March 9-11, 2008
Gainesville, Florida

Proceedings of CIB W99 International Conference
14th Rinker International Conference

Evolution of and Directions in Construction Safety and Health

edited by
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Suezann Bohner
Jeffrey Lew

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PREFACE

The CIB W99 International Conference on the Evolution of and Directions in Construction Safety and Health was organized under the banner of the International Council for Research and Innovation in Building and Construction (CIB) in cooperation with the M. E. Rinker, Sr. School of Building Construction at the University of Florida. This is the thirteenth year of existence of W99 (Working Commission on Safety and Health on Construction Sites) and each year we have met to share research findings. The objective of conferences is to facilitate the exchange information on research that has been conducted on the topics of construction safety and construction health. It is apparent that much of the work in construction is done manually, even in the most developed countries. As such, there is much to be gained by sharing information on construction safety and health.

The sponsors for the conference include two owners (or clients) and three contractors. Only five sponsors were solicited for their financial support. Each agreed to provide conference sponsorship. These five firms were specifically selected because they embody the very concept of zero incidents, incident free, etc. These firms are progressive and even aggressive about safety. Over the past years, they have shown the world that their commitment to safety is heartfelt. We are pleased and honored to have them participating in the conference.

The conference serves as a forum for the exchange of information on construction safety and health on a global scale. The information covers a wide variety of topics from strategies to practices. These topics have been organized into the following categories:

Owners/Clients and Safety	Causes and Analysis of Accidents
Design for Safety	Safety Issues
Culture and Attitudes	Risk
Training	Research Strategies
Technology	Practices/Policies
Road/Work Zones	Other

To ensure the highest quality in these proceedings, a rigorous two-stage system peer review was conducted for each abstract and subsequent paper. The "call for papers" began with a request for abstracts to be submitted for review. Abstracts that were on topics that were not consistent with the theme of the conference were rejected. In some instances, the abstracts were on an appropriate topic but they were written poorly. Assistance was offered on how these abstracts could be improved. This review ensured that the abstracts were relevant for the conference, contained academic rigor and made a meaningful contribution to the existing body of knowledge. When abstracts were approved, the authors were encouraged to submit their papers. The papers that were submitted went through a similar blind review procedure. Thus, the abstracts and the papers went through a peer review procedure. In some cases, extensive anonymous comments were provided to assist the authors in preparing high quality papers. The number of the abstracts submitted was 82 and the number of approved papers was 51.

Jimmie Hinze
Conference Chair
Gainesville, FL
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KEYNOTE ADDRESSES 1

FACILITY OWNER MAKES A DIFFERENCE IN CONSTRUCTION SAFETY PERFORMANCE

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ABSTRACT

Facility owners with substantial construction budgets recognize the considerable benefits of completing projects with minimal injuries. There are a number of ways that owners can positively influence the safety performances on construction sites. This is done largely through initiatives that support the efforts of the construction contractors on site. It is important that owners recognize those areas in which the greatest impact can be realized. The Southern Company, a large utility in Southeastern U.S., is proactive in safety and has enjoyed success through its various efforts to bolster project safety performance. The Southern Company has focused its efforts on such areas as concise contract safety specifications, comprehensive written site specific safety plans, fall prevention, cross functional safety teams, electronic safety inspection process, housekeeping, eye safety and pre-task planning. These efforts have been successful in reducing jobsite injuries to an incident rate of less than 1.2 injuries per 200,000 worker hours. While Southern Company does not direct contractors in the methods to be employed, it does intervene, and if necessary suspend the efforts of contractors when they place their employees at risk. This aggressive approach is ultimately beneficial to the owner, the contractor and the field employees.
.

Keywords: Client, Positive Influence, Greatest Impact, Focused Safety Efforts, Intervention, Owners and Safety

1. INTRODUCTION

Starting in the early 70's safety performance on construction projects improved steadily for many consecutive years. The significant early driving force was in large part due to federal regulatory interventions such as the Occupational Safety and Health Act. Additional strides were made with trade organizations, as the AFL-CIO, demanding safer working conditions. These forces, coupled with progressive safety programs of some of the largest contractors, accounted for the lion's share of the downward injury trends. More recently, the zero accident principles embraced by most large corporations and many medium-sized companies have renewed injury prevention efforts. With this process, most of these companies have expanded their programs to include the contractor workforces that they utilize both for maintenance and capitol projects and are considered industry safety leaders.

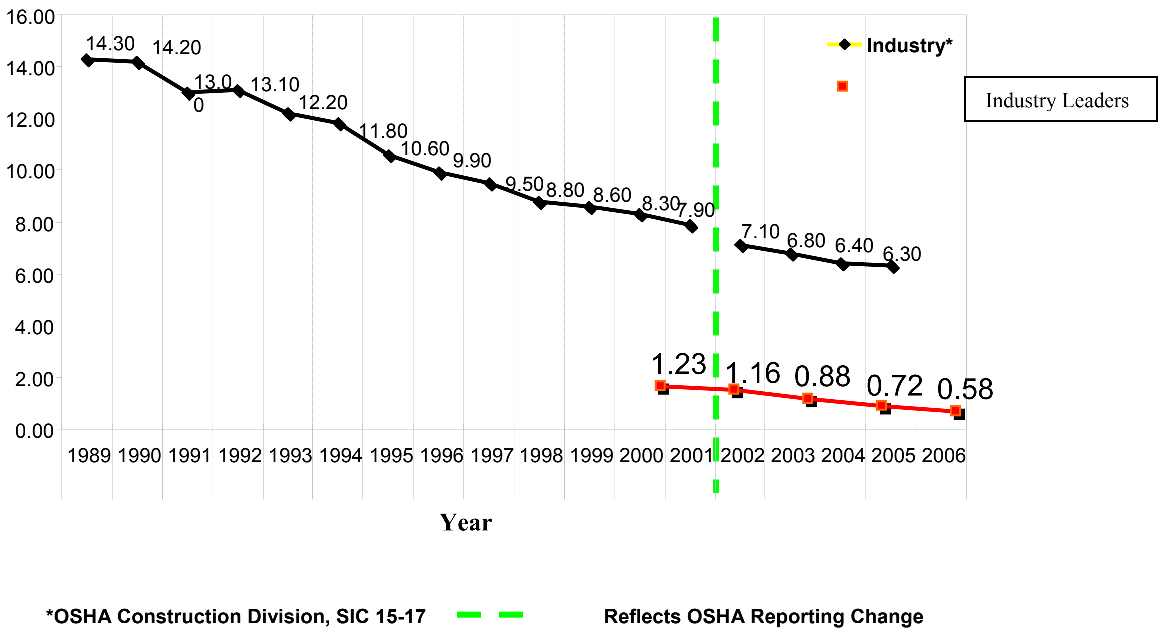

Figure 1. Construction Industry OSHA Recordable Injury Rate Trends (1989-2006)

2. BACKGROUND

Southern Company like most large electrical generation utilities in the United States had huge engineering and construction departments through the growth periods of the 1960's, 70's, and early 80's. The focus of these programs was the construction of new generation capacity, mostly in the fossil fuel and nuclear energy arenas. The utilities, including Southern Company, were very active in contractor safety and in many cases actually self performed significant portions of projects with both staff and direct hire craft personnel. With many of the projects completed and generating electrical power these construction departments down-sized, and in the case of Southern Company, were relegated to executing very small retrofit projects.

This trend continued throughout the 1990's and into early 2000. Increased energy demands, coupled with clean air regulations, ushered in moderate-sized construction projects utilizing gas turbine technology. Since most utilities had severely cut back their in-house construction capabilities, they turned to contractors to help meet their construction goals, mostly in a turn-key role. Additionally, the 1990's had produced a very litigious atmosphere. Many owners received legal advice that the independent contractor was to be treated almost in a "hands-off" manner relative to the execution of their scope of work. This approach was further enhanced by the fact that the location of these projects were either completely separate properties from existing power plants or if on existing plant properties they were sufficiently far away that they had little to no impact on operations.

By the mid-2000's environmental projects to eliminate certain emissions from the burning of coal to generate electricity have begun, and many of these will continue for several years in the future. Often these projects are higher in costs and larger in physical size than the original generating facility. They require significant budgets, complex structures, massive equipment, and large construction workforces. To circumvent any negative impact this increase of activity at operating facilities might produce, renewed efforts to positively influence contractor safety have been implemented.

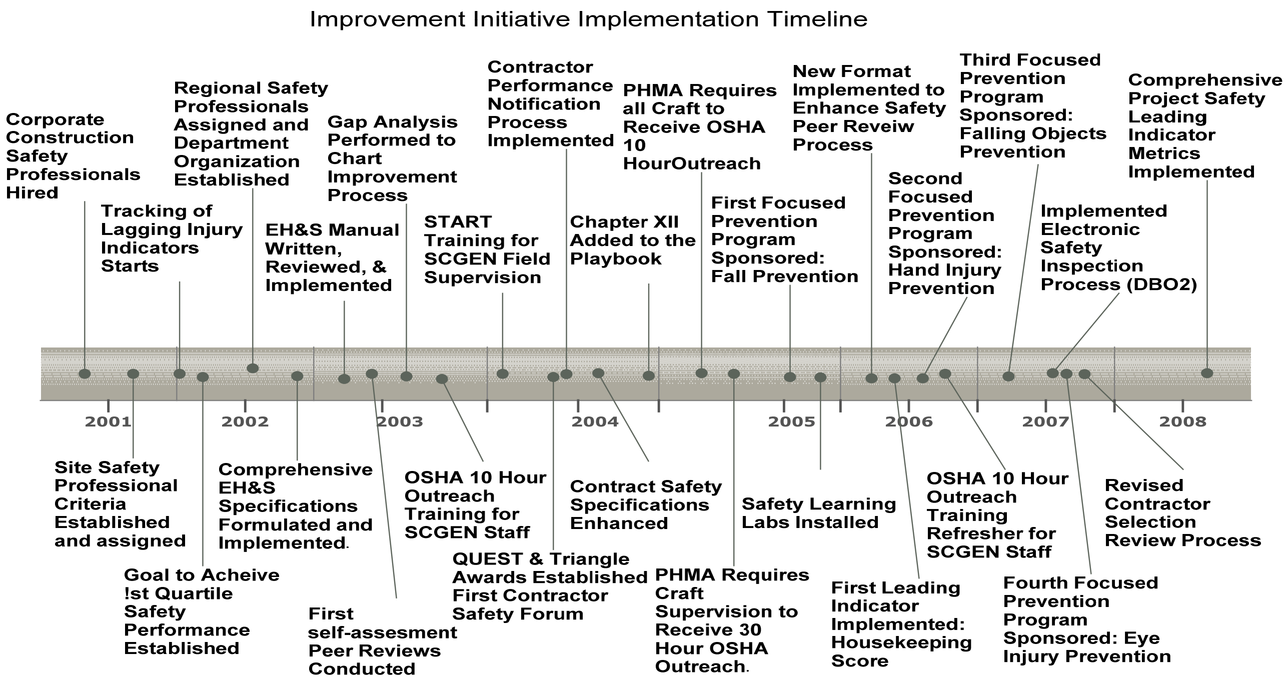

Figure 2. Improvement Initiative Implementation Timeline

Improvement Initiative Implementation Timeline

2001 Corporate Construction Safety Professionals Hired
Site EH&S Professionals Assigned to Projects
Tracking of Lagging Injury Indicators Starts
Goal to Achieve First Quartile Safety Performance Established

2002 Comprehensive EH&S Contract Specifications Introduced
EH&S Manual Written, Reviewed, and Implemented
First Self-assessment Peer Reviews Conducted
Gap Analysis Performed to Chart Improvement Process

2003 OSHA 10 Hour Outreach Training for All SCGEN Staff Personnel
START Training Provided to Site Construction Coordinators
QUEST Awards Established
Triangle Awards Established

Contractor Performance Notification Process Implemented
First Contractor Safety Forum
Contract Safety Specifications Enhanced

2004 Chapter XII Implemented
PHMA Requires All Craft Personnel to Complete OSHA 10 Hour Outreach and First-line Supervisor to Complete OSHA 30 Hour Outreach Training
First Focused Prevention Program Sponsored: Fall Prevention

2005 Safety Learning Lab Implemented
New Format Implemented for Peer Review Process
First Leading Indicator Metric Introduced: Housekeeping Score

2006 Second focused prevention program sponsored: Hand Injury Prevention
OSHA 10 Hour Outreach Refresher for All SCGEN Staff Personnel
Third focused prevention program sponsored: Hand Injury Prevention

2007 Implemented electronic safety inspection process (DBO2)
Contractor Safety Qualification Questionnaire Being Reviewed and Recommendations from Safety Group
Comprehensive Project safety leading metrics and dashboard implemented

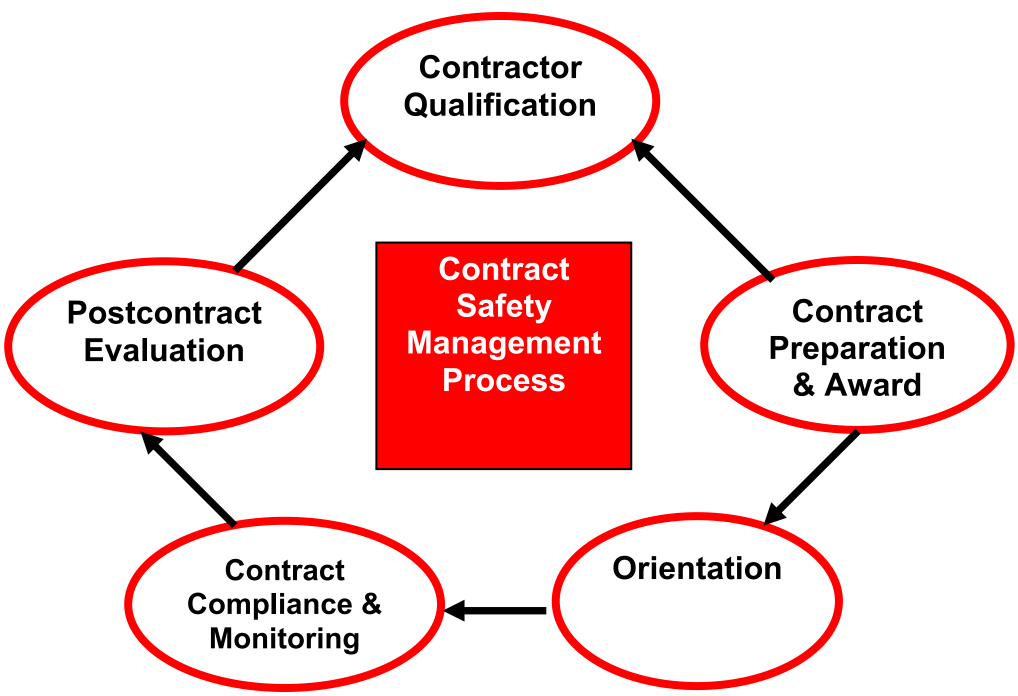

Figure 3. Key Spheres of Owner Influence

Five Step Contract Process

When contracting for construction services, Southern Company Generation (SCGEN) follows well-defined procedures to help ensure the safety environment on the construction site. Contractors are required to meet their responsibility for assuring the safety and health of its employees. SCGEN has developed a five step Contract Safety Management Process to help achieve its safety goals. For contract activities involving low dollar expenditures and/or low risks to the company, the performance of these processes will be at the discretion of responsible company management personnel. Specific examples will be provided during training.

1. Contractor Qualification - SCGEN will identify and evaluate potential contractors with a demonstrated commitment to safety and health.

2. Contract Preparation and Award - SCGEN will establish and communicate during the contracting process its safety and health requirements and expectations. These requirements will be appropriately included in all executed agreements between Southern Company Generation and contractor.

3. Orientation - Prior to the start of work, SCGEN will review contractual safety information with the designated contractor representative(s). Orientation training will be performed with contractor representatives. Contractors will be required to acknowledge receipt and understanding of this information, and document that this information has been communicated to their employees.

4. Contract Compliance and Monitoring - SCGEN will monitor compliance with the contract safety and health requirements. Non-compliances will be documented and reported to company and contractor management. For GEM employees working in or near contractor work areas, SCGEN will monitor the work environment to ensure the safety of its employees, and any unsafe conditions will be reported to contractor management for correction. Failure to promptly correct reported conditions can lead to stoppage of work and termination of the contract.

5. Post contract Evaluation - SCGEN will perform an evaluation of the contractor's safety performance upon completion of the work. This evaluation will be documented and communicated to SCGEN management and the contractor's representative when appropriate. The results and conclusions of this evaluation will be utilized in consideration of awarding future work.

Contractor Qualification Process

Perhaps the first step to ensure good safety performance on a project is to award the construction contract to a "safe" contractor. Although we may feel that there is never a certainty about the outcome of a project, the odds can be improved considerably through a careful selection process. Through a judicious selection process, contracts will be awarded to contractors who have a demonstrated track record in safety. But how should this be done? What measure of past safety performance should be used? There are a number of different factors that should be examined. The careful selection of the set of safety performance criteria that will be used to evaluate contractors is an important step. Of course, there is no single measure that can be used. Instead, a series of safety performance measures are recommended. These include historical measures and also "predictive" measures. Table 1 represents the "Objective Criteria" in use at SC today:

It may be appropriate to consider factors other than past performance measures when selecting contractors. Rather than looking back at what a contractor has done on past projects, it seems logical to consider what the contractor will likely do on the project in question. This assessment is made on the basis of predictors of safety performance.

Table 1. Additional Safety Qualification "Subjective Criteri a"

Criteria	Acceptable Thresholds
Previous Work Evaluations	Satisfactory Safety Evaluations
Experience Modification Rates (3 yrs)	EMR of 1.0 or less
OSHA Recordable Incidence Rates (3yrs)	Acceptable: 5.0 or less
OSHA Citation History (5 yrs)	Zero Willful Citations

Rather than looking back at what a firm has done, this approach looks to the future and involves making assumptions about the effectiveness of implementing certain practices on the project under consideration.

Written safety programs
Company safety commitment

- A mission statement that affirms the company's posture on safety
- A policy statement from the firm that asserts its commitment to safety
- A letter of commitment to project safety signed by the CEO
- A policy stating the active involvement of top managers in project safety

Safety personnel qualifications
Project management team qualifications
Company web-site: Is safety even mentioned?

Contract Document

The Contractor shall observe all federal, state, and local laws and regulations. Attention is directed to the regulations of federal, state and local agencies
Contractor must submit a safety policy signed by its CEO
Contractor must place at least one full-time safety representative on the project

- Safety Representative with other duties at less than 50 workers

- Full-time safety professional at 50 workers up to 250
- One additional safety professional for every 100 workers over 250

Contractor must submit the résumés of key safety personnel for the owner's approval
The Contractor shall implement a safety program that meets or exceeds that of the client
Contractor must submit a site-specific safety plan

- OSHA specific regulations
- Specific safety training sessions
- Contractor's employees must have 10-hr OSHA cards
- Contractor's supervisors must have CPR and First-Aid cards
- Training on the hazards related to the tasks
- Pre-project safety planning
- Task specific PPE analysis
- Conduct regular safety inspections
- Incident reporting and investigations
- Emergency plans (medical and hazardous materials)
- A substance abuse program must be implemented
- Regular safety meetings
- Safety responsibility defined for all levels
- Emergency response team maintained on the project
- Daily JSA (job safety analysis) conducted on the project site

Contractor must implement a permit system when performing hazardous activities (line breaks, lockout/tagout, excavations, proximity to power lines, confined space entry, hot work, etc.).

Contractor is required to provide specified PPE (hard hats, safety glasses, gloves)

Contractor must provide specified minimum training for the workers

The Contractor must train, certify and license equipment to the specific make and model

they will operate on the project

Contractor must submit subcontractor list to owner for approval

Contractor shall ensure that all subcontractors comply with all project safety requirements.

Contractor must implement a substance abuse program.

Contractor must include personnel from the owner in coordination meetings.

Contractor must conduct weekly safety meetings for the workers.

Contractor must participate in site safety audits.

Contractor must promptly report to the owner the occurrence of all lost time injuries and all OSHA recordable injuries. The Contractor will submit a monthly summary to the owner regarding the all first aid injuries.

Contractor Premobilization

After the successful bidder has been chosen, it is prudent for the owner to meet with the contractor's site senior leadership and safety professional prior to the start of construction activities. This will assure that the written site specific programs are in place, the resources such as PPE, training and other materials are available. More importantly, these contractor employees will lead the safety effort for their employees and the owner can take this opportunity to review requirements. This meeting also often makes such a positive impression that it sets the overall tone that the project safety processes take throughout construction activities. SCGEN has developed a written checklist utilized during this meeting to assist in covering the key points and document the discussions.

3. CONTRACTOR SAFETY, HEALTH AND ENVIRONMENTAL ORIENTATION CHECKLIST

Southern Company Generation
Attachment III-1

Company Representative(s) shall review with the Contractor's site management all site-specific and contract-specific safety, health and environmental requirements that are applicable to the Contractor's scope of work as defined in the written contract. It is the Contractor's responsibility to convey this information to all of the Contractor's employees and subcontractors. Contractor site management must acknowledge receipt and understanding of the safety, health and environmental requirements by signing this checklist. Contractor site management must also submit written documentation that all employees and subcontractors have received an equivalent safety and health orientation prior to work activity.

This Checklist shall be used to assure basic safety, health and environmental issues are covered. Any additional project-specific issues should be added in the space provided.

Check each item that is discussed with the Contractor's representative. If the item is not checked, then that item is not applicable to the work being performed

1. Personal Protection Equipment

- □ Head Protection
- □ Eye and Face Protection
- □ Foot Protection
- □ Hand Protection
- □ Traffic Vests
- □ Respiratory Protection
- □ Basic Work Clothing

2. General Safety

- □ Housekeeping
- □ Sanitation

□ Illumination
□ Materials Storage and Handling
□ Signs and Barricades
□ Ladders
□ Scaffolds
□ Manlifts – Use and Training
□ Fall Protection – 100% above 6’
□ Steel Erection
□ Rigging and Lift Plans
□ Crane Suspended Work Platforms
□ Chain & Lever Hoists & Jacks
□ Power Tools
□ Grinders – Pedestal, Bench and Portable
□ Hazardous Energy Control (Lockout/Tagout) and Clearance Procedures
□ Excavation and Trenching
□ Blasting Operations
□ Confined Space Entry
□ Welding, Cutting, Heating
□ Compressed Gas Cylinders
□ Transporting Personnel
□ Working Over or Near Water
□ Demolition Operations
□ Atmospheric Monitoring

3. Major Equipment

□ Mobile Cranes
□ Forklift Operations
□ Earth Moving Equipment
□ Aerial lifts and Bucket Trucks
□ Elevators
□ Overhead Cranes
□ Mobile Equipment Near Electric and Process Lines
□ Vehicles, Carts and Gators

4. Occupational Health

□ Hearing Conservation
□ Hazard Communication Program
□ Bloodborne Pathogens
□ Lead Paint Abatement
□ Inorganic Arsenic
□ Silica
□ Asbestos
□ Abrasive Blasting
□ Industrial Radiography
□ Material Safety Data Sheets

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Contract Compliance and Monitoring

SCGEN will monitor compliance with the contract safety and health requirements. Contract non-compliances will be documented and reported to company and contractor management. For SCGEN employees working in or near contractor work areas, SCGEN will monitor the work environment to ensure the safety of our employees, and any unsafe conditions will be reported to contractor management for correction. Failure to promptly correct reported conditions can lead to stoppage of work and termination of the contract**.**

Safety Violations
If we observe a contractor employee violating a site safety or regulatory rule that poses an imminent danger to themselves, our employees, or our facilities, we should stop the activity and contact the Contractor supervision to request corrective action. If the nature of the violation does not pose imminent danger, the Company employee observing the violation should notify the Company's contract administrator, compliance personnel, or other supervision. The contract administrator or his representative will then notify Contractor management and request corrective action.

Corrective Actions
A Safety Non-conformance Report (SNCR) process will be developed and implemented to document the request for corrective action and to verify follow-up. The Contract Administrator or Safety Personnel will meet with the contractor on a periodic basis to review SNCR records and overall contractor safety performance. The failure to satisfactorily correct reported exceptions to the contract safety terms and conditions, or circumstances where the contractor's work activities are placing our employees or facilities at risk, can result in the work being stopped. Repeated instances could result in the termination of the contract.

4. EXAMPLES OF OWNER INFLUENCE ON CONTRACTOR SAFETY THROUGH FOCUSED OR TARGETED SAFETY PROGRAMS

Eye Safety Program

Brief overview description:
The Eye Safety Program is a program that was designed to dramatically reduce eye injuries on a construction project. The objective of the program was to reduce eye injuries by increasing worker compliance with wearing eye protection. A top level safety manager of the facility owner was the initial party to start the program development, but he enlisted and obtained considerable assistance and support for implementation from safety personnel of the owner at the project site. This program was begun as a project specific program.

1. Motivation for Initiation
This program was developed after it was observed that there were a disproportionate number of eye injuries among the first aid injuries treated at the project nurse's station.

Eye injuries constituted 41% of all the first aid injuries, a value that is far greater than the normal distribution of eye injuries.

2. Benchmark Prior to the Program

There was no actual benchmark regarding eye injury incidents. Once it was decided that a target safety program would be developed for eye hazards, subjective measures were devised. Different site personnel were asked to walk the jobsite and note the number of times they felt compelled to tell workers to wear proper eye protection. A total of 15 individuals made such observations. Each respondent spent approximately 2 hours on each field walkthrough. There was considerable variation between the observations of different individuals; however, the average rate of non-compliance was about 12 incidents per 24-hour period.

3. Target Safety Program Champion

The facility owner's corporate safety manager on the project site was the official champion of the eye safety program. This individual kicked off the program and continued to monitor it during the project execution phase. The site safety officer was a willing and easy recruit to assist in implementing the program.

4. Development of the Program

When the need for an eye safety program was first realized, an assumption was made that most eye injuries were due to workers failing to wear the proper eye protection. This was verified through information obtained from field safety personnel and site supervisors. Proper eyewear was typically considered to consist of safety glasses, "spoggles", and goggles, i.e., workers must determine the proper eye protection for the existing conditions. A review of the first aid injury log showed that most of the eye injuries were from dust blown into the eyes. Because of the nature of the work done at the project, there were many locations that harbored accumulations of dust and iron filings. Since the project already had a safety eyewear policy, it was simply a matter of increasing compliance. It was felt if workers would wear the proper eye protection that a significant decline in eye injuries would occur.

5. Implementation of the program- selling the program

Since there was already a policy of wearing eye protection at all times, the eye safety program was one of getting greater compliance with the policy. While several of the owner's site personnel (not exclusively safety personnel) were told personally of the new initiative to reduce eye injuries by the corporate safety officer, a formal approach was also employed. The first step was to alert everyone of the intent to reduce eye injuries as part of the Target Safety research project of the CII. The memorandum that went to all of the owner's personnel on the project site is shown below (see Figure 4).

Subject: Eye Protection

Most of you are aware that our Company is a member of the CII (Construction Industry Institute), and we have been asked to participate in a study with regards to eye protection. This study is being supported by our corporate safety department and they have requested your help. We have shared all first aid data with regards to eye injuries with them but they have asked if we can quantify on average how many times we would remind personnel in the field to wear the proper eye protection for the tasks they were performing. In the time period form January 2005 thru the end of May 2005, how many times on average did you have to remind personnel in the field to put on proper eye protection? Please respond by quantifying it such as 1/week, 4/day, 8/month, or none.

Please respond as soon as possible,

Thank You,

Project Safety Specialist

Figure 4. Memorandum sent to site personnel about the Eye Safety Program

To re-energize the workers about the need to wear proper eye protection, a number of methods were employed. For example, the eyewear topic was a regular subject of many toolbox meetings. The project newsletter also reiterated the need to comply with the eye protection policy. All supervisory and safety personnel were asked to make a point of noting whenever a worker was not wearing eye protection. When such non-compliance instances were noted, they were to immediately bring this to the attention of the workers and ask them to put on the proper eyewear. New worker orientation stressed the elements of the eye safety program. This orientation included a learning lab in which workers were shown various items related to safety. This included a station related to eye protection. In addition, a job poster was posted at different locations about the project site. This poster stressed the severe consequences of not taking care of the eyes in the workplace (see Figure 5). In essence, the program was implemented by communicating the importance and proper use of eye protection through several different means.

