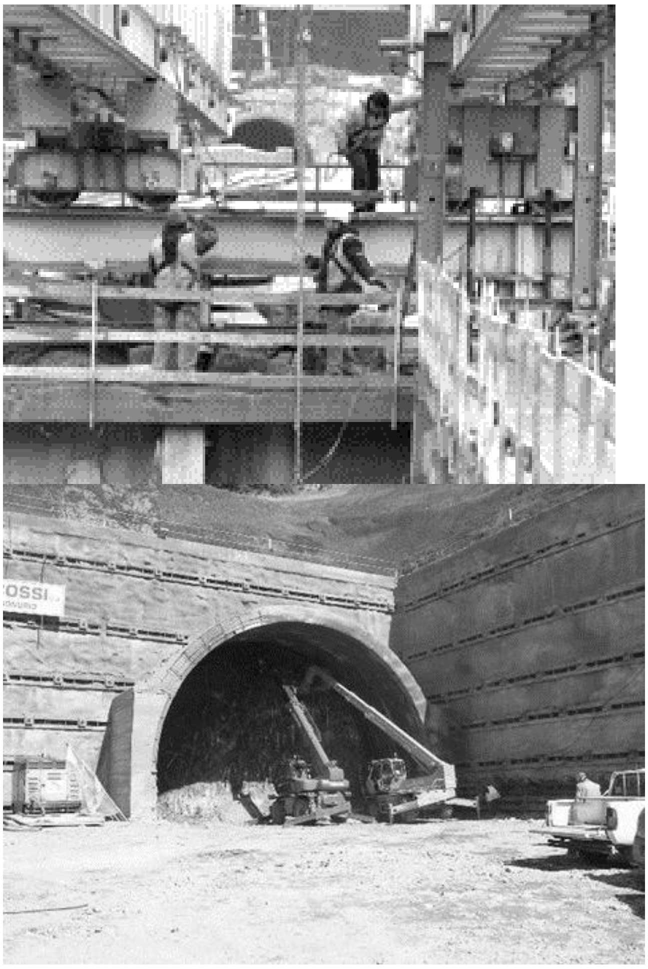


Figure 2: Workers involved in structural changes of the viaduct Sfalassà (h 140 m) and working in a new gallery

A difficult situation occurred causing two fatal incidents, which have happened over two weeks between February and March 2010, at a site building a viaduct near the Palmi junction. This site was run through a series of custody and subcontracts by Anas spa, the joint venture corporation Salerno – Reggio Calabria, from this to EREA Consortium (made up of 92 European companies, Ricci Construction spa and Eurofin spa) and finally to the Sicilian society Edilniti srl in Gela (Caltanissetta province). The first worker had died from a fall from a height and causing the work to be suspended. Tragically, at the resumption of work, the collapse of a support structure during casting had dragged another worker into a deadly fall.

The two incidents show the voltage drop on the most basic security measures and the inability to control the subcontracts chain.

The Anas Office High surveillance issued like first measures the removal company director of the trunk and foremen. The judiciary, in February 2011, indicted on manslaughter charges the companies executives involved in outsourcing and technical managers.

In March 2009, the Scilla Consortium, due to a severe economic and financial crisis, decided the “cessation of all activities and put into liquidation, resulting in the disposal of all assets and the contracts terminal assigned to him by the General Contractors, Society Project Salerno - Reggio Calabria S.C.p.A. (for the V maxi lot) and the Project company in Reggio Calabria, Scilla S.C.p.A. (for the IV maxi lot). The Scilla Consortium staff, who had reached the maximum number of 625 workers, of whom 155 were managers role, and 459 workers. A procedure was activated for the workers to receive unemployment benefits pending the cessation of activities.

At the Ministry of Labor, Health and Welfare among the Consortium representatives and those of trade union federations (national, regional and local) on May 11, 2009 was entered a verbal agreement that program over 24 months under the wage treatment, relocation and employment plan to facilitate the relocation of the redundancies at work, a training program, assigned to FORMEDIL – National Agency For Education and Vocational training in Construction.

6. Continuous Training as a New Goal

In the last year, ESEFS in collaboration with Formedil launched a continuous training activity to provide an effective response to the needs of workers affected by the crisis. In fact, approximately 48% of the training contained in the plan is aimed to retraining redundancy workers in the Calabria Region and included in this category are workers in liquidation by the Consortium Scilla as mentioned above.

The training methodology used for the training courses goes back to the PSP, the Professional Development Project which provides for the setting of trusted procedures for the management of interventions and for the promotion and assistance of the professional careers of workers. Continuous training becomes a path from the generic to individual. We move in this way from a simple supply of training activities to the management of professional progressions over the course of a working life. Workers in this way find within the bilateral institution the opportunities and all the support that is useful to invest in them to better their Professional opportunities.

TRAINING PROVISION BY CALABRIA REGIONAL GOVERNMENT - VOCATIONAL QUALIFICATION AND RETRAINING

Actions aiming at workers on short-time allowance (building site activities)

Subjects	Time	Locations
Information and training	8 hours	Catanzaro Cosenza Reggio Cal.
Scaffolds	32 hours	Catanzaro Cosenza Reggio Cal.
Machines technology	24 hours	Catanzaro Cosenza Reggio Cal.
Machines run	40 hours	Catanzaro Cosenza Reggio Cal.
Machines service	24 hours	Catanzaro Cosenza Reggio Cal.
Bricklayer 1°module	40 hours	Catanzaro Cosenza Reggio Cal.
Bricklayer in natural stone	24 hours	Catanzaro Cosenza Reggio Cal.
Carpentry and armor in the civil works		Catanzaro Cosenza Reggio Cal.

and in the a.c. works	24 hours	
Concrete and other building materials	24 hours	Catanzaro Cosenza Reggio Cal.
Laying roofing sheathings and coverings	24 hours	Catanzaro Cosenza Reggio Cal.
Laying floors and coverings	24 hours	Catanzaro Cosenza Reggio Cal.
Welding 1° level	32 hours	Catanzaro Cosenza Reggio Cal.
Welding 2° level	32 hours	Catanzaro Cosenza Reggio Cal.
Photovoltaic system	24 hours	Catanzaro Cosenza Reggio Cal.
Thermohydraulic	24 hours	Catanzaro Cosenza Reggio Cal.
Mechanic – electrician site	32 hours	Catanzaro Cosenza Reggio Cal.
Tower crane technology	24 hours	Catanzaro Cosenza Reggio Cal.
Tower crane operation and service	32 hours	Catanzaro Cosenza Reggio Cal.
Mobile crane technology	24 hours	Catanzaro Cosenza Reggio Cal.
Mobile crane operation and service	32 hours	Catanzaro Cosenza Reggio Cal.
Tunnels safety	48 hours	Catanzaro Cosenza Reggio Cal.
Tunnels type	8 hours	Catanzaro Cosenza Reggio Cal.

The first results of This activity were presented in November2010 in a seminar entitled for a future beyond the crisis: the continuing training in the constructions sector" in which there was evidence that the path, which interested the Building Schools of Ravenna, Sassari, Siena, Salerno, Avellino, Caltanissetta, Bologna, Parma, Piacenza, Verona, Reggio Calabria, Cosenza, and Catanzaro, has permitted the delivery of more than 237 courses for 1413 workers.

Responding to the notice 2.2008 of Fondimpresa, Formedil network intended to give an effective answer to the need of workers affected by the crisis stating, in particular, that approximately 48% of the training contained in the plan is aimed at retraining of redundancy workers of the Calabria region. The training must follow a scheme to identify the most effective strategies to guarantee a rapid employability of workers that were excluded or suspended from the production process. And to provide companies with a competitive advantage that will allow on one hand their consolidation, and on the other a sudden exit from the crisis facing the all global economic system, especially the building sector in Italy.

7 Conclusions

The experience gained from the events related to the highway sites management show that, (although from invalid assumptions) training is the first step in building a safety process. Often, by not implementing a strict training schedule, trust mechanisms, you can be lost. Then control of the final steps of the corresponding safety requirements during construction is also lost.

Building a safety culture among operators with a continuous and coordinated action in the future may allow the achievement of *zero accidents* and a means to achieve true quality in the building works execution.

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UNIVERSITY EXPERIENCES IN THE TRAINING OF SAFETY MANAGERS

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Abstract

The knowledge accumulated at university leads all training activities dedicated to those engineers who will face issues related to construction site safety. In training safety managers we must be aware of the social role they are going to play.
Università degli Studi Mediterranea in Reggio Calabria has been offering a course on Construction site safety from more than 15 years. We commenced this course at the Faculty of Architecture, then it was implemented at the College of Engineering and more recently at the Faculty of Agricultural Studies. We dedicated our attention to the building sector, to road construction and forest trade. We held several meetings and symposiums addressed to trade associations and firms; they gave rise to a synergy among the different players which led to the ratification of a memorandum of understanding with INAIL (Italian Workers' Compensation Authority). The Consolidated Law on Safety and Health at Work passed in Italy with the legislative decree 2008/81 establishes that INAIL is one of those institutional entities that must support and promote the culture of prevention, focusing its attention on the needs stemming from the working world and from education as a whole.
In order to meet these specific requirements, we are going to launch:

- long-term collaborations in order to envisage and provide training courses on workplace safety;
- work experiences, internships and guidance on safety;
- scholarships and fellowships provided by INAIL to those students who show a sound interest for a prospective career as safety engineers;
- new educational offerings in order to spread among university students a culture of prevention.

We present the training courses we have already implemented to qualify construction site safety managers and their outcomes.

Keywords: education, health and safety, training, undergraduates

1 Preliminary remarks

The seminar "Safety Requirements in Construction" held in March 1995 paved the way to a new research trend in the Faculty of Architecture of Università Mediterranea in Reggio Calabria.
By complying with the new issues of quality in the building sector, we dealt with two significant aspects:
- safety in the built environment
- safety during construction set up stage
In 1994 Italy had passed Legislative Decree n. 626 by which it incorporated the European Directive on Safety and Health at Work; in 1995 the Italian government was about to acknowledge the specific directives aimed to building sector.

In 1996 Università Mediterranea launched an educational program aimed at qualifying Safety Coordinator at project stage and Safety Coordinator at execution stage. The professional requirements for Safety Coordinators had been set in Italy by article 10 of Legislative Decree n. 494 of 1996 which incorporated the European Directive 92/57/EEC *"Implementation of minimum safety and health requirements at temporary or mobile construction sites"*.
Culture, quality and safety are important concepts that need to be implemented by means of education and training. What is more, they must be of the utmost consequence to all stakeholders.
The Construction site safety courses implemented at Università Mediterranea in the years that followed were then introduced also in the College of Engineering and in the Faculty of Agricultural studies.
Students attending the Faculty of Architecture and the College of Engineering are trained in compliance with the guidelines set by the Legislative Decree n. 494 of 1996. We had to ascertain if the compulsory courses fell within this framework.
Joining W099 (Safety and Health on Construction Sites) in International Council for Research and Innovation in Building and Construction as well as attending international meetings and symposia allowed us to compare the problems we find in Italian building sector with the real problems and the development of International scientific research on safety and health in construction sites. We got a sound feedback which makes us more active in training and in research activities.

2 Construction site safety is a milestone of our educational offering

Integrating a course on construction site safety into educational offering for prospective architects aims at making the future planners and designers acquainted with the notions and practical aspects linked to planning with a view to safety. All the new tools dedicated to building processes were always use that knowhow which until then had favored a formal training and paid attention to forms and aesthetics. Unfortunately it was unaware of technological processes that characterize construction site set up stage and *safety* during the execution stage.
The training of Safety Coordinators at project stage, as set by Directives, aims at creating a professional able to liaise and support the planner in his/her choices while focusing on safety. The Safety Coordinator at execution stage must coordinate and liaise with other players in the building process i.e. the developer, the person in charge of prevention and protection services, workers' representative, sub-contractors and external contractors.
In the training process within the framework of the School of architecture, the educational offering initially dealt with the provision of two levels of knowledge. The first level highlighted all information needed to develop safety management embedded in planning choices in the light of the newest legal trends (Consolidated Law on Safety and Health in force in Italy since 2008) which place on the planner all civil and criminal liabilities connected to safety at work.
The second level focused on the operational and planning aspects of construction site safety, providing information about risk management in construction sites within the framework set by the Legislative Decree n.494 of 1996 and subsequent amendments and additions in the years that followed. In our Training course on construction site safety we will deal with the following topics:
- regulations in force concerning safety and health at work;

- occupational diseases;
- statistics on breaches of regulations in construction sites;
- risk analysis;
- good practices and criteria to set up construction sites and work in a safe way;
- methods for developing safety and coordination plans.

In 2004, we launched a degree course in *Construction Management* which in its charter set construction site safety as a one of its objectives. As a consequence, the Faculty regulations offer to all students from different degree courses the chance to gain the qualifications necessary to work as Safety Coordinator.

This new breed of professional was introduced by European Directive 92/57/EEC; in the EU member states he / she intervenes in the building process either at planning stage (Planning – phase Co-coordinator) or at execution stage (Execution – phase Co-coordinator).

In organizing the courses we did not rely only on resources from academic world, but we also met the organizations of developers and workers (thanks to initiatives of cooperation with Scuola Edile (the building craftsmen school), the magistrates, the Labor Inspectorate (controlling body of the Ministry of Labor), INPS (National Social Welfare Institution), INAIL (Italian Workers' Compensation Authority), professional associations and manufacturers of building products.

Every year we hold a symposium to coincide with National Days for Safety and Health at Work, which becomes an opportunity to provide continuous updates about innovations in safety and health at work.

In January 2011 Università Mediterranea and INAIL signed a memorandum of understanding: by implementing the provisions of the Consolidated Act on Safety at Work, it is going to strengthen the synergy between the two institutions aimed at promoting training courses on safety and health at work by means of work experiences, meetings, postgraduate courses, scholarships and fellowships.

3 Planning with an eye to safety and health at work

Training of prospective engineers in the schools of architecture did not pay specific attention to the issues faced during building processes.

For longest time, teaching was based on formal and functional outcomes of the project idea following a tradition that had been marking the schools of architecture until the last decades of the previous century. Attention to design tools connected with architectural processes became fashionable again only in the past few years, also thanks to European directives which aimed to achieve quality standards.

The emergence of a technological culture in projects led to an improvement of technologies and materials, increasing the complexity of organizational structures needed to manage building processes. What needs to be done in order to achieve quality in the construction process was assessed by EU directives and was incorporated in Italy by law n. 109 of 1994, later on integrated and supplemented by the implementing regulation n. 554 of 1999.

The functional needs, the requirements and the performance specifications should be already identified in the early planning stages and in the final draft must be translated into content dealing with technical performance.

Building processes consist of four phases: concept, planning, implementation and management.

Among these phases, planning plays a crucial role and is differentiated by several approaches. The initial research conducted by the client and the development of a program enable to single out general requirements (programming stage) in order to envisage feasibility. Subsequently the planning phase identifies architectural contents, building materials and construction techniques as well as its costs (preliminary design and working plan). Then all features of the building are detailed (structure, materials, facilities, economic aspects) developing what is known as a detailed design.
In this context engineers' knowledge was limited to architectural, structural and engineering aspects of the building whereas they left the developers struggle with organizational aspects in order to set up their construction site. The attention paid to safety requirements within a planning process kept in mind just end-user safety and neglected the execution stage and consequently the safety of intermediate users (i.e. people working in the construction site).
Introducing in our courses operational planning, which includes work planning and construction site set up, was a groundbreaking decision as it made prospective engineers think about a new idea that once the building is finished its construction site must be dismantled, are factors that can mitigate and reduce safety risks during building processes.
Teaching was therefore aimed at these considerations with multi-disciplinary approaches and often with the observation that current design tools offer the possibility to simulate the site structure and allow planning safety planning at the initial stage. This was carried out paying attention to the newest developments in legislation, which by means of the new procurement code adopted in Italy by legislative decree n 163/2006, and the approval of its regulation (decree n. 207/2010) included the organization of site and temporary works in planning documents compulsory for the final plan.

4 In practice

Planning practice carried out in Planning and Organization of Construction site safety in construction site aims at:

- an in-depth analysis of a newly set up construction site;
- planning the work progress analyzing the risks for each activity and with the specific processes risks analysis and interference risks in it;
- modeling with IT tools the site, managing the construction stages until completion.

For the first part is assigned a recently completed construction site (also selected in geographically remote locations).
Students are encouraged to collect via the Internet data about the project: client, designers, construction system used, developer and safety controls implemented. Many developers or contractors publish online their projects with a lot of pictures.
Not to forget unofficial images published in the social networks by private citizens.
These operations evoke great interest in students. Through seminars they are constantly informed of all course work progress and information relating to the security legislation of various countries around the world.
In the second part of the program, attention is focused on the project operational development prepared by the architecture classes, whose initial choices are often

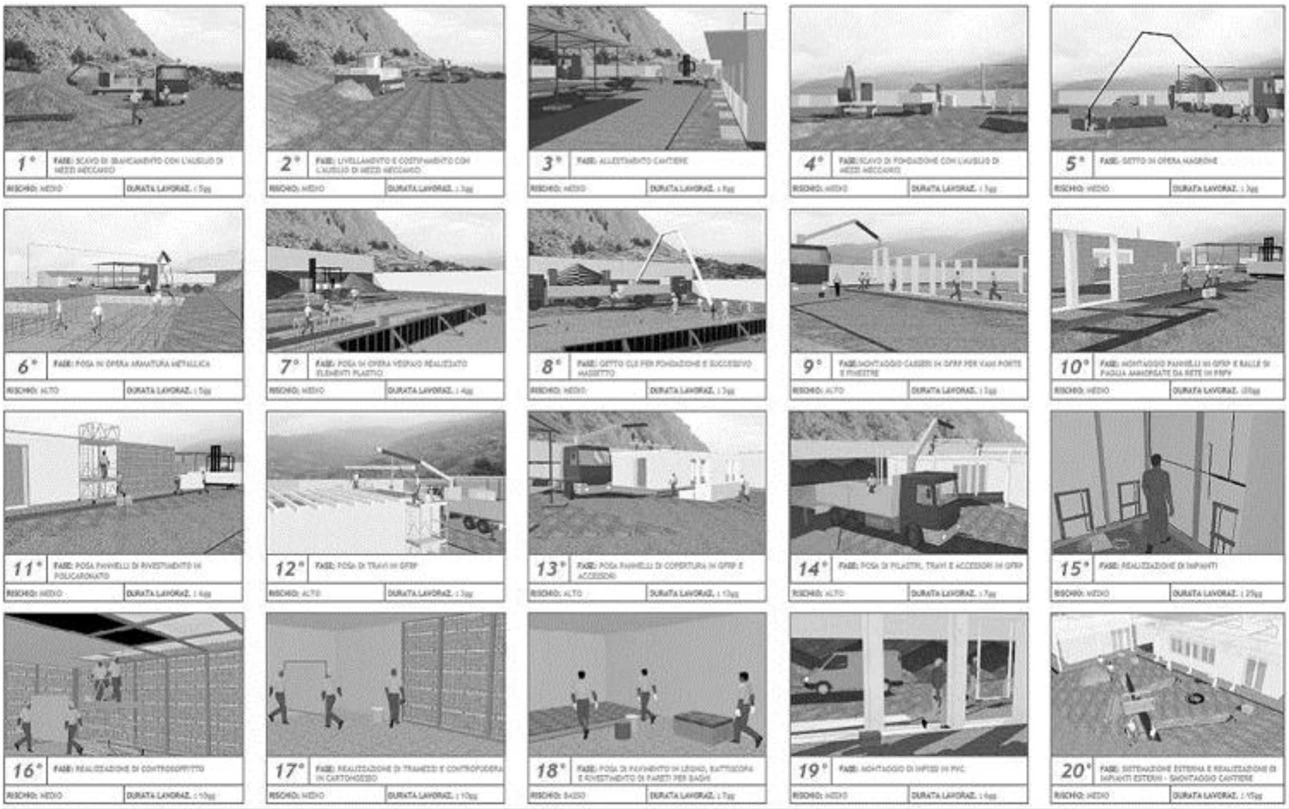
revised on the site functional needs basis and the safety achievement, not only in the site but also in neighborhood.

In the third part, by working on CAD data, we highlight simulations of the development of building activities. This graphical analysis allows to checking if safety measures have been implemented in the different building phases by taking into account all those activities that will become a useful tool to write Safety and Coordination Plans.
This training path trains future designers to identify the best conditions to minimize the risks connected to planning choices as well as to those closely related to operational technologies succeeding in implementing by simulation operations predictions of construction site set up stage.

5 From specific teaching to multidisciplinary approach

Training of planners is not limited to a specific discipline but involves other courses providing students all information concerning practical project management, public works management, contract and specifications preparation, project economic management. The results of the course are put into practice on the occasion of the Laboratory and Final Test during which student's fine tune all knowledge acquired in order to write their degree thesis.
We have noticed a growing interest among students from several disciplines in, to construction site safety. A particular attention has been paid to the following subjects:

1. **Organization of safety in building sites.**
   Planning experiences were built to interface in their development with safety requirement in building process by setting up specific layout and planning documents useful to examine risks and the measures needed to dampen or minimize them.