Figure 5. Jobsite poster that stressed the need to protect the eyes

Site personnel who made jobsite inspections were asked to specifically fill out an Eye Injury Report Form (see Figure 6). Completing this form helped to document information related to eye injuries. This also was helpful in emphasizing the importance of the eye safety program.

Eye Injury Report Form

This form is provided for users of occupational and educational eye and face protection. Completing and returning this form will assist the Z87 Committee on Safety Standards for Eye Protection
to improve this standard and develop others, as appropriate. The Eye Injury Report Form is not subject to
copyright and may be reproduced as needed.

Eye Injury Report Form

Please report all work-related and education-related eye injuries to assist the ANSI Z87 Committee on Eye and Face Protection develop improved standards. Eye injuries include injuries to the eyeball, surrounding tissue such as the lids, and the bones forming the eye socket.

1. Injured worker information **2. Employer information**

. Worker's initials (first/middle/last) __________ Nature of business: ______________________________

Sex ☼ Male ☼ Female Age __________ (describe in detail; e.g., steel ball-bearing manufacturer)

Job title/type of work: _______________________ Contact name ___________________________________

(describe in detail) Title ___________________________________

____ Company name _________________________________

(e.g., journeyman carpenter-concrete form builder) Address _______________________________________

Date of injury (mo/day/yr) _____/_____/_____ City _____________________State ____ Zip __________

Was there 1 day (8 hr) or more of lost work -time? Phone (____) _____________ FAX (____) ____________

☼ Yes ☼ No ☼ Unknown

3. Industry type *(check one)* **4. Part of body injured** *(Check all that apply)*

☼ Agriculture/forestry/fishing ☼ Eyeball, one eye ☼ Other tissue around eye

☼ Mining ☼ Eyeball, both eyes ☼ Bone, eye socket

☼ Construction ☼ Eye lid ☼ Other:______________

☼ Manufacturing

☼ Transportation **5. Nature of injury** *(Check all that apply)*

☼ Public Utility/Sanitation ☼ Corneal scratch/abrasion _ Thermal burn
☼ Finance/Insurance/Real estate ☼ Foreign body on eye surface _ Chemical burn
☼ Retail/wholesale trade ☼ Foreign body in eyeball _ Radiation burn (welder flash)
☼ Services (e.g., lodging/food/health/legal/social/education) ☼ Puncture of eyeball _ Blunt trauma to eye
☼ Public Administration (e.g., govt/police/fire/safety/military) ☼ Laceration to eye or lid _ Blood in eye
☼ Other *(describe)*: ☼ Facial fracture _ Other: ____________________

Figure 6. Example of the Eye Injury Report Form

6. Inspecting and monitoring for Compliance

The information about eye injuries was tracked in a number of ways. The Eye Injury Report Form was completed for each eye injury, in addition to recording some relevant information in the first aid injury log. Information was also maintained on how frequently workers were observed to be in non-compliance, namely the frequency by which workers were told to wear the proper eye protection.

7. Disciplinary Action

While non-compliance with the eyewear policy was noted with some frequency when the program was first implemented, there were no specifically outlined consequences for this non-compliance. Instead, workers were always instructed to put on the necessary eye protection, i.e., no infraction was ignored. The general demeanor of the workforce was such that there was good worker responsiveness to these requests. Rather than imposing penalties for non-compliance, the safety personnel were simply trying to provide friendly reminders to the workers, and the workers generally complied with these requests.

8. Measure of Success

As the program began, there was an average 12 instances of non-compliance per 24 hour work day. In addition, the number of eye injuries constituted 41% of the first aid cases prior to the initiation of the eye safety program. This program was initiated during the month of June, so the data for June were not included in any of the analyses. In the five months that followed the program initiation, there were several indications that the program was successful. First of all, the number of instances of non-compliance dropped to about one per week. In addition, the eye injuries dropped as they constituted only 19% of the first aid injuries.

9. Goal Achievement

The results of the program: five months after program initiation, results showed that the program is a success. It was realized that the effort must be sustained to continually remind workers to wear the proper eye protection.

Owner Can Assist in Employee Orientation and Site Indoctrination

When craft employees report to the project, they receive a very powerful message if a senior owner representative also attends the site orientation session. They can take the opportunity to show support of the contractor's safety efforts and outline the owner's safety expectations. At SCGEN projects, we provide the "Safety Learning Lab" for contractors to orient their employees. The Learning Lab is a hands on, visual, highly interactive training experience that greatly enhances the learning experience.

Figure 7. View of Safety Learning Lab stations 1-5 where such topics as Zero Injury, report all injuries, Fitness for Duty, Behavior Based Safety, vehicle safety, Safety Task Assignment, PPE, Hazard Communication, Hearing Conservation, and housekeeping are discussed

Figure 8. View of Safety Learning Lab station 10 where fall prevention, 100% fall protection, anchorage points, ladder safety, scaffold safety, barricading, and special work permits is discussed

Figure 9. View of Safety Learning Lab station 14 where hand and power tool safety is discussed

Figure 10. View of Safety Learning Lab stations 6 and 7 where the topics lock out/tag out, electrical safety, Process Safety Management, fire prevention, fire protection, and welding safety are reviewed

Figure 11. View of Safety Learning Lab stations 8-13 where excavation procedures, alarm systems, safety showers, rescue, confined space entry, cranes, critical lift permits, rigging, ergonomics, manual material handling, waste disposal, and HAZWOPER topics are discussed

5. CONCLUSIONS

The owner influence on contractor safety is not only inevitable but absolutely essential in regards to successful completion of today's complex construction projects. Tighter budgets, extreme time constraints, limited resources, workforce dynamics, and increased regulations present challenges that can lead to negative consequences without proper controls and interventions. The facility owner is uniquely positioned to assure effective injury prevention measures are implemented by all. The owner provides the stabilizing force with safety leadership, serving as an example, and governance through oversight of the policies, procedures and processes utilized to match the challenges. Figure 12 shows the positive influence on contractor safety that SCGEN has achieved utilizing sound safety principles.

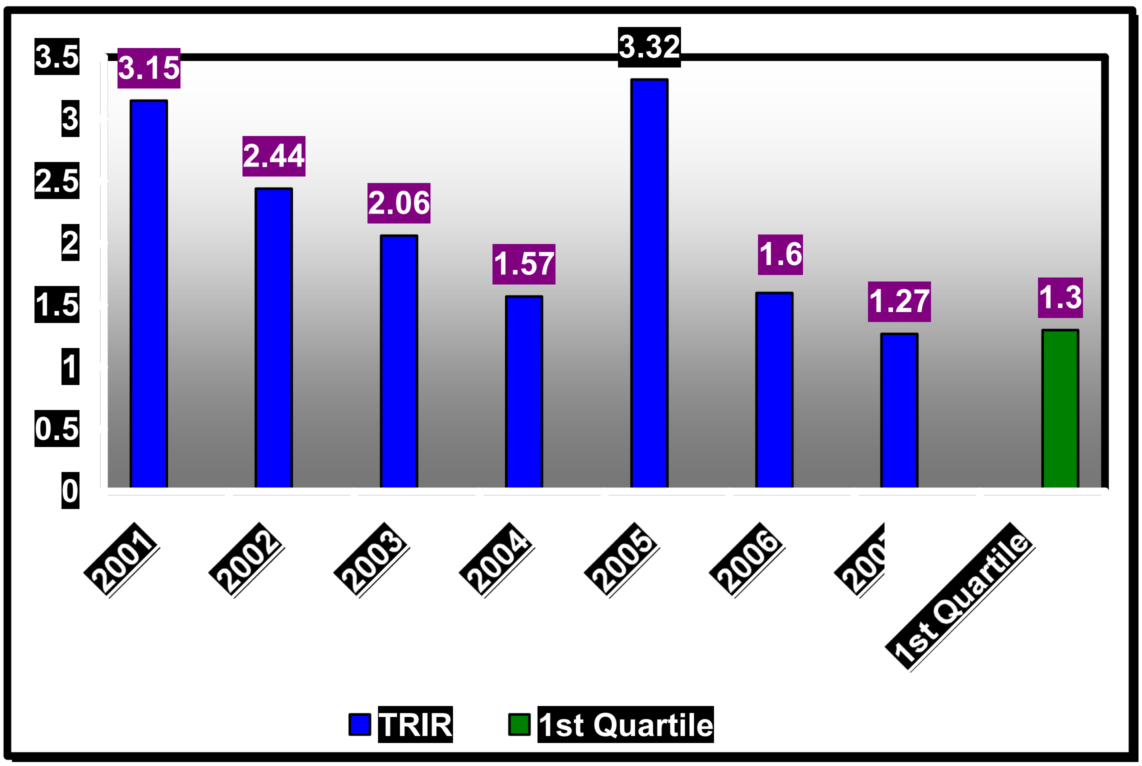

Figure 12. Safety Performance (RIR) as influenced by SCGEN

6. RECOMMENDATIONS

Owners should develop a process to select safe contractors, establish anticipated safety expectations for the project, ensure essential injury prevention methodologies are implemented, monitor ongoing work in progress for compliance, have a system in place to address any non-compliance, and evaluate the contractor's performance at project completion.

Developing an owner contractor safety management process with the elements in the model above can lead to a step change in project safety versus no involvement. It is additionally recommended that as an owner develops and implements contractor safety processes that proper legal advice is also consulted for guidance. The success of each project will have a cumulative effect and over the long term prove to be sustainable with due diligence.

THE VALUE OF A SAFETY COMMUNITY OF PRACTICE

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ABSTRACT

Construction firms function in a competitive world. Because of this competitive environment, firms are often quite guarded about sharing information with others about their successes. Success can be defined and realized in many forms, including the achievement of goals related to costs, schedules, quality, client satisfaction and safety. While firms are often quite guarded about information pertaining to their operations, firms in the construction industry tend to be quite willing to share information on successes in safety. Unfortunately, there has been no viable forum through which this type of information could be shared on an ongoing basis. This can change through participation in a safety community of practice which consists of a group of safety professionals who network regularly through meetings and teleconferences. Through this network, one professional can quickly poll the other members about a specific issue or problem. A myriad of safety topics may be discussed, including interpretations of regulations, techniques used to address specific site conditions, legal concerns, best practices for a particular task, and so on. Through this process, one member might receive an answer to a specific question while another might glean insights about a topic that had not been previously considered. The success of the safety community of practice lies in the continued openness that is maintained within the group.

Key Words: Best Practices, Community of Practice, Safety Network

1. INTRODUCTION

Safety professionals have complex positions which require them to remain informed on many topics. This has become more involved and complex in recent years because the role of many safety professionals has expanded to include health and environmental issues. As a result, the safety professional now has obligations that include various types of regulations, policies and practices. Staying informed on all these issues and staying at the cutting edge of best safety practices can be difficult, especially when new changes occur.

How do safety professionals stay abreast of all these issues involving safety, health and the environment? There has not been a single agency or association that has the mission of keeping up-to-date on all these issues in the construction industry. Even if a resource is found that relates to new regulatory changes, how does the safety professional stay informed on new advances in best practices? There has not been a single entity that has provided this type of information.

The periodic aggregation of several safety professionals may actually be the best means by which these individuals can collectively share valuable insights on the many facets of safety, health and the environment. While construction firms work in a competitive environment where many company secrets are carefully protected, this guarded information does not generally extend to issues related to safety, health and the environment. In fact, most construction firms will readily share any information that relates to successes related to safety, health and the environment. Unfortunately, there has not been a regular means by which the safety professionals could gather for this purpose. Success stories have historically been spread by word of mouth. Even though this information may be shared with some, it is not officially recorded and the information may only be shared with an isolated few firms. This issue can be successfully addressed through a formally established safety community of practice.

2. A SAFETY COMMUNITY OF PRACTICE

A safety community of practice is a formally established group of safety professionals who meet on a regular basis to share information of mutual interest. Such a group has been established through the facilitating efforts of the Construction Industry Institute (CII). The formation of the safety community of practice began in the fall of 2006. The initial efforts were focused on determining the level of interest of selected safety professionals within the CII member companies. After it was determined that at 15 firms were interested in participating in a safety community of practice, a formal meeting was organized. The CII then formally invited all interested safety personnel of the CII member companies to participate in the activities of the safety community of practice. The first meeting was hosted by the CII in its headquarters in Austin, Texas. Since there was no other established community of practice with the CII, considerable latitude was given to the newly-formed safety community of practice to establish how it would function. At the initial meeting of the safety community of practice, over 25 safety professionals attended, including participation form both contractors and owners.

The essential goal of the safety community of practice was to serve as a means by which information related to safety, health and the environment could be shared on a regular basis. The general objective was for each participating firm to participate in the safety community of practice with the "selfish" interest of obtaining valued information in exchange for sharing information with the safety community of practice members. That is, it was felt that the activities of the safety community of practice would be most successful if each participating firm sought to gain real value from the safety community of practice while opening sharing information with others. The stated purpose of the safety community of practice is as follows;

> This is a formal organization working towards an accident free workplace through the leveraging of lessons learned and best practices. Its goal is to increase the overall safety performance of the construction industry by publicizing information through a website maintained by the CII. Information of particular interest will consist of vague or problematic issues that have been faced by safety community of practice members. Current issues and upcoming concerns will also be addressed.

At the first meeting, participants agreed that the safety community of practice could serve as a viable means of getting information on new and proposed regulations, successes related to best practices, new concerns of interest to safety professionals, etc. It was envisioned that some information would simply be provided to the safety community of practice by a single firm that had a particular success story to share. Another means of obtaining information would be through inquiries that would be made by one individual to the entire safety community of practice membership. Furthermore, the responses to an inquiry would be summarized for the benefit of all the safety community of practice members. Emerging issues or concerns, such as a safety alert, would also be shared. The safety community of practice then enumerated the various benefits that might be realized by the participating members. While there was some duplication of ideas, the following captures the general sense of the group about the various benefits that could be realized by participating in the group:

- Success stories of "how to"
- Stories of what has not worked
- Collaborating on data and sharing of strategies, e.g. chromium 6
- Collaboration on challenges, e.g., single language work sites, diverse workforce
- Share innovative ideas and technology that assist and educate the field safety personnel to work more effectively at all levels e.g. supervision, management, craft
- Share ideas that help to simplify procedures for field workers
- Share ideas and chart paths on how safety professionals can be developed (craft and academic experience) and hired to satisfy future demands
- Find ways to positively influence safe work behavior in the workforce
- Provide safety leadership training for foremen
- Come up with a standard means of measuring or evaluating a safety management system (one that might be used by all parties)
- Be informed about new issues that are arising in the area of safety (what safety will look like in the future)
- Know about the leading indicators of safety
- Applying US standards of safety on a global scale, e.g. injury classification
- Obtaining collaborative opinions from fellow experts on specific questions
- Defining the framework for risk management for domestic and international activities

- Designing for safety to eliminate hazards and reduce the need to rely solely on PPE protection
- Safety constructability
- Having open discussions with fellow experts
- Resource sharing
- Sharing of knowledge on SHE topics
- Sharing of lessons learned
- Sharing benchmarking data
- Regulatory input and influence
- Legal ramifications of the work of SCOP participants
- Suggestions for NORA
- Networking with other agencies, organizations, etc.

It was agreed by the members of the safety community of practice their efforts should be archived in some manner so that the safety community of practice would have a well-documented history of the information that has been shared among the members. Since the CII had agreed to host a web site to document the work product of the safety community of practice, the decision was made by CII to use SharePoint for the purpose. This site would be used to record all information pertaining to the activities of the safety community of practice, including the membership roster, meeting agenda, meeting minutes, query summaries, safety alerts, information on topics discussed, governance documents, and other related information.

3. GOVERNANCE

At the first meeting of the safety community of practice it was agreed that guidelines, a charter, or some form of governing document was need to help set standards of procedure for the group. This issue was addressed over the course of approximately six months, with most of the work being accomplished through the efforts of an ad hoc committee. This effort resulted in two documents. One pertained to the membership and leadership of the safety community of practice, known as the charter for the group and the other pertained to guidelines to be followed when presenting a query to the safety community of practice.

While the governance document was carefully drafted and eventually unanimously adopted, it should be noted that governance was never a contentious issue for the safety community of practice. The members of the safety community of practice have agreed to participate in the safety community of practice in order to obtain up-to-date information on a variety of related issues. In effect, the safety community of practice serves as a network of safety professionals where information on safety, health and the environment is readily shared.

4. MEETINGS

It was agreed at the initial meeting of the safety community of practice that meetings should be held on a monthly basis. Meetings would consist of a mixture of face-to-face meetings and teleconference meetings. To date, approximately half of the meetings have been face-to-face meetings held at sites where a safety community of practice member would serve as the host for a one-day meeting. The one-day meetings tend to be adjourned by mid afternoon to accommodate safety community of practice member travel. Face-to-face meetings are also arranged so that members can call in if they cannot travel to a particular meeting location. The teleconference meetings are held for one and a half hours. To avoid confusion, meetings have always been held on the second Wednesday of the month, whether a face-to-face meeting or a teleconference. While every member cannot be expected to attend or participate in every meeting, a set schedule lets the members plan for these meetings in advance. Experience has shown that the probability of safety community of practice members attending the meetings is increased if they have reliable information on the dates for future meetings.

It has been noted that the face-to-face meetings are generally more productive than the teleconference meetings, primarily because more time is allowed to delve more deeply into the various topics. Also, the discussion at face-to-face meetings tends to be more "free-wheeling" and lively with more ideas being generated.

5. RESEARCH WITHIN THE SAFETY COMMUNITY OF PRACTICE

With forty five members in the safety community of practice, it is evident that a viable body of experts have become engaged in the group. Initially, the query process was viewed as being central to the working of the safety community of practice. A query is simply a question that would be posed by one member for comment and input being provided by the other members. The query might be on a particular practice that is employed or an interpretation that is made regarding certain site conditions. The query process is designed so that the person posing the query is referred to as the "champion" of the query. The champion is to process and analyze the responses that are provided for a query and then post the results on the SharePoint site of the safety community of practice.

Once the query process was developed, it became clear that the membership was sufficiently large to actually conduct small research studies within the group. The aim of some research studies might be to find out how practices vary among the safety community of practice members on specific issues. The research may also try to identify best practices among the members. The research could also be used to change the practices of the industry. Since the safety community of practice members represent firms with substantial construction interest (especially in terms of financial outlays), it is felt that viable changes might actually be initiated by the safety community of practice.

There are many different subjects of interest to the members of the safety community of practice. Some may be immediate problems faced by firms but it could also consist of problems that are envisioned as being more distant issues of concern. The different types of issues or "hot topics" to be considered consist of the following:

Worker Issues
- New workforce
- Aging workforce
- Educate craft workers in safety
- Craft training skillset
- Cultural issues along with language issues
- Drug culture
- Craft turnover
- Benefit packages for field workers
- Nuclear workforce

Supervision Issues
- Line management responsibility for safety
- Aging supervision and management population

Management Issues
- Making the business case
- Educate upper management

Measures of Safety
- Consistent and accurate of leading/lagging indicators
- Effective auditing techniques
- What should a senior management dashboard look like? (what metrics should be looked at?)

Major Topics
- Multi-tiered subcontracting
- Health issues need greater emphasis
- Contractor/owner alignment
- Integrated safety management in the front-end or planning phase
- Hexavalient Chromium (also monitoring of exposure)
- Fall Protection and Life Lines
- Arc Flash Protection
- Crane Operations (Most accidents are caused by operator errors and rigging mistakes): certified training, defining competency for operators and qualifications for riggers
- Rise in Muscular-Skeletal Injuries
- Improving quality of safety by rolling out Educational Module #160
- Untrained workers (bolstered somewhat by NCCER training for which many companies give workers added pay)
- Workload strains company resources (cultural issues, standardization, and international challenges abound)

- Tolerance for life critical behaviors (including confined space, fall hazards, trenching, vehicles, electrical equipment), risk acceptance should be low
- Slips, trips and falls resulting from complacency (failure to place emphasis on less serious hazards)
- Demonstrated safety leadership
- Safety execution plans
- Caring for co-workers
- Responsibility is an individual trait (from executive to field worker)
- Building up a workforce and starting from scratch to develop the safety culture
- Process safety design
- Safety accountability for middle management
- Craft training and supervision training
- Where are the key hazards associated with specific crafts and how to prevent injuries
- Supervisors understanding the people component of safety (training them the management techniques)
- Variability of safety emphasis depending on the owner
- Huge work backlog
- Maintaining good safety performance on projects
- Staffing projects with qualified safety personnel (placing new personnel with veteran safety people)
- Addressing differing techniques to effectively train non-English workers
- Pandemic flu planning
- Supervisor-subordinate relationships in the safety area

6. CONCLUSIONS

The safety community of practice is about a year old at this time. A stable group has been formed and a positive experience has been realized by the safety community of practice members. The format for leadership and governance has become well-established and the safety community of practice can now focus its attention on the mission of the safety community of practice.

Questions do arise for which the safety community of practice serves as a valued resource. Without the safety community of practice, some questions would simply go unanswered or they would be answered over an extended period of time through the individual efforts of those with the questions.

7. RECOMMENDATIONS

At the outset, it should be emphasized that these recommendation are specifically those of the authors and may not necessarily reflect the opinions or sentiments of any other members of the safety community of practice. Nonetheless, the participation in the safety community of practice has been strong and sustained, and it is recommended that the activities should continue with no major alteration of the general scope of the activities of the group.

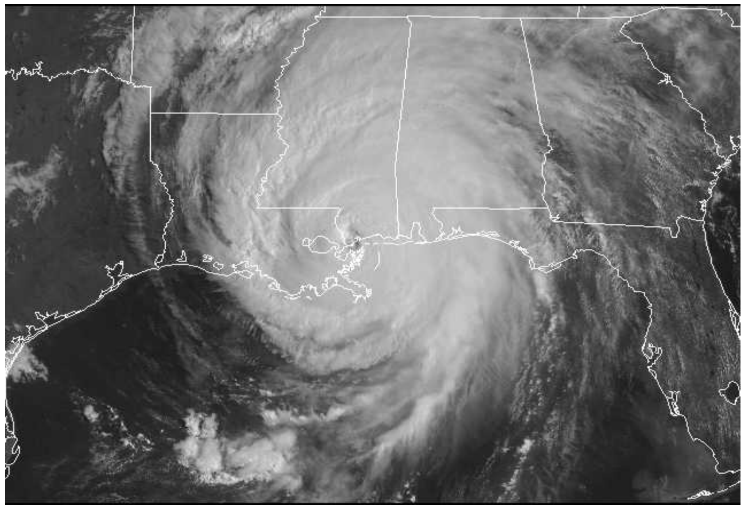
While it is counter to the wishes of the CII, the authors feel that the safety community of practice membership should not be restricted to CII member companies. In the spirit of sharing safety information freely among all interested parties, the authors suggest that membership should be open to any individuals who are interested in safety, health and the environment. The additional members from outside the CII membership could offer additional perspectives that could only help the industry. Also, the influence of the safety community of practice would be broader and improvements in the safety performance of the construction industry could be more readily realized.

In the same vein of thought, the SharePoint site should be open to the public for its use. Currently the web site is only accessible to the CII members who are members of the safety community of practice. While this is an issue over which the CII has exclusive control, it could benefit the construction industry to a greater extent if other could also view the work product of the safety community of practice.

The safety community of practice that has been formed through the facilitating efforts of the CII shows promise of being viable resource group to others with question on matters of safety, health and the environment. Efforts should be made to publicize the existence of this group. Others could then pose questions to the safety community of practice on a variety of issues. In addition, the safety community of practice members should recognize that this group can impact significant changes in the construction industry and it should begin to take steps to pursue initiatives that will improve the overall performance of the construction industry in the area of safety, health and the environment.

With the success of this safety community of practice it is suggested that others consider developing or organizing similar groups. Large companies might consider the establishment of such a community of practice that consists of only its own employees. The membership might also be extended to other large companies with similar interests. For small firms, the establishment of a community of practice for safety would of necessity require the organization to extend across several companies. Industry associations might play value facilitating roles in developing such communities of practice.

KATRINA … EMERGENCY RESPONSE



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ABSTRACT

Hurricane Katrina (Category 4) struck the Gulf Coast in August of 2005 displacing 770,000 residents and causing more than $100 billion in damage. Three weeks later hurricane Rita added to the destruction. Fluor under a response contract with FEMA – Individual Assistance took on the project to provide support to the people of Louisiana, mobilizing over 500 personnel in 72 hours and 1000 persons within 30 days. In just over one year, the project team safely installed more than 54,000 temporary housing units throughout the state—housing more than 160,000 displaced residents. This process entailed over 67 million miles driven—across more than 39,000 square miles—a uniquely challenging feat indeed.

As America nervously watched Hurricane Katrina barrel toward New Orleans, Fluor was already on the ground in Louisiana, hoping for the best, but preparing for the worst. Unfortunately, the worst case scenario quickly became a reality. More than 1,520 people across five states were killed from the Category 4 storm and 1.4 million more were displaced. The number of destroyed households topped 217,000 and more than 18,000 businesses were damaged or destroyed (Heran, 2006). Within days of Hurricane Katrina, pressure was mounting on the Fluor FEMA IA-TAC team in Louisiana, as well as other contractors working in the Gulf Coast, to install temporary housing for displaced citizens and do it quickly. The world was watching.

Yet, no one inside or outside of Fluor knew exactly how to deal with a catastrophe so enormous. It was like God took a broom and swept everything around. In many places, all that was left were slabs where houses once stood. The enormity of the damage was beyond comprehension.

What had worked in the aftermath of previous hurricanes was of little help. Katrina was the greatest natural disaster ever to strike the United States and there was no blueprint for providing temporary homes for hundreds of thousands of displaced Gulf Coast citizens. FEMA tasked Fluor, along with 3 other large firms, under the Individual Assistance contract, with aiding in the recovery of the region, primarily by helping displaced residents transition from emergency shelters to temporary housing. Based on eight years of experience working for FEMA, Fluor was given the responsibility of assisting Louisiana residents across the entire state.

The number of immediate hurdles to be cleared seemed endless. The Louisiana infrastructure was compromised. Lodging for the Fluor team was scarce—some would sleep under desks and in tents for several weeks. There was no suitable office space for Fluor managers and their teams. Logistical support was nonexistent. Communications were spotty at best. The thousands of local workers, such as electricians and carpenters, necessary to execute the temporary housing mission simply were not available. Little did we know Hurricane Rita would strike in three weeks, further complicating recovery efforts.

Fast forward six months to Feb. 28, 2006. The electronic tote board in the Fluor operations center in Gonzales reported that more than 30,000 temporary homes had been installed and were being maintained by Fluor in Louisiana. These temporary homes stretched across 39,000 square miles and were in 62 of Louisiana’s 64 parishes.

The number of units installed and maintained by Fluor would ultimately swell to more than 54,000 by mid-August 2006, providing shelter to more than 160,000 people left homeless by Katrina and Rita. Seventy-five percent of the units were placed on individual, private home sites representing 40,000 different, uncontrolled work environments, each with its specific challenges and local permitting requirements, many of which changed almost daily. The work scope included conducting site assessments and inspections, staffing multiple FEMA Call Centers to interview displaced residents, designing and building sites for temporary housing, hauling and installing housing units and performing operations and maintenance on them.

Most importantly, the work was done safely. By the time Fluor concluded its mission in Louisiana, its team had worked more than 9 million safe hours without incurring a single lost workday incident.

What enabled the Fluor team to succeed in the face of such significant odds and create such value for both the citizens of Louisiana, who lost their homes and possessions, and its client, FEMA? How did Fluor optimize its production rates and develop the innovative solutions to problems that enabled it to outperform by a two-to-one margin the combined efforts of the other two contractors working in the state?

The answers are experienced leadership; a blend of tested and innovative processes and technologies; critical contributions by Fluor, Ameco, Del-Jen, P2S and TRS; and, most importantly, a workforce of 4,300 dedicated people. Here are some of the ways Fluor's project execution excellence was manifested:

Fluor CEO Alan Boeckmann made a decision to staff the Louisiana team with some of the most senior people in the company. A 15-member senior project management team consisted of highly experienced project managers, as well as many of Fluor's top functional leaders, including experts in compliance, project controls, project services, administration, general field operations, field operations, communications and quality control. With Alan Boeckmann's support, the employees were hand-picked to assume leadership roles in the temporary housing project. In the days and weeks immediately following Hurricane Katrina, there was intense media scrutiny of the speed with which hurricane victims were receiving assistance. FEMA turned to Fluor for help in measuring the progress of the four contractors providing temporary housing along the U.S. Gulf Coast. Within five days, a Fluor team had designed and launched a website that tracked the real-time progress of the four contractors. Within a month, more than 400 government officials and others were regularly turning to the website for information. In addition, the Fluor team published FEMA's daily official housing report, which provided critical information on performance to the White House and other senior government officials.