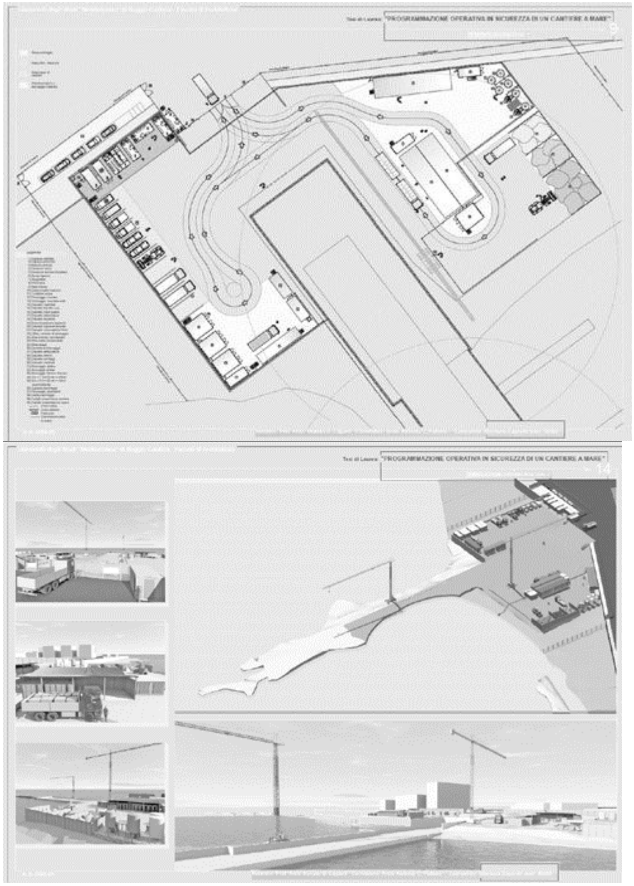
Organization of safety in a small building site - Simulation of the development of a site with analysis of the risks of using experimental technology

2. Site management techniques.

Operational models have been defined by creating small programs with which you can assess, step by step, and control risks. You can also get effective improvements both in simple or complex sites.

3. Integration of health and safety requirements in planning.

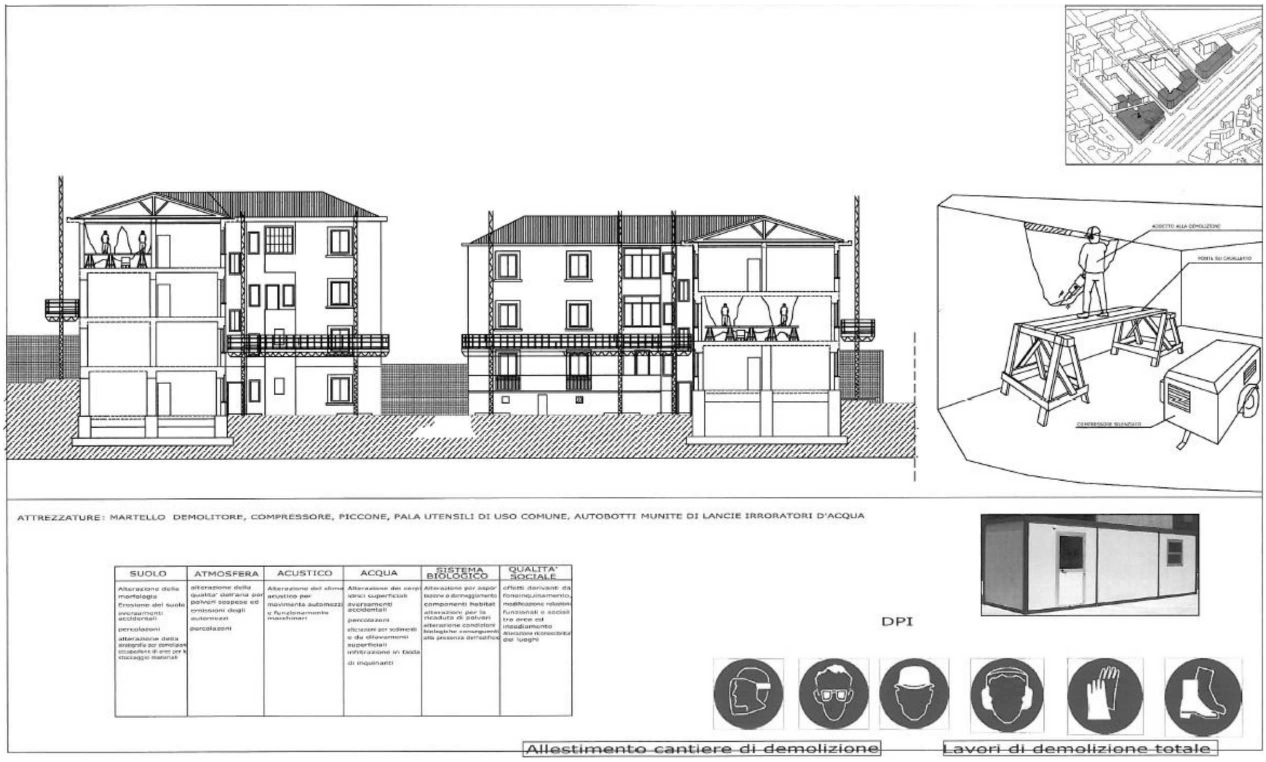
Small programs have been developed to assist designers in choosing sizes and types to identify potential risks and indicate possible solutions to eliminate hazards at execution stage.



Organization of safety in a large building sites - Layout and simulation for a building sea (thesis of Zagordo G.)

4. Organizing the building site in urban-scale architectural renovation.

The complex problems faced in the preparation of sites in urban areas and urban degradation, network infrastructures, project timing, parties involved in the specification of the typical risks of maintenance.



Architectural renovation construction site in Reggio Calabria.

5. Problems in Historic buildings restoration sites.

The static recovery of artifacts should require a specific attention to the initial building conditions and the subsequent development of the site. We need to monitor continuously all phases of work.

6. PPE design.

Attention to PPE ergonomics led to functional improvements in some of them by means of a strong debate with manufacturers and the verifications needed to achieve quality levels.

7. Temporary works design.

Starting from a review of the most popular systems, we developed studied improving solutions in terms of assembly and their relationship with the urban surroundings.

8. Different kinds of Health & Safety files.

Based on the model shown in the specific European Directive we built some examples that can assist the work of safety coordinators in making long-term predictions

9. The assessment of seismic risk in construction sites located in areas subject to frequent earthquakes.

The location of the university and its catchment area in a place marked by high seismic risk makes us put a lot of attention to this kind of risk for both simple and complex sites.

The recent MOU ratified between the university and INAIL – National Institute for Occupational Injury Insurance – Reggio Calabria – to support teaching, as well as some seminars on issues of safety procedures management, allowed to allocate some scholarships to senior year students in the faculties of Architecture and Civil Engineering within the framework of the initiative “Urban Habitat and safe access to workplace”.

6 The structure of Safety Coordinator's courses

The structure of the courses to obtain a qualification as Safety Coordinator is quite different. According to the provisions of the Consolidated Security (Legislative Decree n.81/2008 subsequently amended by Legislative Decree n.106/2009) (Section IV, Art.98 - Attachment XIV) it must consist of 120 hours: 96 hours are devoted to theoretical lessons whereas 24 hours are dedicated to practice. The course ends by a final assessment in which you can evaluate what they've learnt.
At the beginning it dealt with two specific disciplines; starting from 2011 there will be a single course resulting in 8 education units (i.e. 120 hours), which will be enriched by attending seminars and visiting building sites.
The subjects we'll deal with are set by domestic legislation and include:
- 28 hours devoted to legal aspects (Basic legislation, European norms, the Consolidated Law, Public Works Outline Law, players and stakeholders, rules on penalties as well as inspection procedures).
- 52 hours devoted to technical aspects (Organization of site safety, Timetable, different risks, documentation requirements, protective devices and signage).
- 16 hours dedicated to methodological / organizational aspects (minimum contents of Plans, methodological criteria to write them, safety costs as well as communication theories and techniques).
- 24 hours practice (examples of Safety and Coordination Plans, Safety file, Safety operational Plans and Replacement safety planes, Health & Safety file as well as simulations of implementation stages).

Conclusion

In previous meetings we already discussed those issues concerning courses on Construction sites safety and health; we often stated that teaching how to implement safety in construction sites must be done jointly with other already existing disciplines. We can achieve this goal only if everyone involved in the training process is aware of the real meaning of construction site safety.
Stressing the tremendous role played by safety issues in training of future technicians is the first step on the way to go together with all boards in charge of protecting safety and health at work.
Undoubtedly this process needs a preparatory phase passing through an interdisciplinary program which must begin by acknowledging the need to place safety and health at work within the educational framework set for future professionals not only as knowledge but also and above all as the result of experimental planning.
This testing should enable students to get a better understanding of the construction site as a place of production. The man's work, supported by the use of equipment and machinery should be considered ahead of technological choices and characterize all in-depth studies about planning.
Setting out from these assumptions, the operational approach will become easier. Thanks to a careful prevention, it will help achieving the common goal to minimize

the risks in order to put an end to the accidents on construction sites considered as workplaces.

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Trends in Causes of Construction Worker Fatalities

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Trends in Causes of Construction Worker Fatalities

Abstract

For the past four decades, the Occupational Safety and Health Administration (OSHA) has given considerable attention to the causes of construction worker fatalities. Causes of particular interest have been referred to as the "focus four" causes of accidents, including falls, electrocutions, struck-by accidents and caught in/between incidents. While the differences between these causes might be somewhat evident, they provide little details regarding the underlying causes of fatal construction accidents. A research study was conducted on 1881 construction worker fatalities that were investigated by OSHA in the inclusive years of 2007 - 2009. The objective was to identify their specific causes. For this study 33 specific causes of the fatality accidents were devised. For example, instead of having a singular category of "electrocutions", there were a total of five different causes of electrocutions that were identified. Struck-by accidents were grouped into five different categories. Similarly, the remaining causes of accidents were grouped into more detailed categories. Various aspects of accident causation were noted. Over half of the struck-by accidents and over half of the caught in/between incidents involved equipment. The proportion of falls among the causes has increased to 40 percent of all fatalities. Other trends were noted.

Key Words: accident causation, construction fatalities, incident trends

Trends in Causes of Construction Worker Fatalities

1. INTRODUCTION

The construction industry is one of the most dangerous industries in the United States. It has had and continues to have one of the highest reported rates of work-related deaths and injuries. While efforts have been made to make the industry safer, construction continues to have an unacceptable level of safety performance. According to the fatality data recorded by the Occupational Health and Safety Administration (OSHA), the construction industry has the most fatalities of all of the industrial sectors.

The causes of construction worker fatalities have been examined through prior research efforts, but these are conducted infrequently. One major study was conducted in 1990 in which construction fatality causes were identified for those fatalities occurring from 1985 through 1989. Another study was conducted which examined the causes of construction worker fatalities for 1994 and 1995. There has been no major recent study which has examined these causes.

OSHA data have been made available which include descriptions of the construction worker fatalities that occurred through 2009. An examination of the data for the most recent fatality investigation data could shed considerable light on the causes of fatalities resulting from work done in the construction industry.

OSHA uses five main areas by which to categorize the causes of fatalities, including falls, struck-by, caught in/between, electrocution, and other. While these categories provide general information on the causes of worker deaths, they generally are regarded as being too generic to provide real insights about ways to reduce these fatalities. For example, suppose a worker is killed in a trench when a portion of the trench wall becomes dislodged and strikes the worker on the head. This would be classified as a struck-by incident. However, if the worker was killed when the trench wall moved due to the development of a failure plane that caused the trench wall to slide laterally and pinned the worker, the incident would be classified as a caught in/between incident. In either case, the cause of death would have been trench wall failure or cave-in. Herein lays the problem with the current five-category coding system used by OSHA. Greater detail in the definition of the cause categories would provide much more meaningful information.

Accurately coding the cause of each death is important as vague categories do not provide a truly accurate picture of the causes of construction worker fatalities. The fatality data from OSHA have been used to evaluate and look for trends in the causes of fatalities within the construction industry. Unfortunately, this cannot be done with precision if the OSHA causation codes do not accurately depict the causes of death for construction workers. If the true cause of death is not known or is misrepresented, then preventative efforts on future construction projects will be less effective due to the fact that they are targeting a vague cause which is not likely to lead to effective results. A more detailed analysis of the causes of construction worker deaths would provide more meaningful information by which safety efforts could be made more effective.

2. LITERATURE REVIEW

Since 1971, the Occupational Safety and Health Administration (OSHA) has investigated workplace accidents. These accident cases are generally fatalities, as fatalities must be reported to OSHA within 8 hours of the occurrence so that OSHA can conduct an investigation. Prompt notification must also be given of the occurrence of catastrophes, namely incidents involving the hospitalization of three or more workers. Data have been and continue to be collected on fatality incidents. OSHA conducted a detailed analysis of 3496 fatalities that were investigated in the inclusive years of 1985 to 1989 (OSHA database 1990). This effort resulted in widely-publicized data on the primary causes of construction worker fatalities. For example, it was noted that falls accounted for 33% of the construction worker fatalities, followed by struck-by accidents, caught in/between incidents and electrocutions. Ten percent of the causes were categorized as “other” (Figure 1). These are the five standard classifications for the causes of construction worker fatalities.

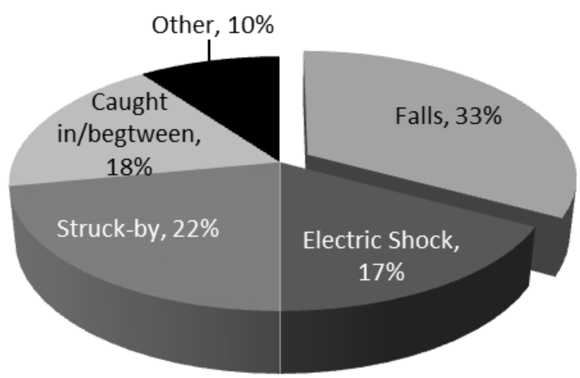

Figure 1. Breakdown of Construction Fatality Causes for 1985-1989 (N=3496)

A subsequent study was conducted at the University of Washington which involved the analysis of the construction fatality investigation data for 1994 and 1995 (Figure 2). One objective was to determine if changes had occurred in the causes of fatalities. The results showed that there were differences in the causes of fatalities, but that these differences were considered minor (Hinze et al., 1998).

In their study, researchers sought to define, with greater specificity, the causes of construction worker fatalities. They concluded that much of the available information regarding the causes of fatalities was too generic to provide a framework by which

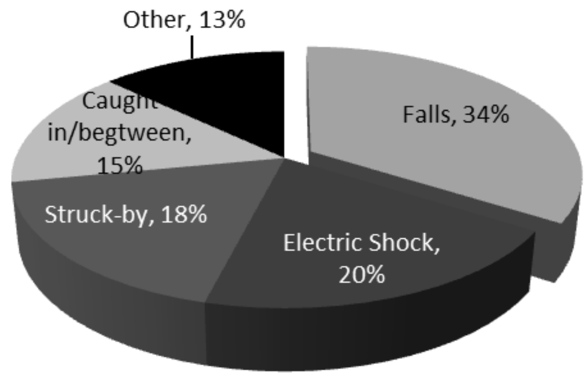

Figure 2. Breakdown of Construction Fatality Causes for 1994-1995 (N=1082)

accident prevention programs could be made more effective. To mitigate the generic information available regarding fatalities, they developed a method for coding the causes in a more detailed manner such that the root causes of fatalities would be more evident. In addition to examining the five generic categories of the causes of fatalities used by OSHA, 20 more-specific cause codes were devised (Hinze et al., 1998). These cause codes, and the distribution of fatalities among them, are shown in Table 1.

Under the system involving five cause codes, an accident might be coded as "struck-by," but this does not disclose whether it was caused by a large piece of equipment, material being handled, or even a trench collapse (Hinze and Bren, 1997). Note that Table 1 makes a clear distinction between the different types of struck-by accidents.

The OSHA database has been used in a number of research studies. One study examined 7,543 construction fatalities that occurred in the time period from January 1990 through October 2001. Falls (both from elevation and from the same level) accounted for 34.6% of the injuries. It was found that for the years before 1996, the average proportion of falls was 34.1%, and in the following years leading up to 2001, the average proportion of falls was 38.4% (Hinze et al., 2002).

Another study was focused on the details associated with struck-by accidents. These accidents included a broad range of causes of fatalities, such as cave-ins, equipment, and materials being handled. Clearly, the term "struck-by" does not provide an accurate portrayal as to what may have caused a particular accident. OSHA struck-by fatality investigation data from 1997 to 2000 were analyzed. The final database included information on 743 struck-by accidents. That study primarily focused on what the victim was struck-by. One focus of the research was to consider the frequency of cases by the material involved in the accidents. This study revealed that a total of 288 injuries/fatalities occurred as a result of the victim being struck-by material. The most common material involved in these struck-by cases was timber or wood assemblies of walls, trusses, and formwork (Hinze et al., 2005). A similar study was conducted that involved caught in/between fatalities (Huang and Hinze, 2003).

Table 1. Expanded Fatality Causation Codes (1994-1995 data)

Cause of Fatality Accident	Portion of Total
Fall from elevation	33.9%
Fall from ground level	0.1%
Electrocution (power lines)	14.4%
Electrocution (building power)	2.6%
Electrocution (faulty facility wiring)	1.0%
Electrocution (faulty construction tool/wiring)	0.8%
Electrocution (other)	1.2%
Struck-by equipment	9.5%
Struck-by falling material	7.2%
Struck-by material (other than falling material)	1.3%
Caught in/between equipment	8.9%
Caught in/between material	1.2%
Cave-in	5.0%
Explosion	2.6%
Fire	0.4%
Explosion/fire	1.8%
Asphyxiation	1.7%
Drowning	1.4%
Natural causes	3.9%
Other	1.2%

An additional study analyzed construction fatalities with the cause code of “other”. That study focused on 9600 construction incidents that were investigated by OSHA between 1990 and 2004. The accident descriptions were examined to identify the causes of the incidents. There were 795 fatality incidents that were attributed to “other” causes. In reviewing these data the researchers concluded that there were several categories used for event categorization that extended beyond the standard five event categories including: “bite/sting/scratch”; “cardio-vascular/respiratory system failure”; “ingestion”; “inhalation”; “repeated motion/pressure”; and “rubbed/abraded” (Hinze and Ballowe, 2008). These categories represented a few of the subcategories that would otherwise be classified as “other.” Ultimately the event code “other” was broken down into seventeen cause codes, with the most frequent causes including natural causes, asphyxiation, drowning, burns, explosion/fire, hyperthermia, chemical exposure, and lightning.

3. Research Methodology

The objective of this research was to identify the distribution of the current causes of construction worker fatalities. It was decided that the OSHA construction fatality data from 2007 to 2009 would provide the basis for this research. In addition to examining the distribution of the causes of construction fatalities, an attempt would be made to identify any trends or patterns regarding the causation of construction fatalities when compared to the results of prior studies.

The data were acquired from the Occupational Safety and Health Administration (OSHA) Office of Statistical Analysis. The data represented inspection information on all the construction fatalities that were investigated by OSHA in the three-year period of 2007-2009. The data were entered into the Statistical Package for the Social Sciences (SPSS) for final analysis. There were 1881 fatality cases that were made available for this analysis.

4. Results

Fatalities investigated by OSHA that are included in the data provided by the OSHA Office of Statistical Analysis are shown in Figure 3. The number of fatalities reported by the U.S. Bureau of Labor Statistics for the same three years are 1204, 975 and 816, respectively. The differences in these numbers of these two data sources have not been explained. It was suspected that the data from some state-plan states may not be included in the OSHA database for some reason (e.g. lack of reporting). Also shown in Figure 3 are the employment values for the inclusive years of 2007 to 2009 (BLS, 2010).

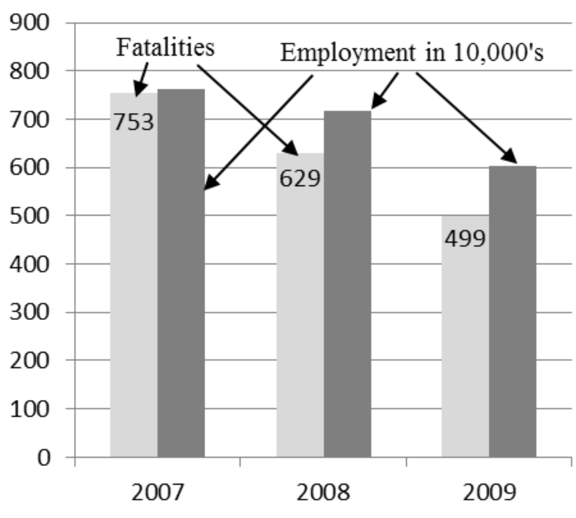

Figure 3. Fatalities and Employment By Year

Fatality Occurrence by Month

The data were examined in terms of the fatality frequency by month of the year. The summer months of June, July, and August account for the highest number of fatalities. The month of June contains the highest number of fatalities (Figure 4). The fatalities declined in September and then increased slightly in October. November and December had the lowest numbers of fatalities with December containing the lowest number overall. These lower numbers can probably be attributed to the reduced number of working days during these months, especially the Thanksgiving and Christmas holidays. In some states, the opening of deer hunting season (generally in November) also reduces the number of days available for work. The winter months from January through May contain approximately the same number of fatalities with February being slightly lower, probably due to the fact that February is a shorter month.

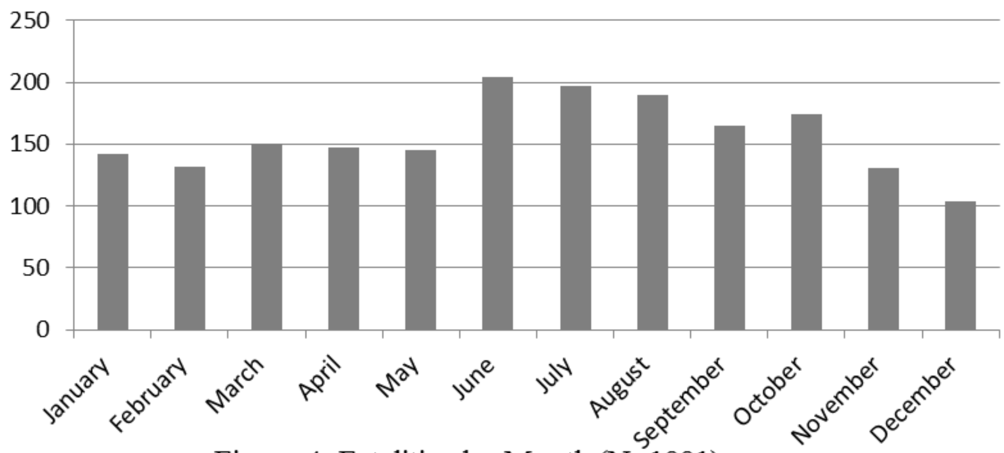

Figure 4. Fatalities by Month (N=1881)

Fatality Occurrence by Day of Week

The data were examined to identify any pattern or trend that related to fatality occurrence by the day of the week. Monday and Tuesday accounted for the most fatalities with Tuesday accounting for the highest number overall (Figure 5). Wednesday and Thursday had similar numbers of fatalities, but were less than Monday and Tuesday. In terms of the five-day workweek, Friday had the lowest number of fatalities overall. Saturday contained approximately half as many fatalities as Friday while Sunday had about a third as many fatalities as Saturday.

Fatalities by Hour of the Day

The data generally included information on the hour of the day when the fatalities occurred. While the actual time was often provided to the minute, the information was reduced to the whole hour, for ease of presentation. Figure 6 depicts the number of fatalities that occurred by hour throughout the day from 6 AM to 6 PM. Although 6 PM to 6 AM is not shown, 162 fatalities did occur during this 12-hour period. With the time frame shown, the highest number of fatalities occurred between 9:00 and 10:00 AM and

1:00 and 2:00 PM with the latter timeframe containing the highest number overall. In the morning sector, the number of fatalities spiked between 9:00 and 10:00 AM and then tapered off to the 12 o'clock hour (noon). After the spike from 1:00 to 2:00 PM, the afternoon fatalities gradually tapered off as they approached 6:00 PM.

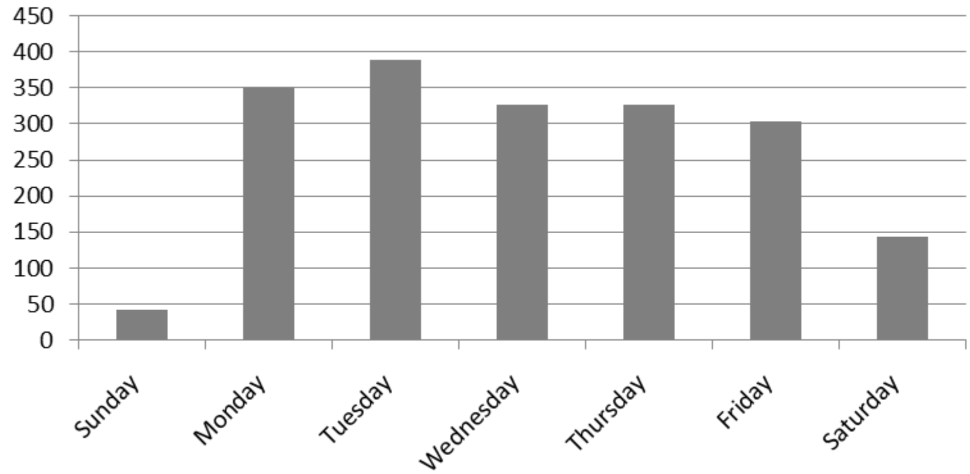

Figure 5. Fatalities by Day of Week (N=1881)

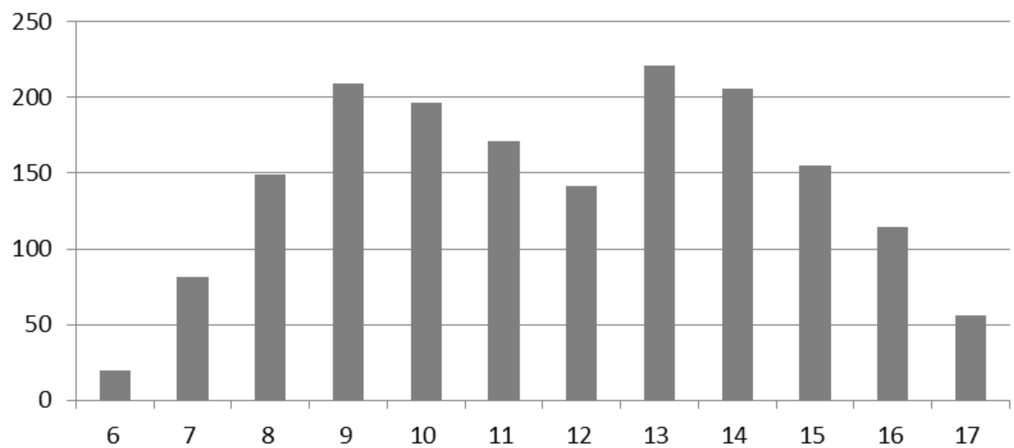

Figure 6. Fatalities by Hour of Day (N=1719)

Standard Industrial Classification

The standard industrial classification (SIC) is a system used by the United States to classify establishments by their primary type of activity. The NAICS, another categorizing system, is used by some agencies, but OSHA has continued to use the SIC format. Many work classifications are included in these SIC codes and this applies to all work sectors. The work classifications of fatality victims were included in the OSHA data. The general work categories of the victims included 13.1% employed by general (building) contractors, 21.3% employed by heavy (non-building) construction firms, and 65.6% employed by specialty contractors. Among the specialty contractors, roofing, siding, and sheet metal work accounted for 193 fatalities over the three-year period or

10.3% of all construction fatalities. Electrical work accounted for 150 fatalities or 8.0% of all construction fatalities.

Cause Codes

The fatality descriptions were carefully examined to identify the specific cause of each incident. The analysis initially utilized the same five cause codes that OSHA has utilized for the past four decades. This information is shown in Figure 7 and reveals that falls have increased significantly as a percentage of all construction fatality causes. Deaths due to electrocution have declined noticeably.

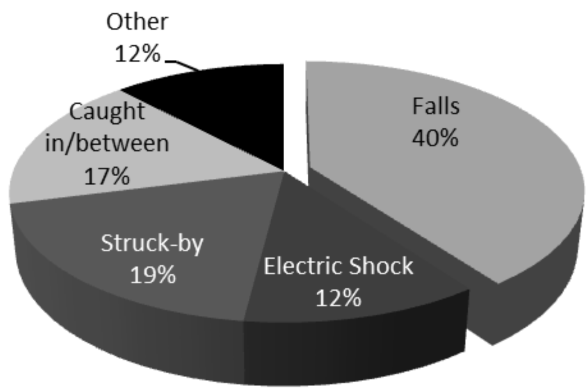

Figure 7. Breakdown of Construction Fatality Causes for 2007-2009 (N=1881)

Additional cause codes were developed to more-accurately describe the various causes of fatalities. There were 33 cause codes that were devised. These cause codes are considerably expanded versions of the codes used by OSHA and help in more-accurately explaining the causes of the fatalities. The cause with the highest frequency of fatalities is falls from elevation (Table 2). There were 748 falls from elevation accounting for 39.8% of all fatalities. The cause with the second highest number of fatalities was victims who were caught in/between equipment accounting for 194 fatalities or 10.3% of all fatalities. Another area of high fatalities were those victims who were struck by traveling or operating equipment, accounting for 121 fatalities or 6.4% of all fatalities. Electrocutions due to power line contacts accounted for 120 fatalities or approximately 6.4% of all fatalities.

Additional Analysis

When information was provided on other aspects of the fatality causes, further analysis was conducted. For example, information was provided in 1439 cases on the use of or failure to use personal protective equipment (PPE). The results showed that for 9% of these cases the appropriate PPE was worn, while in 40% of the cases no PPE was worn and in the remaining cases the use of PPE was generally not relevant to the work being

Table 2. Fatalities by Cause Code

Cause	**Frequency**	**Percent**
Electrocution (Building Power)	71	3.8%
Electrocution (Faulty Tools/Wiring)	8	0.4%
Electrocution (Faulty Existing Wire)	6	0.3%
Electrocution (Power Lines)	120	6.4%
Electrocution (Other)	15	0.8%
Falls (From Elevation)	748	39.8%
Falls (From Same/Ground-Level)	11	0.6%
Caught In/Between Equipment	194	10.3%
Caught In/Between Material	46	2.4%
Caught In/Between Other	11	0.6%
Cave-In (Excavation/Tunneling)	17	0.9%
Cave-In (Trench)	50	2.7%
Struck-by Traveling/Operating Equip.	121	6.4%
Struck-by Falling Equipment	60	3.2%
Struck-by Material Moving Laterally	25	1.3%
Struck-by Falling Material	77	4.1%
Struck-by Other	76	4.0%
Struck Against Equipment	8	0.4%
Struck Against Falling Equipment	4	0.2%
Struck Against Material	5	0.3%
Struck Against Falling Material	3	0.2%
Struck Against Other	1	0.1%
Other: Asphyxiation	23	1.2%
Other: Drowning	21	1.1%
Other: Explosion/Fire	31	1.6%
Other: Natural Causes	68	3.6%
Other: Homicide/Suicide	6	0.3%
Other: Chemical Exposure	2	0.1%
Other: Equip. Mishandling (Mat’l/Struct)	11	0.6%
Other: Structural/Equip. Malfunction	14	0.7%
Other: Heat Related Stress/Stroke	20	1.1%
Other: Lightning	4	0.2%
Other	4	0.2%
Total	1881	100%

performed. In 139 cases, it was noted that the workers were wearing the PPE, but in 27% of these cases the workers removed the PPE prior to being involved in the fatality incidents. It was further noted, based on the incident descriptions of 1288 fatality descriptions, that in 44% of these cases the proper use of PPE would probably have prevented the fatality. Furthermore, in 51% of 1387 cases it appeared that worker actions contributed to the accidents. Also, in 48% of all the fatality cases (N= 1881), the incident resulting in the fatality was predictable based on the description of the work being done.

Additional analysis was conducted on the fall fatalities. This revealed that approximately 29% of all falls result from victims falling from roofs. Falls from ladders, scaffolding, and structure each account for 13% of all falls. Additionally, falls through floor openings accounted for 11% of all falls (Figure 8).

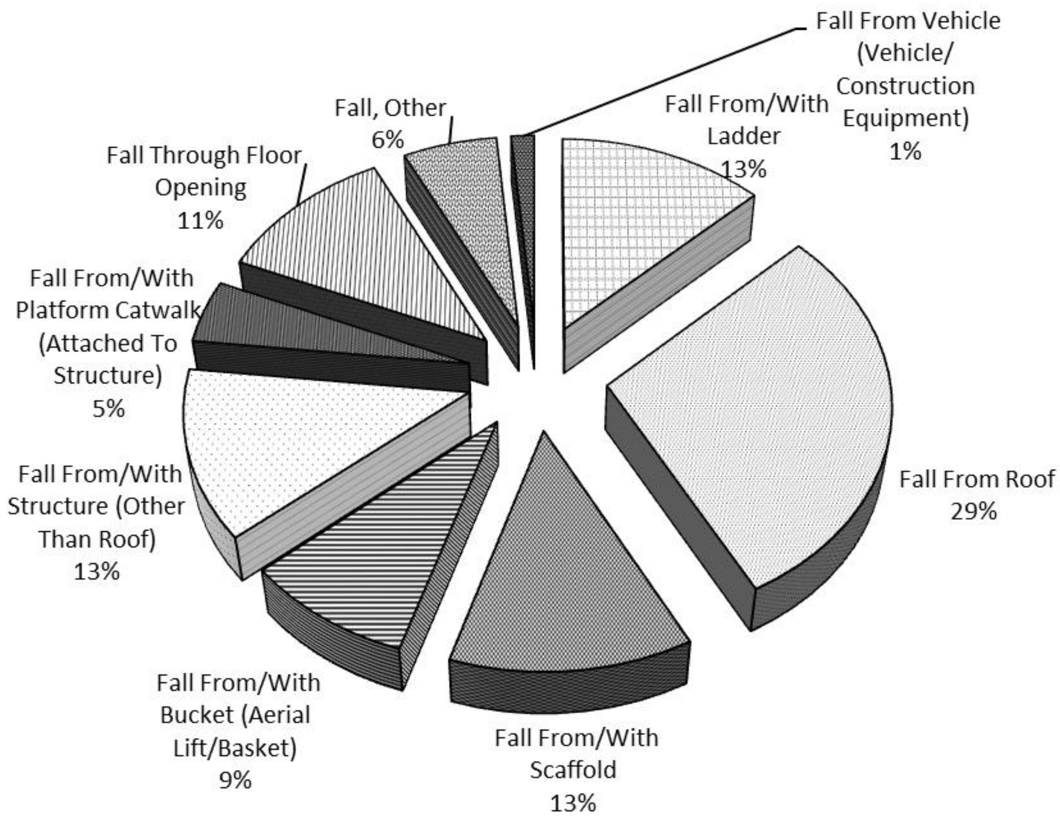

Figure 8. Analysis of Falls (N=759)

Additional analysis revealed that 28.6% of all construction fatalities involve equipment. Operating construction equipment accounted for 20% of all construction fatalities involving equipment (Figure 9). Electrocutions resulting from equipment contacting power lines accounted for 15% of the equipment-related construction fatalities. Another area to note is that 13% of the fatalities involving equipment were the result of victims falling from buckets or aerial lifts.

Approximately 12% of the fatalities were in the causation code of “other”. Natural causes were the leading cause of fatalities under this category accounting for 33% of these fatalities. Fire and asphyxiation are next in terms of prevalence accounting for 15% and 11% of the fatalities, respectively (Table 2).

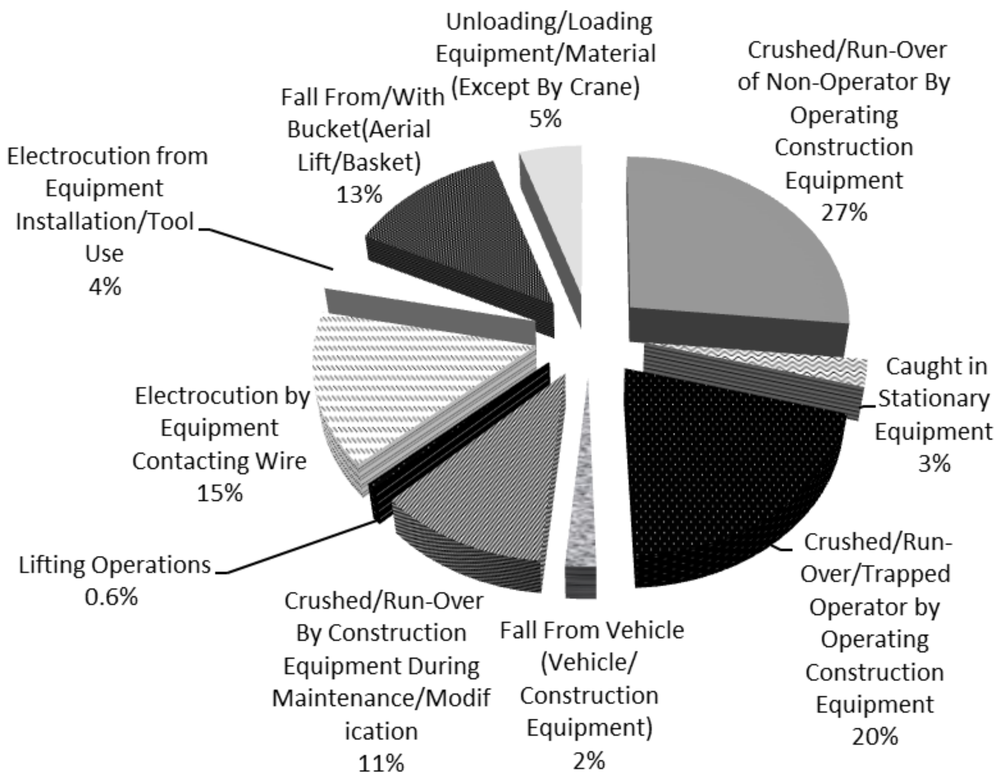

Figure 9. Construction Fatalities Involving Equipment (N=538)

5. CONCLUSIONS

While the construction industry has made dramatic improvements in safety performance in the past decades, the incidence rates of injuries and fatalities continue to be at unacceptable levels. Research results reveal a decline in recent years in the number of fatalities. This decline is not noteworthy as the fatality numbers also match the decline in the number of workers employed in the construction industry from 2007-2009.

As in prior construction safety studies, this research identified the months of June, July, and August as accounting for the highest number of fatalities, probably due to the fact that employment numbers are highest during these months. Ultimately, it cannot be concluded that the summer months are inherently more dangerous. By the day of the week, it appears that during the workweek Mondays and Tuesdays are associated with the highest numbers of fatalities. Fridays have the lowest numbers of fatalities of the weekdays, but this is probably due to the four-10s commonly worked in industrial construction where Fridays are not worked. In regards to when fatalities occur throughout the day, the 9:00 AM to 10:00 AM hour and the 1:00 to 3:00 PM hours accounted for the highest number of fatalities. It is surmised that both of these timeframes represent the time of day when the most intensive work is performed.

Falls from elevation accounted for the highest proportion of fatalities, accounting for 39.8% of all fatalities. There is no definitive contributing factor to this high frequency of falls other than a lack of PPE and the lack of appreciation for the dangers that come with working at elevations. The second highest cause of fatalities consisted of people who were caught in/between equipment. The third highest cause leading to fatalities were victims who were struck by traveling/operating equipment. There were numerous scenarios in which a safety mechanism, such as PPE or a safeguard on equipment, was disabled or malfunctioned and workers still proceeded to perform their tasks. The fourth highest contributing cause of fatalities was electrocutions via power line contacts. Most of these instances involved equipment or people in equipment touching power lines. These tragedies stem from a lack of respect for the danger posed by working around power lines or simply becoming accustomed to working around power lines without taking the proper precautions. In many of these instances the power could have been temporarily disabled or rerouted to ensure worker safety.

When the distribution of the causes of recent fatalities is compared with statistics publicized twenty years ago, there is a notable reduction in fatalities due to electrocutions, which dropped from 17% to 12%. While electrocutions represented the most notable decrease in fatalities, falls from elevation represented the most notable increase in fatalities which rose from 33% in the 1985-1989 timeframe to 40% in the 2007-2009 timeframe. One possible explanation for this increase is that the nature of construction work has changed since the 1985-1989 study. OSHA emphasized the need for fall protection in the 1990s, but the trend did not improve. If all construction workers wore and properly utilized their personal fall protection when working at elevation, these fall statistics would decline dramatically. The fatality data indicate that fall protection is not provided to or utilized by many construction workers. The incidence of struck-by accidents, caught in/between and other causes have realized very small changes since the 1990 study.

It is difficult to state whether or not the construction industry is getting safer. While some improvements are probably being made, the data do not provide convincing evidence. Additionally, the overall fatality numbers have the potential to increase and decrease with fluctuations in the economy. Regardless, the data that reveal the distribution of the causes of fatalities among 33 different cause codes provide valuable information on the primary causes of construction worker fatalities.

6. RECOMMENDATIONS

The 33 fatality cause codes proved to be very helpful in describing the underlying causes of construction worker fatalities. It is suggested that OSHA consider utilizing greater detail in its classification of the causes of fatalities. Industry-wide suggestions for making improvements in safety performance could be readily made if greater details were provided on the causes of fatalities. Such information on construction worker fatalities could be generated when fatalities are investigated by OSHA compliance officers.

While the 33 cause codes are informative, the expanded information on the locations of the falls and the nature of the fatalities involving equipment provided valuable additional useful information. OSHA compliance officers who investigate worker fatalities should gather the relevant information on the locations of falls and the details surrounding equipment-related fatalities so that this information is available to develop preventative measures.

Contractors should evaluate the goal of implementing a 100% tie-off policy on all elevated work. There must also be strict adherence to maintaining the appropriate distance from power lines. In addition to these suggestions, contractors and workers should adhere more closely to the safety rhetoric that is already in place. Safety plans and personal protective equipment exist for a reason. Good safety policies must be enacted and they must be enforced. While there are some fatalities that appear to be “freak” accidents, most of them can be predicted, which means that they can be prevented.

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Occupational Injury and Work Organization among Immigrant Latino Residential Construction Workers

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Abstract

This study sought to determine the potential health threat of work organization to immigrant Latino workers in selected trades in the residential construction industry using longitudinal data from a community-based sample (N=107). 28 participants reported one or more work-related injuries during the 3 month observation period, resulting in an injury incidence rate of 52.8 per 100 FTE. Two injuries involved two or more days away from work, resulting in an incidence rate of 3.8 injuries involving days away from work per 100 FTE. Injuries were elevated among roofers relative to framers and general construction workers. In terms of work organization, variety and control were lowest among roofers and highest among general construction workers, and roofers reported the greatest exposure to occupational hazards. Roofers also reported the lowest levels of supervisory influence over aspects of employment (both negative and positive), and their perceived safety climate was the poorest. Collectively the results suggest that work organization may contribute to elevated rates of nonfatal occupational injury among immigrant Latino residential construction workers.

Work organization is drawing increased attention as researchers attempt to understand potentially avoidable health differences among different groups of people, or health disparities. The World Health Organization recently completed a systematic review of the health disparities literature (Commission on Social Determinants of Health, 2008), and employment-related conditions were addressed in a chapter. Currently, both the World Health Organization and the National Institute for Occupational Safety and Health have commission a set of papers to summarize what is known about occupational health disparities. The fundamental argument underlying these initiatives is that vulnerable populations, like immigrant workers, are disproportionately exposed to pathogenic job designs and work characteristics, health compromising management practices, and injury-prone safety climates that contribute to an unequal and unfair burden of illness and disease.

The organization of work draws attention to the way that jobs are designed and performed (i.e., work processes), management and human resource policies, production methods, as well as labor market policies (Sauter et al., 2002). As such, the organization of work is not a single attribute that exists at a single level. Rather, work organization is a constellation of geopolitical, sociostructural, organizational, and interpersonal factors that operate at multiple levels to affect worker health (Benach et al. 2010; Muntaner et al. 2010; Sauter et al., 2002). Within this constellation, job specific or task level factors are nested within organizational-level factors, which are, in turn, nested within broader social, political and economic external contextual factors that shape and drive employment (see Benach et al. 2010; Muntaner et al. 2010).