Three days after Katrina struck, Fluor leased a vacant, neglected warehouse in Gonzales, La., to be used as the Operations Center for the project. Working around the clock for two weeks, Fluor crews set about turning the windowless brick building into fully functional office space. The leaky roof, air conditioning and heating systems were repaired, restrooms were updated, the entire facility was rewired for phones and computers and a small kitchen area was refurbished so that meals could be served to employees who would routinely be working up to 16 hours a day and often beyond. Small, functional offices and hundreds of office cubicles were furnished with rented furniture to accommodate the 750 people who would work there in support of the field operations.

On Sept. 20, 2005—just 22 days after Katrina made landfall, the Gonzales Operations Center was ready for occupancy, only to be evacuated two days later when Hurricane Rita struck the state. Once the team was finally situated in the Operations Center, the performance of the Fluor team rapidly accelerated.

The Fluor team included 3,800 Louisiana citizens—representing 88 percent of its total employee base in the state. The teams' commitment to the task, coupled with the training received from Fluor, were critical factors to the overall success of installing temporary homes. Over time the workers became much more than just Fluor employees—they became comrades-in-arms focused on the assignment of providing temporary shelter to as many displaced people as possible—as quickly as possible. The ultimate goal was to rebuild Louisiana … one family at a time.

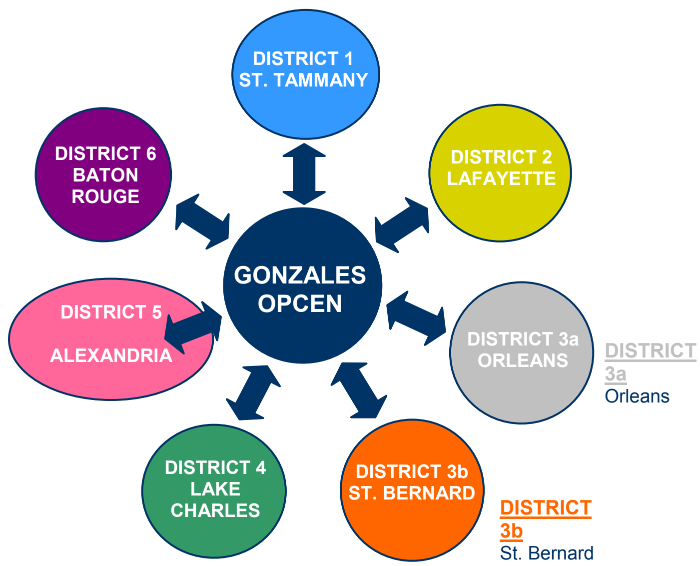
Fluor capitalized on its 45-year relationship with Louisiana's engineering and construction community to build a first-rate team of subcontractors. Within days of Hurricane Katrina, Fluor officials were obtaining long-term commitments from key Louisiana contractors for people and materials to accelerate the temporary housing project.

By the time its work in Louisiana was complete, Fluor had awarded $700 million in contracts to its subcontracting team. Right at 90 percent of those contracts went to Louisiana-based companies. 68 percent of the contract dollars went to small businesses.

The Fluor team conducted much of its work in a volatile and emotionally charged environment given the destruction caused by the hurricanes. As a result, Fluor took steps to protect its people and the assets under its control.

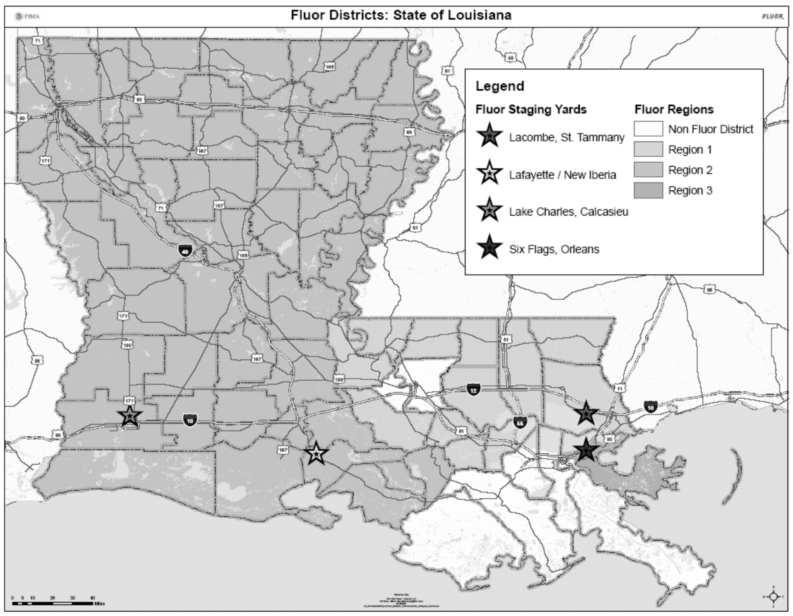
The security team, staffed with 95 percent local hires, ultimately secured eight office facilities, five staging yards and more than 54,000 temporary housing units across Louisiana. At the height of the project, 22 security managers, almost 400 unarmed guards and 100 off-duty, armed law enforcement officers were supporting the project around the clock.

Fluor's unique challenge was to manage a project that spread across 39,000 square miles of Louisiana. Project leaders responded to this challenge by setting up multiple district operating centers across the state. This enabled as many activities as possible to be conducted simultaneously, improving efficiency and effectiveness.



The result of this decentralized approach? The number of temporary housing units installed by Fluor rose from approximately 75 per day in early October 2005 to 175 per day by the first of November to nearly 400 per day by the beginning of 2006. Although this work is being performed on a grand scale, it is the personal encounters with disaster victims which often make the strongest emotional impact. One example came on November 22, 2005, FEMA notified Fluor of a pregnant Louisiana woman. She had lost everything she owned to the hurricane and was living in a tent with her 4-year-old child. Just 24 hours after FEMA and Fluor were informed of her situation, a new trailer was delivered—set up right beside the tent. As the sun went down the night before Thanksgiving, the Fluor Team worked in the dark, building porch steps, and connecting electricity, water and sewer to the unit. The Fluor Team brought Thanksgiving dinner for the woman and her child to eat while their trailer was being set up … this is just one of many stories that had a happy ending. (Heran, 2006).

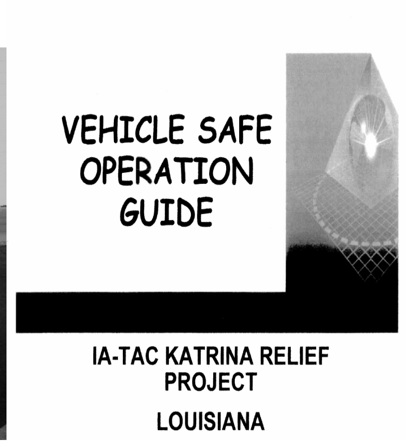
The devastation caused by the hurricanes made site location for temporary homes extremely difficult. Street signs and address numbers were often missing and maps were not always available. Fluor addressed this challenge by developing a planning and coordination tool to maximize its efficiency and effectiveness. This tool used Geographic Information System technology to determine the location of each potential installation site. In a graphical format, it provided near real time information such as the concentration of installations within each region, which was critical in execution planning and determining permitting and code requirements.



Approximately 90 percent of the Fluor temporary housing project workforce was made up of newly hired employees or subcontractors—virtually none familiar with Fluor's safety culture or the requirements for safely installing temporary housing. As a result, the Fluor Health, Safety and Environmental (HSE) management team instituted Safety Leadership Training for more than 700 supervisors. An HSE handbook was developed for the workforce and safety refresher courses were regularly conducted to ensure that the project's safety requirements would be met or exceeded.

A director's safety review committee met weekly to monitor compliance with project safety requirements, track project safety metrics and discuss emerging safety issues. This enabled the management team to take corrective actions, using real-time information, to prevent incidents.

In our quest to carry out the mission, more than 67 million miles were driven—averaging 250,000 miles per day at peak—making highway safety a top priority. To heighten driving safety awareness, all drivers of project vehicles were required to complete a defensive driving course conducted by Louisiana State Police.



One of the most critical elements of Fluor’s success was its ability to develop from scratch a Proliance-based database, STATS, to manage information on the thousands of trailers that Fluor was installing. The database constantly evolved as Fluor’s scope of work was better understood and its approach to executing it was refined.

Ultimately the system would track almost 450 different data points for each of the more than 54,000 temporary homes Fluor installed, providing reliable information on when and where a specific trailer was manufactured; when it entered and exited Fluor’s staging yard; when and precisely where it was installed; when the necessary permits were obtained; when it was occupied and by whom; and dates, times and specifics about maintenance of the unit.

A key to maximizing procurement efficiency and effectiveness was the implementation of a statewide material control plan. It was designed to ensure that excess material supplies in one district were used to fill shortfalls in another. It is estimated that this system ultimately generated more than $1 million in procurement savings.

The Fluor procurement team fully understood the importance of local content and supplier diversity. More than 90 percent of every procurement dollar spent went to Louisiana businesses and within days of Katrina making landfall, the Fluor purchasing team was finalizing agreements with several minority-owned suppliers.

At its peak, Fluor maintained almost 54,000 trailers spread across Louisiana – providing routine maintenance on 10 percent of them each week. On average, Fluor responded to emergency maintenance service calls in less than four hours. Routine unscheduled maintenance service was provided, on average in two days. The backbone of this effort was the 450-person maintenance workforce Fluor hired and trained.

The Fluor team in Louisiana was constantly looking for ways beyond providing temporary housing to give back to the people of Louisiana. Almost 40 employees who spent Thanksgiving 2005 in Louisiana, away from their families, volunteered to serve meals to emergency workers and the homeless in Orleans Parish. Each of the five district offices had programs to raise money for Christmas presents for needy children and ultimately supported 200 Louisiana families. For example, Fluor crews in St. Tammany

Parish raised enough money to fill a semi-truck with toys. Much of the money was donated by workers who had themselves been displaced by the hurricanes.

The Fluor temporary housing team had a natural bond with another organization that provided temporary housing to needy people—the New Orleans Ronald McDonald House. The building, which provides housing to the families of sick children from across the state, had suffered extensive flood damage and was forced to close its doors. The Fluor Foundation helped replace flood-damaged furniture, kitchen cabinets and appliances. Fluor team members convinced a local nursery to donate plants and shrubs to upgrade the landscaping at the house and donated their own time to tear out the old landscaping and plant the new shrubs and trees. And the Fluor team held a golf tournament and conducted a toy drive to benefit the sick children and families who would reside in the Ronald McDonald House, which reopened in August 2006.

"In times of great tragedy, there is a call to action; the actions taken must be swift and decisive," said Fluor Chairman and CEO Alan Boeckmann in announcing that the FEMA IA-TAC Katrina/Rita Project Team had received Fluor Corporation's most esteemed award—the 2006 Hugh Coble Award for Project Excellence. The accomplishments of the FEMA team proficiently demonstrated, in the most challenging of environments, excellence in execution—a distinguished achievement in which all team members should take great pride.

Even though Fluor was judged, in many cases, on the number of housing units installed, it was never completely about the numbers. It was always about helping people, which enabled Fluor to succeed in the face of great odds and long, pressure-packed days. Focusing on those who desperately needed help was the bond that linked everyone together—passionately enabling a team determined to make a difference.

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2

OWNERS/CLIENTS AND SAFETY

THE INFLUENCE OF CLIENTS ON CONTRACTOR HEALTH AND SAFETY (H&S)

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ABSTRACT

Clients influence contractor health and safety (H&S) directly and indirectly. The direct means of influence include the choice of structural frame, the selection of materials, and the provision of finance and incentives. Indirect means of influence include the appointment of designers, decisions regarding contract duration, pre-qualification of contractors, contract documentation, and contractor required reporting on H&S matters. The degree to which clients influence contractor H&S depends upon the status of H&S within their own organisations.

Inadequate H&S negatively affects cost, productivity, quality, schedule, environment and client satisfaction. Conversely, client involvement in the contractor's H&S results in enhancements which accrue as benefits for both clients and contractors.

Traditionally, worldwide, petro-chemical organisations have maintained rigorous contractor H&S management programmes. Given this, a study was initiated to investigate the influence of Shell's H&S requirements on contractors' H&S performances while undertaking the construction of service stations. Selected findings emanating from a survey of contractors include: H&S is perceived to be more important to Shell than other project parameters; the positive impact of Shell's project H&S requirements manifests itself in a number of ways; and a range of procurement, design and construction related interventions can contribute to an improvement in construction H&S.

Keywords: Client Influence, Petro-Chemical, Contractor Health and Safety

1. INTRODUCTION

Traditionally, cost, quality and time have constituted the parameters within which projects have been managed. However, increasing awareness relative to the role of H&S in overall project performance and the inclusion of H&S as a project performance measure by inter alia, petro–chemical organisations, has engendered a focus on H&S by a range of stakeholders. Furthermore, the Construction Regulations promulgated on the 18 July 2003 in South Africa have effectively resulted in major client responsibilities for construction H&S (Republic of South Africa, 2003).

Given the completion of a previous study on the client influence on contractor H&S in South Africa in 1998 and the involvement of the author in Shell Construction and Project's H&S related endeavours, a study was conducted among Shell's consultants and contractors to determine the:

- perceived importance of various project parameters to Shell and themselves;
- influence of Shell on contractors' H&S performance and consultants' degree of consideration of H&S, if any, and if so, the benefits thereof;
- extent to which inadequate or the lack of H&S negatively affects the various project parameters;
- perceived status and source of their H&S knowledge, and needs relative thereto;
- potential contribution by various stakeholders to an improvement in construction H&S on Shell projects, and
- potential contribution by various aspects/actions to an improvement in construction H&S on Shell projects.

2. REVIEW OF THE LITERATURE

Statistics

During 1999, the latest year for which comprehensive occupational injury statistics are available, a total of 14,418 medical aid cases, 4,587 temporary total disablements, 315 permanent disablements, and 137 fatalities were reported to the Compensation Commissioner in South Africa (2005). These equate to 1 temporary disablement for every 102 workers, 1 permanent disablement for every 1,041, and 1 fatality for every 3,925. The disabling injury incidence rate (DIIR) 0.98 means that 0.98 workers per 100 incurred disabling injuries, the all industry average being 0.78. The number of fatalities among the workers insured by the Accident Fund (AF) is the equivalent of a fatality rate of 25.5 fatalities per 100,000 full-time equivalent construction workers, which does not compare favourably with international rates.

The severity rate (SR) indicates the number of days lost due to accidents for every 1,000 hours worked. The construction industry SR of 1.14 is the fourth highest, after fishing, mining, and transport, the all-industry average being 0.59. Given that the average worker works 2,000 hours per year, if the SR is multiplied by 2, the average number of days lost per worker per year can be computed – the construction industry lost 2.28 working days per worker during 1999. This is equivalent to 1.0% of the working time.

The holistic issue relative to statistics is that the outcome of accidents is largely fortuitous; it can be minor, moderate, major, or even catastrophic. An accident could result in a project coming to a standstill, hence the relevance to clients, particularly when a project is on an existing facility. Furthermore, H&S is not solely a contractor issue as clients are employers that are required to address the H&S of their employers, in both the office environment, and on projects.

Cost of accidents (COA)

The COA can be categorised as being either direct or indirect. Direct costs tend to be those associated with the treatment of the injury and any unique compensation offered to workers as a consequence of being injured and are covered by workmens' compensation insurance premiums. Indirect costs which are borne by contractors include: reduced productivity for both the returned worker(s) and the crew or workforce; clean-up costs; replacement costs; costs resulting from delays; supervision costs; costs related to rescheduling; transportation, and wages paid while the injured is idle (Hinze, 1994).

Based upon the value of construction work completed in the year 2002, the total COA in South African construction was estimated between 4.3% and 5.4% (Smallwood, 2004). Given that the COA is included in contractors' cost structures, clients ultimately incur the COA. Consequently, a potential reduction in the COA constitutes the motivation for clients to include H&S as a project parameter and to contribute financially and in other forms to contractor H&S endeavours.

Cost of prevention (COP)

Recent research conducted among a group of 'better practice H&S' general contractors (GCs) in South Africa included the question: "On average, approximately what percentage does the cost of H&S constitute of total project cost?" Eight GCs responded. Two GCs (25%) recorded a percentage, namely 3% and 0.5%, and six (75%) identified ranges: three (37.5%) '0 ≤ 1%', and three (37.5%) '> 1 ≤ 2%' (Smallwood, 2004).

The COP and the COA are key issues relative to the influence of clients on and role in contractor H&S, as the COP is generally substantially less than the COA, and therefore the absolute and percentage difference constitutes a further motivation for clients to include H&S as a project parameter and to contribute financially and in other forms to contractor H&S endeavours.

Synergy

The Associated General Contractors of America (AGC) (1992) defines synergism as "The interaction of different entities so that the combined effect is greater than the sum of individual efforts." Research conducted among project managers (PMs) in South Africa (Smallwood, 1996) determined that productivity (87.2%) and quality (80.8%) predominated in terms of aspects negatively affected by inadequate H&S, followed by cost (72.3%), client perception (68.1%), environment (66%), and schedule (57.4%). Also, 95.8% of the PMs stated that inadequate or the lack of H&S increases overall project risk - risk increases as a result of increased variability of resources. Therefore, synergy constitutes a further motivation for clients to include H&S as a project parameter and to contribute to contractor H&S endeavours.

Construction Regulations

In terms of the Construction Regulations (Republic of South Africa, 2003) a client is required to inter alia:

- prepare and provide the Principal Contractor (PC) with an H&S specification;
- provide the PC with any information that may affect H&S;
- appoint each PC in writing;
- ensure that the PC implements and maintains the H&S plan – conduct audits at least monthly;
- stop work not in accordance with the H&S plan;
- provide sufficient H&S information when changes are made to the design and construction;
- ensure that every PC has workers' compensation insurance coverage;
- ensure that PCs have made provision for the cost of H&S in their tenders;
- discuss the contents and approve the H&S plan;
- ensure that a copy of the H&S plan is available, and
- appoint a PC that is competent and has the resources.

However, clients may appoint an agent in terms of the responsibilities, but the agent must be competent and have the resources.

The Construction Regulations effectively require that clients include H&S as a project parameter, liaise with designers and contractors relative to H&S, and monitor the construction process in terms of H&S.

Role of clients

According to The Business Roundtable (1995) construction H&S can be successfully influenced by clients, however, clients have a legal and moral responsibility to warn contractors of any non-apparent hazards present on the site and to make sure contractors recognise and meet their contractual responsibility to work in a healthy and safe manner.

Jeffrey and Douglas (1994) maintained that clients play a critical role in construction H&S, which is complementary to their cost, quality and schedule requirements and therefore successful projects tend to be healthy and safe projects. The briefing of the design team by the client is a critical phase in ensuring project H&S, as deviations from the initial brief at a later date can be the catalyst that triggers a series of events from designer through to operatives that culminates in a site accident.

Client actions

The Business Roundtable (1995) recommends that clients take the following actions: become committed to H&S; support contractors' H&S efforts financially; include H&S as a criteria for pre-qualification; schedule H&S requirements prior to the bidding process; structure documentation to ensure equitable provision for H&S by contractors;

require a formal H&S programme, use permit systems for potentially hazardous activities, designate a contractor H&S co-ordinator, and reporting and investigation of accidents; conduct H&S audits during construction, and adopt a partnering approach.

The effect and benefits of client involvement

A study conducted by Stanford University quantified the effect of client involvement in contractor H&S – the percentage of client actions were all greater relative to contractors that had accident frequency rates below the industry average, than those with accident rates above the industry average (The Business Roundtable, 1995).

According to The Business Roundtable (1995) the benefits of client involvement are: lower construction costs; quality work; improved productivity; completion on schedule; reduced exposure to bad publicity resulting from accidents, and minimal disruption of the client's employees and facilities where work is in progress on existing premises.

3. RESEARCH

Sample stratum and response

The sample stratum was comprised of thirteen 'Shell' consultants and fifty-five 'Shell' contractors surveyed by means of postal surveys mailed by the researcher. Respondents were required to return the survey questionnaires directly to the researcher – nine and thirteen responses were received and included in the analysis of the data, which equates to response rates of 69.2% and 23.6% respectively. It should be noted that follow-up letters were mailed in an endeavour to improve the response rate, particularly in the case of the contractors. However, these resulted in limited further response.

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 importance of various parameters; potential contribution by various stakeholders and aspects/actions; extent of impact, contribution and need, and to rate various issues. Given that a five-point scale was used, it was necessary to compute a mean score based upon the percentage responses to enable an evaluation of the responses and rankings. The mean scores range between a minimum of 1.0 and a maximum of 5.0, the midpoint score being 3.0.

Findings

Table 1 indicates the importance of five parameters to Shell as perceived by consultants and contractors in terms of a mean, based upon percentage responses to a range of 1 (not important) to 5 (very important). It is notable that the mean scores emanating from both consultants and contractors are all above the midpoint score of 3.00, which indicates that in general the respondents can be deemed to perceive all the parameters as important to

Shell. However, consultants perceive cost to be more important to Shell than project H&S, whereas contractors perceive project and public H&S to be equally and more important to Shell than quality, cost and time. This finding differs from that emanating from a previous generic client influence on contractor H&S study, which indicated that contractors perceived H&S to be fifth in terms of its perceived priority to clients out of a total of six parameters (Smallwood, 1998). Further, these findings possibly indicate a difference in emphasis by Shell relative to the respective project stakeholders.

Table 1 Importance of project parameters to Shell as perceived by consultants and contractors.

Parameter	Consultant		Contractor		Mean	
	Mean score	Rank	Mean score	Rank	Mean score	Rank
Project H&S	4.44	2	4.92	1=	4.68	1
Public H&S	4.22	3	4.92	1=	4.57	2
Cost	4.67	1	4.38	4	4.53	3
Quality	3.56	5	4.77	3	4.17	4
Time	4.11	4	4.08	5	4.10	5

Table 2 indicates the importance of five project parameters to consultants and contractors in terms of a mean score, based upon percentage responses to a range of 1 (not important) to 5 (very important). It is notable that all the mean scores of both consultants and contractors are above the midpoint score of 3.00, which indicates that in general the respondents can be deemed to perceive all the parameters as important. However, construction H&S is more important to contractors than consultants. Furthermore, consultants view construction H&S as less important than quality, time, cost and public H&S, whereas contractors view construction H&S as being equally important to quality and public H&S, and more important than time and cost.

Table 2 Importance of project parameters to consultants and contractors.

Parameter	Consultant		Contractor		Mean	
	Mean score	Rank	Mean score	Rank	Mean score	Rank
Quality	4.67	1	4.62	1=	4.65	1
Public H&S	3.89	4	4.62	1=	4.26	2
Time	4.33	2	4.08	4	4.21	3
Project H&S	3.67	5	4.62	1=	4.15	4
Cost	4.00	3	3.92	5	3.96	5

The respondents were asked to rate their H&S on a scale of very poor to very good using average as the industry benchmark. Most (92.4%) of contractors rated themselves better than the industry–average (7.7%), good (46.2%), and very good (46.2%). Consultants were asked to rate H&S on Shell projects on the same basis as contractors. Similarly, 88.8% rated the H&S better than the industry average–average (11.1%), good (44.4%), and very good (44.4%), which validates the contractors 'self-rating'.

Respondents were also asked to rate themselves in terms of their knowledge of H&S on a scale of 'minimal' to 'substantial'. 33.3% of consultants rate themselves above average and 55.6% average, whereas 92.3% of contractors rate themselves above average – average (7.7%), above average (53.8%), and substantial (38.5%). The consultants' rating of H&S on Shell projects validates the contractors' 'self-rating' of their knowledge of H&S.

Table 3 indicates that experience predominates in terms of the sources of H&S knowledge, followed by conference papers, workshops, and practice notes. However, experience is not an ideal source as it may have been as a result of an accident. Furthermore, in terms of differences in stakeholder emphasis, consultants rely more on experience, practice notes and magazine articles than contractors, whereas contractors rely more on workshops and continuing professional development (CPD) seminars than consultants.

Table 3. Sources of H&S knowledge.

Source	Response (%)		
	Consultant	Contractor	Mean
Experience	88.9	69.2	79.1
Conference papers	44.1	46.2	45.2
Workshops	22.2	61.5	41.9
Practice notes	44.4	15.4	29.9
CPD seminars	11.1	30.8	21.0
Tertiary education	11.1	23.1	17.1
Magazine articles	33.3	0.0	16.7
Journal papers	11.1	7.7	9.4
Postgraduate qualifications	0.0	7.7	3.9

Table 4 indicates the extent of impact of Shell's H&S requirements on contractors' H&S performance and consultants' degree of consideration for H&S according to consultants. It is notable that both mean scores are above the midpoint value of 3.0, and that the perceived impact is greater relative to consultants than contractors.

Table 4. Extent of impact of Shell's H&S requirements on consultants' consideration for H&S and contractors' H&S performance according to consultants.

Scope of impact	Response (%)						Mean score	Rank
	Unsure	Minor…………………….…. Major						
		1	2	3	4	5		
Consultants	0.0	0.0	0.0	33.3	22.2	44.4	4.11	1
Contractors	0.0	11.1	11.1	22.2	33.3	22.2	3.44	2

Table 5 indicates the extent of impact of Shell's H&S requirements on the contractors' Shell projects and organizational H&S performance according to contractors. It is notable that the impact on respondents' organizational H&S performance was ranked with the same as shell project H&S performance, which indicates that individual clients can contribute to overall industry change.

Table 5. Extent of impact of Shell's H&S requirements on contractors' H&S performance.

Scope of impact	Response (%)						Mean score	Rank
	Unsure	Minor……………….… Major						
		1	2	3	4	5		
Shell project	0.0	0.0	7.7	30.8	23.1	30.8	3.83	1=
Organisation	0.0	7.7	7.7	7.7	38.5	30.8	3.83	1=

Improved housekeeping predominates in terms of the manifestation of the impact of Shell's H&S requirements on the contractors' performances according to contractors (Table 6). The other manifestations were identified by less than 50% of respondents. However, between a third and half of the respondents identified increased client satisfaction, enhanced environment, and increased productivity. Further, the second ranking of increased client satisfaction (by 46.2% of respondents) confirms that project H&S is important to Shell.

Table 6. Manifestation of the impact of Shell's H&S requirements on contractors' performance.

Manifestation	Response (%)
Improved housekeeping	53.8
Increased client satisfaction	46.2
Enhanced environment	38.5
Increased productivity	38.5
Reduced cost	15.4
Less rework	15.4
Less hassles	15.4

Table 7 indicates that client satisfaction predominates in terms of the negative effect of inadequate or the lack of H&S on project parameters. However, the higher percentage response of consultants when compared to contractors is notable. This finding further substantiates the importance of H&S to Shell.

Table 7. Negative effect of inadequate or the lack of H&S on project parameters.

Parameter	Response (%)		
	Consultant	Contractor	Mean
Client satisfaction	66.7	38.5	52.6
Quality	33.3	46.2	39.8
Environment	33.3	38.5	35.9
Time	33.3	30.8	32.1
Productivity	33.3	23.1	28.2
Cost of construction	22.2	23.1	22.7

Table 8 indicates the potential contribution by various stakeholders to an improvement in construction H&S on Shell projects. It is notable that with the exception of quantity surveyors (according to consultants and contractors) and manufacturers/suppliers (according to consultants), all the mean scores are above the midpoint score of 3.00, which indicates that all the various stakeholders are deemed to have the potential to contribute to an improvement in construction H&S on Shell projects. It is notable that general contractors and project managers predominate. However, the fourth ranking of the client (Shell) could indicate that Shell has already engendered consideration by consultants for H&S and contributed to the improvement of contractors' H&S through requirements (Tables 4 and 5). Furthermore, it should be noted that consultants perceive the potential contribution by Shell to be greater than that perceived by the contractors. Ultimately, the recognition that all stakeholders have the potential to contribute to an improvement indicates that there is potential to improve construction H&S on Shell projects.

Table 8. Potential contribution by various stakeholders to an improvement in construction H&S on Shell projects.