Research focused on work organization in relation with occupational health and safety outcomes in the construction industry is underdeveloped, despite construction consistently ranking among the most dangerous occupations in terms of occupational fatality, injury, and illness. Work scheduling, an area of work organization that speaks to the temporal structure of how construction work is performed, has been linked with health and safety outcomes among construction workers (Dong, 2005; Goldenhar et al., 2003). Shimazu and de Jong (2009) documented an association between effort-reward imbalance, a measure of job stress, and greater risk for physical complaints among Japanese construction workers, and the risk for recurrent low back pain over a three-year period was elevated for scaffold workers with high levels of psychological demand and low levels of control (Elders and Burdorf, 2004). Despite the absence of previous research, systematic reviews suggest that work organization factors play an important role in safety violations (Alper and Karsh, 2009), and that construction managers recognize the importance of work organization in maintaining safety on the construction site (Törner and Pousette, 2009).

The goal of this analysis is to determine the potential health threat of work organization to immigrant Latino workers in the residential construction industry. This study focuses on Latino workers in residential construction because a sizeable and growing proportion of construction workers are Latino (BLS, 2008), many of whom are believed to be undocumented (Pew Hispanic Center, 2009), and Latinos within the industry experience higher rates of fatality, injury and illness (Dong et al., 2004; 2010). To accomplish this goal we use longitudinal data obtained from a community-based sample of Latino residential construction workers (n=107) in selected trades to: 1) document 3-month incidence of work-related injury among Latino residential construction workers, and variation in incidence by age, time in the US, country of origin, and worker classification; 2) delineate work organization characteristics of immigrant Latino residential construction workers, including variation job in structure (i.e., work hours, precariousness), job design (i.e., skill variety, control, psychological demands, hazards exposure), supervisory practices (i.e., power, retaliation, ability to communicate) and safety climate experiences; 3) describe variation in injury risk attributed to work organization characteristics.

Methods and Materials

The data for this study are from a broader project designed to determine the feasibility of using computer-assisted telephone survey (CATS) technology to collected daily diary data from Latino residential construction workers (OH009761-01, subproject #647). The original project involved four separate data collection components: a baseline interviewer administered survey, a 21-day daily diary period using CATS technology, a debriefing interview at the end of the diary period, and a follow-up interview 3 months after completing the diary period. The current paper uses data from the baseline and the 3-month follow up interviews.

Sample

Baseline data were obtained from a non-probability sample of residential construction workers who self identified as Latino (N=119). Participants were recruited in partnership with HOLA of Wilkes County, a 501c3 non-profit organization that serves the Latino communities of Wilkes and surrounding counties in western NC. HOLA staff purposefully targeted identifying residential construction workers through a combination of techniques including known individuals within existing social networks, snowball, and referral. Study inclusion criterion were age 18 years or older, Latino (self or parents born in a Latin American country, or self-identified as “Latino” or “Hispanic”), and employment for 35 or more hours per week in construction. There were no exclusion criteria. Three-month follow-up interviews were obtained from 107 study participants (89.9%).

Data Collection

The baseline interviewer-administered interview assessed stable attributes of the individual (e.g., age, country of origin), occupational characteristics (e.g., years in construction, primary tasks performed in construction), health history (e.g., presence of chronic conditions), and multiple aspects reflecting the organization of work. The baseline interview took, on average 48 minutes to complete, and participants received a $15 incentive. The follow-up interview focused primarily on experiences of injury and changes in health during the preceding 3 month period. The follow-up interview took 24 minutes, on average, to complete, and participants received a $25 incentive. All recruitment and data collection activities were approved by a federally authorized Institutional Review Board (FWA #00001435).

The content of the baseline and follow-up interviewer-administered survey questionnaires underwent thorough translation and back-translation procedures. Content from validated Spanish instruments was used without modification where they were available. English-only instruments and items developed for this project were translated into Spanish by a native Spanish-speaker. All items were then back translated into English by a fluent Spanish-speaker. Discrepancies identified in the back translation were corrected through consensus and incorporated into both the Spanish and English versions of questionnaires (Behling & Law, 2000).

Survey questionnaire data (i.e., baseline and 3-month follow up) were collected by four trained interviewers. All interviewers were native Spanish-speakers. Training consisted of a thorough review of study purpose, screening and recruitment procedures, line-by-line review of the interviewer-administered questionnaires, and progressively more realistic practice interviews.

Measures

Dependent Variable. *Injury Incidence*, the primary dependent variable, was assessed at the three-month follow-up interview by reading a list of six statements describing specific types of injuries (i.e., sprains or strains, cut or laceration, flame or chemical burn, bruise or contusion, broken or fractured bone, dislocation, other) and asking whether the individual experienced that injury in the past 3 months while performing paid construction work. Individuals who reported one or more injuries in the past 3 months were then asked "How many days after [INSERT INJURY/your most serious injury] did you go back to work?". Response options were "same day/did not take off from work," "the day after the accident," separate response options for the second, third, and fourth "day after the accident," "the fifth day after the accident or longer" and "still off paid work". Individuals reporting returning to work on the second day after the accident or longer were classified as having experienced an injury requiring time off from work.

Work Organization. Work organization variables were organized into three categories. The first category is structural attributes of the construction job and is evaluated with two variables. The first, *long work hours,* was constructed based on the average number of hours typically worked in construction and dichotomized such that those working 45 or more hours per week were coded one, zero otherwise. The second structural characteristic of the construction work job, *precarious employment*, was measured with a single question asking "which statement best describes your work arrangement in construction" with three response options: "I am a construction contractor or subcontractor and do trades work myself," "I have worked for the same contractor or subcontractor for 3 months or longer," and "I have worked for several contractors or subcontractors during the past 3 months." Individuals who reported working for several individuals in the past 3 months were coded one for precarious employment, all others were coded zero.

The job design domain of work organization was assessed using a modified version of the Job Content Questionnaire (JCQ)(Karasek & Theorell 1990). *Control* was assessed with 3 items tapping opportunities to exert control over work (e.g., "How often are you allowed to make your own decisions about your work?"). *Variety* was assessed with 6 items tapping how jobs vary in content, location, and routine (e.g., "How often do you do a variety of different things on your job?"). *Psychological demand* was assessed with 9 items tapping the job-related stressors (e.g., "How often is your job hectic?"). Exposure to perceived hazards was assessed with 6 items asking about the frequency participants encountered environmental hazards ("How often does your job require you to work in areas where you are exposed to fire, burns, or shocks?") or dangerous equipment (e.g., "How often does your *job require* working with tools, machinery or equipment that could be dangerous?") while working in construction. Response options for each item in the modified JCQ ranged from "seldom or never=1" to "almost always=4). Each variable was constructed by summing items so that higher values indicated greater levels of the attribute. This modified instrument has been used in previous research with immigrant Latino workers where each of the subscales were the reliability of each set of items, assessed via Cronbach's alpha, ranged from a low of .72 to a high of .79, suggesting good reliability (Grzywacz et al. 2007).

The supervisory practices domain of work organization was assessed with several instruments. First, two aspects of supervision were assessed using an established scale (Tepper, 2000) that has been used in previous research with immigrant Latino workers (Grzywacz et al., 2007, 2010; Marín et al., 2009). *Powerful influence* reflects the extent to which workers' believe their supervisor can shape or influence their opportunities on the job was assessed with 4 items (e.g., "My supervisor could….influence my getting a pay raise," or "…provide me with special benefits"). *Retaliatory supervision* was assessed with 3 items asking about the extent to which workers believe that supervisors use their authority to punish workers (e.g., "My supervisor could…. give me undesirable job assignments" or "Make things unpleasant here"). Response options ranged from "strongly disagree=1" to "strongly agree=4". Both the powerful influence and the retaliatory supervision variable were constructed by summing items so that higher values indicated greater levels of the attribute. *Poor communication* with supervisors was assessed with a single item from the JCQ asking "how well are you able to communicate with your immediate supervisor?" Possible responses were "very well," "somewhat," and "not at all;" individuals who reported "somewhat" or "not at all" were coded one for having poor communication, all others were coded zero. *Safety climate*, reflecting management's commitment to maintaining a safe worksite, was assessed using the 10-item Perceived Safety Climate Scale (Gillen et al., 2002). Items are scored such that higher values indicate greater management involvement in safety and health.

Covariates. *Age* (measured in years) and *educational attainment* assessed based upon the grading system used in Latin American countries (i.e., Primaria, Secundaria, Preparatoria, Universidad) were assessed. Multiple aspects of acculturation were assessed including *country of origin*, *language preference*, assessed using seven items from the Acculturation Rating Scale for Mexican-Americans-II (ARSMA-II) (Cuéllar et al., 1995), and *length of residence* in the U.S.

Analysis

Injury incidence statistics were calculated using the Bureau of Labor Statistics incidence rate calculator and comparison tool (see http://data.bls.gov/iirc/). Univariate statistics including percentages and means and standard deviations were calculated to describe the organization of construction work. Comparisons of work organization factors among framers, roofers and general construction workers were evaluated using chi-square or F-test statistics for work organization factors with discrete and continuous distributions, respectively. A series of logistic regression models were fit to explore the prospective bivariate association of each work organization factor, assessed during the baseline interview, with work injury assessed at the follow-up interview. Each bivariate model was then expanded to control for worker type and total work exposure during the observation period. All analyses were performed using SAS v9.2 (SAS Institute, Cary, NC), and used a Type I error rate of 0.05.

Results

Participants were, on average, 31.7 years of age (SD=7.6), and most had little formal education; 37.4% (n=40) of the sample reported a primary education or less (equivalent to 6^{th} grade in the US) while 42% (n=45) reported having up to a secondary education (equivalent to 9^{th} grade in the US). On average, participants had been in the US for 9.7 years (SD=6.0), and Spanish was the dominant language for nearly all participants (n=100, 93.5%). Nearly one-quarter of the sample (22.4%) reported having completed an apprenticeship. Most workers (n=73, 68.2%) indicated that the statement "I have worked for the same contractor or subcontractor for 3 months or longer" best characterized their connection with the construction industry, while a sizeable minority (n=29, 27.1%) indicated that that the statement "I have worked for several contractors or subcontractors during the past 3 months" described their recent construction work experiences. At the baseline survey participants worked an average of 38.3 weeks (SD=16.9) in construction in the previous year, and an average of 42 hours per week (SD=8.6). Participants reported working, on average, 7.7 weeks (SD=3.3) of the 12 week period preceding the follow-up interviews, and typically working 34.2 hours per week (SD=12.7) during that period.

A total of 28 participants reported one or more work-related injuries during the observation period prior to the follow-up interview. The total number of hours worked by participants in the sample during the three month observation period was 26,492. The annualized total work hours would be 105,968 hours (26,492 X 4), resulting in an injury rate of 52.8 per 100 FTE. Injuries included broken or fractured bone (n=4), dislocation (n=3), sprain or strain (n=7), flame or chemical burn (n=1), as well as cuts or lacerations, and bruises or contusions. Two of the reported injuries involved two or more days away from work, resulting in a 3.8 injuries involving days away from work per 100 FTE. Injury risk among Latino residential construction workers did not differ by age, years in the US, educational attainment or country of origin (Table 1). However, injuries were more frequent among roofers than framers or general laborers, and trend-level evidence ($p < .10$) suggests that the absence of an apprenticeship may increase the risk for injury.

Several indicators of work organization differed by construction trade (Table 2). In terms of job structure, long work hours were reported least frequently by roofers and most frequently by framers. Precarious employment did not differ by trade. Turning to indicators of job design, skill variety and control were lowest among roofers and highest among general construction workers. Psychological demand was higher among general construction laborers, but differences were not statistically significant. Perceived hazards were highest among roofers and lowest among framers. In terms of supervisory practices, framers had the strongest beliefs of their supervisors' ability to influence their job opportunities, while general construction laborers had the strongest beliefs that supervisors would engage in retaliatory practices on the job site. There were no differences by trade in difficulties communicating with supervisors. Appraisals of the safety climate were poorest among roofers relative to frames and general construction workers.

Simple bivariate analyses indicated little evidence that work organization factors were associated with injury risk (Table 3). Greater perceived exposure to hazards was associated with greater injury risk (OR=1.10). After adjustment for worker type and variation in total exposure to construction during the observation period, two work organization factors were associated with greater injury risk. For every unit increase in psychological demand the odds of experiencing an injury increased by 4%. Similarly, for every unit increase in perceived hazards the odds of experiencing an injury increased by 12%.

Discussion

The goal of this study was to determine the potential health threat of work organization to immigrant Latino workers in the residential construction industry. While an understanding of how work organization contributes to occupational health within the construction industry is important onto itself (Murie, 2007; Schulte, 2006), a specific study of immigrant Latino's experiences in the industry is important because it offers insight into potential sources of occupational health disparities: evidence indicates that fatalities, injury, and illness within the construction industry are disproportionately borne by Latino workers (Dong et al., 2004; 2010). Several strands of evidence from this study suggest that work organization poses real threats to immigrant Latino worker health and safety.

Injury rates in this sample were substantial and elevated in contrast to previous reports. The estimated incidence of work-related injury observed in this sample was 52.8/100 FTE. Published injury incidence for construction is 4.2 injuries per 100 workers (BLS, 2010). Dong and colleagues (2010) reported rates of 100 to 150 injuries per 10,000 Latino workers between

2002 and 2008. Although it is widely accepted that injury rates among construction workers are likely underestimated, especially among immigrant workers (Azaroff et al., 2002; Dong et al., 2011; Schoenfisch et al., 2010), the scope of underestimation has been unknown. Our observed rate suggests a 12-fold underestimation. If estimates are limited to "major" injuries such as broken or fractured bones, dislocations and burns only, the observed injury incidence is 33.9 injuries per 100 workers: an eight-fold increase over published rates.

A unique contribution of this study is the description of several work organization factors among Latino residential construction workers. Although there is little comparative data, the overall pattern of results from this study is that the organization of construction work is relatively benign: there are few points of overt problems but there are also no points to suggest construction jobs occupied by immigrant Latinos are designed to protect much less promote worker health. For example, over 20% of workers in this sample typically worked 45 or more hours per week, and over one-quarter of the sample (27.1%) were classified as having "precarious" employment, both of which have been linked to poor occupational health outcomes (Dong, 2005; Goldenhar et al., 2003; Quinlan et al., 2001), although only long work hours has been examined in the context of construction. On the more positive side, average "variety" scores were above the midpoint of the possible range of scores suggesting that Latino construction workers are engaging in a relatively diverse set of work-related activities and are avoiding repetitive and potentially monotonous tasks. Further several variables reflecting both job design (e.g., "psychological demand" and "hazards") and supervisory practices (e.g., powerful influence, retaliatory supervision, safety climate) had average scores located at the midpoint of the possible range. Thus, while there were few areas with clear problems, there was also substantial room for improvement.

The organization of construction work systematically differs across the trades. In terms of job design characteristics, roofers reported the lowest skill variety, the lowest level of control, and the highest exposure to hazards among the trades studied. Roofers also reported the lowest average safety climate scores. However, roofers were less involved in long work hours, and they reported more favorable supervisory practices, including the lowest average powerful influence and retaliatory supervision scores. Nevertheless, consistent with previous research (Dong et al., 2010), injuries were elevated among Latino roofers relative to Latino framers or general construction laborers. Although there was little evidence in this small sample that work organization factors robustly predicted injury, the differential exposure of roofers relative to framers and general laborers to several job design features believed to undermine worker health and safety may play a role in their elevated incidence of injury (Dong et al., 2010). This is a ripe area for future research, especially given the suggestive evidence that greater psychological demands and perceived hazards may increase injury risk.

The contributions of this study must be considered in light of its limitations. First, the generalizability of study findings is unknown because the sample was small, regional, and recruited using non-probability methods. Next, the incidence of work injuries involving time away from work should be interpreted with caution because the measure used to capture work-loss time did not differentiate whether the amount of time before returning to work rested solely on the injury, the day of the week the injury occurred, or both. If a worker who typically works Monday thru Friday experienced an injury on Friday, and reported not returning to work until the second day after the injury (or later), it is possible that there was no lost work time. Finally, there was no non-Latino comparison group so it is not clear if the experiences observed in this study are specific to Latinos in residential construction, or whether they reflect experiences of workers in this subsector more broadly. Future comparative research is needed to determine if the experiences of Latino workers in the subsector differ from other workers in the subsector.

Limitations notwithstanding, this study also has several strengths and it makes several contributions to the construction safety and health literature. A key strength is the prospective design of the study with the relatively short look-back period for reporting injury incidence which offers insight into the relative magnitude of injury under-reporting among immigrant Latino workers. This is one of the first studies to describe the organization of construction work as it is experienced by immigrant Latinos. Although there were few glaring problems, it was also imminently clear that there is room for improvement. Latino residential construction workers have little variety in their jobs, little control over their work arrangements, and the safety climate on most construction sites is (at best) moderate. Collectively the results suggest that work organization may contribute to elevated rates of nonfatal occupational injury among immigrant Latino residential construction workers. Although more research with larger probability sampling methods is needed, improving work organization may be essential to reducing occupational health disparities experienced by immigrant workers.

Table 1. Incidence of work-related injury in the past 3 months by personal characteristics.

	Injured while Working (n=28)	p-value†
Age		0.6274
< 35 years	17	
≥ 35 years	11	
Years in the US		0.4663
<10 years	15	
≥ 10 years	13	
Educational Attainment		0.3016
< Secondary (9th grade)	17	
≥ Secondary	11	
Country of Origin		0.6360
Mexico	20	
Other	8	
Worker Type		0.0187
Framer	7	
Roofer	13	
General Labor	8	
Apprenticeship		0.1042
No	19	
Yes	8	

†p-value obtained using Chi-Square test

Table 2. The organization of work among Latino residential construction workers in eastern NC.

	Sample		Worker Type Framer		Roofer		General Laborer	
Job Structure								
	N (%)	M (SD)	N(%)	M (SD)	N (%)	M (SD)	N (%)	M (SD)
Long work hours†*								
Yes	25 (21.2)		10 (8.5)		6 (5.1)		9 (7.6)	
No	93 (78.8)		16 (13.6)		28 (23.7)		49 (41.5)	
Precarious†								
Yes	31 (26.1)		9 (7.6)		8 (6.7)		14 (11.8)	
No	88 (74.0)		17 (14.3)		27 (22.7)		44 (37.0)	
Job Design								
Skill variety‡**		8.4 (2.3)		8.7 (2.1)		7.4 (1.8)		8.8(2.6)
Control‡*		6.2 (3.5)		5.5 (3.2)		5.3 (3.2)		7.1 (3.6)
Psychological demand‡		9.8 (3.1)		9.1 (2.4)		9.5 (3.4)		10.3 (3.2)
Hazards‡*		17.2 (5.1)		16.1 (5.0)		19.2 (5.1)		16.6 (4.9)
Supervisory Practices								
Powerful influence‡***		10.4 (3.2)		12.2 (3.1)		9.1 (3.5)		10.3 (2.7)
Retaliatory supervision‡*		6.9 (2.0)		6.7 (1.6)		6.3 (2.2)		7.3 (2.0)
Inability to Communicate†								
Yes	25 (21.0)		5 (4.2)		6 (5.0)		14 (11.8)	
No	94 (79.0)		21 (17.7)		29 (24.4)		44 (37.0)	
Safety Climate‡***		23.0 (5.3)		24.3 (4.8)		19.9 (5.6)		24.3 (4.7)

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$ (two-tailed)

†p-values obtained using a Chi Square test. ‡p-values obtained using a one-way ANOVA across worker type groups.

Table 3. Work organization and its implications for work-related injury among Latino residential construction workers eastern NC.

	Simple* OR (95% CI)	Adjusted† OR (95% CI)
Job Structure		
Long work hours (Yes vs. No)	1.52 (0.51,4.56)	1.46 (0.39,5.43)
Precarious (Yes vs. No)	0.81 (0.29,2.27)	1.12 (0.36,3.52)
Job Design		
Skill variety	1.01 (0.84,1.22)	1.09 (0.87,1.36)
Control	1.00 (0.88,1.13)	1.07 (0.93,1.24)
Psychological demand	1.01 (0.88,1.16)	1.04 (1.00,1.22)
Hazards	1.10 (1.00,1.21)	1.12 (1.00,1.25)
Supervisory Practices		
Powerful influence	0.98 (0.85,1.13)	0.99 (0.84,1.17)
Retaliatory supervision	0.90 (0.72,1.12)	0.96 (0.75,1.22)
Inability to communicate (Yes vs. No)	0.53 (0.16,1.71)	0.56 (0.16,1.93)
Safety Climate	0.95 (0.88,1.03)	0.97 (0.88,1.07)

*bivariate model with no adjustment

† model adjusts for worker type and differential exposure to construction work between baseline and 3 month follow up interviews

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Rooftop Vegetation: An Opportunity to Influence Green Buildings via Prevention through Design

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Abstract:

Vegetated roofs are becoming increasingly popular in the United States due to their environmental benefits and their ability to earn credits in the green building certification process. With the exception of one international guideline, we find little mention of safety and health in green roofs codes and literature. Field investigations of nineteen vegetated roofs in the United States revealed unsafe access for workers and equipment, a lack of fall protection measures, and other site specific hazards. Prevention through Design strategies and the integration of life cycle safety thinking with green building credits systems are seen as methods to reduce risk to workers on vegetated roofs. Additionally, and more importantly for the larger safe green jobs initiative, safe designed vegetated roofs serve as a means to demonstrate the synergies between green building elements and worker safety that can serve as a foundation for future integration. On-going research and recommendations for future research are described.

Keywords: Safe design, vegetated roof, green roof.

1. Introduction

Vegetated roofs are recognized by urban planners as an advantageous technique for providing thermal insulation, reducing the urban heat island effect, improving storm water retention, increasing natural habitat, enhancing air quality, and providing an aesthetically pleasing environment for building occupants. The use of these architectural techniques presents potential hazards to workers involved in installation and maintenance. The hazards are not new, but there is an increased frequency of roof access required to maintain vegetated roofs compared to a conventional roof. Moreover, the integration of worker safety into green building features complements a recent National Institute for Occupational Safety and Health (NIOSH) Safe Green Jobs campaign (Schulte et al, 2010). The green movement is an entry point for new sustainable ideas (including worker safety) which can trickle down to all industries or become standard practice as has been seen by many green ideas. Green and sustainable construction practices do not currently include safe design as a method to enhance the safety record of an industry that employs 7% of the United States' workforce but yet accounts for close to 20% of its fatalities.

This paper proposes that worker safety on vegetated roofs can be enhanced through Prevention through Design (PtD) techniques and offers suggestions for further research. This conference proceeding reports on 1) a search for safety and health issues associated with vegetated roofing, 2) a review of green roof codes for safe design specifications, and 3) field investigations of nineteen vegetated roof projects and the observed safety issues that could be eliminated or reduced through PtD suggestions.

The growing interest in the use of vegetated roofs means that their design and maintenance have to be investigated more thoroughly in order to determine the sustainability of such systems (Emilsson et al, 2007). Dvorak and Volder (2010) concluded that as North American green roofs continue to become regulated and adopted in policy, further development of standards and guidelines are needed. Worker safety can continue to be an afterthought or the design community can embrace best practices, such as PtD, to be incorporated into these new ideas, guidelines, and standards. This paper will add to the body of knowledge by documenting what is known about the safe design of vegetated roofs in order to make recommendations for future guidance, research, and application.

2. Literature Review

A comprehensive literature review was completed to determine if any research or guidance exists regarding worker safety and health on vegetated roofs. We did not find any peer-reviewed archival literature that mentioned worker safety and health in articles about green or vegetated roofs. However, we found one magazine article. *Turf Magazine* provided an overview of safety issues for vegetated roof maintenance. In this article, Mulhern (2008) reports that her review of numerous articles and Web sites on green roofs reveals little or no mention of safety issues. The article identifies falls, material access, and planning for emergencies as the major potential safety issue.

Vegetated roofs are becoming increasingly popular in the United States for their environmental benefits and their ability to earn credits in the green building certification process. Additionally, municipalities are providing tax incentives to encourage vegetated roof installation and passing regulations that require government buildings to provide vegetated roofs. Vegetated roofs can directly provide building owners with numerous LEED credits in the sub-categories of reduced site disturbance, site development, stormwater design, water efficient landscaping, heat island effect, and innovative design (Luckett, 2009; Carter and Fowler, 2008). Additionally, vegetated roofs may count for up to 15 points under the LEED system depending upon how well the roof is integrated into other building systems (Kula 2005).

To be precise in terminology and avoid confusion for the scope of this proceeding paper, the term “vegetative roof” rather than “green roof” will be used when specifically referencing the author’s ideas and work. While the two are utilized interchangeable within the peer-reviewed archival literature in meaning plants on roofs, the term “green roof" has been utilized to include all roofs with environmentally friendly features such as solar panels, reflective properties, wind turbines, vegetated roofs or other green technologies. Therefore a vegetated system is not the only option worthy of the green roof designation. Moreover, according to Cavanaugh (2008) a definition of "green" is one that considers the sustainable qualities of a roof rather than the nature of its particular components. The terms "eco-roof" and "living roof" are also frequently used to describe roofs with vegetation. However, our review of the peer-reviewed literature finds these terms used less than green or vegetated roof. Berndtsson (2010) commented that there seems to be no consistency in the use of the terminology and the different terms are often used interchangeably.

3. Methods

The objectives of the research were to 1) search for documented safety and health issues associated with vegetated roofing, 2) learn about incorporation of worker safety into green roofs guidelines, and 3) to investigate design practices by visiting vegetated roofs. In addition to the literature review, we searched world and local newspapers via LexisNexis Academic Search for reports of falls, injuries, and deaths from vegetated, green, and eco-roofs. Falls would be the source of the most severe injuries and thus, if any were reported, we believed this type of safety issue would be reported in the newspapers. Additionally, we searched the internet using Google for the same. A green roof textbook author was contacted and his ideas solicited on safety issues. The author joined three green roof social networking sites to discuss the topic of vegetated roof safe design; two were green roof networks on LinkedIn and third was the Green Roof Think Tank, a Portland, OR based networking site. At the time of the social networking postings, the Singapore guidelines were located via a Google search and purchased. The following description and request was posted on all three sites.

> "I have a small grant to study green roofs from a worker safety standpoint. I am trying to learn more about hazards and risks to roofers and landscapers which could be eliminated or reduced through better design practices and work planning. Specifically I'd like to know two things from the group:
>
> 1. If you know of any landscapers or maintenance workers that have died or been seriously injured while working on a green roof.
> 2. If there are any guidelines for the safety design and maintenance of green roofs. I have a guide from Singapore, CS E 02:2010 Design for Safety for Rooftop Greenery, but this is the only one I could find."

For the site visits, all roofs were a convenient sample. Nineteen vegetated roofs were visited in Portland (n=9), Chicago (n=5), and the U.S. mid-Atlantic (n=5). A contact at the United Union of Roofers, Waterproofers and Allied Workers in Washington D.C. recommended visiting Chicago and Portland because green roofs are increasing in popularity due to city tax incentives for green construction and roofs in particular. A contact with the local roofers union in Chicago arranged site visits. In Portland, a contact with a large construction company provided the names of a roofing company, landscape architects, landscapers, and a large developer. In the mid-Atlantic, a contact at a university allowed four roof visits, and one other visit was to a green roof that was available to be viewed from public areas. Roofs were evaluated for safe design including: safe access, roof edge protection, proximity to hazardous machinery and skylights, and other hazards unique to the work (i.e., proper water access for vegetation). Discussions with landscape architects, roofers, and landscapers provided additional insight. The author's university Institutional Review Board determined the research protocol to meet exempt certification requirements.

4. Results

Web-based Searches

There were issues with the combined search of safety and vegetated roof terminology in the newspapers. Fall or Autumn, is a season marking the transition from summer to winter. We found no "fall to lower level" type safety issues in newspaper articles; however, we located several hundred discussing the "Fall" seasonal description with regards to vegetated roofs. We also found no safety related articles while using the word "death". Rather, we found approximately 50 articles describing the death of the vegetated roof for a variety of reasons which required re-planting, removal, or the complaints about misuse of funds for such projects. We found one newspaper article highlighting labor concerns that mentioned that the worker's harnesses "were not attached to anything" (Simmons, 2009). In summary, we could not find any evidence that any serious injuries or deaths have occurred from vegetated roof installation or maintenance.

Social Networking Results

We received twelve total comments on the social networking sites. Five of the respondents referred the author to guidelines from Germany and three referred the author to guidelines from Green Roofs for Healthy Cities (GRHC). Two mentioned OSHA standards. None of the respondents mentioned that they knew of any serious injuries or worker deaths from installation or maintenance on vegetated roofs.

Vegetated Roof Guidelines

The Landscape Development and Landscaping Research Society in Germany, translated as Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau or (FLL), is frequently mentioned in numerous peer-reviewed articles and in discussions the author has had with industry experts. Dvorak and Volder (2010) provided a recent background of the existing guidelines for the vegetated roof industry and described FLL as a recognized source of authority regarding the design, construction and maintenance of green roofs in Europe and throughout the world. The FLL's Guidelines for the Planning, Construction and Maintenance of Green Roofing provide guidance on fall protection, determining design loads, and fire characteristics. Fall prevention during the planning and tendering stages is mentioned. Fall protection and prevention measures from the edge and through building components such as skylights are mentioned. The guidance is written based on the philosophy found in the European Directive 92/57/EEC of 24 June 1992 on the Implementation of minimum Safety & Health Requirements at Temporary or Mobile Construction Sites in that the responsibility of the protective measures lie with the client and their appointed safety coordinator. However, unlike the Directive, design phase modifications to include or facilitate fall protection measures are not mentioned. The FLL guidelines are focused on downstream safety measures.

Green Roofs for Healthy Cities' mission is to increase the awareness of the economic, social and environmental benefits of green roofs and green walls, and other forms of living architecture through education, advocacy, professional development and celebrations of excellence (GRHC, 2011). They are a not for profit group based in Toronto. Three respondents from the social networking site mentioned this organization as one to explore for guidelines that might include worker safety. We emailed the education director at GRHC twice inquiring about the integration of safety into their guidelines and training programs, but did not receive a response. An owner of a green roof installation company who had gone through the GRHC training mentioned that they did discuss OSHA standards for fall protection in the introductory course.

The Association of Standards and Testing Materials (ASTM) develops and publishes numerous green roof standards including one for determining the dead load of green roof systems. There were no specific mentioning of worker safety considerations (falls, access, etc.) in the summary and outline of the ASTM standards. The American National Standards Institute (ANSI), in cooperation with Green Roofs for Healthy Cities, wrote and published the standard, External Fire Design Standard for Vegetative Roofs in 2010. The National Association of Fire Marshalls created an entire website devoted to fire safety and green buildings, and it includes a vegetated roof section. See http://greenbuildingfiresafety.org/index.html.

The Singapore Center for Urban Greenery & Ecology's (CUGE) Design for Safety for Rooftop Greenery provided the only recommended guidelines for worker safety and its focus was on design. According to Singapore's Workplace Safety and Health Act, similar to safe design legislation in Europe and Australia, the person who creates the risk is responsible for mitigation (Workplace Safety and Health Council, 2008). In specifying the design of a building or structure, the designer should understand how the building or structure can be constructed, cleaned, maintained, and decommissioned or demolished safely (Workplace Safety and Health Council, 2008). Therefore, the designer must study and evaluate the risks to those carrying out the proposed works and others affected by it, such as the public or people using the building or structure in the future. The CUGE standard defines for rooftop greenery in the design, installation, and maintenance phases. The design phase considerations include:

1. Building Considerations. The building's established load bearing capacity; greenery on sloped roofs; protection from falling; roof penetrations (skylights); access; fire safety; working at height; and lightning protection.
2. Service Considerations. Appropriate facilities for washing / potable water; storage provisions; and taking onto account mechanical and electrical systems on the roof in relation to the vegetation.
3. Health Conditions. Reducing the use of hazardous materials; reducing noise through scheduling; and mosquito control.
4. Plant considerations. Plant selection; plant maintenance' proper tree anchorage and maintenance; height control and health of trees; and provisions for tree removal.
5. Work scheduling considerations. Features to reduce the risk of falling; prevention equipment falling from height; design to simply construction; and the use of crane and aerial platforms.

Site Visits

Fall protection issues were observed on 11 of the 19 roofs visited. See Table 1 below for a summary. Six of the roofs had poor access; two of these roofs are not maintained any more due to unsafe access, and another is maintained sporadically and not as frequently as the building occupants would like. Potentially fragile skylights adjacent to vegetation were observed at 2 roofs. Water access was an issue at four roofs. For example, at one 20' roof with no parapet, no anchorages and poor access through the middle of the building, a spigot was only available at ground level at one side. When the roof is to be watered, a hose will have to be lifted / elevated to the roof and someone will need to be at the roof's edge without fall protection. Understanding the work to be performed in relation to the vegetated roof is of the utmost importance. These issues can be solved by proper building design and planning; Prevention through Design is a preferred solution.

Table 1. Observed Fall Protection Status on Vegetated Roofs

Fall Protection	**Comments**	**Freq.**	**%**
39" Parapet (100%)	Very Good	5	26.3
N/A - roof in usable area	Very Good	2	10.5
Horizontal Lifeline	Good – requires worker understanding	1	5.3
39" Parapet (partial)	Poor – potentially deceptive to worker	2	10.5
Davits available	Poor – these are for window washing and not in readily observable or usable locations	4	21.1
None	Very Poor	5	26.3
Total		19	100.0

5. Discussion

As part of the Prevention through Design (PtD) initiative, the National Institute for Occupational Safety and Health (NIOSH) and its partners are developing a framework to create awareness, provide guidance, and address occupational safety and health issues associated with green jobs and sustainability efforts (NIOSH, 2011). In January 2011 the National Occupational Research Agenda Construction Sector Council created a Green Jobs Coordination Committee, which is co-chaired by the author. The specific aims of the committee are to:

1. Explore and evaluate for practicality the notion of the Leadership in Energy and Environmental Design (LEED) pilot credit initiative for integrating worker safety and health into green building (e.g., two credits for ergonomics).
2. Explore and evaluate for practicality the notion of LEED innovation credits, and how they can be amended to integrate worker safety and health to improve design concepts and address fall prevention when installing roofs (conventional and vegetated), wind turbines, and solar panels, for example.
3. Identify methods for measuring the effects of prevention through design in installation.

The committee is considering the value of both an incremental and a comprehensive approach. A comprehensive approach might look like a separate stand-alone system such as that proposed by Rajendran and Gambatese (2009). An incremental approach would entail the development of new credits or the modification of existing credits to include safety and health considerations across the life cycle. The safe design of vegetated roof systems would be an example of the incremental approach. A separate credit might be considered utilizing safe design criteria as outlined by the CUGE guidelines. Alternatively, safety could be a stipulation for awarding any credit – an unsafe vegetated roof is not green and would therefore not be awarded that LEED credit if certain safe design considerations were disregarded.

Other researchers are also linking potential synergies between safe and green. Silins (2009) examined several green building rating systems, including the United States' Green Building Council's (USGBC) LEED rating systems, to identify areas where and how occupational safety and health are addressed and where they are lacking. Silins (2009) found that none of the rating systems currently include a credit or prerequisite for including a safety plan or program, either during initial construction or renovation, or for the post-occupancy engineering and maintenance workers. At the 2009 W099 CIB, a paper provided an argument and a rationale that for green buildings to be considered sustainable, safety and health concepts must be integrated into upstream considerations (Behm et al, 2009). The authors suggested that if construction worker safety and health is not part of the green and sustainable arrangement, any additional improvements in construction safety and health would certainly lag behind environmental improvements. Without integration, green and sustainable buildings will continue to be built by a process that employs 8% of the U.S. workforce yet experiences over 20% of its deaths (Behm et al, 2009).

6. Recommendations and Future Research

This research is the first of its kind in an effort to associate safe design with a specific green building element. This research focused on vegetated roofs because they are becoming popular worldwide and in the United States due to the environmental benefits, green credits, and city tax incentives described earlier. Secondly, vegetated roofs pose a potential increased risk to roofers and landscapers charged with their installation and maintenance. Thirdly, risk countermeasures can be solved with proper prevention through design strategies, such as designing the built environment to ensure safe access, fall protection measures are provided, and considering the relationship of the work to other rooftop hazards. There are several research efforts stemming from this initial work. They include:

1. Specific safe design suggestions for vegetated roofs are being developed from this initial research endeavor. A journal paper is in preparation.
2. Building designers will be surveyed to determine their views on permanent safe design suggestions and how it would affect their work and the building (aesthetics, ease of implementation, cost, value for safety, etc.).
3. The NIOSH Green Jobs Coordination Committee continues to work toward specific goals to develop a strategy and tactics to integrate with LEED and other green systems.
4. The author will be appointed to a 2011 summer research fellowship in Singapore at the CUGE to evaluate the safe design for rooftop greenery strategies and their effect on building design and life cycle safety. Additionally, vertical greenery systems (green walls) will be examined.

7. Acknowledgement

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The Influence of Project Personnel's Emotional Intelligence, Interpersonal Skill, and Transformational Leadership on Construction Safety Climate Development

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The Influence of Project Personnel's Emotional Intelligence, Interpersonal Skill, and Transformational Leadership on Construction Safety Climate Development

Abstract:

Project personnel play an important role in construction safety management which requires them to have relevant capabilities. Research has shown that emotional intelligence, interpersonal skill, and transformational leadership are competences that generate superior performance in today's workplace. The aim of this research is to investigate the influence of project personnel's emotional intelligence, interpersonal skill, and transformational leadership on the implementation of safety management tasks and the development of construction safety climate. Structural equation modelling (SEM) was applied to analyse 273 valid responses collected via an online survey. The results indicate that emotional intelligence is a key factor for developing interpersonal skill and transformational leadership. Emotional intelligence also has positive influence on the implementation of safety management tasks which can lead to the development of construction safety climate. In addition, interpersonal skill is crucial to develop transformational leadership, which in turn, contributes to the development of construction safety climate. The implication of this research is that in order to improve safety performance, construction companies should consider the relationships among various aspects discussed in this research and incorporate them into their human resource development program.

Keywords: construction safety climate; emotional intelligence; interpersonal skill; safety management tasks; transformational leadership

1. Introduction

Statistics show that safety performance (based on numbers of accidents and fatalities) in the construction industry has remained roughly the same since the early 1990s (Holt, 2005; López et al., 2008). Modern technology, automation, and safety management system are not enough to further improve safety performance. Reason (1990) argued that safety improvement can only be achieved through an attention to human error mechanism. This human factor is particularly important in the construction industry due to its labour-intensive characteristic (Lingard and Rowlinson, 2005). Consequently, safety research and safety management implementation need to focus on the human side of safety to promote further safety improvement (Sunindijo and Zou, 2009).

Project personnel play an important role in construction safety management. They are responsible to perform certain safety management tasks to lead safety implementation in their projects (Dingsdag et al., 2006). Sunindijo and Zou (2009) suggested that performing these safety management tasks proficiently is crucial for developing construction safety climate. This role of project personnel in performing safety management tasks and developing construction safety climate, has not been investigated. Therefore, the research aims to fill this research gap.

Project personnel need to have capabilities to meet their responsibilities. Research has shown that emotional intelligence, interpersonal skill, and transformational leadership are essential in today's workplaces (Bass and Riggio, 2006; Goleman, 1998; Goleman, 2001; Janasz et al., 2006; Robbins et al., 2009; Robbins and Hunsaker, 2009; Strohmeier, 1992). Emotional intelligence is "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". It has been closely associated to superior performance (Goleman, 1998, p.317), thus it is argued that emotional intelligence should also influence the efficacy of project personnel in performing their safety management tasks. Furthermore, many of the safety management tasks require project personnel to work with others. Therefore, project personnel need interpersonal skill to interact effectively during the implementation of safety management tasks (Strohmeier, 1992). Lastly, project personnel also have a safety leadership role in implementing safety management tasks and developing construction safety climate (Dingsdag et al., 2006; Sunindijo and Zou, 2009). Transformational leadership is widely considered as a leadership style that produces higher levels of employees' effort and performance than the traditional leadership styles (Robbins et al., 2009).

To sum up, the objectives of this research are twofold. First, the influence of emotional intelligence, interpersonal skill, and transformational leadership on the implementation of safety management tasks and the level of construction safety climate is explored. The second objective is to reveal the interrelationships between emotional intelligence, interpersonal skill, and transformational leadership, which can serve as guideline or an approach for improving project personnel's capabilities.

2. Research model and hypotheses

Safety climate is "shared employee perceptions of how safety management is being operationalised in the workplace, at a particular moment in time" (Cooper and Phillips, 2004, p. 497). Safety climate was chosen as an indicator of safety performance in this research because of its many advantages: (1) it is a leading indicator that can identify safety problems before they manifest into accidents and injuries, (2) it provides a mechanism to optimise investment on safety-related improvements, (3) it serves as a valuable tool to identify safety trends and establish benchmarks, (4) a safety climate survey costs less money and time to be carried out, (5) it involves employees in the process, which helps identify key issues that need to be addressed, and (6) many studies have revealed the importance of safety climate in predicting or measuring safety-related outcomes (Davies et al. 2001; Glendon and Litherland, 2001; Seo et al. 2004).

Top management should be the first one who initiates safety implementation and develop safety climate in the organisation. However, top management should not be the only one responsible for safety. Every employee must participate and be accountable. The commitment of top management is obviously critical, but commitment alone is insufficient. There must be some clear processes or tasks to implement safety and develop safety climate. Dingsdag et al. (2006) have identified 39 safety management tasks that project personnel should perform for this purpose. A safety management task is a definable activity, action, or process that project personnel need to perform to provide safety leadership. In other words, these tasks are what project personnel should do to lead safety implementation and promote the development of construction safety climate in their project.

As stated earlier, emotional intelligence, interpersonal skill, and transformational leadership have been considered as essential capabilities in today's workplaces. Therefore, this research investigates their roles on implementation of safety management tasks and development of construction safety climate. The research model, as illustrated in Figure 1, integrates all the aspects discussed here. Emotional intelligence is the initiator signifying that project personnel should start inwardly by understanding and managing emotions (both self and others). Then emotional intelligence is manifested in effective interactions through the application of interpersonal skill. By means of effective interactions, project personnel can become transformational leaders who generate superior performance from their teams (Goleman, 1998; Robbins and Hunsaker, 2009; Sunindijo et al., 2007). It is argued that the three capabilities are required by project personnel to perform well during the implementation of safety management tasks. Finally, successful implementation of safety management tasks leads to the development of construction safety climate which serves as the safety goal in this research. Based on this research model, seven hypotheses were formulated as follow:

Hypothesis 1: The higher the emotional intelligence, the higher the interpersonal skill.
Hypothesis 2: The higher the interpersonal skill, the higher the transformational leadership.
Hypothesis 3: The higher the emotional intelligence, the higher the transformational leadership.
Hypothesis 4: Emotional intelligence has positive influence on the implementation of safety management tasks.
Hypothesis 5: Interpersonal skill positively affects the implementation of safety management tasks.
Hypothesis 6: The higher the transformational leadership, the higher the implementation of safety management tasks.
Hypothesis 7: Implementation of safety management tasks influences the development of construction safety climate.