Stakeholder	Consultant		Contractor		Mean	
	Mean Score	Rank	Mean score	Rank	Mean	Rank
General contractors	4.44	2	4.27	1	4.36	1
Project managers	4.78	1	3.91	2	4.35	2
Subcontractors	4.00	4	3.73	3	3.87	3
Client (Shell)	4.33	3	3.18	7	3.76	4
Architectural designers	3.44	5	3.45	4	3.45	5
Engineering designers	3.11	6	3.40	5	3.26	6
Manufacturers/Suppliers	2.89	7	3.27	6	3.08	7
Quantity Surveyors	2.25	8	2.45	8	2.35	8

Table 9 indicates the extent to which various aspects/actions can contribute to an improvement in construction H&S on Shell projects. It is notable that with the exception of partnering, all the means are above the midpoint score of 3.00, which indicates that in general the aspects/actions are deemed to have the potential to contribute to H&S. However, it is notable that the consultants identified the highest contributions to be made by contractors and designers, whereas contractors identified quality related aspects/actions as making the greatest contribution to H&S. Further, the mean twelfth ranking of client actions/contributions could indicate that Shell has already contributed to an improvement in H&S as previously discussed relative to Table 8. Furthermore, the recognition of the potential various aspects/actions to contribute to an improvement confirms the potential to improve construction H&S on Shell projects.

Table 9. Extent to which various aspects/actions can contribute to an improvement in construction H&S on Shell projects.

Aspect/Action	Consultant		Contractor		Mean	
	Mean score	Rank	Mean score	Rank	Mean score	Rank
Project specific plan for H&S	4.33	3=	4.36	4=	4.35	1
Integration of design and construction in terms of H&S	4.22	5=	4.45	2=	4.34	2
Pre-qualification of contractors on H&S	4.22	5=	4.36	4=	4.29	3
Project specific plan for quality	4.00	10=	4.55	1	4.28	4
Contractor H&S programme	4.56	1	3.91	9	4.24	5
Prioritisation/consideration by designers	4.44	2	3.80	10	4.12	6
Pre-qualification of contractors on quality	3.67	13	4.45	2=	4.06	7=
Quality Management System (QMS) during construction	4.11	9	4.00	7=	4.06	7=
Constructability reviews by designers	4.22	5=	3.64	12	3.93	9
Quality Management System (QMS) during design	3.78	12	4.00	7=	3.89	10
Environmental Management System (EMS)	4.00	10=	3.70	11	3.85	11
Client actions/contributions	4.22	5=	3.36	13	3.79	12
Contractor programming	3.44	14	4.09	6	3.77	13
Contract documentation	4.33	3=	3.10	15=	3.72	14
Optimum project schedule (time)	3.33	16	3.20	14	3.27	15
Choice of procurement system	3.38	15	3.10	15=	3.24	16
Partnering	3.29	17	2.11	17	2.70	17

Table 10 indicates the need for H&S related continuing professional development/education in terms of a mean score. With the exception of the role of quantity surveyors and the role of manufacturers/suppliers, all the means are above the midpoint score of 3.00, which indicates that there is a need for the related aspects to be addressed by continuing professional development/education. Furthermore, in terms of differences in stakeholder emphasis, the consultants' needs are substantially greater than that of the contractors relative to the role of project managers, subcontractors and clients, whereas the contractors' need is substantially greater than that of the consultants relative to the role of engineering designers.

Table 10. Consultants' and contractors' need for H&S related CPD/education.

Aspect	Consultant		Contractor			
	Mean score	Rank	Mean score	Rank	Mean	Rank
Role of general contractors	4.13	1	4.00	1=	4.07	1
Role of architectural designers	3.88	4=	4.00	1=	3.94	2
Role of project managers	4.00	2=	3.56	4=	3.78	3
Role of engineering designers	3.50	6	4.00	1=	3.75	4
Role of subcontractors	3.88	4=	3.56	4=	3.72	5
Role of clients	4.00	2=	2.56	7	3.28	6
Role of quantity surveyors	2.75	7	2.89	6	2.82	7
Role of manufacturers/suppliers	2.67	8	2.46	8	2.57	8

4. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Perceived importance of various project parameters to Shell, consultants and contractors

Consultants and contractors perceive project H&S to be more important to Shell than to themselves. Furthermore, both project H&S and public H&S, which are perceived to be equally important to Shell, are perceived to be more important than the other project parameters. The recognition that inadequate or the lack of H&S impacts mostly on client satisfaction further reinforces the importance of H&S. Clearly, project H&S and public H&S are the primary Shell project parameters.

Based upon the conclusions relative to this objective, and those relative to other objectives such as the benefits to contractors arising from Shell's influence on their H&S performance, Shell should continue to include H&S as a project parameter. Furthermore, both contractors and consultants should intensify their endeavours relative to and consideration for H&S respectively.

Influence of Shell on contractors' H&S performance and consultants' degree of consideration for H&S, if any, and if so, the benefits thereof

Contractors rated themselves higher than the industry in terms of H&S performance and knowledge of H&S. Given the validation of this rating by the consultants together with the finding that Shell's H&S requirements contributed to an improvement in H&S on both Shell's projects and contractors' projects in general, leads to the conclusion that Shell has influenced their contractors' H&S and H&S performance. The finding that Shell is perceived as being able to make a lesser contribution to an improvement in construction H&S than other stakeholders or aspects/actions reinforces this conclusion. Although the percentage responses relative to many of the manifestations of such influence were below 50%, the influence did nevertheless manifest itself. Further, the low percentages may well be attributable to the lack of measurement and quantification of potential benefits.

The consultants' indication that Shell's requirements had influenced their degree of consideration for H&S reinforces the contention that clients can influence construction H&S. Furthermore, the indication also reinforces the catalytic role clients can play in realising performance improvement in general.

Shell should continue to require designers and contractors to consider H&S and undertake a range of interventions relative to H&S. Furthermore, Shell, designers, and contractors should collectively endeavour to evolve optimum designs in terms of H&S and other project parameters. Shell and contractors should focus on quantifying the benefits of designers' consideration for H&S and contractors' H&S related endeavours.

Extent to which inadequate or the lack of H&S negatively affects the various project parameters

Although the negative effect of inadequate or the lack of H&S on project parameters is mostly relative to client satisfaction, other project parameters are to a degree perceived as being negatively affected thereby. However, based upon the review of the literature it can be concluded that inadequate or the lack of H&S negatively affects the various project parameters. Furthermore, it can be concluded that Shell consultants and contractors do not understand and appreciate the synergistic effect of H&S on overall project performance.

This conclusion further amplifies the need for Shell and contractors to quantify the benefits of designers' considerations for H&S and contractors' H&S related endeavours. Furthermore, contractors should determine the costs of accidents and the impact of incidents in the form of 'near misses', and first aid cases.

Perceived status and source of their H&S knowledge, and needs relative thereto

The finding that experience, followed by workshops, predominates in terms of sources of H&S knowledge leads to the conclusion that H&S knowledge acquisition is informal. The consultants' and contractors' need for H&S related continuing professional development and education further reinforces this conclusion.

The need for holistic construction H&S education is reinforced by the identification of the role of architectural designers, project managers, and engineering designers in terms of the need for H&S related continuing professional development/education.

All tertiary built environmental education curricula, including that of designers, should address construction H&S. Built environment councils, professional associations and institutes, and employer associations should lobby for the inclusion of such construction H&S education, evolve H&S related practice notes, and provide H&S related continuing professional development.

Potential contribution by various stakeholders to an improvement in construction H&S on Shell projects

With the exception of quantity surveyors all stakeholders are deemed to have the potential of contributing to an improvement in construction H&S on Shell projects. This finding underscores the relevance of the promulgation of the Construction Regulations in South Africa; in particular, the client and designer related requirements and contributions.

Built environment councils, professional associations and institutes, and employer associations should promote the role of their constituencies in and the improvement of construction H&S. Although client actions/contributions was ranked twelfth in terms of the extent to which various aspects/actions can contribute to an improvement in construction H&S on Shell projects, pre-qualification of contractors was ranked third, which indicates that Shell should continue with their client H&S related actions/contributions.

Potential contribution by various aspects/actions to an improvement in construction H&S on Shell projects

The finding that project specific plans for H&S, integration of design and construction in terms of H&S, and pre-qualification of contractors on H&S and also on quality predominate in terms of aspects/actions which can contribute to an improvement in construction H&S on Shell projects, also underscores the relevance of the promulgation of the Construction Regulations. In particular, there is a need for project specific H&S specifications and plans for H&S, and the requirement that clients ensure that the principal contractor has made adequate allowance for H&S.

These findings and conclusions indicate the need for Shell to promote the integration of design and construction, realise collective constructability reviews, pre-qualify designers and contractors on quality, implement the requirement that designers and contractors implement quality management systems and environmental management systems, and evolve project quality plans. In addition, Shell should ensure that project durations are compatible with the nature and scope of the work, and that procurement systems, procedures, and practices always complement H&S, and that contract documentation facilitates the financial provision for H&S.

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CLIENT INVOLVEMENT IN CONSTRUCTION SAFETY AND HEALTH

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ABSTRACT

The nature of activities of the construction sector makes it vulnerable to safety and health hazards. These include injury to people and processes, loss of production, legal proceedings, financial loss, contracting of chronic diseases by workers and even death. Various efforts have been in place to address safety and health issues in the industry but less has been attained as result of client involvement being at a low profile. This paper assesses the clients' role on safety and health issues in the construction process in Tanzania. A survey was conducted with 40 firms to establish the adequacy of the conventional and alternative roles played by clients to address safety and health issues. Findings indicate that clients' roles are to ensure incorporation of health and safety component in project design and tender documentation, close follow up of health and safety matters in site meetings, preparation of possible hazards occurrence checklist before and during construction, and provision of personal protective equipment (PPE). The study recommends that each construction project should have a health and safety plan which spans from pre-tender to post-tender stages with a clear delineation of the responsibility of each party to the contract.

Keywords: Construction Industry, Safety and Health, Client

1. INTRODUCTION

The nature of activities of the construction sector makes it vulnerable to safety and health hazards. The concern worldwide is how to make the industry a safer place to work by involving both practitioners and the society surrounding construction processes. Health and safety hazards such injury to people and processes, loss of production, legal proceedings, financial loss, contracting of chronic diseases by workers and even death have had far reaching effects on the image of the industry. There have been various efforts geared to address the problem by the government and stakeholders at large. In Tanzania for the past 50 years we have witnessed the formation of Workmen's Compensation Ordinance (WCO), 1949; Factories Ordinance, 1950; Employment Ordinance, 1957; Factories (Occupation Health Services) Rules, 1985; Occupation Safety and Health Authority (OSHA), 1997 and Occupation Safety and Health Act, 2003. Similarly, for the stakeholders there has been noted abidance through tender and contract documentation. Traditionally, the client pays for the cost to cover PPEs and other related safety measures and gets involved in paying the premium for insurances and guarantees.

Studies (Loosemore et al. 2003; Smallwood, 2004; Musonda, 2005) have revealed that allowance of H&S in the tender which in most cases is included in the P&G section have always been disregarded. On the other hand, the standard form of contracts in most cases provided for compensation of damages done and not for mitigating H&S incidents in the construction processes. In Tanzania, the enforcement of H&S provisions in the contract documents is left to the Contractors Registration Board (CRB) through its By Laws (1999) and Occupation Safety and Health Authority (OSHA). Studies (Smallwood, 2003; Loosemore et al, 2003; Hinze; 2005; Ngata, 2005; Deeks, 2005; Vedsman, 2006) have established that clients have roles to play in improving health and safety performance of their projects. The main objective of this paper is to assess the clients' traditional and alternative roles on safety and health issues in the construction process in Tanzania.

2. HEALTH AND SAFETY ISSUES IN CONSTRUCTION

Worldwide the construction industry is known for its poor image. You-Jie and Fox (2001) disclose that several writers on the industry have captured the essence of negative characteristics when talking about the 3Ds (Difficult, Dirty and Dangerous) or 3Ks in Japanese (Kitsui, Kitani and Kiken). Of the 3Ds or 3Ks the dangerous or Kiken is the main concern that construction activities are subjecting practitioners and the community in the vicinity of the construction site to dangerous working and living environments due to lack of commitment to improve safety performance by key players. Konkolewsky (2004) observes that more construction workers in the European construction industries are killed, injured or suffer ill-health than in any other industry. A survey by OSHA in 2001 (Mwombeki, 2005) on 63 sites identified 3 fatal accidents; 33 sites experienced accidents such cut by sharp edges, nails puncture, hits by hammer and bruisers; 27 sites recorded accidents from fall of objects and tools; and 23 recorded accidents from handling of tools and equipment and/or plants. The effects of non-observation to H&S requirements in the construction process are far reaching as they lead to loss of life, loss of production, suffering of ill-health, compensation costs and legal proceedings. Sometimes a loss of life can give rise to a number of consequences. A case in point is the loss of life and associated consequences or penalty. OSH Act (2003) provides that *"where any person is killed or suffers serious body injury in consequences of the occupier or owner of a factory or work place having contravened any provision of this Act or of any regulation, rule or order made there under, the occupier or owner of the factory or workplace shall without prejudice to any other penalty be liable to a fine of not less than TZS ten million (U$ 8510) or to imprisonment for a term not exceeding two years or to both such fine and imprisonment"*

In Tanzania, consideration of health and safety aspects for workforce evolved in the colonial period with the Workmen's Compensation Ordinance (WCO) in 1949 which covered all workers regardless of type and duration of their employment. The main cover involved personal injury and/or disabilities at place of work inviting conservation by the employer. Later the government gave guidelines in terms of laws including: Factories Ordinance which was fairly comprehensive in safeguarding the workmen's life, and the employment ordinance 1957 that catered for care and welfare of employees. As a result of increased production activities, the Government announced another piece of rules, the Factories (Occupational Health Services) Rules of 1985 as an advisory mechanism to workers, employers, representatives and supervisors. Due to the increase in infrastructure development, globalization and change in production methods, the Government established OSHA in 1997 to oversee the implementation of OHS issues. The Government also enacted Occupation Safety and Health Act of 2003 which repealed the factory ordinance of 1985. The OSHA of 2003 contains more than 35 provisions, whose breach by the employer constitutes a criminal offence chargeable in the court of law. In summary, the Act requires the employer to provide workers with effective PPEs which are properly maintained by employer, ensure suitable goggles or effective screens are provided to protect the eyes of workers, and ensure periodical examination are carried out by a qualified medical practitioner. A shortfall in this Act in the construction context the employer referred is the "Contractor". This means failure in compliance the contractor will be responsible not withstanding the provisions in the contract documents. This also was observed by Ngata (2005) that the current regulations for construction industry (1985) place all responsibilities for OHS onto the general contractors. As a result contractors are put in the dilemma of having to implement H&S matters in construction projects while leaving the clients observing their priorities. Explaining the situation as a barrier to H&S implementation, Musonda (2005) observes that clients are not investing as much in H&S as contracting organizations are being required to do. Loosemore et. al. (2003) observe that in some organizations safety is seen as a barrier to the attainment of corporate objectives and a necessary cost burden which provides little return. In 1994 the UK attempted to overcome some of these problems (Loosemore et. al., 2003) by enacting Construction (Design and Management) (CDM) which identifies key parties to a construction project. These include clients, construction advisors, designers, principal contractors and subcontractors or self employed persons with each being assigned statutory duties for ensuring that OHS risks are managed during the life of the project. In South Africa (Deeks, 2005), the construction regulation of 2003 imposed clear obligations on all parties to a construction contract and owners of an assert, namely the client, the client's agent, the designer, the principal contractor, the contractor and the owner of the structure.

3. THE CLIENT AND HEALTH AND SAFETY

Conventional Roles

Studies have disclosed that the traditional role of clients contributes to health and safety risks. Haywood (2004) observes that good standards of safety and Health on a construction project starts with the decisions made by the client who procures the work. Vedsman (2006) had it that traditional roles may be described as fattest possible ending of building phase for less money; this means that beginning at "scratch" every time a new building project is to be performed i.e. new client, new or other contractors and other designers which create many coordination problems leading to elevated risk of work accidents. Gameson and Sher (2005) state that (Egan Report, 1998) the clients immediate priorities are to reduce capital costs and improve the quality of new buildings. Loosemore et. al. (2003) identified economic conditions as one of the factors affecting safety programmes; particularly, the increase in time and cost pressures in the construction sector.

Clients are involved in project health and safety issues through provisions in the contract documents. The Preliminary and General (P&G) section of the contract bill of quantities which has provisions for matters related to safety and health on construction sites and the standard form of contracts that contain clauses which provide for insurance to cover injuries, loss of life, loss of properties and damages to the works. It has been a common practice to include safety and health matters under Preliminaries and General section of the Bill of quantities under item '***SAFETY, HEALTH AND WELFARE'*** with the instruction*" comply with enactments, regulations and working rules relating to safety, health and welfare of work-people, be they your own, sub-contractors, suppliers or persons employed directly by the Employer.* The enforcement of this Clause and associated sub clauses in Tanzania is left to the Contractors Registration Board (CRB) through its By Laws (1999) Section 14 (1); Section 20 (3); Section 20 (4); Section 20 (9); Section 20 (11); and Section 20 (12)

The standard forms of the conditions of contracts in use in Tanzania recognize the safety and health hazards and provisions are made to mitigate their effects. The commonly used standard forms in Tanzania are the East Africa Institute of Architects (EAIA) Agreement and Schedule of Conditions of contract and the National Construction (NCC) Agreement and Schedule of Conditions of contract. The EAIA (1993) standard form of contract provisions under Clause 10: Clerk of Works sub clause (2); Clause 18: Injury to Persons and Property and Employer's Indemnity; Clause 19: Insurance against Injury to Persons and Property; and Clause 20: Insurance of the Works against Fire, contain conditions which facilitate H&S performance. Similarly, the NCC (2000) standard form of contract provisions under Clause 12: Clerk of Works, Sub clause 12.2 (c); Clause 21: Indemnification, Sub clause 21.2 (a) and (b); Clause 22: Risks, Sub clause 22.2; Clause: 23 Insurance. Efforts to improve safety performance through provisions in the contract documents have not been realized. This is partly due to the provision in P&G section not being adequately covered and if covered not adequately priced. And partly because the contract provisions cover for compensation and not improving safety performance.

Alternative Roles

Generally, the involvement of clients in heath and safety issues in Tanzania has been low. As a result, the Contractors Registration Board of Tanzania and OSHA have been at the forefront in administering safety and health matters and ensuring the consequences are shouldered by the contractor. Several writers have maintained that clients should take an active role in project H&S issues. According to Gameson and Sher (2005) clients needed to be a driving change force in implementing change and developing "best practice". Client leadership (Haywood, 2004) is recognized as a crucial driver for improving health and safety performance throughout the supply chain. H&S implementation must also be accompanied by commitment from all construction project clients, all levels of management, and a reciprocal commitment by construction workers (Musonda, 2005).

Similarly, Ngata (2005) points out that clients too have roles in ensuring high standards of OHS as are the ones who decide on the overall schedule of the project and have the cardinal duty of ensuring the firm awarded the contract has the necessary qualifications. Vedsman (2006) observes that client's use of a "Model Construction Site" reveals a significant decrease in working incidents and injuries in the Danish construction industry. Hinze (2005) argues that owners have a significant role to play on improving project safety performance. Hinze (2005) further lists different levels of owner influence on safety performance as the use of safety as a selection criterion for contractors; incorporation of safety language in the construction contract; providing funds to support safety effort; and the active involvement of the owner during the construction phase.

Smallwood (2004) expresses the need for the client to assume the following responsibilities:

- Prepare and provide principal contractor with health and safety specification;
- Provide contractor with any information that may affect health and safety;
- Provide sufficient health and safety information when changes are made to design and construction;
- Ensure that the contractor makes provision for the cost of HSE in their tenders
- Discuss contents and approve health and safety plan; and
- Appoint an agent in terms of the responsibilities, who must be competent and have the resources.

The obligations of the client (Deeks, 2005) in a construction contract as far as H&S performance is concerned (South Africa OSH Act. No.85 of 1993) are:

- Prepare a "health and safety specification" and provide this to any Principal Contractor bidding for, or appointed to perform the construction work;
- Promptly provide the Principal Contractor in writing with any information which might affect the H&S of a person at work;
- Appoint the Principal Contractor in writing;
- Ensure that tendering Principal Contractors have made provision for the cost of H&S measures and be reasonably satisfied, before appointing the Principal Contractor, that has the necessary competencies and resources;
- Take reasonable steps, including periodic audits (at least monthly), to ensure that a Principal Contractor's H&S plan is implemented and maintained; and
- Stop any contractor from executing work which is not in accordance with the Principal Contractor's H&S plan or which poses a threat to H&S

4. RESEARCH APPROACH

A regional questionnaire survey and interview was designed to assess the involvement of clients in health and safety performance of construction projects. The assessment classifies the involvement at traditional and alternative levels. At the traditional level, roles which have been played by the client are revisited and assessed if they suffice on improvement of health and safety performance in construction projects. At the alternative level, new responsibilities to be taken by clients are explored and documented for use in

Tanzanian construction sector. Earmarked groups included clients, Consultants (architects, quantity Surveyors, engineers and project managers) and contractors. Others include regulatory boards and other government bodies.

5. SAMPLING

There are about **4300** firms registered by CRB of which 70 per cent are located in Dar es Salaam. In addition, there are about **391** consulting firms registered in the categories of Quantity surveying and Architectural both registered by the Architects and Quantity Surveyors Registration Board (AQRB), and Engineering registered by Engineers Registration Board (ERB) of which about 60 per cent are located in Dar es salaam. To facilitate the survey, 20, 40, 5 and 5 copies of questionnaire were sent to consulting firms, contracting firms, clients and regulatory bodies and other government bodies respectively.

6. DATA COLLECTION

Generally, the response was fairly good. Out of 70 questionnaires distributed 50 were returned of which 40 were fairly answered equivalent to an average of 57 per cent.

Table 1: Questionnaire responses

S/No	Firm/Authority	Distributed	Returned	Percentage success
1	Clients	5	4	80
2	Consultants	20	13	65
3	Contractors	40	18	45
4	Regulatory boards and other Government bodies (OSHA, CRB, AQRB, ERB, NCC)	5	5	100
	TOTAL	70	40	57

7. RESULTS AND DISCUSSION

Assessment of Awareness and Practice of H&S Requirements in Construction

The study reveals that few practitioners are aware of and have been practicing or involved in improving safety performance in construction. Out of 40 respondents only 5 are aware and have been practicing, 28 are aware of and sometimes practice, while the remaining 7 have knowledge of but are not practicing. An assessment of the responses indicates that management and supervisory level practitioners are aware of the H& S requirements in construction. On the other hand, adherence or practicing depends heavily on the provisions of the contract and the level of enforcement.

The level of Implementation of H&S improvement measures in construction

There was a general consensus that the level of implementation of H&S requirements is still inadequate. This due to the fact that those who have been involved in project undertakings have witnessed major and minor accidents and heath incidents with no action taken to improve the situation. Some of the reasons given are:

- H&S is not taken seriously by parties involved in construction projects, clients and consultants are more concerned with quality of finished work rather than H&S matters
- Most sites do no have safety personnel and safety equipment
- Construction workers are not sensitized or trained on the need to observe H&S requirements
- H&S matters are not budgeted for
- H&S matters are not considered at the tendering stage as result clients expect contractors to bear H&S associated cost during project execution
- Clients and contractors assume that by not making allowance for H&S the project construction cost is reduced

Efforts by Contractors Registration Board and Occupational Safety and Health Authority in addressing address H&S issues in construction project.

Poor safety performance has been noted in construction projects in Tanzania despite the existence of regulatory bodies. 25 of 40 respondents have indicated that the efforts are not sufficient to address H&S issues. Some of the reasons cited are:

- Regulatory bodies lack resources to cover scattered construction sites
- Contractors intervening such regulations are not dealt with accordingly i.e. closing of the site when H&S requirements are not properly observed
- Clauses or regulations used by Regulatory bodies to enforce H&S requirements do not clearly state the obligation of each party to the contract
- Efforts are not coordinated i.e. only contractors are expected to deliver
- Construction contracts are administered by consultants who are more concerned with quality, cost and time of completion but less involved in the health and safety of workers
- Contracts talk of OHS but remedy for non-adherence is not provided for
- Lack of H&S training on the part of clients for them to perceive their roles in H&S issues
- Low level of awareness of H&S requirements by construction workers both skilled and unskilled
- Five out of forty indicated that the efforts adequately address the H&S matters with the reservation that they have limited capacity in terms of manpower and finance. The rest 10 respondents agreed with no reason.

Clients' Participation in Improving H&S Performance in Construction

Conventionally, clients have been involved in improving H&S performance in construction projects. However, the involvement differs from one client to another, there are clients who genuinely take part in improving safety performance while others assume H&S issues are the responsibility of the contractor. In order to decide in which areas clients are more active than others, the responses are summarized, tabulated and ranked.

Table 2: Clients Traditional Roles

S/No	Role	Responses	Rank
1	Provision in the contract documents safety equipment and welfare facilities and insurance premiums	27	1
2	Restrict access to site unless a person has attended H&S induction course and wears protective equipment	7	5
3	Clients/contractor H&S policy	9	4
4	Training on H&S issues	5	6
5	Employing a competent contracting firm	15	3
6	Provision in the contract clauses that direct parties to observe H&S issues	4	7
7	**Request of H&S plan as part of method statement**	**21**	2

It can be seen from the ranking that in most cases clients have been active in providing safety equipment, welfare facilities and paying insurance premiums during project undertakings. However there is still a problem in provision of PPEs as most clients regard it as an unnecessary project cost and do little to provide it. As observed by Loosemore et. al. (2003) that other organizations have not been safety conscious and have done nothing more than to fulfill minimum legal requirements. On the other hand, increasing campaigns to observe H&S matters in construction projects has lead to a requirement in the tender document to include H&S plan as part of method statement in their submission.

Use of H&S Measures in Construction Projects in Tanzania

Certain H&S measures have been in use in Tanzanian following the Government and stakeholders' requirements to observe H&S in construction. Responses indicate that they have encountered some measures in the order of 2 out of 40 very often, 8 out of 40 often, 20 out of 40 fairly often, 8 out of 40 seldom and 2 out of 40 none. Generally, most respondents have seen the provision of PPEs by contractors used at their work sites, though there is a consensus that they are not adequate. Reasons given are either they are not provided in the contract documents or contractors are making savings by not purchasing all required PPEs. On the H&S plan, respondents agreed that in tenders where there is such a requirement, once the contract is awarded its use ceases. The rest of the measures such as toolbox meeting, Checklist of possible hazards, house keeping, H&S induction course etc. were rarely seen on site.

Clients Assumed Responsibilities at Various Stages of the Project

Studies (Hinze, 2005; Smallwood, 2003; Ngata, 2005; and Loosemore at. el., 2003) maintain that clients should assume more responsibilities towards improving safety performance in construction projects. These responsibilities can be assumed at different stages of the project namely design, tendering, contract award, and during construction. These are summarizes, tabulated and ranked as follows:

Table 3: Client Responsibilities at the Design Stage

S/No	Responsibility	Response	Rank
1	Involve competent professionals who can study well possible H&S hazards and incorporate preventive measures in their designs	26	1
2	The design team to consider H&S issues in line with the type of project and the kind of safety measures to be observed for a specific project	10	6
3	All H&S matters should be regularly updated and incorporated at the design stage	12	5
4	The OHS Clause should be considered at the design stage and regulatory bodies overseeing H&S matters in the construction industry to approve the design	15	4
5	Clients demand that design and specifications clearly address aspects of H&S	24	2
6	**Clients ensure that the design team produce a risk free design bearing in mind the method of construction and site involvement**	**20**	3

From the ranking in the table above, it is evident that involving competent professional who are responsible for their designs and can take necessary precautions as far as H&S is concerned is one step to improving safety performance by the client. Similarly, designs and specification which clearly address H&S aspects have a significant impact on H&S performance of the project.