3. Research Methods

A quantitative research method was chosen to test the hypotheses because the main aim of the research is theory testing which involves determining the degree of relationships among measured variables. Since a large sample of quantitative data is required to test the theory, questionnaire survey is the most appropriate data collection method to achieve this purpose. Furthermore, questionnaire survey is easy to be conducted, inexpensive, and suitable for measuring unobservable constructs (Tharenou et al., 2007).

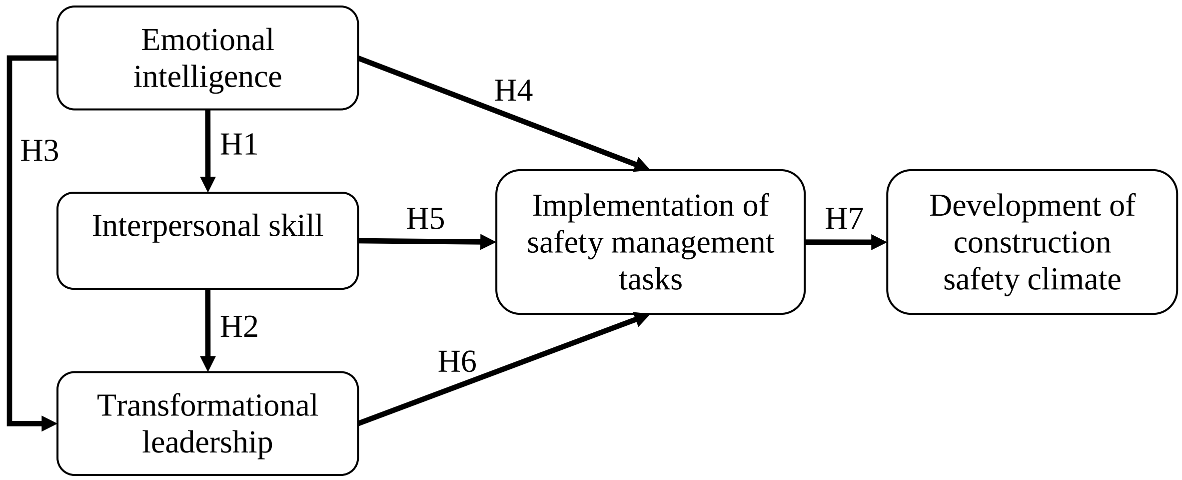

Figure 1 Theoretical research model

The questionnaire for this research was divided into five sections. The first section is the 28-item Emotional Intelligence Appraisal which has been validated across various industries and job positions. It was designed to assess four dimensions of emotional intelligence, namely, self-awareness, self-management, social awareness, and relationship management (Bradberry and Greaves, 2001-2010). The second section assesses the interpersonal skill of project personnel, particularly their communication, motivation, conflict resolution, and teamwork development competencies. It contains 15 items and was developed based on previous studies (Carlopio and Andrewartha, 2008; Culp and Smith, 1992; Robbins et al., 2009; Strohmeier, 1992). The third section is the Global Transformational Leadership (GTL) scale, which contains seven items. The GTL has been tested in Australia with satisfactory reliability and validity to measure transformational leadership (Carless et al., 2000).

The fourth section assesses the level of implementation of safety management tasks. It was developed based on 39 safety management tasks identified by Dingsdag et al. (2006). The fifth section for assessing construction safety climate was developed based on the review of several previous safety climate studies (Brown and Holmes, 1986; Cox and Cheyne, 2000; Dedobbeleer and Béland, 1991; Glendon and Litherland, 2001; Lin et al., 2008; Mohamed, 2002; Williamson et al., 1997; Zhou et al., 2009; Zohar, 1980; Zohar and Luria, 2005; Zou and Sunindijo, 2010). All questionnaires are self-assessed and use a six-point Likert scale response format for Emotional Intelligence Appraisal and five-point Likert scale response format for other sections.

Data were collected using a web-based survey from construction companies. Prior to the distribution of the questionnaires, the researchers met with safety managers of the companies to explain the aims and benefits of the research. Project personnel who were working in construction projects at the time of the survey were invited to respond to the survey. The safety managers provided valuable support by distributing the web survey links to their colleagues and subordinates. In addition, they sent reminders periodically to encourage more responses.

Structural equation modelling (SEM) was the main method applied to test the hypotheses of this research. SEM is suitable because it provides a quantitative test of a theoretical model so that complex relationships among constructs or variables can be understood (Schumacker and Lomax, 2010). AMOS 18 (analysis of moment structures version 18) developed by SPSS Inc. was the SEM software package used in this research.

4. Data Analysis and Discussion

There were 356 respondents participated in the survey in which 273 were valid and analysed further. Various project personnel have participated ranging from safety personnel, site supervisors, engineers, site managers, project managers, and construction managers. The result of the SEM analysis is presented in Figure 2. The probability value of the chi-square test is higher than 0.05 (P=0.260) indicating that the model fits the data. All [unstandardised regression] coefficients are statistically significant providing strong support for the hypothesised model.

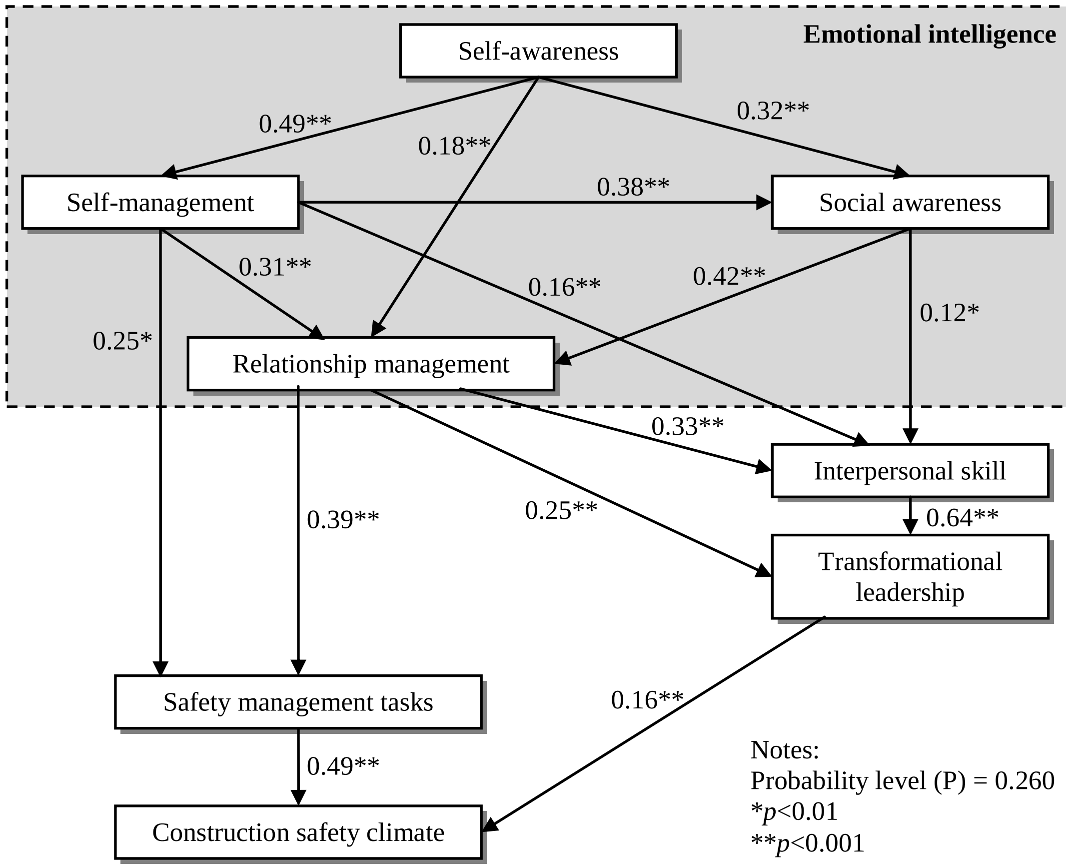

Figure 2: Final model of the SEM analysis

The interrelationships among the four dimensions of emotional intelligence

Self-awareness is a prerequisite of the other three dimensions and also the dimension that starts all relationships in the model. Research showed that people with high self-awareness understand their strengths and limitations, a competency prominent among best performing managers. Self-awareness also makes people search for feedback, learn from their mistakes, and understand when to work with others who have complementary strengths. It often leads to greater understanding of others, thus people high in self-awareness appear trustworthy and perceived as being more competent (Janasz et al., 2006). Furthermore, self-awareness leads to the development of self-confidence, which is a significant predictor of performance (Goleman, 2001). The finding of this research supports a proposition indicating that self-awareness is the core of emotional intelligence (Jordan and Ashkanasy, 2006) as well as a key to succeed and work effectively with others (Janasz et al., 2006).

Self-management is the predictor of social awareness and relationship management. The relationships are obvious since people who cannot control their emotional outbursts will have less chance to be effective in understanding others and developing relationships (Goleman, 2001). At a neurological level, it has been found that self-management is the foundation for social effectiveness (Damasio, 1994). Lastly, social awareness is also a predictor of relationship management. Lane (2000) found that understanding of own emotions and the emotions of others is a way to create effective social interactions. People with high social awareness can understand different points of view, thus they can interact effectively with different types of people. It is easier for them to get along in organisational life, build networks, and employ influence tactics to achieve positive results (Robbins and Hunsaker, 2009).

Emotional intelligence and interpersonal skill

Interpersonal skill refers to the ease and comfort of interactions between project personnel and other project stakeholders. Motivating people, resolving conflicts, communicating effectively, and building teamwork are interpersonal issues that require the attention of project personnel (Strohmeier, 1992; Sunindijo and Zou, 2010a). The model in Figure 2 shows that emotional intelligence, particularly self-management, social awareness, and relationship management, is the prerequisite of effective interpersonal skill.

It is important to be effective self-managers before project personnel can overcome barriers to interpersonal effectiveness and become effective role models. The ability to manage oneself gives project personnel credibility in their interactions with others. This credibility and the capacity to manage emotional outbursts are keys to effective communication, which is a foundation to resolve conflicts and build teamwork (Janasz et al., 2006). Furthermore, self-management is the source of achievement drive (an optimistic striving to improve performance) and initiative (proactive in seizing opportunities and pursuing goals beyond what is required) which are crucial to motivate oneself and others (Goleman, 1998).

A study (Sunindijo et al., 2007) indicated that social awareness is related to sharing and open communication. This sensitivity to others is critical for superior job performance whenever the focus is on interactions with people (Robbins and Hunsaker, 2009). Goleman (2001) suggested that relationship management dimension can be used to develop, coach, mentor, and persuade others to achieve common goals. It is a source of effective communication and conflict management as well as needed in networking, collaboration, and teamwork. People high in relationship management use their understanding of emotions to inspire change and lead people towards something better, to build teamwork, and to resolve conflicts as they arise (Robbins and Hunsaker, 2009). In overall, this finding confirms Hypothesis 1 concerning the positive relationship between emotional intelligence and interpersonal skill.

Emotional intelligence, interpersonal skill, and transformational leadership

Transformational leadership is seen as an effective leadership style by subordinates and superiors. The SEM analysis shows that relationship management and interpersonal skill are the predictors of transformational leadership. The relationship between interpersonal skill and transformational leadership is clear and expected as included in Hypothesis 2. Transformational leaders have to exercise their interpersonal skill to interact effectively with others. There is no leadership without these interactions. Consequently, people need to understand how to communicate, motivate, resolve conflicts, and build teamwork before they can be effective leaders. Goleman (2001) suggested that people high in relationship management can sense people's developmental needs which make them excellent coaches and mentors. They are influential and articulate a shared vision that arouses enthusiasm and inspires others to work together towards common goals. They are also change catalysts which bring greater efforts and better performance from their subordinates. In short, relationship management generates competencies required by transformational leaders. This finding confirms Hypothesis 3 in this research.

Emotional intelligence and safety management tasks

The model also provides support to Hypothesis 4 by indicating that two dimensions of emotional intelligence, i.e., self-management and relationship management, are required to perform safety management tasks. Self-management is a form of self-leadership where people need to influence themselves to achieve their goals (Robbins and Hunsaker, 2009). In practising self-management, project personnel should include safety as one of their values and goals. This will influence project personnel's decisions and behaviour, thus they will be motivated in performing their safety management tasks.

The role of relationship management dimension is also critical in the implementation of safety management tasks. Nearly all safety management tasks require project personnel to develop relationships with other project stakeholders. Consequently, relationship management is needed to connect with others in ways that build positive relationships (Robbins and Hunsaker, 2009), thus project personnel can perform and lead the implementation of safety management tasks effectively.

The model, however, does not support Hypotheses 5 and 6. Interpersonal skill and transformational leadership have no influence on the implementation of safety management tasks. This may be due to the fact that safety management tasks are activities that should be performed by project personnel themselves, thus "internal" capability like emotional intelligence is more important than "external" capability like interpersonal skill and transformational leadership.

Safety management tasks and construction safety climate

The implementation of safety management tasks and transformational leadership are the predictors of construction safety climate. The positive relationship between safety management tasks and construction safety climate was expected and consistent with the theory used to develop the original research model. Accordingly, the result supports Hypothesis 7 in this research and confirms the value of safety management tasks in developing construction safety climate.

Transformational leadership is required to develop construction safety climate because it helps build commitment towards safety. Project personnel should become role models to build this safety commitment. They need to inspire others by articulating a clear vision and showing the moral values involved in safety implementation, thus increasing the intrinsic value of achieving safety goals. This charismatic approach should be supported by necessary training and mentoring to provide others with a sense of increased competence to carry out safety duties. This creates more satisfied followers, while simultaneously promotes positive perceptions and attitudes towards safety which basically refer to construction safety climate (Bass and Riggio, 2006).

5. Conclusions

The results of this research indicate that project personnel can use emotional intelligence, interpersonal skill, and transformational leadership, to implement safety management tasks and develop construction safety climate. Emotional intelligence, particularly self-awareness, is a core factor that contributes to improvement of individual performance and development of effective relationships with others. Project personnel can manifest their emotional intelligence in their interpersonal relationships through exercising their interpersonal skill, such as communicating effectively, motivating others, resolving conflicts, and building teamwork. Effective interpersonal relationships are needed for project personnel to become transformational leaders who inspire their teams to generate superior performance. This development process leads to effective implementation of safety management tasks which will promote positive construction safety climate.

Construction companies should recognise the role of these capabilities in construction safety by providing relevant training and development strategies for their project personnel. They can integrate emotional intelligence measurement in their recruitment procedures to employ the right individuals that can contribute to safety improvement and organisational success in general. Interpersonal skill and leadership development are other aspects that may require more attention, especially concerning their potential influence on construction safety. Safety management tasks should also be enforced in every construction company to promote construction safety climate development and safety performance improvement.

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A Socio-Technical Systems Analysis of OSH Decision-Making in the Early Stages of Construction Projects.

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A Socio-Technical Systems Analysis of OSH Decision-making in the Early Stages of Construction Projects

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Abstract

The opportunity to improve the occupational safety and health of construction workers through decisions made upstream of the construction stage is understood to be significant. As a result, policy makers and OSH advisors advocate measures to integrate OSH considerations into the pre-construction activities of planning and design in construction projects. However, OSH guidelines often assume a degree of simplicity in the way that they ascribe responsibility for clients, designers and other stakeholders. This paper explores the ways in which construction projects comprise a complex network of tasks, requiring contributions from many specialists and the involvement of a complicated 'web' of inter-organizational relationships. The paper describes a socio-technical modelling approach that is being used to examine how decisions affecting OSH in the construction stage of projects are made during the planning and design stages. The research will test the oft-cited propositions that the earlier OSH is considered in the life of a project, the greater the opportunity to eliminate/reduce OSH risk at source. The modelling method is illustrated using data collected at a pilot study construction project in Melbourne. Australia.

Keywords: socio-technical systems, occupational safety and health, design, procurement, planning, construction project management

1. Introduction

Poor OSH performance of the construction industry

Internationally the construction industry generally performs poorly in terms of occupational safety and health (OSH). However, the OSH performance of the construction industry varies substantially from country to country. International comparative figures produced by the International Labour Organization suggest that the OSH performance of the US construction industry is notably poorer than that of Australia. For example, the ILO LABORSTA database reports a fatality rate of 4.4 per 100,000 workers for the construction industry in Australia in 2008, compared to a rate of 10.0 for the USA in the same year (See Figure 1). Given these differences, it is useful to undertake cross-national research to understand differences in OSH management practice and performance and to enable international benchmarking of OSH for adoption or adaptation of best practices.

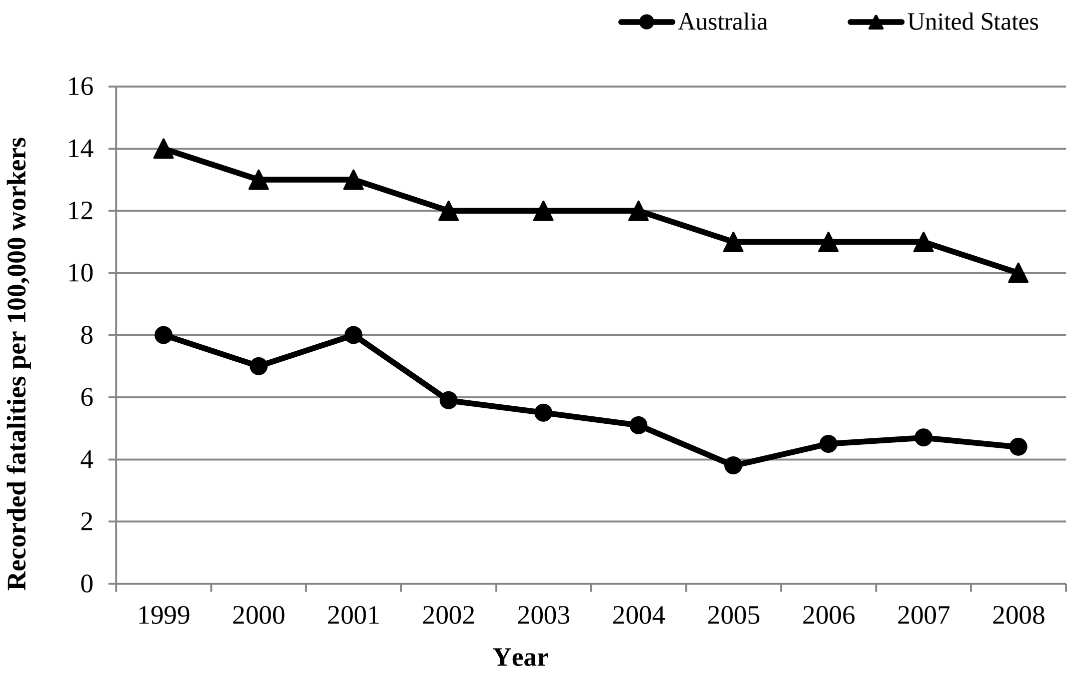


***Figure 1**: Fatality Rates for USA and Australia*

Aim

This paper reports on collaborative research that is being undertaken by researchers in Australia and the USA. The research aims to identify critical socio-technical determinants of project OSH performance in construction projects in both the USA and Australia. Specifically, stage one of the research is mapping, analysing, and modelling the sociotechnical roles, relationships, interactions, and interdependencies occurring during the pre-construction stages of construction projects that subsequently impact on OSH outcomes during the construction stage. The research seeks to empirically test the oft-cited (but as yet untested) propositions that:

(1) The earlier OSH is integrated into project decision making, the greater the realization of hazard elimination/risk reduction at source;
(2) A failure to consider OSH in ‘upstream’ project decision making will create the conditions in which hazard-producing decisions are more likely to be made; and
(3) ‘Higher order’ OSH risk controls (i.e., hazard elimination and engineering solutions) are associated with greater concentration of OSH information exchange and stakeholder interaction early in the project process (i.e., in the planning and design stages).

This paper describes the methods being used to analyse construction projects as complex socio-technical systems to gain a better understanding of how decisions made in the early stages of construction projects impact upon project OSH outcomes during the construction stage. Socio-technical systems are those comprised of two or more workers interacting with technology within an organizational and management structure, and internal physical and cultural environment and in the context of an external environment (Kleiner, 2008).

The importance of early consideration of OSH in construction projects

In recent years it has become 'conventional wisdom' to state that the earlier OSH is integrated into construction project decision-making, the more likely it is that OSH problems will be eradicated. Much of this work has focused on the concept of Construction Hazard Prevention through Design (CHPtD) and/or the involvement of construction owners and clients in procuring healthy and safe construction projects. For example, researchers have provided considerable evidence that the design of buildings/structures is a relevant factor in the occurrence of 'downstream' OSH incidents during construction (Behm, 2005, Gibb *et al.* 2004; Gambatese *et al.* 2008). Huang and Hinze (2006a; 2006b) also demonstrate a statistical link between owner/client actions and project OSH performance. Prevention through Design has been deemed worthy of a major goal in the US National Occupational Research Agenda (NORA) strategic plan.

It is often purported that opportunities to reduce OSH risks diminish over time as a construction project progresses through its lifecycle, with risks identified after the detailed design stage of a construction project difficult to eliminate or reduce (Symberski, 1997). Empirical evidence to support Symberski's theoretical 'time-safety' influence curve is almost non-existent. However, some research suggests that project decision-makers' emphasis on safety varies over time and is greatest in the middle of a project, i.e., demonstrating a curvilinear (inverted U-shaped) relationship between emphasis on OSH and time in projects (Humphrey *et al.* 2004).

Policy makers and OSH specialists have advocated interventions aimed at construction professionals in the early stages of projects. However, the extent to which current policy and legislative developments adequately reflect the complexity of construction project decision-making has been questioned and researchers have identified a 'disconnect' between the policy position relating to 'Construction Hazard Prevention through Design' and industry practice (Weinstein *et al.*, 2005).