Table 4: Clients responsibilities at the Tendering Stage

S/No	Responsibility	Response	Rank
1	Ensure that the procedure used suffices for obtaining a contracting firm that is financially stable with good business record, for which the size of the project is neither too small nor too large, that is well aware of the safety measures for a given particular project	23	3
2	H&S requirements should be included in the tender documents in such that the tenderers awareness of H&S matters can be assessed	10	8
3	Clients should make sure an allowance for H&S is included in tender documents	28	1
4	There should be a special clause concerning H&S performance in the tender documents	14	6
5	A clause to be included in the tender documents explaining that non-adherence to H&S requirement is a ground for termination of the contract	10	8
6	Cost estimate prepared by the consultants should include an item of H&S	17	5
7	Present the tenderer a checklist of possible H&S hazards prepared by the design team for information and updating	23	3
8	Tenderer is required to produce H&S plan and the method statement as part of tender responsiveness	20	4
9	The item that covers H&S matters should be detailed and given the same weight as other items	12	7
10	**Documents should include a clear demarcation on H&S responsibilities of the parties to contract**	**25**	2

As the results reveal, it has been proposed that at the tendering stage clients should ensure that the procedure set for obtaining tenders provides for selecting a competent contracting firm with a good in H&S performance; an allowance to cover H&S is included in the tender documents; tender documents include a clear demarcation on H&S responsibilities of the parties to the contract; submission of H&S plan by the contractor, and make available to the tenderer a list of possible H&S hazards as predicted at the design stage.

Table 5: Clients Responsibilities during Contract Award

S/No	Responsibility	Response	Rank
1	All measures should be taken to avoid corruption and clients should take into account recommendation for award made by their consultants	20	3
2	Contract be awarded on H&S practicing and awareness merits	24	1
3	Award should consider a tenderer who has responded well to the clause on H&S matters	22	2
4	Contract award should also consider the company's safety policy submitted by the tenderers.	14	4
5	A good H&S plan to be one of the requirements for contract award	20	3
6	**Address H&S matters during contract negotiation**	**8**	5

At the time of awarding a contract the survey reveals that clients can influence the award to be made on the merits of H&S good records in awareness and practicing; if there is a clause in the tender documents will be taken as one of the conditions of tender responsiveness, or the H&S plan submitted by the tenderer. Experience shows that many clients and their advisors consider the award of contracts to lowest price tenders. It is of utmost important that since the client has a final decision on contract award to make sure that the contract is awarded to the competent contractor. It is therefore of fundamental importance to the client, when selecting contractors and others, to ensure that those appointed are able to carry out the work competently (Haywood, 2004)

Table 6: Clients responsibilities Construction Stage

S/No	Responsibility	Response	Rank
1	Involving professionals who are competent and have the knowledge in construction technology and methodologies	22	4
2	Ensure skilled and unskilled labour undergo H&S induction course before given access to site.	21	5
3	Client ensures that the contractor is complying to H&S plan and all requirements during construction and disciplinary action are taken for non-compliance	30	1
4	Ensure the contractor prepare and update a checklist of possible H&S hazards	24	3
5	There should be a separate consultant dealing with H&S matters on construction sites	10	8
6	Clients through consultants and clerk of works should ensure that to ensure that the contractor and all subcontractors adhere to H&S requirements	15	6
7	Initiate H&S department on construction sites	11	7
8	Client ensures no access to site any person not wearing safety equipment	24	3
9	Ensure that H&S Obligations is the main agenda items of the each site meeting	28	2
10	**Consultants should be made agents of regulatory bodies in making sure that all aspects of OHS are adhered to, otherwise should be taken as basis for determination**	9	

At the construction stage, a lot needs to be done so that most of the proposed actions contribute in one way or another in improving safety performance**.** However, the first four according to the ranking namely, ensure compliance to H&S plan and other requirements; ensure H&S matters is always among the site meeting agenda items, ensure the contractor prepare and update a checklist of possible H&S hazards; and provision and use of safety equipment are seen to be imperative in implementation of H&S programmes.

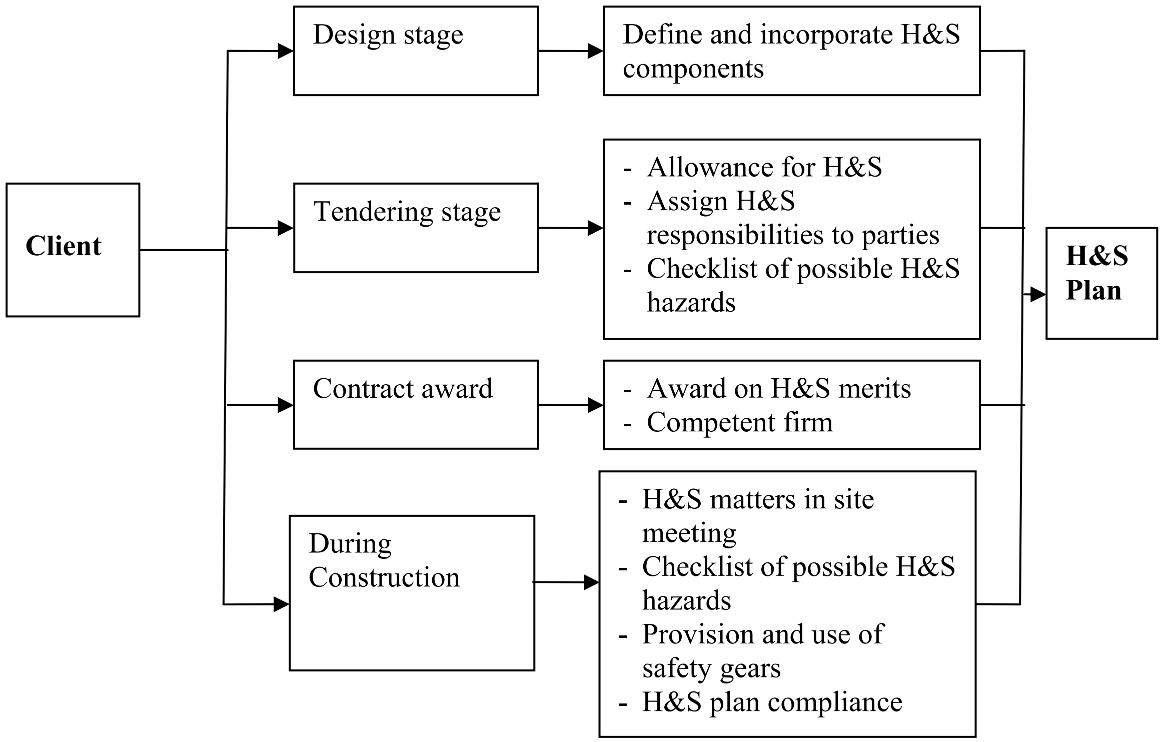

Figure 1: Road Map to Implementing H&S Plan

Circumstances in which H&S Aspects are included in the Site Meeting as Main Agenda

H&S requirements to be a main agenda or among the main agenda items have been the concern of various studies as one of the measure to be taken during construction. Respondents were requested to indicate their experience in regard and the result was as shown below.

Table 7: Experience on inclusion of H&S in the site meeting main agenda items

S/n	Statement	Responses	Ranking
1	When there is an occurrence of major accident, injury or death or damage	31	1
2	When there is a provision in the contract documents	28	2
3	At the commencement of the project	5	4
4	Whenever there is a need to remind site worker to use safety equipment	15	3
5	Always	4	5

The above results imply that H&S is included after an accident occurs rather than being pro-active and preventing accidents before they happen. The results also suggest that inclusion of the provision in the contract document has shown a positive response however, it was revealed that few contract documents had such a provision. It was also learned that minor accidents and injuries are not disclosed to consultants or clients.

Challenges facing the Tanzanian Construction in implementation of H&S measures

The Tanzanian construction industry as many other industries worldwide, is facing challenges in improving H&S performance. The following challenges were cited:

- Laxity of consultants, clients and contactors
- Low level of awareness on the consequences of not implementing H&S measures among clients, consultants and contractors
- Little or no allowance in tender documents to cover H&S matters
- Lack of formal H&S training programmes such as in schools, colleges and universities
- Site workers not willing to wear PPEs on the grounds that they reduce their efficiency (hot or heavy).
- Recording and reporting of H&S incidents is almost non-existence.
- Increasing competition in the local construction industry tends to make contractors lower tender prices.

8. CONCLUSION

The traditional roles of the client to improving H&S performance are proven but a number of practitioners have accepted them with the thinking that the client is not directly involved in project safety undertakings. The provision of safety equipment for instance, has been improving significantly, while the H&S plan submitted during tendering and approved at the time of awarding the contract has its usefulness cease when the contractor goes on-site. As a result, the industry has been performing poorly in H&S aspects. This lead to a suggestion that since the client has a final say on cost and time of the project it is time to take up H&S obligation. Similarly, OSHA has realized a shortfall in its regulations and is currently reviewing its 2003 Act to incorporate clients' obligations.

9. RECOMMENDATION

There have been various measures geared at improving H&S performance in construction projects. Most of these initiatives have directed at contractors to observe all H&S requirements on their construction sites. This has left clients observing time and cost matters of the project which in turn has a great impact on H&S issues. It should be noted that clients (with the help of their consultants) monitor time and cost matters of their projects from the inception to commissioning stages in order to maximize their investment returns. To address this, each construction project should have an H&S plan which spans from pre-tender to post-tender stages with a clear delineation of the responsibility of each party to the contract.

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CLIENT ATTITUDE TO HEALTH AND SAFETY (H&S) – A REPORT ON CONTRACTOR'S PERCEPTIONS

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ABSTRACT

Purpose – The purpose of this paper is to present findings of a preliminary survey on Contractors' perceptions of clients, attitude relative to health and safety (H&S) implementation in Botswana's construction industry.

Methodology – A questionnaire survey was conducted on construction projects to establish clients' attitude towards H&S. Interviews were also conducted with contractor's representatives on selected construction sites in and around Gaborone, Botswana.

Findings – Findings from the survey include: clients do perceive H&S to be very important on construction projects, most clients do not address H&S adequately in contract documentation and H&S is rarely a major agenda item in progress meetings. Findings were also that clients are not fully committed to H&S implementation. The Client sets the tone for H&S culture. Client attitude is therefore very important for H&S performance improvement as all stakeholders are compelled to act in line with the client's values.

Originality / value – The importance of the client to H&S performance improvement has been recognised by various researchers. The extent to which they are involved in H&S implementation has however not been researched extensively especially in Southern Africa. This paper therefore provides an insight on the clients' attitude towards H&S and in a way explains the reason for the current state of H&S in Botswana's construction industry.

Keywords: Attitude, Botswana, Client, Construction, Health and Safety

1. INTRODUCTION

Although Botswana's economy is dominated by the diamond mining industry which has been the largest contributor to GDP for the past thirty years, accounting for 38% of GDP, followed by services at 44%, construction also contributes significantly to GDP accounting for about 7% (http://web.worldbank.org/WBSITE/EXTERNAL/

COUNTRIES/AFRICAEXT/BOTS...) .The construction industry has also been growing at a very high rate with a development expenditure estimated to be well over hundreds of billions of Dollars at least for the next ten years. What is notable as well in this part of Africa is that infrastructure is becoming more complex compared to the past years and inadvertently will cause many challenges for H&S.

The construction industry is dominated by a large number of small and medium size contractors having sprung from the citizen empowerment programs implemented in most Southern African countries. Most of the labour force is also either semi skilled or unskilled with little education. This poses a great challenge in managing H&S. Risks to H&S increases with a low level of awareness and lack of training.

Research conducted in Botswana revealed that the level of H&S awareness in the construction industry is low, H&S legislation is not complied with, the management of contractors is not committed to H&S implementation, there is a lack of H&S management systems, procedures, and protocol, and clients and designers do not adequately participate in the implementation of H&S (Musonda 2005). A similar study conducted by P. Van Ooteghem (2006) revealed that occupational accidents and fatalities continue to be recorded in Botswana. Between the period 2000 and 2003, a total of 251 occupational fatalities were registered with the workmen's compensation authority from all sectors (Ooteghem 2006). 96 accidents in the construction sector alone were registered with the workmen's compensation during the same period. Allowing this status quo to continue considering the contribution construction makes to the economy, the amount of labour force that is at risk, the anticipated complexity of projects that are going to be implemented, the human suffering that has occurred and continue to happen and considering the people that continue to face H&S risks, is totally un acceptable and thus the motivation for this study.

The need to find solutions to improve the above picture and work at building a better H&S culture in the construction industry is now just as compelling as before.

In this paper, a key proposition is that although safety is everyone's business, improving H&S performance would be realised with the right attitude by the client to H&S. Clients set tone for H&S.

2. BACKGROUND

2.1 Client role

Striving for a better H&S performance will remain elusive if the client is not seen to be actively involved in H&S implementation especially in Southern Africa. Huang and Hinze (2006) rightly argue that the involvement of clients (owners) is an essential requirement for the zero injuries objective. Other researchers have also recognised the importance of the client in the management of H&S. Smallwood (1998) noted that construction H&S can be successfully influenced by clients.

Suraji (2001) contends in his paper on accident causation that construction accidents are caused by inappropriate responses to certain constraints and the environment. He observed for example that the client (owner) responses are the actions or failure to act in response to constraints that emerge during the development of the project scope. According to him, these include for example reducing the project budget, adding new project criteria, changing project objectives and accelerating the design or construction efforts of the project. All of which are factors that impact on H&S.

Clients have a positive role to play in lowering injury rates (Smallwood: 1998, Hinze & Gambetese: 1991)

2.2 Client Attitude

Clients' attitude can be deduced from the extent to which they are involved in the management of H&S. Until now, as Smallwood observed (1998), the major agencies of client influence have been prescriptive, regulatory or coercive measures as opposed to upstream proactive measures such as design, detail and specification and more importantly prioritisation.

Clients can be seen to be more involved by for example clients setting H&S objectives, selecting suitable contractors in terms of H&S and participating in H&S management (Huang & Hinze: 2006). Smallwood outlines further by saying that clients should:

- Provide financial support;
- Include H&S as a prequalification criteria;
- Schedule H&S requirements prior to bidding process;
- Structure contract documentation to allow for H&S and,
- Conduct audits in H&S.

One of the areas where clients can show leadership and attitude to H&S is by conducting periodical audits. Auditing, if properly done, has many benefits for the implementation of H&S. According to Thompson (1999), successful auditing provides a methodical and comprehensive approach to the H&S program analysis. Auditing also identifies new areas of concern as the program and project evolves. It is clearly an essential activity for the client to undertake and tells of their attitude to H&S in construction.

In order to show commitment, clients should input adequate resources into construction H&S instead of relying on contractors (Huang & Hinze: 2006). Successful implementation of H&S also depends on the extent to which construction-project clients participate and assign resources to the process.

H&S performance improvement depends on the extent to which construction-project clients provide leadership on H&S matters. Loosemore, Lingard, Walker, and Mackenzie (1999) identified the importance of this and contend that the lead must come from clients themselves. They maintain that without this, the construction industry has a long way to go in changing attitudes towards H&S. Levitt and Samuelson (1993) also argued that monitoring which is one of the activities in providing leadership, makes a difference, and that excellent H&S performance can be obtained with the active participation of clients, even from average contractors. If the clients are taking the lead, they must know exactly what is required to develop a detailed comprehensive brief for the design team and to issue H&S specifications. Further, as suggested by Suraji, Sulaiman, Mahyuddin, and Mohamed (2006) the client must take responsibility for preventing accidents. The client should carefully consider H&S control in ordering works, exercising supervision, and providing instructions. As Huang (2006) correctly put it, clients set the safety culture tone for a project.

3. RESEARCH METHODOLOGY

The study was quantitative and was aimed at determining the level of client commitment to H&S in construction projects. The survey instrument therefore needed to be designed so as to capture clients' actions or lack of it and perceptions from contractors as they are the direct implementers of project goals. Because of the type of data that was to be obtained, it was found that questionnaires with supervisory staff on construction sites coupled with physical observations constituted the best method to conduct the research.

Questionnaires were preferred to face-to-face interviews because respondents find it easier to answer questionnaires in privacy and during their spare time. On the negative side, the response rate is usually lower with questionnaires that have to be returned. Questionnaires are also a good way of obtaining information because it is cheap and less time consuming. A pilot study was conducted in the preliminary stages and the response rate was determined as being between 50% and 70%.

The questionnaire was designed to address among other areas, the clients' level of participation or commitment to H&S on construction projects. Both open and closed ended types of questions were used. Care was taken to avoid bias by providing for alternative responses by related and preceding closed questions. Respondents were asked to 'state or specify'. Closed questions were put before open-ended questions. Rating scales were also used for respondents to mark the level of importance, frequency, or severity.

On the clients' level of commitment, the evaluation was conducted through the following questions:

- Evidence of active participation, as seen in the client project meetings, by establishing whether H&S was a major agenda item;
- Respondents' view on how clients and designers regarded H&S in relation to other factors on a construction project;
- The purpose of the third question was to identify the respondents' opinion on how H&S could best be improved; client and designer participation is also included to assess whether respondents deemed it important, and
- The extent to which clients and designers address H&S in contract documents.

3.1 Analysis of Data

Primary data that was obtained through questionnaires and physical observations by using checklists was analysed and interpreted relative to secondary data obtained from the literature review. From observations and responses, inferences were drawn about the larger and general practice relative to client commitment and thus their attitude towards H&S.

The calculation of scores was also done to establish the order of importance or severity. A score was given to each factor. This was done by adding up multiples of the opinion and the number of respondents with that particular opinion. The marks have been allocated as presented in Table 1.

Table 1: Opinion marks on the level of importance.

Opinion	Mark
Very important	25
Important	20
Fairly important	15
Slightly important	10
Not important	5

3.2 The Population

The selection of the sample stratum was based on the following:

- Number of registered building contractors that were currently undertaking projects in Gaborone, Botswana;
- Limitations of time and financial resources, and
- Anticipated response rate.

A survey was conducted before the study and it was determined that there were at least 47 building construction sites in and around Gaborone. It is recommended that, for small populations of less than 100, there is little point in sampling (Leady and Ormrod 2001). The entire population was surveyed as a result. With a response rate of 50% to 70%, it was determined that at least 21 building contractors would respond to questionnaires.

The study excluded private homebuilders and civil engineering contractors. The justification for this delimitation was the time limit, resources, and the difficulty in obtaining information, especially from private homebuilders.

For the sample to be representative, it was ensured that all categories were represented in the study. The Public Procurement and Asset Disposal Board (PPADB) categorisation is based upon five categories: for projects worth up to P0.5 Million, between P0.5 Million and P1 Million, between P1 Million and P4 Million, and more than P10 Million.

A sample of 40 contractors was randomly selected. Each category contributed 8 contractors. The only exception was the lowest category because there were only 5 building construction sites at the time. Three more construction sites were randomly selected for the survey. Although some building contractors were working on more than 1 construction site, only 1 site was selected for each building contractor. As there were at least 47 active construction sites within Gaborone during the research period, this meant that all the contractors were surveyed. Table 2 tabulates the summary of the sample stratum.

Questionnaires were addressed to site managers, site engineers, and site agents as they are based on site and are able to relate what actually transpires on projects. This group was viewed as having sufficient knowledge and being impartial relative to top management and the actual practice on sites and their perception of the client.

Site observations were conducted for all 40 contractors that had been interviewed. Checklists were used to record or tick off the observed elements on sites.

3.3 Response Rates

In total, 40 questionnaires were distributed to building contractors. Twenty-five questionnaires were completed and collected by the researcher, which equates to a response rate of 62.5%. Response rates for all categories are as tabulated below in Table 3.

Table 2: Sample stratum

Category	Value in USD	Construction sites	Questionnaires distributed	Observations
OC	< 100,000.00	5	5	5
A	>100,000.00< 200,000.00	11	8	8
B	>200,000.00< 800,000.00	10	8	8
C	>800,000.00<2,000,000.00	8	8	8
D & E	>2,000,000.00	13	11	11
Total		47	40	40

Table 3: Questionnaire response rates

Category	Value in USD	Response (No.)	Response rate (%)
OC	< 100,000.00	1	20.0
A	>100,000.00< 200,000.00	3	37.5
B	>200,000.00< 800,000.00	8	100.0
C	>800,000.00<2,000,000.00	6	75.0
D & E	>2,000,000.00	7	63.6
Total		25	62.5

4. FINDINGS

Respondents were asked in question 1 how frequently H&S audits and inspections were conducted by clients and other key stakeholders. With respect to clients' commitment to H&S, 56% of the respondents indicated that clients had 'never' conducted H&S audits and inspections, and 28% 'rarely'. The above compared to 40% of the respondents who indicated that contractors top management 'never' conducted H&S audits and inspections, 36% 'rarely', and 20% 'often' (Table 4) showed a little bit of more commitment by contractors than clients. Only 8% of the respondents indicated that clients 'often' conducted audits and inspections. None of the respondents indicated that clients 'always' conducted audits and inspections. The clients' leadership in H&S and thus their attitude is even more questionable as over 50% of the respondents indicated that neither the supervising consultants nor the Government Factories Inspector conducted H&S audits and inspections. Supervising consultants are directly answerable to clients. The above may probably confirm the respondents perception that clients consider cost, time and quality to be more important than H&S (table 7).

Table 4: Frequency of audits and inspections by all stakeholders

Entity	Response (%)				
	Never	Rarely	Sometimes	Often	Always
Contractor top management	40.0	36.0	0.0	20.0	4.0
Client	56.0	28.0	8.0	8.0	0.0
Supervising consultants	52.0	20.0	16.0	12.0	0.0
Factories Inspector	56.0	32.0	8.0	4.0	0.0
Civil organisations	84.0	4.0	8.0	4.0	0.0

Apart from inspections, site project meetings are important events where all issues regarding H&S can be raised and discussed. To indicate the extent of participation by clients and designers or supervising consultants, the position that they accord to H&S on the agenda of project site meetings would be used for measurement. This is all the more true because they mostly visit the sites at the time of these meetings. Question 2, therefore, sought to determine whether H&S was a major agenda item during client progress meetings. 28% of respondents indicated that H&S was a major item on the agenda and 72% that it was not (Table 6).

Table 6: Status of H&S in progress meetings

Response	(%)
Yes	28.0
No	72.0
Unsure	0.0
Total	100.0

It was deemed that contractors would best describe clients' attitudes towards H&S. This would, in turn, explain the level of commitment by clients and designers. Therefore, contractors were asked to rate the importance of various aspects to clients on projects. Remaining within budget was the most important, followed by contract period. Quality and avoiding litigation were ranked third and fourth, whilst H&S was identified as the least important (Table 7).

Table 7: Perceived importance of H&S according to clients

Aspect	Score
Remaining within budget	590
Contract period	565
Quality	555
Avoiding litigation	515
H&S	270

In an endeavour to further establish the extent to which clients participate in H&S, respondents were asked whether, in their opinion, contract documents always addressed H&S implementation. The reasoning behind this question was that one way in which clients would definitely participate in H&S implementation is through allowing and addressing it in the contract documents. Seventy-one percent of the respondents indicated that H&S was addressed and 29% that it was not addressed. A follow-up question to check the validity of these responses was posed. The responses ranged between 'not being addressed' and 'being fairly addressed'. Only 4.2% and 8.3% of the respondents, respectively, indicated that H&S was 'addressed' and 'fully addressed' in the contract documents (Table 8).

Table 8: Extent to which H&S is addressed in contract documents

Scale	Extent	Response (%)
1	Not addressed	25.0
2	Slightly addressed	29.2
3	Fairly addressed	25.0
4	Addressed	4.2
5	Fully addressed	8.3
	No response	8.3
	Total	100.0

One of the other areas believed to be where clients could show commitment and leadership and thus their attitude towards H&S is in insisting and ensuring that contractors have safety programs in place. Respondents were therefore asked whether they had H&S policy, procedures, programs, meetings, representatives, and documented work procedures on their projects (Table 9). More than 50% of respondents indicated that they never had any of the above. Between 20% and 30% of respondents indicated that they had whilst less than 10% of respondents were not sure.

Table 9: Existence of H&S programme elements

Element	Response (%)			
	Yes	No	Unsure	No response
H&S policy	20.0	64.0	4.0	12.0
H&S procedures	28.0	60.0	0.0	12.0
H&S programs	4.0	64.0	8.0	24.0
H&S meeting	20.0	64.0	0.0	16.0
H&S representatives	12.0	68.0	4.0	16.0
Documented work procedures	32.0	56.0	0.0	12.0

Specifically, 64% of respondents responded in the negative relative to having the required elements of a management system.

5. DISCUSSION

Given the aforementioned, it can be concluded that the contribution by non-contractor stakeholders specifically clients and their agents, designers, is virtually non-existent. Such stakeholder input and commitment is cardinal and essential to H&S performance improvement and describes the clients' attitude towards H&S. The respondents' ratings of the perceived importance of H&S to clients reveal the extent to which the client is committed and attitude to H&S. Relative to cost, time, quality, and avoiding litigation, clients view H&S to be the least important aspect on a construction project. The attitude seems to be wrong here and it can be argued that this influences H&S performance in construction.

Based upon clients' attitudes and actions, respondents perceived that they considered H&S not to be important. Responses relative to whether H&S was a major agenda item in client progress meetings validates the perception rating - almost 71% of the respondents said that H&S was not a major agenda item. Client progress meetings are an important event during a project as all stakeholders are required to attend such meetings on site. It is also a forum where progress is evaluated and problems on site are discussed. If clients have the right attitude and committed to H&S it will be an agenda item. Standard contract documentation also does not reflect commitment by clients to H&S. Although 70% of the respondents said that H&S was addressed in contracts, only 8% indicated that it was extensively addressed. On average, 26% said it was not, slightly, or fairly addressed. A positive attitude towards H&S by the client would have had influenced a different perception by respondents especially regarding the rating of H&S among other traditional project parameters.

6. CONCLUSIONS

It can be concluded that participation and commitment by clients to H&S is low and thus in a way describes their attitude towards H&S which is seen to be negative because of the following;

- Clients and even designers never or rarely conduct H&S audits and inspections;
- H&S is not regarded as a major agenda item in clients' progress meetings; 72 % of the respondents indicated thus, and only 28% indicated that H&S was regarded as a major agenda item. Clients influence project progress meetings. With the right attitude therefore would have seen higher percentages of respondents indicating that H&S was a major agenda item and;
- According to contractors, it was found that clients and their agents, designers, regarded H&S to be the least important aspect on a construction project. It follows that, if clients perceive the importance of H&S to be low it is because their attitude is not positive towards H&S. In fact, avoiding litigation and quality was rated higher than H&S.

Clients set the H&S tone for construction projects. Their attitude therefore has great influence on the performance of H&S especially among smaller national contractors. Improving or addressing clients' attitude would greatly contribute to the improvement of H&S in the sector. The question however is, how can that be achieved?

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AN EXPLORATORY INVESTIGATION INTO THE POTENTIAL IMPACT OF PREQUALIFICATION ON H&S PERFORMANCE

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ABSTRACT

This paper argues that construction procurement practices based on a lowest cost "one size fits all" approach and unsatisfactory supply chain management result in inefficiencies in health and safety (H&S) performance. Given that procurement arrangements should be proportionate to project complexity and risks, prequalification of all participants in the project is a management tool for selecting contractors and suppliers on 'best fit' criteria rather than on 'lowest possible cost'. Prequalification is a formal process that can be used to evaluate a contractor's health and safety competence. In addition, prequalification provides the basis for risk profiling and risk management. The risk profiles ensure a single point of accountability, safe work execution, stable industrial relation climates and, at the same time, promotes lower risk vendor selection. An active risk management approach seeks to identify and reduce potential health and safety risks to an acceptable level. The paper incorporates qualitative data from an exploratory study conducted among 115 contractors tendering for electrification projects. This paper emphasizes the need to infuse health and safety systems into the commercial process. Prequalification at the procurement phase provides a systematic approach to evaluate and assess health and safety knowledge, experience and ability. The paper illustrates that prequalification is the ideal tool to screen contractors for health and safety competence.

Keywords: Procurement, Supply Chain Management, Prequalification, Risk

1. INTRODUCTION

Prequalification provides a systematic approach to evaluate and assess contractors and other service providers for health and safety knowledge, experience, and ability. Prequalification is widely used as part of pre-contract supplier appraisal. It is an essential step in deciding whether a supplier or contractor can adequately perform a construction project without exposing the client, for example, to claims for damages from third parties. It is, therefore, necessary for contractors to have an appreciation of constructability or buildability, the ability to recognize limitations, task-related faults and errors, and to identify appropriate remedial or corrective actions. If the prequalification criteria are met, the contractor may be invited to tender or negotiate for the client's business.

There are usually two steps to prequalification, namely finding contractors and verifying that they are suitable for the project at hand. It is critically importan for all client organizations to be clear about why they want to measure contractor performance. This measurement should take in account what is being procured, the amount that will be spent and the risk of failure to deliver.

Clearly a blanket approach is not feasible as it typically generates the same amount of information for non-critical services as for critical services. Criticality can change. It is, therefore, important that any prequalification system be flexible so that it can be extended to contractors and suppliers as the need arises. A growing number of South African companies are starting to recognize that in order to achieve the health, safety, environmental and social goals that satisfy the demands of clients, they need to ensure that they and their suppliers are also achieving acceptable health, safety, environmental and social standards.

2. LITERATURE REVIEW

The Construction Best Practice Programme (1998) suggests that construction businesses are beginning to realize that their success is increasingly dependent on the organizations they supply to and buy from, and that for continued success they need to cooperate and collaborate across customer/supplier interfaces in South Africa. The South African construction environment presents challenges relative to effective supply chain management. Construction projects are usually unique and one-off in character. Most construction projects are procured by inexperienced clients and constructed by numerous specialists who have little or no contact with the client. Despite regulatory compliance requirements, there is relatively little consideration of health and safety issues. With respect to procurement processes and practices characterized by the "low bid win" approach, production processes are geared to lowest cost rather than to "right first time" or to "better value" bidding processes. These latter processes encourage a culture where service providers will agree to almost any parameter to get the work. Once the work is procured they strive to achieve a cheaper solution or a higher price; and are either unable or unwilling to cooperate in specialist design, innovation or collaborative problem-solving.

The situation in the South African construction community is further exacerbated by the need for transformation and Broad Based Black Economic Empowerment (BBBEE). The government-driven Accelerated and Shared Growth Initiative for South Africa (AsgiSA) supports BBBEE to address the disadvantages of past procurement practices. Health and safety management practices are briefly mentioned within the framework of AsgiSA and Preferential Procurement Policy Framework. However, there appears to be little or no focus on health and safety criteria when it comes to BBBEE companies.

Key areas that receive specific attention during BEE status evaluation include:

- Black ownership and management;
- Skilled black employees as a percentage of all skilled employees;
- Purchases from black suppliers;
- Black female management participation;
- Employment of persons with disabilities; and
- Joint ventures with black suppliers.

Once these criteria are met, SA companies, government departments and other organizations seem to be satisfied that the BEE suppliers and contractors have met all their qualification criteria. Governance is not taken seriously in terms of risk management and assurance, and prequalification is not stipulated or required. When prequalification is required, health and safety are not considered within the accreditation process.

South African companies are legally bound to meet government-set AsgiSA targets. One of the binding constraints is the shortage of suitably skilled labour amplified by the impact of apartheid spatial patterns on the cost of labour. The current infrastructure investment in South Africa has spawned huge construction projects. Government and public enterprise investment expenditure for the period April 2005 to March 2008 is estimated to be about R370 billion (about $50 billion U.S.). Another key challenge in the infrastructure sector relates to preparations for the 2010 FIFA World Cup. This includes building or improving the ten stadiums to be used, investment in the surrounding environs and access to the stadiums. Clients will be hard-pressed to find the skills to complete the many new and refurbishment projects. The authors argue that this situation will undoubtedly result in clients taking short cuts to obtain the necessary scarce skills required to complete these projects.

Health and safety competence still remains a critical issue for the South African construction industry. The entry point of contractors takes place during the procurement phase of the commercial process and generally contractors and suppliers are not assessed for health and safety competence. In most cases contractors and suppliers are only commercially assessed in terms of capability, equipment and availability of skilled resources, and they are financially assessed to check for credit worthiness. There are arguments that health and safety competence is assessed before a contractor is listed on the vendor databases. However, anecdotal evidence suggests that most South African clients use the following seven generic criteria for evaluating and awarding contracts, namely

- Commercial;
- Administrative Performance;
- Delivery and Cycle Time;
- Responsiveness;
- Business Management;
- Quality;
- Environmental Management; and
- Technology.

It is also argued that the quality criterion includes health and safety. However, after careful evaluation of the quality management appraisal systems of the largest South African utilities, it was found that criteria for safety equate to only five percent of the total appraisal score. The safety criterion included questions related to safety awareness and job assessment. There were no criteria for the assessment of health.

Most of the procurement and purchasing policies, standards and procedures that have been developed seem to have sound health and safety principles. However, one of the greatest difficulties is the lack of implementation of these policies, standards and procedures within construction.

3. PREQUALIFICATION

Prequalification is a formal process which usually requires prospective tenderers to answer a standard questionnaire followed by a briefing session. Where the prequalification process includes health and safety, the questions focus on the contractor's health and safety records, health and safety training and qualifications and experience of their staff and operatives. In all cases, contractors must be able to demonstrate that they have appropriate procedures in place to comply with the health and safety regulatory framework, as well as possessing the usual qualilities and resources expected of a competent contractor. Prequalification is part of the strategic process of assessing or demonstrating competence and resourcefulness.

Table 1 Assessment Stages: Competency and Resource

Approach	Competency Comment	Resource
One stage	Competency assessed for the range of work types likely to be encountered. Specific project details may or may not be known at this stage, but sufficient detail may be confidentially predicted.	Resource assessed for the range of work types, based on confident predictions of work situations, hazards and the like. This may be from a generic knowledge or from the specific project details.
Two stage • 1 (Prequalification)	Generic competency established broadly independent of specific work type.	Generic assessment for those elements of 'resource' that allow prediction and description, in advance of the known work.
• 2	Project specific competency elements established at time project is known or proceeds.	The balance of 'resource' assessment that is specific to the actual work.

<u>Key requirements of prequalification</u>

1. Contractors/Suppliers must meet trustworthiness, quality, fitness, capacity, experience and safety standards in order to pre-qualify to bid.
2. Clients should require contractors and subcontractors to submit completed, standardized questionnaires which seek information necessary to determine whether the contractors have met these standards.

3. Uniform, subjective rating systems must be used to determine "both the minimum requirements permitted for qualification to bid, and the type and size of contracts upon which each bidder shall be deemed qualified to bid."
4. If a contractor is pre-qualified and awarded a contract, the client may still determine that one (or more) of its subcontractors are not 'responsible' and remove the individual subcontractor from the project.

Advantages of prequalification

1. Clients can determine if any special expertise is required to be a responsible bidder on a particular size or type of project and screen for that expertise.
2. Clients can take adequate time to determine whether a (potential) bidder is indeed a responsible bidder.
3. A common database of listed contractors and suppliers can be readily available.
4. Rating of contractors according to expertise and reliability will be more probable.
5. Blacklisting of contractors on a common database will be absolute.

Disadvantages of prequalification

1. In a good economy (such as the current situation in South African), some contractors may decide not to expend the extra effort to go through the prequalification process.
2. Clients may be concerned that a prequalification process will increase the number of contractor challenges. While this may be true, the procedure for addressing a challenge to the prequalification decision is no more difficult than when bidders are not pre-qualified.

In South Africa, as in many other countries, an employer has both legal and moral obligations to ensure that contractors undertaking work on their behalf are competent. The Department of Labour in South Africa has successfully prosecuted local authorities and major contractors after their contractors or consultants failed in their duties under prevailing health and safety legislation. Poor health and safety performances also have serious and long-lasting negative impacts on and consequences for the image of a company or organisation. It therefore becomes important that all reasonable steps are taken to ensure contractors are competent.

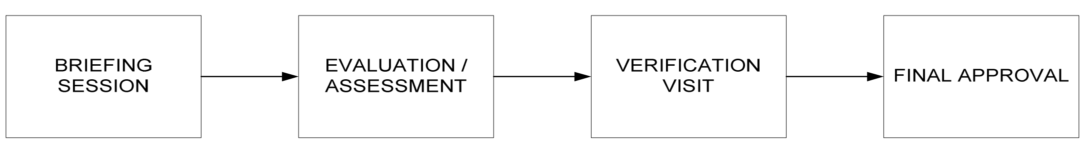

Figure 1. Integrated model for prequalification

4. RESEARCH

An exploratory study was done in one of the regional divisions of a major construction organization in South Africa with an average annual construction expenditures of $150 million dollars. The sample consisted of 115 contractors who wanted to be added to the vendor database in order to tender for electrification projects in the region. These projects ranged from approximately R1 million (about $140,000 U.S.) to approximately R20 million (about $3 million U.S.) in value. Projects varied between minor works, schools electrification, reticulation and refurbishment projects. The sample consisted of emerging contractors, Black Women-owned, BEE and established contractors.

Contractors were invited to attend a briefing session where they were informed of the prequalification process. They were assessed in terms of the following aspects, namely

- General Information of their company;
- Health and Safety Management System;
- Operating procedures and practices;
- Training and Competencies of Employees;
- Communication;
- Incident Management;
- Machinery and Equipment;
- Environmental Issues;
- Subcontractor Management; and
- Membership.

The contractors were required to score 70% to be declared competent but they would only be listed on the vendor database after they had passed the verification assessment stage. The results are listed in Tables 2 to 4. The distribution by turnover (annual business volume) and number of employees was

Contractors with < R3 million turnover and < 20 employees – 40%;
Contractors with R3 -R10 million turnover and < 50 employees – 41%; and
Contractors with > R10 million turnover and > 50 employees – 19%.

Table 2. Contractors with < R3 million turnover and < 20 employees

No. of contractors	No. failed	Mean Score
46 (100%)	33 (72%)	51

Table 3. Contractors with R3 -R10 million turnover and < 50 employees

No. of contractors	No. failed	Mean Score
47 (100%)	15 (32%)	74

Table 4. Contractors with > R10 million turnover and > 50 employees

No. of contractors	No. failed	Mean Score
22 (100%)	7 (32%)	78

Table 2 comprised mainly of undeveloped and underdeveloped contractors and small and medium enterprises (SMEs) who lacked significant health and safety knowledge and experience. Whereas larger construction companies in Tables 3 and 4 appeared keen to embed health and safety as a priority and value, smaller companies had traditionally been more reluctant to do so. A significant failure rate of approximately 32% still resulted in the larger construction companies. However, they achieved much higher mean scores than the smaller companies. These small firms were less likely to comply with existing legislation (Westwick-Farrow, 2006). A number of factors appeared to prejudice the attainment of better health and safety performance scores in smaller companies. Smaller contractors were reported to feel inhibited by small profit margins and a lack of financial reserves (Gillen et al, 2004). Construction SMEs could generally be characterized as 'price takers' (Miller et al. 2001). In addition, they lacked the human resources and management commitment necessary to improve occupational health and safety (OHS) performance (Lin and Mills, 2001; Hasle and Limborg, 2006). Furthermore, construction SMEs often did not focus on health and safety because they, inter alia,

- failed to recognize the economic returns of OHS;
- suffered generally from poor scheduling of work; and
- held that workers were capable of protecting themselves (Mayhew and Quinlan, 1999).

Smaller firms also adhered more to the widely reported "culture of cost cutting" (Ferguson, 2004).

5. CORPORATE GOVERNANCE

The King Report on Corporate Governance for South Africa 2002 (King II Report) adopted the aim of the King Report 1994 to "promote the highest standards of corporate governance in South Africa." The scope of the King II Report included:

- The review and clarification of the proposal for an inclusive approach adopted by the King Report 1994;
- The recognition of the increasing importance placed on reporting on social, ethical, environmental, health and safety matters; and
- The recommendation that the new code of corporate governance for South Africa should be measured and based on outcomes.

Corporate governance influences corporate social responsibility which in turn promotes responsible care and social responsibility. Prequalification can be seen in the same light given that it assists clients to ensure that contractors and suppliers meet health and safety competency in the construction environment. In most instances the client presumably has little interest in mandating improved health and safety and may consequently assume that health and safety is up to the individual, or else the principal contractor. This sort of client may not know what corporate social responsibility is, let alone have any active interest in pursuing it. What is more, the client would surely list cost, quality and completion time ahead of health and safety as project parameters.

6. OBSERVATION AND RECOMMENDATION

South Africa, unlike the United Kingdom and other developed countries, does not have support for a Competence/Passport Scheme for contractors. The UK government and its agencies provide contractors with health and safety knowledge based on the passport syllabus. This knowledge is tested under controlled conditions, before issuing passports to individuals. The South African government has not interfaced with any agency to develop and rollout such an initiative as yet. Therefore; the best option for South African clients is to adopt the prequalification model to screen contractors and suppliers for health and safety competence. In the absence of passport schemes, South Africa and other developing countries should adopt a VCP (voluntary code of practice) in using prequalification as a tool for health and safety competency and resource evaluation and assessments. Small firms are not just smaller versions of large organisations. While small firms are not opposed to the idea of health and safety regulation they need help in understanding their problems and meeting their legal obligations. Prequalification can definitely help them to understand their problems and meet their legal obligations.

7. CONCLUSION

The exploratory study tests the notion of developing a standard set of prequalification criteria based on best-value criteria (to which individual clients can attach their own weightings) with definitions of key health and safety aspects that would be required to be reported before contractors would be listed on the client's database. Table 5 below illustrates the weightings of each section of the prequalification process.

Table 5. Weightings of factors for the prequalification process

Section	DESCRIPTION	Total Score
1	General Information	0
2	HSE Management System	20
3	Operating Procedures & Practices	30
4	Training & Competencies of Employees	30
5	Communication	15
6	Incident Management, Claims, Workers	25
7	Machinery and Equipment	20
8	Environmental Issues	10
9	Subcontractor Management	15
10	Membership	5
Total		170
Total score required to be declared competent = 119		

Sections 2, 3, 4, 5, 6 and 9 of the questionnaire dealt with the assessment of health and safety criteria of the contractor's management system. Seventy two percent of the undeveloped and underdeveloped contractors in Table 2 scored poorly in all of the above mentioned sections. Thirty two percent of the more established contractors illustrated in Tables 3 and 4 failed to pre-qualify mainly because of their assessment scores in sections 3,4, and 6. These sections had higher weightings for health and safety, as they covered critical aspects such as workplace risk assessments, safe work procedures, training matrices and incident management systems.

The results of the exploratory study provide evidence that most contractors (more so than undeveloped and underdeveloped contractors) have their limitations with key aspects of health and safety management. The study also reveals that there is an urgent need for industry, especially in developing countries, to move toward greater industry-led self-regulation (such as the prequalification process) which will integrate OHS into their procurement and supply chain management systems. The key health and safety aspects identified could be incorporated for use as a broader-based procurement and supply chain management approach to health and safety performance measurement thus providing leading indicators of likely success or impending problems.

The study is also not without limitations. The integrated model for prequalification, in Figure 1, was tested using verified data from one sub-area (namely the distribution division) within one of the six regions of the whole organization. While the potential for respondent bias is an inherent problem in exploratory studies, its impact on the validity of results cannot be overlooked. Similarly, despite attempts to obtain a large, diverse sample, the size and composition of the sample limits the ability to generalize the results broadly across all six regions of the organization. While the statistical analysis shows that the sample data fits the integrated model for prequalification, the possibility exists that there are other variables pertinent to the constructs of health and safety interest and that these constructs may be multi-dimensional. Nevertheless, the results of the exploratory study provide the basis to move towards a prescriptive supply chain-wide health and safety regulatory regime such as prequalification. Prequalification would have the potential to ensure overall health and safety performance especially with the massive growth of construction projects in developing countries such as South Africa.

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DESIGN FOR SAFETY

3

PREVENTION THROUGH DESIGN PRACTICE AND RESEARCH: A U.S. CONSTRUCTION INDUSTRY PERSPECTIVE

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ABSTRACT

Addressing construction worker safety and health in the design of a project, also referred to as prevention through design (PtD) and designing for construction safety and health, has seen expanded interest and activity in the U.S. construction industry. The positive influence that PtD can have on not only reducing construction site hazards and improving worker safety and health, but also improving quality and productivity, has motivated the construction community to explore and implement the concept. However, barriers to PtD's widespread implementation in the U.S. exist, including the lack of regulatory requirements for PtD to be incorporated into construction projects. Leaders in the PtD effort from across the U.S. participated in a recent workshop sponsored by the National Institute for Occupational Safety and Health (NIOSH) to develop a national strategy for studying and diffusing the PtD concept. As part of the workshop, attendees took part in focus groups related to construction industry practice and to PtD research. This paper presents the outcomes from the focus groups and discusses their relationship to the findings of PtD research described in previously published literature and the current and planned PtD activities in the U.S. construction industry.

Keywords: Construction, Safety, Design, Architect, Engineer

1. INTRODUCTION

Prevention through design (PtD) is a fundamental concept within the field of occupational safety and health. It is well known that when designing a work environment, it is better to design out the safety and health hazards than to simply protect the workers from, or warn them of, the hazards (Manuele 1997). Eliminating safety and health hazards from the workplace provides workers a safe environment from the moment they step onto the job.

Application of the PtD concept in the construction industry can be challenging. Safety and health hazards for construction workers can be difficult to foresee given the nature and complexity of construction jobsites. The environment surrounding construction workers can change frequently as a facility gets built and jobsites often incorporate the work of many different trades and organizations each with different goals, priorities, and schedules. Depending on the contracting arrangement selected, the process used to construct the facility, and therefore some safety and health hazards that arise, may not be known until after the design is complete and construction services are contracted. There are impediments to the implementation of the PtD concept in construction that exist outside the jobsite as well. These include: designers traditionally limiting their focus to the safety of the facility end-users; a lack of education, training, and resources to assist architects and engineers to design for construction safety; perceptions of increased liability exposure to third-party lawsuits; the codes and standards to which designers prepare their designs; and the customs and culture of the construction industry. The absence of a legal requirement to apply PtD principles for construction workers in the U.S. is also limiting its application.

Although there are barriers to the implementation of PtD in the U.S. construction industry the benefits for PtD are recognized. Research has identified a link between the design and construction site injuries and fatalities. The European Foundation (1991) found that 60% of the accidents it surveyed could have been eliminated, reduced, or avoided with more thought during the design stage. Gibb et al (2004) reviewed 100 construction accidents and found that in 47% of the cases, changes in the permanent design would have reduced the likelihood of the accident. In an effort aimed at linking the design for safety concept to construction site injuries and fatalities, Behm (2005) found that the design was linked to 42% of 224 fatality incidents in the U.S. from 1990 to 2003. Constructors recognize the impact of the design on safety and health as well. In a study in South Africa (Smallwood 1996), approximately 50% of the 71 contractors who were interviewed identified the design as an aspect or factor that negatively affects health and safety. The design was the highest of any component identified that negatively affected safety. Almost 90% of the contractors stated that there is a need for safety education at the university or technical college for architects and engineers.

It is clear that considering construction worker safety and health in the design of a project can eliminate jobsite safety and health hazards and therefore positively influence worker safety and health on projects. Other countries, such as those in the European Union and Australia, have recognized the beneficial impacts of PtD, taken formal action, and are leading the way through PtD legislation. Recognition of and interest in PtD throughout the U.S. construction industry is growing. However further efforts are needed to cause diffusion of PtD throughout the U.S. construction industry.

NIOSH Workshop

To facilitate and grow PtD in all industry sectors in the U.S., the National Institute for Occupational Safety and Health (NIOSH) began a national PtD initiative in 2006 (http://www.cdc.gov/niosh/topics/PTD/). The initiative is designed to promote the PtD concept and highlight its importance in all business decisions. The ultimate goal of the PtD initiative is to prevent or reduce occupational injuries, illnesses, and fatalities through the inclusion of prevention considerations into all designs that impact workers.

As an initial step in the initiative, NIOSH hosted a Prevention through Design Workshop in Washington, DC, from July 9-11, 2007 to launch the initiative. The workshop attracted approximately 225 participants from diverse industry sectors and disciplines. The workshop: spotlighted the success of PtD in several industries in the U.S. and internationally; engaged participants in industry-centered breakout sessions to identify opportunities and barriers and to develop recommendations for each industry; and included cross-industry breakout sessions to map out the top over-arching issues for PtD in Research, Education, Practice, and Policy. The output from the workshop will be used to develop a strategic plan that highlights actions and milestones to institutionalize the PtD concept throughout the U.S.

Much can be learned about diffusing PtD in the construction industry from the input provided during the focus group (breakout) sessions at the workshop. This paper presents a summary of the input related to the construction industry that was provided during the Construction Industry and Research sessions along with an evaluation of its merits. An evaluation of the input is also provided with respect to previous PtD research and current and planned PtD activities in the U.S. construction industry.

2. FOCUS GROUP (BREAKOUT) SESSIONS

The second and third days of the NIOSH PtD Workshop were devoted to a large extent on focus group sessions. On the second day, the focus group sessions were organized according to eight work industry sectors (Agriculture, Forestry and Fishing; Construction; Healthcare and Social Assistance; Manufacturing; Mining; Services; Transportation, Warehousing and Utilities; and Wholesale and Retail Trade). Those interested in the construction sector, approximately 85 attendees, gathered together in one room to discuss PtD in construction. This group, which amounted to approximately one-third of the conference attendees, consisted of employees of large engineering/construction firms, large owner firms, academic researchers, design professionals, and national occupational safety and health organizations. The participants were asked to address questions related to four functional areas within construction: *practice*, *policy*, *research*, and *education*. For each functional area, the participants were asked to discuss and respond to the following questions:

a. How can PtD *practices*, *policy*, *research*, or *education* address specific goals or important areas identified within the construction sector?

b. How can we overcome barriers and use drivers to promote PtD *practice*, *policy*, *research*, or *education* in the construction sector?
c. What PtD *practice*, *policy*, *research*, or *education* opportunities are there for immediate action and how do we move forward on these opportunities?

As a means for discussing each functional area, the participants were separated into small focus groups using the Café method (World Café Community 2002) of group discussion. A total of 12 tables were set up for the discussion (three for each of the four functional areas). The discussion at each table focused on a particular functional area (*practice*, *policy*, *research*, or *education*). Each focus group was asked to discuss the questions related to the functional area of interest at that table. After allowing time for discussion, the participants were asked to move to another table (not a table covering the same functional area) to participate in discussion with a different group of participants. A total of four tables were visited by each participant. This process permitted the participants to provide input on all functional areas and allowed for "cross-pollination" of ideas. A table "host" was present at every table to facilitate and record the discussion that took place. The records taken by the table hosts were then organized and reviewed by a rapporteur who wrote a summary report on the breakout session.

On the third day of the workshop, the focus group sessions were organized according to functional area: *Practice*, *Policy*, *Research*, and *Education*. This format allowed practitioners from different industry sectors to come together to share ideas within a particular functional area. For the Research functional area, the research-related input from all industry sector discussions gathered on day 2 of the workshop was collected and organized. From this information, seven topic areas were identified as important to PtD research and were used to facilitate further discussion of PtD research during the breakout session. The seven topic areas were:

1. The economics/business case for PtD
2. Design-related causality of occupational injuries and illnesses
3. The development of PtD devices, tools, and processes
4. Worker, machine, structure, and environment interaction
5. Diffusion, sustainability, and the communication of design innovations
6. Methodologies for PtD research
7. Leveraging PtD methods and technologies from other industry sectors

Participants in the breakout session were asked to consider each of these topics and to provide input and guidance for conducting PtD research in these areas. The Café method of group discussion that was used for the focus group sessions on day 2 was used again for the Research functional area discussion. Similarly, a rapporteur collected, organized, and summarized the input provided during the Research functional area discussions.

3. RESULTS
Construction Sector Focus Group Responses

The Construction sector focus group sessions provided valuable insights into the needs, challenges, and opportunities for PtD in the construction industry. A summary of the input is provided below. The Construction sector rapporteur's report (Behm 2007) provides a more detailed description of the focus group results.

PtD Practice. With regards to PtD practice, some standardized tools are available and utilized, including the Construction Industry Institute's (CII) Design for Construction Safety Toolbox (CII 1996) and variations of the Construction Hazard Assessment Implication Review (CHAIR) process developed in Australia (Workcover 2001). Individual firms who currently have PtD processes in place also utilize design reviews, constructability reviews, checklists, and risk assessment processes and forms.

A PtD practice issue commonly cited by the focus group participants was that of liability exposure. Unlike in Europe and Australia where PtD is mandated via legislation, in the U.S. architects and engineers commonly resist incorporating PtD for construction based on advice from legal counsel. When responsibility for safety is contractually placed on the constructor, it is believed that additional liability will be assumed if a designer implements PtD concepts into their designs. To mitigate this fear, opportunities exist to work with innovative firms to understand how the liability issue was overcome. Additionally, firms could work with attorneys and insurance companies to discover methods to eliminate the liability risk or minimize it to an acceptable level.

The participants provided several suggestions regarding ways to increase awareness and acceptance of PtD in construction. Case studies must be developed and geared towards owners and designers. A set of case studies from across the multi-faceted construction industry is needed, as is a prescribed methodology to incorporate PtD and measure its effectiveness. Linking PtD with sustainability was also suggested. The concepts of sustainability and PtD were identified as very congruent and should be able to co-exist. Opportunities to partner with the U.S. Green Building Council (USGBC) which developed the popular *Leadership in Energy and Environmental Design* (LEED) rating system should be sought. Additional assistance in spreading PtD throughout the industry could be provided through: a "hot list" of design suggestions, identifying tangible benefits designers will receive if they implement PtD concepts, demonstrating ease of use, and collaboration with and education of key professional organizations such as the American Institute of Architects (AIA) and Construction Users Round Table (CURT).

PtD Policy. Looking at PtD from the broader view of policy, the focus groups identified a need to define what "prevention through design" means in the construction sector. Some of the questions raised that should be clarified by a common definition were: Is it design or is it re-design? Are all engineering controls considered under the umbrella of PtD? If someone designs a better scaffold, for example, is that PtD or is PtD about seeking methods to reduce work at height through better project design, or are both examples of PtD? NIOSH or another national organization should develop and put forth a definition of PtD in construction so that all parties within the industry have a common understanding of PtD. The participants voiced their opinion that governmental agencies should take a lead in PtD by changing standard contracts to make its use a requirement on government projects. However, the participants also believed that governmental regulation of PtD in construction is not a viable short-term strategy.

PtD Research. When asked to focus on PtD research in construction, the focus group participants agreed that the research needs to be applied rather than theoretical. Studies to measure PtD's impact and effectiveness were identified as a high priority. Measuring PtD effectiveness can be difficult because of the impacts of other safety program elements that are implemented on projects in addition to PtD. Individual, in-depth case studies may be the most feasible means for understanding the impact of PtD on a project or a firm. Case studies should begin in the project's conceptual design stage and follow PtD through the completion of construction. The following research study topics were suggested: analyses of the link between PtD and the sustainability movement; investigation of issues surrounding liability; and how to diffuse PtD throughout the construction industry.

PtD Education. Lastly, the focus group participants provided input on PtD education. Education efforts should cover two aspects: continuing education and university education. Creating PtD education workshops for Continuing Education Units (CEUs) required for Professional Engineer and Registered Architect licensure renewals is necessary to diffuse the PtD concept among practicing architects and engineers. Challenges to doing this include the fact that each state has its own engineering licensing system and the difficulty of developing adequate educational materials for the various design and engineering specialties. With regards to education at the university level, the participants felt that this was needed but not a priority at this time compared to other issues. One of the most compelling factors discussed was that entry-level architects and engineers will commonly focus on learning what their employers and clients want them to practice, not on suggesting major changes in policies and processes. Given that practicing design professionals typically do not incorporate PtD in their design work, an educational effort aimed at colleges and universities may be ineffective until the industry standard changes to incorporate PtD in practice at some level.

Research Functional Area Focus Group Responses

The Research functional area focus groups identified PtD research opportunities and needs for all industries, many of which are applicable to the construction industry. A summary of the focus group results is provided below. The Research functional area rapporteur's report (Gambatese 2007) provides a detailed description of the results.

The Economic/Business Case for PtD. Anecdotal evidence suggests that PtD can improve productivity, quality, and cost; however further research is needed to fully understand and quantify the economics of implementing PtD. Research is needed that examines the costs associated with both the process of PtD and the manufacture and construction of specific safe designs. Research should be conducted that addresses the economic impacts of not integrating safety early into the design process. Addressing safety issues through retrofitting has been shown to be quite expensive. Further documentation of the expense is needed. When economic evaluation is conducted at an industry-wide level, assessments should consider human, environmental, and social costs and benefits. Making a business case for PtD is usually done at the individual company level and should include both direct and indirect costs and benefits. It may be that a business case study does not indicate a positive return on investment while societal economic evaluations suggest a benefit to society as a whole. Both types of analyses provide valuable insights into the PtD concept and are needed. Developing an appropriate benefit-cost model and comparing the expected benefits to the costs is needed in order to provide a means to assess PtD from a financial perspective.