Construction projects as complex socio-technical systems

Construction project decision-making is characterised by complex inter-organizational relationships, sub-clustering, information dependencies and considerable division of labour (Gray *et al.* 1994, Pietroforte 1995, 1997, Nicolini *et al.* 2001). Significant co-ordination, inter-stakeholder negotiation and compromise is required to complete construction planning and design tasks, often in an environment of uncertainty and characterised by significant external influences (Bibby, 2003). In this context, the influence of a single project stakeholder, i.e, 'the client' or 'the designer', is inherently limited. Consequently, decisions that impact upon OSH cannot easily be traced to a single project participant acting in isolation. As an example, design decisions are not made by a single professional contributor to a project, i.e., the architect or engineer. Rather, design in construction is a political, reflexive process of collective negotiation between multiple contributors and stakeholders (Tryggestad *et al*. 2010) exemplified by numerous interactions. It is therefore difficult to ascribe responsibility to the occupant of a single socio-technical role, i.e., ‘the designer’. Rather, in order to integrate OSH thinking into construction project decision-making, it may be more appropriate to understand construction projects as complex socio-technical systems in which OSH responsibility is a collective rather than individual requirement.

2. Research methods

Case study projects and sampling

A structured case study approach is being used in the research. Project-level data are being collected and analysed to reveal the aetiology of OSH hazard-producing decisions, as well as the decision points and information flows required to achieve the elimination/reduction of construction OSH risks at source. The research involves the collection of data from projects representative of all sectors of the construction industry (e.g., residential, commercial, industrial and heavy engineering), as well as projects procured using different delivery mechanisms (e.g., design-bid-build, design and construct (i.e. build), accelerated (fast-track) and collaborative (alliance)).

Data collection

Data collection at each construction project involves a number of different methods, including: (i) direct observation of project team interactions; (ii) interviews with project team members and other relevant stakeholders; and (iii) inspection of relevant artifacts, such as aspects of the physical worksite and project documentation.

Data analysis

Data are then used to construct a graphic representation of the decision-making of each construction project that impacted upon OSH during the construction stage. This representation maps: (i) decisions taken; (ii) the reasoning for choices made between alternative technological options; and (iii) the social networks of project participants involved in decision-making as the project ‘unfolded’ (See Decision Model below).

The Decision Model components

Project decision-making impacting on OSH is represented in the form of a Decision Model (see Figure 2). The Decision Model uses a socio technical ‘lens’ to reveal construction project decision-making as it impacts upon OSH during the construction stage. The model comprises three components: (i) *layer 1*- an analysis of the rationale of project decisions; (ii) *layer 2* - a process map of key project decisions taken; and (iii) *layer 3* - a social network analysis relating to key project activities. These three components are represented as ‘layers’ in the resulting Decision Model.

3. Pilot study results

Case study project

The Decision Model was piloted and tested at an industrial construction project located in the outer suburbs of Melbourne, Australia. The project involved the reconstruction of a food processing plant that had been damaged by fire. The project was partially subsidised by the State Government of Victoria, which had an interest in maintaining employment created by the food processing plant. The client entered into an accelerated design and construct contract with a builder for the reconstruction of the fire damaged buildings. Data were collected through participatory observations at project meetings, from personal interviews, and from documentary analysis. Data were combined to develop the Decision Model depicted in Figure 2. The model is explained and illustrated below with reference to the design and construction of the structural steel columns at the pilot study food processing plant.

The Decision Rationale

The first layer of the Decision Model represents the rationale for decisions made during the pre-construction stages of the project. This approach draws on a technique used to analyze decisions taken in the design of an artifact, making it particularly helpful for representing decisions made during the planning and design stages of construction projects (Chachere and Haymaker, 2008). The decision rationale 'layer' of the model captures choices that are made between available options at key points during project planning and design. The reasons for these choices and 'trade-offs' involved form a critical component of the decision rationale, as they highlight constraints and factors that can have important implications for OSH outcomes during the construction stage.

In the case study project, the original fire-damaged production facility was partially intact, yet the design team and constructor expressed a preference for demolishing the entire facility. However, the client's brief required that only three of the structural steel columns supporting the building be replaced, with the remaining structural components to be retained. This influenced design work, which was further complicated when the client/owner decided to increase the operational capacity of the facility and it was also discovered that many of the columns to be retained were rust-affected. This decision necessitated that existing columns needed to be substantially strengthened to accommodate additional plant/equipment to be installed in the building.

The structural engineer worked in close consultation with the sub-constructor engaged to undertake the column construction work and a number CHPtD solutions were incorporated during the design stage. Prefabrication was not considered to be an option in strengthening the columns because each column varied in its degree of dilapidation and sections of varying length needed to be replaced. The main OSH risk identified in the strengthening work was identified as the risk of falling from height and an elevated mobile work platform was to be used. However, the initial design required temporary props to support columns during the work, preventing workers from gaining access safely. The design was adapted to utilize stiffening plates and remove the need for props, permitting safe access to heights using the elevated mobile work platform. Stiffening plates were to be welded to the columns so that workers would not need to align pre-drilled holes in the columns with holes in the plates at height, further reducing exposure to work at height.

An extract from the Decision Model (Figure 3) shows the design rationale for the structural steel column design, capturing the choices available at key decision points. Decision-makers were faced with a number of constraints and with limited information (for example, not knowing the dilapidated state of the columns when the decision was made to retain the majority of columns from the original structure). Consequently, some key decisions were based upon assumptions made about the structural adequacy of what remained of the original building. Figure 3 shows that the decision pathway changed as information came to light. For example, when the owner/client made the decision to increase the operational capacity of the facility after the commencement of the facility's design, this had an impact upon requirements for the structural steel columns. In the context of these constraints and stakeholder influences, CHPtD solutions that were eventually implemented do not constitute 'ideal' solutions, but represent a 'workable' decision path in the context of the complex project environment. The decisions that impacted CHPtD were influenced by interactions between project stakeholders, available technologies and the project environment, e.g. government funding available to the owner/client to increase the scope of the project. In this context, decisions made reflected 'trade-offs' between technological feasibility, production imperatives and OSH requirements of the operational facility and the construction workforce.

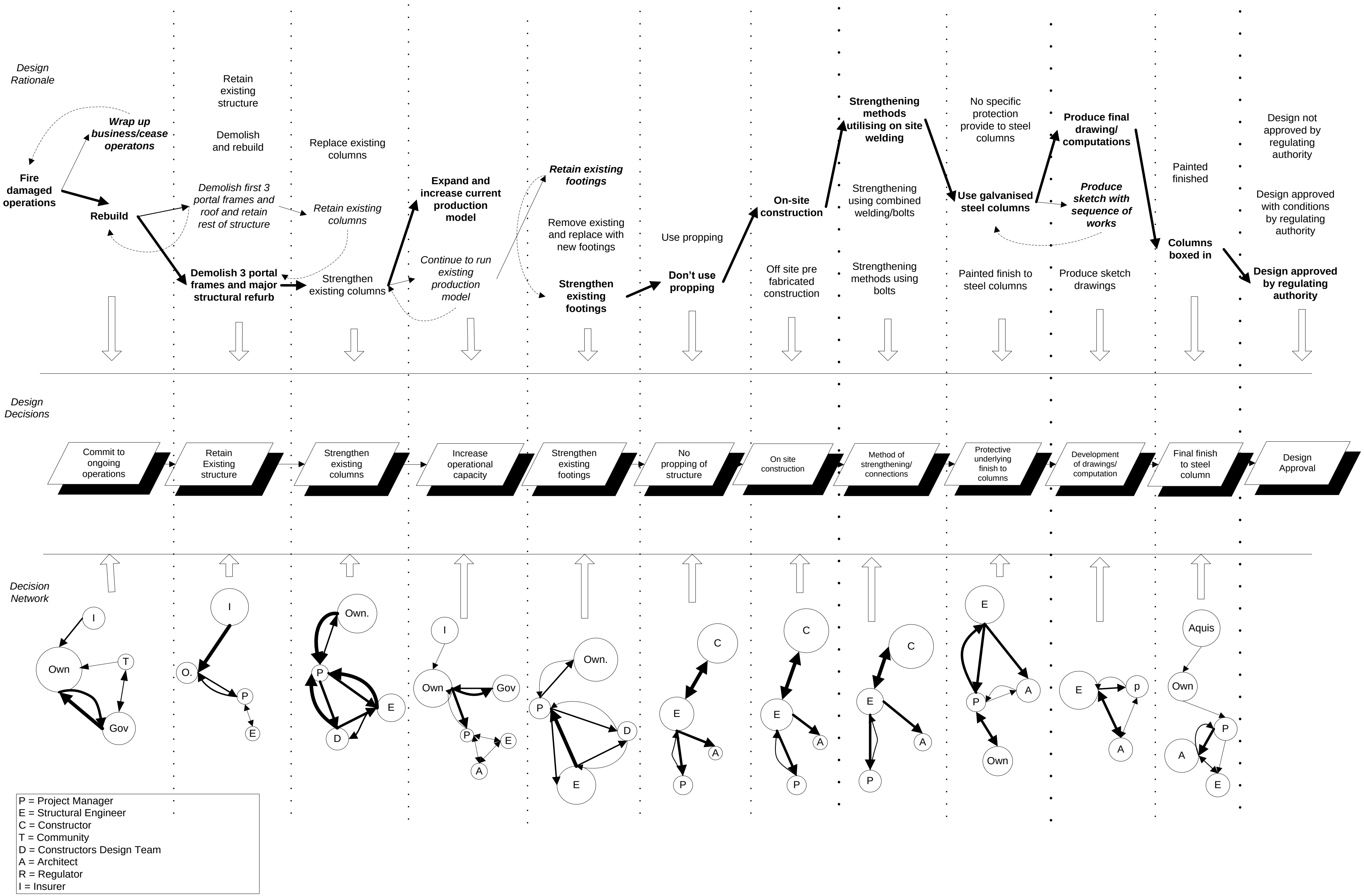


Figure 2: *Pilot Study Decision Model*

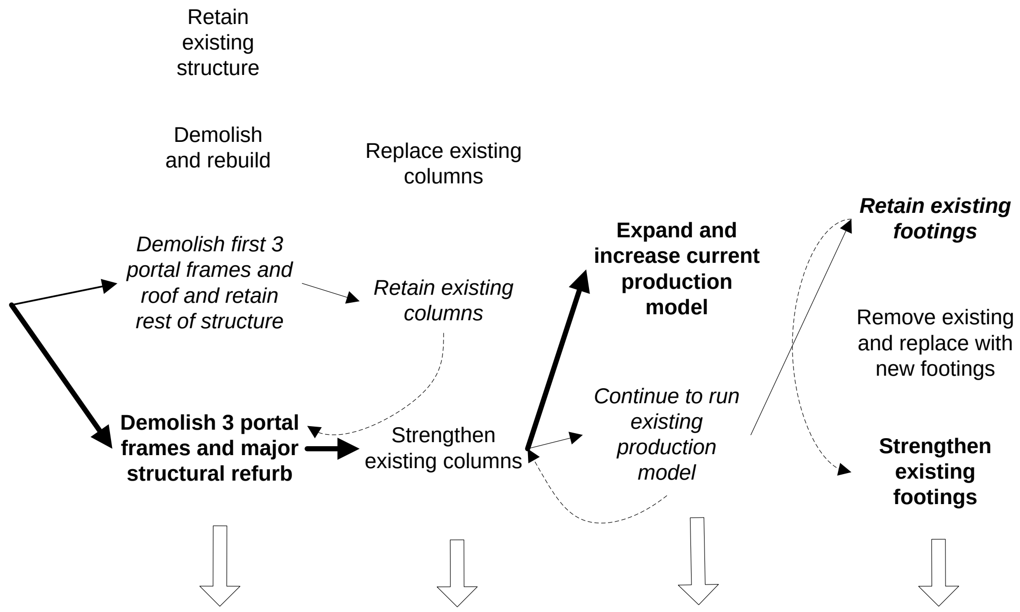
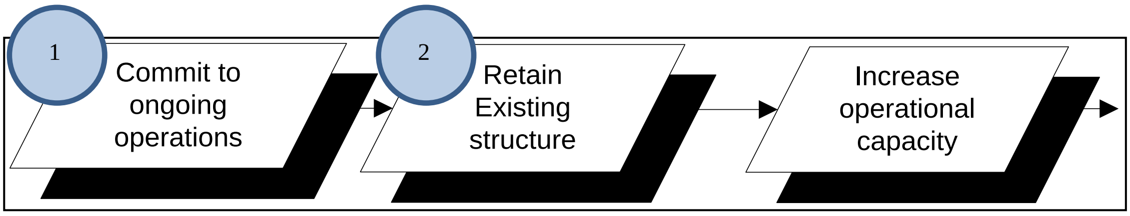


Figure 3*: Extract of Design Rationale from the Decision Model*

The Decision Process

The second layer of the Decision Model borrows from the IDEF0 methodology by focusing on the process functionality (i.e. what is happening) and not on the process organizational structure (who is doing it) (Ang *et al.*,1997). Key decision points within the project are identified. For each decision point, the Decision Model represents: (i) inputs to the decision, e.g., what information was provided to guide the decision-making; (ii) any resources/assistance available to or factors constraining the options available to decision-makers; and (iii) the output, i.e., any product or artifact generated by the decision that was made (See Figure 4).

The extract of the Decision Model reflecting the steel column design is shown in Figure 4. Two key decision points are represented: (i) the decision to rebuild the food processing plant on the basis of a government subsidy awarded to the owner/client; and; (ii) the decision to retain as much of the original fire-damaged facility as possible Each of these decisions was informed by a number of inputs, producing at least one output and was made in the context of a range of constraints and resources, each of which is also captured in the Decision Model. In the case of the pilot project, the column design was primarily driven by time and cost. The client set an ambitious date for the re-opening of the plant, compressing the design and construction work into a ten month period. This set the ‘tone’ for the project with CHPtD decisions contingent on these constraints.



Key Decision Number	Inputs	Constraints	Resources	Outputs
1	▪ Strategic plan for the company ▪ Insurance policy coverage ▪ Employment opportunities in local area	▪ Profit forecasting for operations ▪ cost	▪ Support from Government to fast track permits ▪ Community support to continue operations ▪ influence of permit authority own engineering evaluation	▪ MOU between client and government on funding and permit arrangement ▪ Commitment to continue operations
2	▪ financial support from insurance ▪ operational requirements ▪ structural report on what could be retained ▪ clients identification of what was to remain	▪ cost to rebuild ▪ operational downtime ▪ insurance coverage ▪ time	▪ CAPex ▪ Construction history with constructors and designers ▪ Production outputs	▪ Scope of works

Figure 4*: Extract of Decision Process from the Decision Model*

Social Network Analysis

The third layer of the Decision Model identifies the social entities (individual stakeholders and contributors) involved in a particular cluster of project decisions (for example, decisions made during the design of a particular building element). Social network analytical techniques were used to reveal the relationships and interactions between social entities involved in a decision activity (Scott, 2000; Wasserman and Faust, 1994). Social network analysis is useful because it captures formal as well as informal interactions and is capable of revealing much more information about the social influences on project decision-making than an analysis of formal project documentation can provide (Haythornthwaite 1996). The analysis of social networks enables the most influential stakeholders to be identified within complex project decision networks (Garton *et al.*, 1997).

Figure 5 shows example data pertaining to the social networks involved in the design of the structural steel columns at the food processing facility. The social networks illustrate the stakeholders involved in making key decisions (which subsequently impacted on OSH during construction) and reveal the way decisions are made in the context of a construction project. Each network identifies stakeholders involved in a decision, represented as circles (nodes). The arrows between the nodes indicate incoming and outgoing connections, while the thicker lines represent the strength of the relationship and/or frequency of interactions between the stakeholders. The size of the circle represents the power influence in decision making, the bigger the circle, the more decision-making ability that person has.

Figure 5 shows that three key decisions were taken that resulted in retention of most of the original building's columns. While the design team advocated that the remaining structure be demolished and rebuilt to enable the use of off-site prefabrication of new building components, the 'power' stakeholders, the insurer and the owner/client were the most influential in the decision to retain the original structure. Underpinning these decisions were expectations about cost and time associated with demolishing and re-building the whole facility. Ironically, the constructor later commented that the column strengthening "…*took us longer to fix than it would to build a new building*."

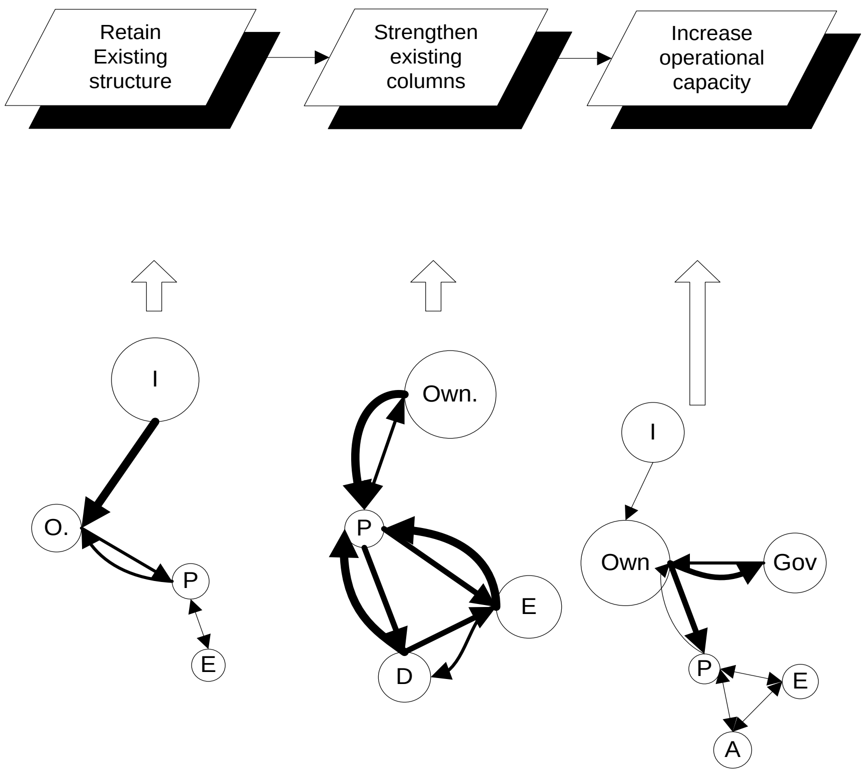


Figure 5: *Extract of Social Network analysis from the Decision Model*

4. Discussion

A socio-technical approach to the integration of OSH 'uptream' of construction

Construction projects comprise a network of tasks, requiring contributions from many specialists (Pryke, 2004). In this paper we investigate the integration of OSH into a construction project decision-making using a socio-technical approach.

Data from the preliminary pilot study project reveal that decisions were influenced by multiple stakeholders with different interests in the project and in the OSH of construction workforce. This is consistent with role analysis in Kleiner's MEAD STS framework (Kleiner, 2008). This was evident in the client's decision to reduce costs by retaining as much of the existing structure as possible, which in turn was influenced by the decision made by the insurance company to only commit to the financial costs of replacing three columns. The initial design appeared to be straightforward, with only three new columns required. However, as the design progressed the scope and complexity increased. Not only did the owner/client's objectives change, but assumptions about the structural integrity of the original building were challenged. Consequently, the steel columns were re-designed in the context of environmental constraints that restricted design choices and introduced specific OSH hazards.

Early integration of OSH into decision-making

While the design team endeavoured to systematically resolve problems as they arose the ability to successfully implement CHPtD proved difficult, with aspects of the project continually changing. The design of the steel columns was an ill-structured problem that evolved as new information came to light. Wholton and Ballard (2002) suggest that this type of problem-solving rarely allows designers to identify all possible solutions, having to settle for choices that satisfy the problem as it is understood at a particular point in time. 'Trade-offs' are inevitable, with decision making becoming as much a social and political process as it is a technical process.

Further, the structural engineering design team were impacted by decisions relating to the selection and positioning of new plant and equipment to be installed in the facility. It is not uncommon for the design of a structure to be decomposed into smaller tasks, assigned to different specialist design 'teams'. The elements in these tasks are designed individually and then combined into larger solutions (Lu, 2000). However, decisions made in one design task that resolve identified OSH hazards create constraints relating to other design tasks. Further, the 'knock-on' effects may not be realised until construction when the constructor is expected to transform the various parts of the design into physical reality.

OSH risk controls

The way in which OSH was dealt with in the design of the structural steel columns at the pilot study project revealed that OSH was integrated into the engineering design of the columns. This was facilitated by close communication and cooperation between the structural engineer, the principal contractor and the subcontractor engaged to undertake the column strengthening work. For example, the decision to bolt sections of steel plating to strengthen the columns constituted an innovative engineering design solution. In this way CHPtD was integrated into the design, albeit in relation to designing the process of construction rather than in the design of the columns themselves.

The modelling of decision-making across multiple projects in different industry sectors will enable an analysis of the extent to which early involvement of construction knowledge and/or frequent and strong relationships between multiple project stakeholders early in the project enhances the implementation of technological solutions to OSH risk.

It was not possible to state, with any certainty, the degree to which the CHPtD choices made in the design of the steel columns at the pilot study project 'succeeded' or 'failed'. However, involving the contractor in the design, upstream of construction was perceived to be particularly beneficial to the workers OSH , "*on other jobs they just give you stuff and you end up having to deal with it." (interviewee).*

Safety critical roles - Stakeholder Influence

Identification of the stakeholders involved in the design of the steel columns showed that those involved in the decision making extended beyond the 'traditional designer' of architects and engineers, to include the client and the insurer. What was also evident was that the decision making process was not a consistent social network over the course of the column design, with the participation of different stakeholders at different stages of the design. As a result the source of the decision power also changed, depending on the stage of the key decision. This in turn impacted on the criteria used to determine the suitability of a key design. Friedman and Miles (2002) found that the interests of stakeholders can vary over the life of a project, as can alliances between stakeholders. External reasons have also been cited as causing changes in the objectives of stakeholders, such as a modification of community preferences which in turn influences political, environmental and community stakeholders, government policy, and the position of other stakeholders (Frooman and Murrell, 2005).