Design-related Causality of Occupational Injuries and Illnesses. Research is needed to determine how to effectively assess design-related causality and to determine the connection between specific design features and worker injuries and illnesses. This is a very important first step. Understanding injury and illness causality allows for analyzing and re-designing work environments, tools, and systems to eliminate the associated hazards. To facilitate this research, better surveillance data on worker injuries and illnesses is needed. The research should consider both the frequency and severity of injuries and illnesses when identifying new designs.

The Development of PtD Devices, Tools, and Processes. Additional tools and processes are needed that assist design professionals with hazard recognition and design optimization in a wide range of contexts. Research is needed to investigate and develop new designs that create a safe and healthy work environment. Including the views and input of the workers affected by the designs and the manufacturers of the products is an important aspect of this research. The designs should consider not only the controlling system but also all sub-systems so that some sub-systems are not negatively impacted.

Worker, Machine, Structure, and Environment Interaction. In addition to developing tools and processes to implement the PtD concept, research is needed to understand how to design to account for human interaction with machines and their work environment. The ways in which workers approach, operate, and view machines can impact the hazards which they experience. Workplace dynamics and organizational culture have also been shown to influence worker safety and health. Research is needed to understand these impacts in the context of PtD, and could be accomplished through ethnographic studies aimed at creating and developing products and services that better meet worker needs. Once implemented, maintenance of the tools and continuance of a positive PtD climate will be concerns. Research should be conducted to address how to maintain PtD throughout the lifecycle of a project or within an organization.

Diffusion, Sustainability, and Communication of Design Innovations. Research is needed to determine what avenues are available to disseminate PtD information and to measure their effectiveness. This research should be followed up by implementing successful communication strategies so that actual diffusion of the information occurs. Research related to this topic should also consider bringing in a global perspective.

Research is also needed to explore what drives the design community to act and how best to create this demand. The research should involve worker organizations, educational institutions, compliance organizations, and professional groups associated with the design communities to determine how each of these can affect the demand.

Methodologies for PtD Research. Conducting PtD research is a complex venture often involving numerous stakeholders trying to study a new process and measure an outcome that may not be directly quantifiable. There is a need to establish PtD research methods that account for these factors and result in reliable research findings under practical research limitations and resources. Research is also needed to develop evaluation metrics, measure the performance of specific designs, identify benchmarks for safety and health performance, and assess the performance relative to the benchmarks. The research should consider performance not solely related to worker safety and health, but also to other outcomes such as cost, quality, and sustainability. There is a need to conduct simple, small studies that focus on specific designs. While these types of studies may not be groundbreaking nor considered high profile research, they can contribute to a significant safety and health issue, and when combined, can provide a magnified impact. Efforts should also be made to coordinate studies under a common funding program such that they complement each other and combine to create a greater impact than each could have on its own.

Leveraging Methods and Technologies from Other Industry Sectors. Innovation often occurs in an industry sector as a result of the integration of ideas, tools, and technologies from another industry. Research studies are needed to: identify existing PtD practices in each industry sector; evaluate the practices in terms of their transferability to other industries; and develop the practices for application in other industries. Conducting this research requires that connections be made between industry sectors to enable the communication of ideas and experiences. One way in which this can be accomplished is by creating a national clearinghouse of PtD information. Access to such a clearinghouse would allow researchers to learn from other industries and keep from duplicating research efforts.

4. CONCLUSIONS AND RECOMMENDATIONS

The responses provided by the focus groups point to important activities and research that need to be undertaken to diffuse PtD into the construction industry. It is clear that without continued research and dissemination efforts, acceptance and implementation of the PtD concept in the construction industry will be slow to take place. Moving forward to accomplish the identified research requires efforts on numerous fronts. Questions still remain regarding PtD's impact and the most effective tools for its implementation. Using previous and on-going research as the starting point, additional research should be conducted to validate the impact of PtD on construction worker safety and health and on other project properties such as cost, quality, and schedule. Since PtD knowledge may be incorporated into the design in various ways, assessing the impact of PtD should be conducted in conjunction with the development of PtD processes and tools used for implementation. Parallel efforts are also needed to educate and train design professionals to assist and promote the implementation of the design processes and tools.

The growth of PtD in the U.S. construction industry is expected to take place. The responses from the focus group sessions suggest the paths, or "trajectories", it should and will take in its development. Paths which PtD will take have been identified in previous scholarly work. Toole and Gambatese (2007), for example, identify four trajectories through which PtD concepts will evolve in the construction industry. These are: increased prefabrication, increased use of less hazardous materials and systems, increased application of construction engineering, and increased spatial investigation and consideration. The activities suggested by the focus groups can be "mapped" to coincide with the identified trajectories and enhance their effectiveness.

There was much enthusiasm within the Construction sector for PtD. However, numerous challenges exist and among those, the liability issue must be resolved at a national level. While not an issue in other countries where PtD is legislatively mandated, liability is commonly the biggest obstacle to PtD implementation in the U.S. Additional work needs to be done to investigate the probability and magnitude of added third-party liability exposure when designing for construction worker safety and health. Once this is understood, work should be conducted to develop tools and contracting strategies that can be implemented at the project, organization, and industry levels to mitigate the liability. This effort most likely will involve the participation of insurance representatives and construction legal counsel along with professional design associations.

Comprehensive PtD research will require multiple studies over an extended period of time. Like research in many other fields, occupational safety and health research is commonly conducted by independent organizations and researchers who are often working independently and occasionally in collaboration. Communication of investigative efforts, barriers, and findings takes place through publications, presentations, and in some cases informal contact. The autonomous nature of research efforts, along with the often lengthy time period between performance and publication of the research, can inhibit timely, comprehensive, interconnected research of a particular topic. Studies that are undertaken may overlap or result in knowledge gaps. Effective performance of PtD research can benefit from a concentrated effort that integrates and coordinates the individual activities of separate efforts. When study is required on multiple fronts, this allows for planning and conducting integrated research studies and ensures that all research needs are addressed without duplication of efforts. Because of the many and varied PtD research needs remaining, such a combined effort is suggested for continued research on the topic.

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SOFTWARE TO SELECT DESIGN FOR SAFETY SUGGESTIONS

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ABSTRACT

Construction safety is impacted by many parties involved in the construction process. This begins with the designers of projects who often make decisions that directly impact the procedures employed to complete the facility. While these design decisions influence construction worker safety, designers are often ill-equipped to address construction worker safety in their designs. One reason for this is that designers generally are not trained in construction safety. To assist the designers in their design efforts, a software program was developed to provide designers with direct access to hundreds of design for construction worker safety suggestions. While prior research efforts have developed software with a similar objective, this software was designed for ease of use. This tool will be described. The software gives the user quick access to design for safety suggestions. The user can select those suggestions that are applicable for subsequent use.

Key Words: Design for Safety, Construction Safety, Safety Software

1. INTRODUCTION

Safety in the construction industry is a major concern that can be addressed by many parties involved in the construction process. One of the earliest stages in which to address construction worker safety is in the design stage. Architects and engineers consider safety when they make design decisions, but they usually consider only the safety of the end user, i.e., the contractors are expected to determine the best way in which to construct the project safely. Unfortunately, few designers consciously make design decisions for the safety of the construction worker. According to one study, "The lack of designers' involvement in worker safety is attributed to their minimal education and experience in addressing safety on the construction site, and their attempt to minimize their liability exposure" (Gambatese, 1997).

This paper is focused on the development of a software tool created to aid designers in the daunting task of making construction projects safer for workers by making design decisions with construction worker safety in mind. By implementing the design for construction worker safety suggestions that have been developed, designers could significantly decrease the number of injuries incurred on projects. A software tool that provides easy access to these design ideas would be an effective means by which designers could quickly become familiar with the concept of designing for construction worker safety.

Software has been previously designed for professionals to serve as an aid in incorporating design for construction worker safety suggestions into their projects. In 1996, the Construction Industry Institute (CII) sponsored the development of a software tool to assist designers in designing for construction worker safety. It was developed by John Gambatese, under the guidance of Dr. Jimmie Hinze. That software, entitled "Design for Construction Safety Toolbox," was fully functional, but it was quickly found to be cumbersome, hard to update, and hard to use because of the limitations of the authoring software at the time. As a result, the tool has not been used to the extent anticipated and CII expressed a desire to have a newer version created which utilizes the most current authoring software to display the most updated list of design suggestions in an easily updatable, user friendly environment.

The objective of this research was to develop software built specifically to give design professionals the ability to quickly and easily access and select from hundreds of compiled design for construction worker safety suggestions for use in their projects via the Web or a compact disc. With the proposed software, the user could bypass the data which are not applicable to a specific project, thus limiting the amount of information that has to be entered to access a suitable report of the suggestions relevant to their project. The goal was to create a software tool that would aid designers in making decisions that could ultimately reduce injury and death on construction projects by providing them with design suggestions in an easy to update, user friendly environment.

2. LITERATURE REVIEW

Every party involved in the construction process can have an impact on safety, including designers. By taking appropriate actions in the design phase, some of the inherent dangers can be minimized if not eliminated completely. In fact, "research studies have identified the design aspect of projects as being a significant contributing factor to construction site accidents" (Gambatese et al, 2005). Designing for construction worker safety requires a unique thought process where the designer must consider the people who construct the project, not just the end users. It entails utilizing modern technology, previous construction experience, common sense and other means necessary to explicitly design for construction worker safety.

In 1992, one of the earliest design for construction worker safety research studies was conducted by Dr. Jimmie Hinze and Francis Wiegand concerning the role that designers play with regard to construction worker safety. They contended that "despite the obvious reasons for placing the primary responsibility on the contractor, the safety performance on a project may well be dictated to a large extent by decisions made by the designer" (Hinze et al, 1992). With that research, a well-formed concept of designing for construction worker safety was born despite the existing culture which dictated that designers simply had no responsibility for a project being constructed safely.

Standard industry practice continues to place the responsibility for the safety of construction workers solely on the contractor. Besides the widely accepted idea that contractors are responsible for worker safety, AIA documents clearly reinforce this by stating that the responsibility of worker safety does not fall on the designer. According to AIA201 (Section 3.3.1),

> The Contractor shall supervise and direct the Work, using the Contractor's best skill and attention. The Contractor shall be solely responsible for and have control over construction means, methods, techniques, sequences and procedures and for coordinating all portions of the Work under the Contract…

While the above statement does not explicitly place the responsibility of worker safety on the contractor, it does not imply in any way that designers have a responsibility to produce construction documents which promote worker safety. This is more explicitly stated in the AIA code of ethics which states quite clearly that the architect's role in terms of safety is limited to "the safety to the public of the finished project" (AIA, 2004).

Two other issues that tend to deter designers from designing for construction worker safety are liability and a lack of knowledge. John Gambatese summarized this with a statement that "the lack of designers' involvement in worker safety is attributed to their minimal education and experience in addressing safety on the construction site, and their attempt to minimize their liability exposure" (Gambatese et al, 1997).

Despite the many obstacles to having design for worker safety become a widely accepted practice, there has been an increasing amount of interest in designing for construction worker safety since the initial research in 1992. Ways have been sought in which to aid designers in taking on the daunting task of creating designs that will improve safety in the construction industry. After years of working in an industry culture where the designer assumes little responsibility for the safety of construction workers, it is now becoming apparent that action at the design phase is a very important element which is necessary to reduce the number of injuries and deaths on construction projects.

According to various studies, scheduling, planning, and designing activities can decrease the risk of incidents on construction projects. 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, 2004). There is also evidence that design elements serve to protect the health of construction workers, not just their immediate safety. For example, "50% of the 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" (Smallwood, 1996). Based on these and other studies, it is becoming increasingly apparent that appropriate design initiatives can significantly reduce injuries in construction.

Although the design community has not come very far in terms of implementing worker safety-in-design since 1992, there have been several studies performed, publications written and even tools developed to aid designers in designing for construction worker safety. The main goals of these endeavors have been to increase the awareness of designers to their responsibility for the safety of construction workers and to devise ways in which to provide designers with the knowledge necessary to create safer working conditions on construction sites.

One way in which researchers have attempted to increase designers' knowledge of construction safety is by devising suggestions that can be accessed and utilized by design professionals when planning their projects. The Construction Industry Institute (CII) developed over 400 design suggestions through one of its research projects on construction safety. This was done with the objective of aiding designers by compiling many useful designing for construction worker safety suggestions. The intent was for designers to consider each design suggestion for its viability and that selection of specific design suggestions "should be conducted by the designer as specific project objectives are examined" (Hinze et al, 1996). Thus, the idea was to provide design professionals with the information and tools necessary to make effective design decisions with regard to construction worker safety.

With the development of many useful worker safety-in-design ideas came another problem. The ideas were available but so abundant (over 400) that designers could quickly become overwhelmed by the numerous ideas. CII recognized the necessity for a software tool specifically developed to compile the many valuable design for worker safety suggestions and make them easily accessible for design professionals. This resulted in a software tool called "Design for Construction Safety Toolbox" which was developed by John Gambatese, under the guidance of Dr. Jimmie Hinze, in 1996. While that software was fully functional and contained hundreds of design for construction worker safety ideas, industry users of the software determined it to be very difficult to use and update, due mostly to the limitations of the authoring software.

3. RESEARCH METHODOLOGY

CII recently expressed a desire to implement a new version of the software which would take advantage of the powerful authoring software available today. The ultimate goal was to develop a tool that could compile the ever-growing list of designing for construction worker safety suggestions in a user-friendly environment. The software tool was to be easy to use so more design professionals would be willing to actually use it thus exposing more and more designers to the suggestions. It should also be easy to update as new suggestions were devised. In addition, it would be accessible via the Web – a feature not possible with the previously developed software – making worldwide distribution simple and promoting the concept of safety-in-design.

The objective of this research was to create a tool that would provide designers with quick and easy access to applicable design for construction worker safety suggestions.

This effort was begun by researching existing tools and existing ideas related to designing for safety. The approach consisted of four phases. First, the existing design for construction worker safety suggestions that had already been developed were researched. Second, new suggestions were devised to ensure that a more comprehensive list was entered into the new software database. Third, research was conducted to choose the most suitable authoring environment for this type of application. Finally, after an authoring environment was chosen and the design suggestions were compiled into a usable format, the software was designed, coded, tested, modified, and finalized.

When the design for construction worker safety suggestions were compiled, they were grouped into categories that had been previously developed through research by John Gambatese and Jimmie Hinze in 1996 for the CII. The following list shows how the existing suggestions were sorted:

- Administrative
    - Layout
    - Planning
    - Design
- Sitework
    - Layout
    - Roads and Paving
    - Earthwork
- Foundations
- Roofing
- Structural
    - Steel
    - Concrete
    - Masonry
    - Timber and Wood
- Finishes
    - General
    - Stairs and Railings
    - Ladders
- Doors and Windows
- Mechanical and HVAC
- Electrical
- Industrial Piping
- Tanks and Vessels

The CII design for safety suggestions were placed into a spreadsheet using Microsoft Excel so that as additional design suggestions were identified or devised, it was a quick and easy process to ascertain if they were already listed. Additional ideas were devised by various means, including input from safety researchers, graduate student participation and observations on construction sites. The suggestions were then evaluated and logged for possible inclusion in the software database.

In order to produce effective and usable applications, software development requires research to choose the best authoring environment before the design and coding of an interface can take place. Since it has become a standard for the development of similar applications, Macromedia Flash 8 Professional (Flash) was chosen as the authoring environment. It was also chosen due to its high level of scalability, usability, accessibility and the powerful nature of Action Scripting (Flash's programming language) which permitted the creation of a database to which new design suggestions could be added in the future by simply editing a text file. Flash applications can be accessed via the Web, a compact disc, hard drive, or any storage device with the necessary file capacity (in this case, the application itself is only about 250 kilobytes). Flash applications do require the use of Flash Player, but "Flash Player is installed on 98% of Internet-enabled desktops worldwide and on a wide range of popular devices" (Adobe Systems Incorporated, 2007). In addition, the player is a free download for anyone with Internet access. The powerful features mentioned above made Flash the best choice for authoring the new designing for construction worker safety software.

The new software was to be user-friendly and utilize a database that could easily accommodate future design for construction worker safety suggestions as they are devised. Various design elements were added to increase usability and to decrease the amount of user training necessary to effectively operate the software. Difficult navigation was a weakness of the 1996 "Design for Construction Worker Safety Toolbox." Therefore, simplicity was the focus of the navigation in the new application to further ensure that it was optimized for ease-of-use, with minimal training requirements. Since the other main drawback of the original 1996 CII software was that its database could not be updated, the new database consisted of a simple, external, text-based (XML) file designed specifically to allow for easy updates, most of which can be done even without the use of Flash authoring software.

The new software was designed for use on a one-session basis. That is, users would not have the ability to save their progress, but they do have the ability to access their report by either printing it or copying and pasting it. One excluded feature was the inability to edit design suggestions within the interface. If a design suggestion is to be edited, it would need to be edited in the database and not in the software interface itself. The above limitations exist mainly due to restrictions that were found while attempting to optimize the application for deliverability and ease-of-use. In essence, it was deemed acceptable to trade certain functionality for ease-of-use and software deliverability.

4. THE DESIGN FOR SAFETY SOFTWARE

The designing for construction worker safety software contains 20 categories of design suggestions, with a total of 807 suggestions that can be accessed through the new software database. This software serves as a tool with which design professionals can easily sort through many useful suggestions. The output is a generated report of the suggestions which were selected by the user. The suggestion database consists of a text file (XML) which is updatable even without the use of the Macromedia Flash 8

Professional authoring software. There are other elements incorporated into the software as well, including illustrations that describe complex suggestions, Help sections, a Tour, and an About section.

The software tool offers substantial improvements not included in the 1996 version. For example, the list of suggestions has been expanded, the software is now more user-friendly, the software is deliverable by many different means (including via the Web, via compact disc, or hard drive), and the suggestion database can be easily updated.

The design of the application focused on the effective use of graphics, colors and other elements to optimize the user's experience when using the software. For example, the Start screen (see Figure 1) is simple and does not visually confuse users. The use of the same header throughout a session when using the software gives users a sense of where they are at all times and that all sections are related. To further ensure simplicity of use, the layout was based on only three main screens; The Start screen (Figure 1), Step 1 screen (Figure 2), and Step 2 screen (Figure 3). The Start screen is the launching pad for the software which includes a Take Tour button, Start button, and an About button. The Step 1 screen is the input screen where users actually choose suggestions which are appropriate for their project. As such, it is on the Step 1 screen where most of the users' time will be spent when reviewing and selecting design for construction worker safety suggestions. The Step 2 screen is an output screen where users can print, copy, or simply view their selected suggestions. With a brief introduction to the software, novice users can comprehend and use the software with confidence within about five minutes.

The navigation of the software is straightforward and intuitive and allows users to go to any screen with no more than two mouse clicks. Once the user clicks the Start button, the Step 1 screen appears. Along the left side of the screen, the categories mentioned above, such as Administrative: Layout, Administrative: Planning, etc., are listed for quick access. When users continue to Step 2, the navigation becomes very simplistic.

Figure 1. Screenshot of the Start screen.

Users have minimal choices on the Step 2 screen. They can go to the step-specific Help screen by clicking on the Help button, they can view the About screen by clicking on the About button, they can print the compiled suggestions by clicking on the Print Report button, or they can go back to the Step 1 screen and add or remove suggestions. The latter allows users to read their report and decide if they want to discard suggestions or add suggestions. The text on the Step 2 screen is selectable allowing users to copy and paste their report into Microsoft Word or any other word-processing application to facilitate the creation of an editable list of project-specific suggestions.

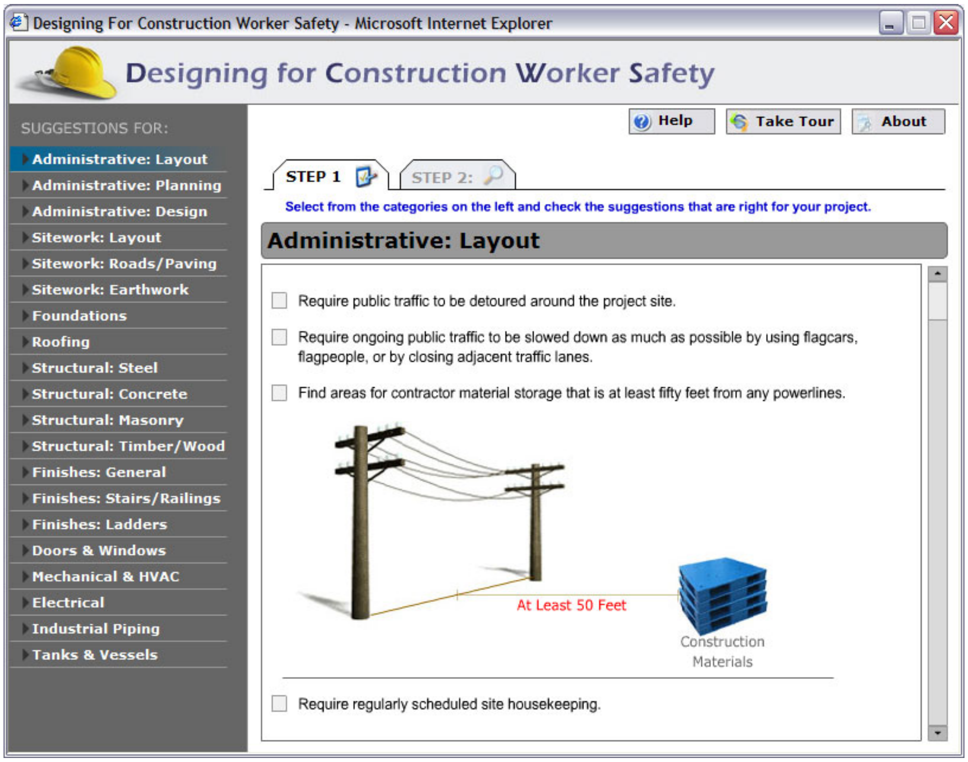

Figure 2. Screenshot of the Step 1 screen.

5. NAVIGATING THE SOFTWARE

The input, output, and various features of the new software can more specifically be described by explaining the functionality of each of the three screens (Start, Step 1, and Step 2). When users launch the software, the Start screen is displayed. It is from this screen that the user can take a tour of the software by clicking on the Take Tour button, read information about the software by clicking on the About button, or simply begin using the software by clicking on the Start button. The Take Tour screen was intended as a means by which users could get an overview of how the software works. The About screen is simply an informational screen which displays data about the software such as licensing information, software version, and other pertinent information. The third and final button on the Start screen, the Start button, takes the user directly into Step 1 (input screen) of the sequence.

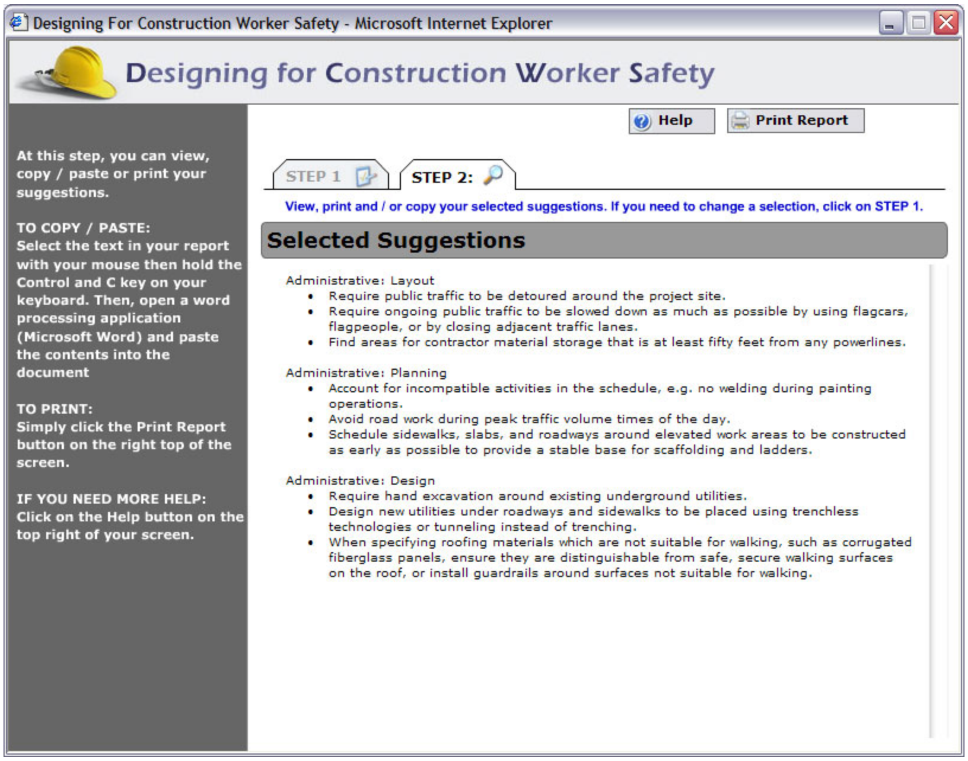

Figure 3. Screenshot of the Step 2 screen.

On the Step 1 screen, the input screen, the user can examine the full array of design for safety suggestions in the software. The user can then choose the suggestions that are relevant to the project. The user has the ability to choose from the various categories (with an average of over 40 suggestions per division). By default, the suggestions for the first category (Administrative: Layout) are displayed in the center of the screen under their respective heading and the button for that category is highlighted (see Figure 2). When a user clicks on a different category, that button becomes highlighted and its suggestions are then displayed in the center of the screen along with their respective heading, and so on. When all suggestions for one category cannot be viewed at one time, a scroll bar can be used to view those suggestions not viewable on the default screen. No more elements change until the user actually selects a suggestion by clicking on its corresponding checkbox. At that point, a checkmark is displayed next to the suggestion which has just been selected. In addition, a checkmark is displayed next to the category button on the left side of the screen which indicates that the user has visited that category and has chosen at least one suggestion from it. Both of those checkmarks will remain until the user deselects the suggestion(s) or exits the program. Since some of the design suggestions listed in the database were not intuitive with a verbal description alone, graphics were included under some suggestions to ensure that each suggestion would be thoroughly understood by the user. Once the user has chosen the suggestions that are deemed appropriate, the Step 2 tab can be clicked to access the Step 2 screen.

The Step 2 screen (see Figure 3) is the equivalent of a report page as it compiles those suggestions that have been selected in the Step 1 screen and places them into an easy-to-read format, sorted by category, for quick reference. The users can simply view the report in the interface, they can print their report by clicking on the Print Report button, they can copy and paste their report into Microsoft Word (or any similar word-processing application), they can go to the step-specific Help screen, they can view the About screen, or they can go back to Step 1 to edit the list of suggestions which appear in the report. Another important addition to this step is the information listed on the left-hand side of the screen. This information provides users with a quick reference as to their choices on the Step 2 screen.

6. CONCLUSIONS

The software tool developed through this research achieved the goal of developing a program by which design professionals can access hundreds of designing for construction worker safety suggestions in an easy-to-use application that requires little training or computer knowledge. It does not confuse the user with extraneous screens and features because it works in a sequential manner by using two simple steps. Help, Tour and other features are incorporated into the software to further ensure usability. An easily expandable database, along with the original, editable Flash (FLA) files, gives this software the potential to be used for years to come. In short, it performs the primary tasks associated with the 1996 software in a much more manageable virtual environment, making it a very useful tool.

A useful property of the new software is the ease with which it can be delivered to many users with minimal effort. The software can be accessed by users via the Web, a compact disc, a hard drive or even a small storage device such as a flash memory card. With its relatively small file size, the application is deliverable by almost any means available today. This means that downloading the software via the Web, even with a dial-up connection, will be fast. It also means that widespread distribution of the software will be simplistic should this be the desire of the CII.

7. RECOMMENDATIONS

There is a “compelling need to better understand how to put the safety-in-design concept into practice” (Weinstein et al, 2005). Since construction is a dangerous industry in which to work and since several million workers are employed in the industry, every step necessary should be taken to ensure that workers on construction projects return home safely at the end of each day. Focusing on safety in the design phase of construction is one such step.