Understanding the roles and social relationships within construction projects is vital for appreciating how OSH can be integrated into project decision making. Our results indicate that simple attributions of OSH responsibility to persons who occupy a particular professional role, e.g. a 'designer' does not reflect the division of intellectual labour, power and influence in project teams.

5. Conclusion

The integration of OSH into pre-construction decision-making is strongly advocated and there is compelling evidence that the activities of clients/owners and design professionals have an important impact on the OSH of construction workers. However, to understand the how best to actively integrate OSH into pre-construction project decision-making, it is important to understand not only the determinants of technical decisions that are made, but also the role, power, interactions and influence of multiple stakeholders whose actions and interests play a critical part in shaping the many decisions that impact upon OSH in the project.

This paper introduces a three level Decision Model that is being deployed in an attempt to gain a better understanding of how social and technical subsystems interact to shape construction OSH outcomes in case study projects in both the USA and Australia. Ultimately, this will assist with "joint optimization", the STS concept of jointly designing the social and technical systems. The pilot study suggests that project decision-making that impacts upon construction OSH is influenced by multiple stakeholders and their interface with technologies. In this context, the prescriptive application of safe technologies can only solve part of the construction OSH problem as genuine integration of OSH into upstream decision-making will require collective action on the part of multiple stakeholders, whose interests may not naturally align with construction workers' OSH.

Future Research

Data will be collected at approximately 32 case study projects representing four industry sectors and four different procurement approaches in both Australia and the USA. The research will enable an analysis of the conditions in which OSH outcomes are enhanced by effective upstream integration of OSH considerations. Opportunities to transfer good practice between countries and/or between industry sectors will be identified. The research will also test the proposition that collaborative project procurement lends itself to more effective integration of OSH into early project decision-making than traditional design-bid-build approaches. Finally, the socio-technical systems analysis will enable safety critical roles to be identified and provide guidance for a realistic basis for sharing OSH responsibility within project teams.

Acknowledgements

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Systems Modeling of Design to Reduce Downstream OSH Incidents in the Construction Supply chain

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Systems Modeling of Design to Reduce Downstream OSH Incidents in the Construction Supply Chain

Abstract

The current understanding of the role of design in construction safety is limited to connecting potential hazards with particular design elements. In order to improve safety through design it is necessary to understand the causal mechanisms of design's influence. Additionally it is necessary to consider the costs and benefits associated with safety interventions in design. This paper discusses the potential of systems modeling to address these issues and identifies important factors that must be considered in such a modeling effort.

Keywords: construction safety, safety in design, costs of safety

Safety in Construction in Singapore: Policies, Assessment and Further Development

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Safety in Construction in Singapore: Policies, Assessment and Further Development

Abstract

Safety performance in any organization or sector is an important consideration owing to the potential adverse effects of poor safety practice in terms of loss of life and property, and impact on psychological and social wellbeing of workers and their families, as well society as a whole. In almost all countries, the construction industry is one of the worst performers among the sectors of the economy with regards to safety performance. This has made construction one of the least attractive sectors of the economy in most countries. For this reason, governments in most countries have formulated programmes for improving performance in safety in the construction industry.

What is Singapore's record in terms of safety in the construction industry? How effective are Singapore's policies and programmes on safety in its construction industry? What are the drivers and obstacles? What are the future policy intentions? What can be done to facilitate the efforts towards attaining the policy intentions and targets?

Keywords: C21, policies, safety improvement programmes, Singapore

1. Introduction

Performance improvement has been a major consideration in Singapore's construction industry since the 1960s. In these regards, the following areas have been given priority: (i) buildability of design; (ii) maintainability; (iii) productivity; (iv) quality; and (v) safety. Several programmes and initiatives, supported by law, and with the provision of incentives and facilitating schemes, have been introduced.

The main agent in the formulation and implementation of the performance improvement programmes has been the government of Singapore. The government has long recognized the need for the country to have a construction industry which enables it to attain its developmental aspirations. The main agency has been the Building and Construction Authority (BCA), which was formed in 1984 (as the Construction Industry Development Board (CIDB) until its name was changed when it was restructured in 1999). Among the public-sector client organizations, the public housing authority, the Housing and Development Board (HDB) has lent its support by launching its own programmes, and providing its projects for demonstration and training purposes.

What has been the situation in performance improvement in the construction in Singapore over the past decade? What have been the policies? Which programmes and initiatives have been implemented? What has been achieved?

Research aims and objectives

The paper reports on part of an ongoing two-and-half year research study being undertaken to assess the implementation of the construction industry improvement programme in Singapore which had been launched with the publication of the Report of the Construction 21 Steering Committee (Construction 21, or simply, C21) at the end of the last century. The objectives of the larger research study are:

a. To ascertain and evaluate against their original objectives, the outcomes from the implementation of the construction industry performance improvement programme in Singapore since 1999.
b. To assess the respective roles of government agencies and the private sector including professional and trade bodies, in the implementation of the advocated reforms.
c. To understand the extent to which the institutional characteristics of the construction industry in Singapore influenced the implementation of the above reforms.
d. To draw lessons from the implementation programmes for future construction industry improvements in Singapore.
e. To develop a research agenda in support of ongoing efforts to realize improvements in the construction industry in Singapore.
f. To present specific recommendations for the development of appropriate performance metrics and targets, with particular emphasis on sustainable monitoring and continuing improvements.

The larger study is a collaborative endeavour involving the University of Hong Kong, University of Reading, UK and National University of Singapore. The broad intention is to undertake a review of the implementation of the industry improvement programmes which had been launched in the three countries around the same period (in the UK, following the publication of the Egan Report entitled “Rethinking Construction” in 1999; Construction 21 also in 1999, and the Report of the Construction Industry Review Committee” of Hong Kong in 2001. This paper focuses on the aspects of the study in Singapore which relate to safety in construction. It focuses on policy considerations at the broad industry level.

2. The Study

Research method

To accomplish the aims and objectives of the research study, empirical data was collected. It comprised a set of interviews, a questionnaire-based survey, a conference and an industry forum. In the interviews, 9 interviews were held with a total of 12 senior practitioners who had played key roles in the C21 process were interviewed to obtain their views on the impact of the initiatives of C21. They were mainly former presidents or senior members of the executive committees of professional institutions in construction, or chief executive officers of key organizations. The sets of questionnaires, which had been formulated from the review of the literature, were sent to 174 clients, 524 consultants (of different areas of specialization) and 1,671 contractors of various sizes.

Table 1 Questionnaires sent and response rates

Respondent	Sent out	Wrong addresses	Sub total	Usable responses	Response rate
Clients (public and private)	174	18	156	22	14.10%
Architectural firms	337	2	335	45	13.43%
Quantity surveying firms	44	1	43	11	25.58%
Engineering firms	143	7	136	29	21.32%
Main contractors	1,671	11	1,660	150	9.04%
Total	**2,369**	**39**	**2,330**	**257**	**11.03%**

3. Construction 21 report

The Construction 21 Committee on Manpower was established in May 1998 by the Ministry of Manpower (MOM) in Singapore to address the manpower problems in the construction industry. The main issue is the reliance of the industry in Singapore on foreign workers at the operative levels; around 80 percent of construction workers in Singapore are foreign workers from designated countries in the region. The MOM's committee was subsequently merged with the Committee on Practices in the Construction Industry set up by the Ministry of National Development (MND) to form the Construction 21 Steering Committee. The members of the committee and its task force were prominent practitioners representing both the public and private sectors.

The C21 Steering Committee, its task force and the four working groups comprised more than 80 persons who were drawn from the private, public, and people sectors. They were from:

a. professional institutions: Singapore Institute of Architects (SIA) and Institution of Engineers Singapore (IES);
b. trade associations: Singapore Contractors Association Limited (SCAL) and Real Estate Developers Association of Singapore (REDAS);
c. a regulatory agency: BCA;
d. a public client agency: Housing and Development Board (HDB);
e. the unions: National Trade Union Congress (NTUC);
f. tertiary educational institutions: Nanyang Technological University (NTU), NUS and Ngee Ann Polytechnic; and
g. the public.

The members of the committee undertook study missions to Hong Kong, Japan, the UK and US to learn the best practices in the industry.

It was initially intended that the committee would investigate issues related to labour supply and productivity in the industry, but it conducted a thorough investigation and cover many aspects of the industry, from Processes (practices, techniques, and integrated approach to construction) and Players (professionalism and skills) to Products (exporting expertise).

The C21 report, published in 1999, adopted the vision for Singapore's construction industry for the 21st century: "To be a world class builder in the knowledge age", with the change in public perceptions from a Dirty, Demanding and Dangerous (3D) industry to a Professional, Productive and Progressive (3P) industry. The radical tone of the C21 report is evident from its title, "Reinventing Construction".

The committee highlighted the following key problems of the industry in Singapore:
a. low productivity level and negative productivity growth;
b. multi-layered subcontracting system;
c. segregation of industry's activities;
d. poor worksite safety; and
e. malpractices and social problems.

The committee made 39 recommendations under the following six strategic thrusts:
a. enhancing the professionalism of the industry;
b. raising the skills level;
c. improving industry practices and techniques;
d. adopting an integrated approach to construction;
e. developing an external wing; and
f. a collective championing effort for the construction industry.

The C21 report highlighted the following desired outcomes of the transformation exercise:
a. a professional, productive and progressive industry;
b. a knowledge workforce;
c. superior capabilities through synergistic partnerships;
d. integrated process for high buildability;
e. contributor to wealth through cost competitiveness; and
f. construction expertise as an export industry.

In the C21 report, the subject of this paper, safety, was covered under strategic thrust 3: improving industry practices and techniques. Before discussing the field study of the research and its results, a summary of the current situation with respect to safety performance in the construction industry in Singapore is presented.

Current situation of construction safety performance in Singapore

In considering the current situation with regard to safety performance in the construction industry in Singapore, it is pertinent to discuss developments since the launch of the C21 report. The C21 report recommended the introduction of the Construction (Design and Management) Regulations after the enactment of the Occupational and Safety Health Act (OSHA) in 2000/2001. To this end, the first significant development was the introduction of the new Occupational Safety and Health (OSH) framework on 10 March 2005. It was guided by three basic principles: requiring all stakeholders to eliminate or minimize the risks they create, instilling greater ownership of safety and health outcomes by industry, and preventing accidents through higher penalties for poor safety management (MOM, 2008). The target was to halve the occupational fatality rate within 10 years and attain standards of the current top 10 developed countries with good safety records.

The Joint MND-MOM Review Committee (JRC) on Construction Safety was convened after the two major accidents in Singapore in quick succession in April 2004. These are known as the Nicoll Highway and Fusionpolis Complex incidents in April 2004 to review the regulatory framework and ancillary systems to raise safety standards in the construction industry (JRC, 2005). The committee identified gaps in the regulatory framework and ancillary systems. It made recommendations to help strengthen the legislative provisions pertaining to temporary structures; raise the professionalism and competency of professionals, contractors, and supervisors; and make transparent the public sector procurement system to take safety into account.

The Workplace Safety and Health Act (WSHA), which came into effect on 1 March 2006, is an essential part of the new safety framework in Singapore. It replaced the Factories Act. Under the Factories Act, the main contractor was principally accountable for ensuring worksite safety. This had engendered a culture where safety was viewed as being only the concern of the main contractor. WSHA prescribes general duties for owners, occupiers, employers, designers, suppliers of machinery, equipment and hazardous substances, and individual workers. This is consistent with the principle of holding accountable those who create risks or have primary control over these risks (JRC, 2005).

The Construction (Design and Management) or CDM Regulations require designers to work closely with contractors in thinking through safety management for the entire life-cycle of a project. The UK implemented such regulations in 1995, and adherence to its principles have since helped its construction industry achieved one of the best safety records in the world (Gan, 2008).

The WSH Council, established on 1 April 2008, comprises 18 leaders from the major industry sectors (including construction, manufacturing, marine industries, petrochemicals and logistics), the government, the unions, and professionals from the legal, insurance and academic fields. The council works closely with MOM to improve WSH performance in Singapore. The MOM has been working with the Workplace Safety and Health (WSH) Council in Singapore to develop this set of guidelines based on the UK's CDM Regulations. With the new guidelines, the construction industry will be better able to fulfill one of the key principles of the WSH framework – "eliminating risks at source". It aims to create buildings that are safe to build, safe to maintain, and safe to demolish (Gan, 2008).

“Implementing WSH2015 for Construction Industry” was launched in 2007 to guide the efforts of the construction sector. Since then, there have been many key developments with regard to the formulation and implementation of policy on safety in the industry. These include the development of the Construction Safety Audit Scoring System (ConSASS), the review and enhancement of the mandatory Construction Safety Orientation Course (CSOC), the publication of the construction accident case study booklet, the release of the Guidelines on Design for Safety (DFS) in Buildings and Structures as well as the inaugural Construction Chief Executive Officer (CEO) Summit, where CEOs from top construction companies signed to pledge management commitment for zero injuries.

The construction safety guide has since been updated to include areas for enhancement and new areas of work to achieve sectoral targets by 2018.

”Implementing WSH 2018 for Construction Sector in Singapore” (WSH Council, 2010) was published in April 2010 as part of the national WSH 2018 strategy. It sets out the targeted outcomes, and the key strategies and initiatives to further enhance WSH standards in the construction industry in Singapore. The aim is to guide all stakeholders to create a safer and healthier construction industry with a progressive and pervasive WSH culture.

According to the guide, the long-term goal is to achieve zero injury in the construction industry. Figures 1 and 2 show the current statistics on construction safety in Singapore. The more immediate goals are:

a. A workplace fatality rate of less than 3.4 fatalities per 100,000 workers by 2013 and less than 1.8 fatalities per 100,000 workers by 2018; and
b. Workplace injury rate of less than 390 injuries per 100,000 workers by 2013 and less than 200 injuries per 100,000 workers by 2018.

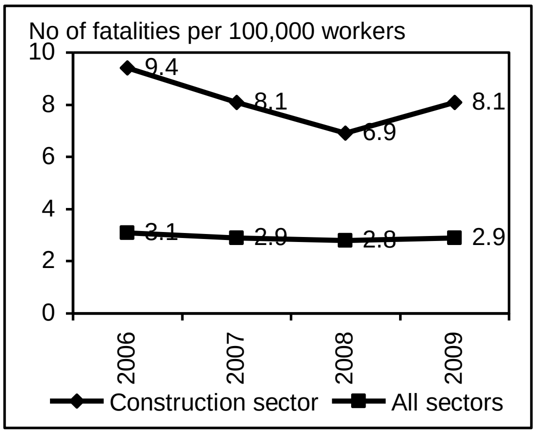

Figure 1 Accidents in the construction sector by fatality rate compared to all sectors, 2006-2009
Source: WSH Council (2010)

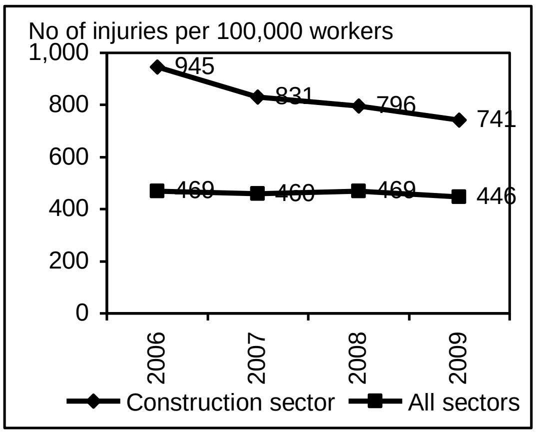

Figure 2 Accidents in the construction sector by injury rate compared to all sectors, 2006-2009
Source: WSH Council (2010)

The guide specifies action plans to improve WSH standards in the construction sector. These plans are as follows:

a. Strategy 1: Building strong capabilities to better manage WSH
    - Individual level: management, workers and supervisors, WSH professionals, designers and architects
    - Corporate level: self investigation, managing main and subcontractors
    - Industry level: enhancing Risk Management (RM), cultivating WSH culture
b. Strategy 2: Developing a performance-based regime
    - Include designers and developers in the regulatory framework
    - Improved management of workplace health
    - Self regulation
    - Setting industry standards
c. Strategy 3: Promoting the benefits of WSH and integrating WSH into business
    - Driving improvements through large organizations
    - Assessment of safety and health management systems
    - Business case

d. Strategy 4: Creating and building partnerships
    - Coordination of work
    - Industry-led taskforces.

4. Results from the field study

As mentioned above, empirical data and information for the study were collected through a set of interviews and a questionnaire-based survey. It is pertinent to state again that this paper reports only on the part of the study which concerned safety.

Interviews

Nine in-depth, face-to-face, interviews with twelve key people in the industry were conducted in September to November 2009. The interviews were intended to gain a better understanding of the implementation of the C21 report from the people who have been involved during the preparation of the report or during the implementation period.

On construction safety, the interviewees acknowledged the progress on the safety regulations. However, despite the extensive regulations on construction safety, one interviewee believed that it is the mindset of the developers, project managers, and contractors that should be improved. Emphasis on safety should also be placed on the lower levels, such as the supervisory and workers levels. Teo and Phang (2005) found that contractors understand the importance of a safety culture but do not have the right mindset or attitude towards implementing it. One interviewee felt that Singapore construction is still lag behind in terms of safety. He commented: “In terms of safety, we are just two or three only on a scale of one to ten, considering where we’ve started from – zero”.

Questionnaire survey

A questionnaire survey was conducted to assess the effectiveness of the strategic thrusts. As mentioned above, 2,369 questionnaires were sent to the stakeholders of the construction industry in March 2010. A total of 257 usable responses were received, which reflected a response rate of 11.03%.

A number of questions were asked to assess the level of effectiveness of the measures under Strategic Thrust 3 (improving industry practices and techniques) of the C21 report. The respondent was asked to rate the level of effectiveness from a scale of 1 to 5 (1 being very effective and 5 being not effective at all).

Mean ratings were calculated from the feedback received. Besides the overall mean, mean ratings were also calculated for the three different categories of respondents, which were clients, contractors, and consultants. The purpose was to ascertain whether different construction industry participants had different views about the various initiatives presented.

The average of the means for construction safety was 2.36. All three groups of respondents agreed on the measure that had been rated the lowest in terms of effectiveness. It was the reduction of the number of unskilled foreign workers on site. The consultants and main contractors indicated the development of a pool of supervisors trained in proper site management and site procedures as the measure with the highest rating in terms of effectiveness. For the clients, the measure with the highest rating with regard to effectiveness was providing harsher penalties for poor safety management.

Factor analysis was also performed in order to extract the underlying constructs out of a set of observed variables. Under strategic thrust 3 of the C21 report, three factors were extracted. The order of factors was the same for all firms and main contractors: quality (Factor 1), buildability (Factor 2), and safety (Factor 3). It shows that main contractors believe that the quality measures under strategic thrust 3 had been most influential to improve industry practices and techniques, above buildability and safety measures. For consultants, the most important factor is buildability (Factor 1), followed by quality (Factor 2), and safety (Factor 3).

5. Discussion and recommendations

In Singapore, the safety improvement program in the construction industry has gone through a long period of intensive development, during which some of the changes have been quite radical. The country has learned from the experiences of other countries. The measures have included:

1. Increasingly more stringent legislation and regulations targeting the construction industry
2. Mandatory requirements in terms of safety personnel and implementation of management systems. These include not only the employment of safety managers, but also, that of various types of engineers for particular types of projects
3. Establishment, resourcing and strengthening of relevant public organizations such as the office of the Commissioner of Safety, the Workplace Safety and Health Council and the Workplace Safety and Health Institute
4. Launching and offering training programmes and instituting mandatory requirements on minimum levels of attainment by various categories of personnel
5. Offering of business incentives on the basis of safety performance through revisions in the procurement mechanisms and criteria to accord safety some weight in the evaluation of bids for projects
6. Fostering a culture of safety awareness and continuous improvement
7. Establishment of effective government-industry collaboration for enhancing safety performance.

The review of the literature showed that the current safety targets set in Singapore are highly ambitious when compared with the previous record. Among the sections of the economy, the construction industry will face the greatest challenge in meeting the targets.

The field study showed that, whereas construction practitioners welcomed the initiatives which had been introduced with regard to safety after the publication of the C21 report, they considered them to be the least effective when compared with those which had been put in place to address industry performance. There are setoffs and tradeoffs which must be considered at both the design and construction stages when seeking to attain the improvement in performance along the key parameters of cost, time (productivity), environmental considerations, quality, maintainability (durability), and health and safety. In Singapore, assessment systems for several of these areas are already in place, and are being used extensively, in some cases, being mandatory requirements. These include:

1. Buildable Design Assessment System (BDAS)
2. Construction Quality Assessment System (CONQUAS)
3. Constructability Assessment Score
4. Green Mark Scheme – for assessing the environmental performance of various types of buildings and infrastructure.

The scores on all these assessment systems are widely published to enable benchmarking within the industry. There is a challenge for the research community to develop measurement and benchmarking, evaluation and monitoring frameworks which combine these different metrics. Then, computer-based decision-support systems could be developed. In the continuing research on Building Information Modelling which is now being accorded a great deal of attention in the construction industry in Singapore, it would be appropriate to devote effort to the incorporation of such a framework in the models.

As so much in Singapore's construction industry depends on government leadership as translated into legislation, regulation, policy, programmes and enforcement, it is necessary that these instruments, systems and mechanisms are the most appropriate, most effective and most efficient. For example, the field study on this research identified the measures which have been effective (training of supervisors and institution of stiffer penalties). This calls for more joint action by government and industry, and for greater consultation of industry by the government, and the putting in place of effective feedback systems for garnering inputs into the periodic fine-tuning or revision of laws, policies and initiatives. The collective championing effort between the BCA and CIJC which had been envisaged in C21 is highly relevant with respect to the initiatives on safety.

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