If the general attitude towards the designer’s role in construction worker safety can be changed by tools such as the software application developed in this research or by increasing awareness of designing for construction worker safety in other ways, then the practice could become more widely accepted in the industry. Along with institutions such as the CII, owners, construction managers, general contractors, subcontractors and vendors can play a role in convincing architects and engineers that design elements in projects often make a difference and may ensure a safer working environment for construction workers. Increasing the awareness of designing for construction worker safety should begin in university programs where engineers and architects are trained. Making tools such as the one developed for this research easily accessible to academic programs is recommended. This would increase the knowledge of designers concerning designing for construction worker safety. Architectural classes and classes for design engineers are encouraged to incorporate the concept of designing for construction worker safety. In fact, the accreditation boards for architecture and engineering are encouraged to stipulate that designing for construction worker safety principles be included in the curriculum of these professionals.

It is recommended that the software be run from a web server utilizing database technologies such as SQL enabling the creation of accounts which would allow expanded functions such as searchable databases, saving project information, etc. While this would require hosting services, additional action scripting and database coding, it would be helpful if designers concluded that the inability to save a file reduced their willingness to use the software. Such a server could also allow for a suggestion submission form allowing users to enter their own design suggestions for analysis and possible inclusion in the database. Another recommendation specific to the software has to do with distribution. Making this software (and other tools like it) readily available to design schools, construction management schools, and any other schools where graduates plan to enter careers related to the construction industry could help facilitate the awareness of future generations of construction professionals and bring about a wider realization of the effectiveness of incorporating worker safety in the design phase, and thereby reducing injuries and fatalities in the construction industry.

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GUIDELINES FOR CONSIDERING CONSTRUCTION SAFETY REQUIREMENTS IN THE DESIGN PROCESS

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ABSTRACT

Considering a process view of design, this paper presents guidelines for integrating safety into that process in the construction industry. Two major sources of evidence were used for developing the guidelines: (a) interviews with seven designers from the construction industry; (b) an empirical study of the integration of safety into design in an industrial building project. It is proposed that design for construction safety (DFCS) is organized as a multi-stage managerial process, starting with a preparatory stage involving decision-making on the major standards to be adopted during that process (e.g. stakeholders and their responsibilities). Then, the proposition is made that, during all stages of design (e.g. conceptual design, executive design), the safety integration into that process follows the stages of the risk management cycle: identification, assessment, response and monitoring. The risk management tasks should be supported both by existing databases of practical suggestions to integrate safety in the design and by a set of DFCS principles. In this respect, based on the above-mentioned sources of evidence, this study has proposed ten DFCS principles.

Keywords: Safety, Design, Risk Management

1. INTRODUCTION

Both in construction and other industries, the consideration of safety requirements since the early design stages has been widely recognized as a beneficial approach for safety management, since it is an effective way of either reducing or eliminating hazards at their sources. Moreover, once hazards are anticipated at the very early project stages, there will be more time available to plan safe construction methods. Regardless of this, negligence of safety issues during design has been pointed out as a major category of accidents root causes in construction sites (Gambatese et al., 2007; Behm, 2005; Churcher and Starr, 1997). For instance, based on the review of 224 fatalities in the USA, Behm (2005) concluded that in 42% of the cases poor design was a major contributing factor for the accidents. Churcher and Starr (1997) analyzed a large number of fatalities from 1986 to 1989 in the UK and concluded that 36% of the cases were strongly linked to design failures.

The demand for considering safety requirements into design seems to be stronger in the European Union countries that have adopted the European Directive 92/57/CEE (Temporary and Mobile Construction Sites). This Directive makes it mandatory that designers carry out formal safety risk analysis. According to Lakka and Sauni (1999), the European regulations have changed the focus of accident liability towards those responsible for safety planning, including designers and owners. During both design and construction stages, Directive 92/57 requires a health and safety coordinator (a person or a company) assigned by the owner. In Finland and France, owners have often designated the architect as the coordinator during the design phase (Lakka and Sauni, 1999). According to Gambatese et al. (2007) architects are more likely to have a positive impact on construction safety compared to electrical, mechanical and civil engineers.
Legal pressures have also contributed to make safety an integral part of design in the USA, even though in that country there is no equivalent to the European Directive. In the USA, Prugh (1996) has reported the increasing incidence of litigations against designers, mostly architects, due to their negligence in considering safety requirements during the design process. According to Hecker et al. (2006), even though design for construction safety remains in its early stages in the USA, there are several signs that the situation is starting to change. Those authors presented a set of academic and government led initiatives that have been undertaken in the US to disseminate the design for construction safety concept.

However, a number of barriers for integrating safety into design have been pointed out by Hecker et al. (2006), Mackenzie et al. (2000) and Hinze and Gambatese (1996), such as: (a) in the USA, there are liability fears on the part of architects and engineers for becoming involved in construction site safety; (b) design for safety reviews may increase professional fees; (c) tight project schedules established by owners may discourage a thorough analysis of safety issues in favor of other design requirements; (d) the lack of information and high uncertainty, noticeably in early design stages; (e) the limited education architects and engineering designers receive on construction safety; (f) limited availability of safety-in-design tools, guidelines and procedures; (g) limited pre-construction collaboration between the designer and constructor due to the traditional contracting structure of the construction industry; (h) the narrow specialization of construction and design professionals, which may make it difficult their involvement in safety management.

Regardless of those drawbacks, several studies have proposed practical safety measures to be adopted in design (Hislop, 1999; Hinze and Gambatese, 1996; MacCollum, 1995; Fundação Européia…, 1989). In the UK, the Health and Safety Executive has developed web resources that provide a number of case studies and practical suggestions aimed at supporting designers´ compliance with the Construction Design and Management Regulations, which are based on the European Directive (Safety in Design, 2007; Design

Best Practices, 2007). Construction and maintenance workers could also benefit from a set of safety solutions in design proposed by Sinnott (1985) for the safety of end users.

However, the practical use of the solutions proposed by those studies is not always straightforward. Some of the design suggestions are specific for certain climate conditions (e.g. when designing ramps, take into account sun orientation in order to minimize snow accumulation), while others are vague or out of the scope of product design (e.g. schedules should minimize the use of overtime). Moreover, their underlying principles are often unclear, since these have not been systematically analyzed in previous studies. Of course, those principles could be fairly easy deduced from the myriad of design suggestions existing in the literature. The lack of such principles might also explain why there are not yet tools to assess the extent to which designs comply with the design for safety concept.

Moreover, there is also room for investigating design solutions that could be applied by the designers of construction equipment and materials, such as cranes, hammers, drywalls, masonry, formwork and utilities. In fact, this means that the design for construction safety concept should ultimately involve the whole supply chain. Some design solutions related to the design of equipment and material (e.g. redesign masonry blocks with hand holds and design bent handle hammer) were compiled by Schneider and Susi (1996), even though those authors recognize that the solutions should be evaluated as to their efficacy.

While some research topics have been fairly well explored, such as the proposition of practical safety measures to be adopted in design and reports on the implementation of the European Directive 92/57, other dimensions of this subject have not been sufficiently investigated, such as the integration of safety into design from a process perspective. In fact, if design is considered as a process composed by an agreed set of procedures, it is necessary to establish how safety should be positioned within such a broad framework (e.g. in what design stages should safety issues be introduced? What stakeholders should perform a role to integrate safety into design? How safety could be integrated into existing design models and tools?). An exception detected in the literature review is the guidance developed in the UK by the Construction Industry Research and Information Association (CIRIA), aimed at supporting designers to comply with regulations. It takes a broader perspective of the design process and it shows designers how particular hazards that have been raised during the early stages of the design process can be tracked through project files and all decisions recorded (Churcher and Starr, 1997).

In this context, this article has the objective of proposing guidelines for integrating safety into design from a process perspective in the construction industry. It is based on two major sources of evidence: (a) interviews with seven designers from the Brazilian construction industry and; (b) an empirical study of safety integration into design in an industrial building project in Brazil.

2. RESEARCH METHOD

In addition to the literature review, this study involved four other stages in order to develop guidelines for integrating safety into design:

A) Interviews with designers from the construction industry

Seven semi-structured interviews were carried out with designers in order to obtain their perceptions on the integration of safety into design. While four designers were structural engineers (interviewees A, B, C and D), the remaining three were architects (E, F and G). They all had at least 15 years of experience and the majority worked for private clients (85,7%), mostly from other industries (71,4%), such as manufacturing and petrochemical. The reports were grouped into five topics: main assessment criteria adopted by clients; strengths and weaknesses of the design processes in which the designers have been involved; previous experiences in considering safety into design; opinion on the hypothetical introduction, in Brazil, of a regulation that makes it mandatory that designers take safety into account into design and; barriers to integrate safety into design.

B) Development of a check-list of safety measures to be integrated into design

A check-list containing a number of suggestions of safety measures was developed to be used in the design process. The main sources of information used to develop such checklist were the interviews mentioned in the previous item and the studies of Hinze and Gambatese (1997) and Sinnott (1985).

C) Empirical study

This study was conducted in the enlargement of an industrial building of a plastic manufacturer. The duration of the project was six months, including the time necessary to finish the architectural design and the development of structural and building services design. The construction company that was in charge of this project was a medium-sized firm, which typically carriers out industrial, commercial and hospital projects. Such company has its safety management system fairly well integrated to the production planning and control system. It usually works for private clients that have strict safety requirements. This study adopted an action research strategy, since both researchers and the construction company staff worked in close collaboration to effectively integrate safety requirements into design.

D) Proposal of guidelines for integration

The guidelines were developed based on both the literature review and the data collected in all of the previous stages of the research method.

3. RESULTS
3.1 Interviews with designers from the construction industry

Cost and time are the main assessment criteria adopted by the clients of the interviewed designers – each obtained 38,5% of the total of criteria mentioned. It is worth noting that cost and time, as reported by the interviewed designers, are related both to the cost and time necessary to develop the design (i.e. drawings and specifications) and to the cost and time expected in the construction stage, which to a great extent are a result of design decisions. The reported criteria are not necessarily in conflict with safety. For instance, the criteria mentioned by designers A (flexibility for future building enlargements) and B (effective matching solutions among construction subsystems, such as walls and utilities) tend to have a positive impact on constructability and, as a result, on safety. All designers reported that they informally take into account constructability requirements.

The designers also reported some of the characteristics of the design processes in which they have been involved. Four out of the seven designers (51,7%) complained that clash detection meetings were very time-consuming and that their active participation occurred during little time. Nevertheless, designer G reported that clash detection meetings with representatives of all design disciplines were a major opportunity to learn about the project.

Designer A emphasized the importance of involving the owner as early as possible into the design process. This involvement tends to be critical for safety, since the owner will be the ultimate decision-maker that will either approve or not design changes that have an impact on safety issues. Designers C and D reported they had a design practice that indirectly supported hazard identification: the use of checklists during early design stages to identify features of the structural design, such as the type of brick and the type of water reservoir. None of the designers reported that they developed production-oriented designs that specified sequencing and construction methods, which is negative from a safety perspective.

Only designer C (pre-cast concrete structures) reported that he voluntarily took into account safety of construction workers in his designs. This attitude is probably due to the fact that that designer has been working for fifteen years nearly on a full-time basis to the company that manufactures and installs the pre-cast concrete structures. Therefore, differently from the other designers that were interviewed, designer C works in close collaboration with the contractor and so he will be directly affected by design decisions that neglect safety and constructability. However, designer C emphasized that his focus is on safety during the manufacturing and assemblage of structures by the pre-cast concrete manufacturer personnel. Little or no attention is given both to maintenance and to the impact of the assemblage of pre-cast structures on safety of other construction crews. In fact, when firms bring the design and construction functions and personnel into the same entity, they improve the opportunity for integrating safety, usually a constructor concern, into design (Hecker et al., 2006).

The designers also emphasized that safety requirements to be integrated into design should be primarily pointed out by the owner and the contractor, especially the latter, since from a legal perspective it is the main accountable party concerning safety during the construction stage. Nevertheless, designers perceive that owners and contractors are rarely concerned with safety into design, so there is inertia from all involved parties.

By contrast, three out of the seven designers reported that, even though their clients are not concerned with construction safety, they are usually concerned with safety of end users of the buildings. For example, one of the designers reported that some of his clients demanded the development of formal fire risk assessments during electrical designs for industrial buildings. For those three designers, it could be easier to consider safety requirements of temporary users, since similar risk assessment techniques might be adopted both for end and temporary users.

Even though all designers have been able to mention at least one construction or maintenance safety hazard derived from their design solutions, none of them formally communicates hazards to contractors and owners. The reports also pointed out several barriers for considering safety into design: (a) the lack of feedback about poor constructability and safety hazards during construction and maintenance that were a result of poor design decisions; (b) the insufficient knowledge of designers on safety issues; (c) the lowest price criteria adopted by government agencies to select contractors; (d) the budgets that ignore the costs involved in building maintenance; (e) the designers and owners resistance to accept their share of responsibility for construction safety; (f) the lack of full implementation of the Brazilian Code of Consumers Rights, since there is usually no legal penalties for those designers that created latent conditions that favored accidents during maintenance; (g) the perception that constructability can only be achieved through expensive technological solutions; (h) the lack of proper identification of both temporary and end users requirements since early design stages, which provokes a lot of rework either or not the issues are related to safety. Barriers (b) and (e) are equivalent to barriers found in the USA and EU reported by Hecker et al. (2006), Mackenzie et al. (2000) and Hinze and Gambatese (1996).

All designers also considered that the introduction of mandatory requirements to integrate safety into design would be an important step to move the industry towards a better safety performance. Moreover, they perceived that developing designs that can be safely built should be considered a matter of professional ethics. However, they pointed out two potential barriers for introducing this new requirement in Brazilian regulations: (a) the lack of enforcement by government agencies, which is a frequent problem for many other regulations in Brazil; (b) the perception that most owners would not be willing to pay higher professional fees for this new task. According to the designers, those problems tend to be more serious in the residential building construction industry, since in this sub-sector the predatory competition among designers is more frequent and the profit margins are lower.

3.2 Analysis of suggestions for integrating safety measures into design

It was developed a checklist with 49 suggestions for integrating safety into design. The share of suggestions assigned to each design discipline was as follows: architecture (45,8%); structure (33,3%); utilities (20,8%). In order to clarify the nature of the proposed suggestions, they were analyzed from two perspectives: the hazards they were supposed to tackle and their underlying design principles.

Considering that 53 hazards were associated with the 49 proposed suggestions, the analysis pointed out that 45,3% were hazards of falls from different levels, 11,3% were primarily production hazards (i.e. there could be re-work or unnecessary tasks could be created if the suggestion was not followed), 9,4% involved hazards of being struck against, 7,6% were hazards of falls at the same level, 7,6% involved awkward postures or overexertion, 5,7% involved structure collapses or cave-ins, and 13,1% involved other hazards, such as electrical shocks, fire, cuts and run over.

Moreover, the analysis pointed out that the 49 suggestions adopted the 10 design for construction safety principles that are presented below (of course, this implies that each principle was underlying more than one suggestion):

(a) design to make it easier the installation of safeguards for construction and maintenance – e.g. design holes in columns to pass lifelines and guardrails. This principle was used in 26,1% of the total of suggestions;
(b) design to avoid interferences both among different building elements and among specific building elements and temporary/pre-existing site facilities (23,9%) – e.g. avoid designing stairways opposite to glass doors and/or glass windows;
(c) design accesses for carrying out maintenance tasks (15,2%) – e.g. incorporate ladders in the final structure to allow access to roofs;
(d) design building elements that can perform the role of safeguards, making them unnecessary (8,7%) – e.g. design parapets at least 1,20 m height, which is the guardrails height required by regulations;
(e) anticipate accidental loads during the construction stage (6,5%) - e.g. Brazilian regulations require the installation of platforms all around the building to gather residuals of construction materials during the execution of the external envelope;
(f) improve hazards visibility (6,5%) – e.g. specify colors of formwork panels that contrast with ironwork;
(g) design to prevent work at height, specifying tasks that can be done at ground level (4,4%) – e.g. design concrete and steel structures that can be pre-assembled at ground level;
(h) design to make it easier respond to emergencies (4,4%) – e.g. place mechanical, hydraulic and electrical switches in visible and readily accessible areas;
(i) do not design parts with sharp edges and that tangle (2,2%) – e.g. design rounded edges of guardrails rather than sharp edges;
(j) design to incorporate temporary facilities into the final structure (2,2%) – e.g. place crane foundations where they do not need to be demolished. This suggestion aims at preventing unnecessary workers´ exposition to the hazards involved in the demolition of the crane foundations.

3.3 Empirical study
Approach adopted for integrating safety into design

Due to time pressure, the construction stage started without completion of all designs. Therefore, demands for both developing new designs and modifying existing designs were frequent during the construction stage. While the owner assigned the architect as both its representative in the design process and the coordinator of that process, the contractor assigned a member of top management and a production engineer as its representatives during the design meetings. On a weekly basis, during two months, there were meetings to match the different design disciplines at the contractor´ headquarters. In addition to the owner´ and contractor´ representatives, those meetings also had the attendance of other designers whose disciplines were related to the subject of the meeting.

One of the authors attended just two of those meetings, since they were usually too time-consuming and the discussion of a myriad of design requirements made it difficult to introduce the discussion of safety issues. However, the attendance of those meetings helped the researchers to improve their understanding on the scope and details of the project. Overall, four major steps were carried out in order to integrate safety into design: (a) to analyze both architecture and pre-cast concrete structure designs from a safety perspective, since those were the only disciplines that had existing conceptual designs when the study began; (b) to develop a list of potential safety requirements to be taken into account by designers, with the support of the checklist of safety suggestions that had been previously developed; (c) to discuss that list with the designers both on an individual basis and during the weekly clash detection meeting; (d) to assess the extent to which the requirements were actually taken into account during the construction stage, based both on an interview with the production manager and on visits to the construction site. While stage (c) was undertaken by the contractor´ representatives in the design process, the remaining tasks were carried by a member of the research team.

Results of the integration

Table 1 shows how safety requirements were documented in the empirical study. It is worth noting that although just the architecture and pre-cast concrete structure designs were analyzed, it was possible to identify safety requirements related to other design disciplines that were in early development stages, such as steel framing and roofing.

Table 1. Safety requirements detected in the empirical study

Requirement	**Justification**	**Design discipline**
1. Anchorage points at the beams of the steel frame that supports the roof	Attach lifelines for both body harnesses and tower scaffolds, making it safer both construction and maintenance	Steel frame
2. Anchorage points a the external face of columns	Attach lifelines for both body harnesses and tower scaffolds,	Precast

	making it safer both construction and maintenance	
3. Protect steel sharp edges of the precast columns	Avoid being struck by or struck against those steel sharp edges	Precast
4. Ladders to access the roof from outside of the building	Safe access to the roof both for construction and maintenance workers	Architecture
5. Lifelines on the roof	Safety during roofing and roof maintenance	Roofing
6. Development of a mechanism to change lamps in high ceiling areas	Safety during changes of lamps in high ceiling areas	Electricity and architecture

Requirement 1 (anchorage points for both body harnesses and tower scaffolds at the steel beams that would support the roof) was eventually considered unnecessary. This was due to the fact that the contractor that was responsible for designing, manufacturing and installing the steel framework, proposed that lifelines were directly anchored at the trusses, which are illustrated in Figure 1. This contractor also presented a standard plan it used as a basis to assembly the steel frame – of course, this plan was adapted to this specific construction site. Requirement 2 (anchorage points for both body harnesses and tower scaffolds at the precast concrete columns, which were 12 m length pieces that had several iron sharp edges throughout it) was easily implemented, since the manufacturer usually installs some anchors to make it easier the transportation of the precast pieces. It was also made the decision to make holes in the columns in order to pass lifelines, at the heights of 3,0 m, 6,0 m and 9,0 m.

Figure 1. On the left: steel framing and pre-cast framing. On the right: pre-cast columns in which holes were made to allow the passage of lifelines.

Requirement 3 (cover iron sharp edges along the pre-cast columns) was also implemented. Due to the contractor request, all edges were bent before being delivered in the construction site. Requirements 4 and 5 (ladder to access the roof and lifelines over the roof, respectively) were implemented, in spite of some delay to determine the exact position of the ladder. Requirement 6 (mechanism to change lamps at high ceiling areas) was not implemented, since it was not found a more effective solution than the one currently adopted by the owner. In the existing building, the owner crews change lamps with the support of forklifts and cranes. Long life light bulbs could have been specified in order to reduce frequency of maintenance (Design Best Practice, 2007).

4. GUIDELINES FOR INTEGRATING SAFETY INTO DESIGN

This study proposes to organize DFCS as a multi-stage managerial process. It should start with a preparatory stage involving decision-making on the major standards to be adopted during that process, such as: (a) who will be the stakeholders and what will be their responsibilities; (b) what will be the adopted risk management techniques; (c) what will be the level of detail of the safety plans; (d) what sources of information will be required to carry out the risk management tasks (e.g. blueprints, accident statistics, etc.); (e) what will be the metrics to assess the effectiveness of the DFCS effort. Although the data collected in this study are not sufficient for proposing detailed guidelines on each of these issues, some guidelines might be proposed concerning the responsibilities for analyzing each design from a safety perspective.

Of course, this responsibility should be ideally attributed to designers, since more than any other stakeholder they have control on the creative process, maturity level of design solutions and the pace of the design. In particular, it is critical that the architect take the initiative to integrate safety into design, since its discipline has usually the strongest interfaces with all remaining disciplines. Moreover, the architecture design usually includes specifications on materials and construction methods for several building elements that often do not have specific designs, such as masonry and floors.

The little safety knowledge of most designers may be minimized if they carried out risk assessments with the support of production managers and safety specialists. While the production manager might provide essential information on construction methods and their associated hazards, safety personnel will provide specialized advices to designers. Gambatese et al. (2007) suggest that the design for construction safety intervention requires a team-oriented approach relying on collaboration of the designer, owner, constructor, and other project parties for it to be meaningful. In fact, since the design team should have a realistic mental model of temporary users´ behavior, it would be desirable if lower hierarchical levels could be involved, such as foremen and front-line supervisors. Since this teamwork will imply additional costs, the contracts between owners and designers should explicitly include the necessity of considering safety requirements and their related professional fees.

The existence of a design coordinator might also support the introduction of safety requirements into the design process. This coordinator could be in charge of both monitoring the designs compliance with safety requirements identified during the design process and sharing safety information with all designers. For instance, as soon as a risk analysis of the architectural conceptual design is available, it should be shared with all designers, pointing out the potential impacts of that analysis on every design discipline. The coordinator also might facilitate the matches among design disciplines due to safety requirements. For instance, the development of means to safely change lamps in high ceiling areas might have an impact on both the architecture and electrical / lighting designs, which in turn will require that they are compatible.

Since the major standards of the DFCS process are defined in the preparatory stage, the proposition is made that, during all stages of design (e.g. conceptual design, executive design), the practical safety integration into that process follows the stages of the risk management cycle (Baker et al., 1999): identification, assessment, response and monitoring. Although the four stages of the risk management cycle should take place during each major stage of design, it is likely that after the conceptual design, only revisions will be necessary. It is worth noting that a revision of the risk management cycle will also be useful after developing the as built design, mostly to check hazards related to maintenance.

In the design language, hazard identification is equivalent to capturing client requirements, which in this case are construction and maintenance workers. However, the characteristics of the workforce should not be taken for granted by adopting stereotypes of construction workers. In fact, designers should have a realistic image of the temporary users, both from a physical and cognitive perspective (Hollnagel and Woods, 2005). For instance, there are reports that in some European countries the demographics of construction workforce has changed drastically due to the increasing amount of migrant workers who dot have a command in English (Bust et al., 2007). High rates of illiteracy and a substantial amount of more than forty-years old workers is also a well-known characteristic of the construction workforce in Brazil. While it is a neglected issue in literature, construction workforce is also formed by a substantial amount of impaired and disabled people, whose physical and cognitive skills are compromised to some extent. According to Newton and Ormerod (2005), while contractors are unlikely to recruit disabled people, they are more likely to continue to employ people once they become disabled, but there is very little monitoring of this process by contractors. Further studies are necessary to investigate the implications of such workforce characteristics on product and process design.

A set of well-known techniques might support hazard identification, such as failure mode and effects analysis, meetings involving designers and production personnel, check-lists of hazards and their respective design suggestions, constructability reviews, 3D or 4D simulations of construction and, prototypes of some building elements. Those techniques are also likely to support the assessment and response risk management stages.

Risk assessment is the second stage of the risk management cycle. It includes the understanding of the nature of all hazards previously identified, setting up the basis for calculating a risk index (severity versus probability) associated with each design discipline. However, a thorough understanding of all hazards tends to be very difficult during early design stages, since there is usually a substantial uncertainty concerning the construction methods. This uncertainty has also an impact on the calculation of the risk indexes, which might support the prioritization of construction stages in terms of safety management efforts. Therefore, calculated risk indexes should be revised on a regular basis (e.g. by the end of every design stage) in order to take into account varying levels of uncertainty during the design process.

Risk response is the third stage of the risk management cycle, involving the definition of measures to control the hazards that were previously identified and assessed. According to Baker et al. (1999) there are four typical responses to hazards: elimination, reduction, transfer and retention. The first two types of responses might be developed based on both DFCS principles and existing databases of practical suggestions of safety measures to be adopted in design. Moreover, designers should look for opportunities for devising fail-safe barriers, which is an approach consistent with the dynamics of construction sites and with the previously mentioned fact that the construction workforce is increasingly diverse. A fail-safe barrier is one that prevents an accident from taking place and that has a shutdown function (i.e. no degrees of freedom are left). Based on this concept, fail-safe barriers can only be physical or functional barriers. According to Hollnagel (2004) physical barriers block the transportation of mass, energy or information from one place to another (e.g. walls and fences) and functional barriers create one or more pre-conditions that have to be met before an action can be carried out (e.g. by establishing an interlock, either logical or temporal).

It is essential to identify the hazards that were not eliminated during the design and, as a result, will require management efforts during the construction stage. Of course, it is worth emphasizing that design decisions do not necessarily should be modified to eliminate safety hazards. Even hazard retention can be acceptable in the case that an architectonical element adds value to the client, in spite of being difficult to be built. Indeed, this hazard retention only makes sense if it implies that there will be safe and effective construction methods. In other words, there can be sometimes a trade-off between temporary users and end users requirements. It is worth checking whether this trade-off is real, since end users requirements are not often systematically identified and so there can be a big gap between the designers´ image of end users requirements and their actual needs.

Hazard monitoring is the last stage of the risk management cycle and it takes place during both the design and construction stages. During all design stages, hazard monitoring should involve tracking of hazard identification, assessment and response. Concerning the construction stage, monitoring should ensure that the safety measures specified in design are implemented. The resulting feedback will be useful for developing safer designs in the future.

It is also proposed that the risk management related tasks (e.g. identifying hazards and devising preventive measures) should not be primarily undertaken during clash detection meetings. This proposition is due to the fact that those meetings might be too long, involving too many people and dealing with a myriad of design requirements. Decision-making on safety issues is likely to be realized as less urgent than other decisions that are essential to allow the beginning of construction. Of course, clash detection meetings might perform an essential role both as a source of information for undertaking risk management tasks and as a forum to ideas exchange among the stakeholders.

5. CONCLUSIONS

Based on interviews with seven designers from the construction industry and an empirical study, this paper proposed guidelines for integrating safety into design. It is proposed that the design for construction safety (DFCS) process starts with a preparatory stage involving decision-making on the major standards to be adopted during that process (e.g. stakeholders and their responsibilities).

Based on the preparatory stage, the four steps of the risk management cycle (hazard identification, assessment, response and monitoring) should take place during every major design stage (e.g. concept, outline, scheme, detail). The tasks of the risk management cycle might be carried out based on both well-known risk management tools and databases of design suggestions available in literature. Moreover, risk management might be supported by ten DFCS principles that were compiled for supporting the empirical study.

This research has pointed out opportunities for further studies in this area, such as: (a) the improvement and testing of the proposed guidelines – in fact, these guidelines could be a basis for developing a well structured DFCS method; (b) the development of other guidelines and methods for integrating safety into design; (c) to extend and validate the set of DFCS principles proposed in this study; (d) develop methods to assess the extent to which a design is safe. These studies should consider the existing models of the design process in the construction industry, so the integration could be based on theoretically agreed perspectives on design (e.g. what is design, what is its scope, what are the major design stages, etc.).

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DESIGNING FOR CONSTRUCTION SAFETY – A CONSTRUCTION MANAGEMENT APPROACH

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ABSTRACT

Studies have suggested and confirmed that designers can provide critical input involving construction worker safety. Continued progress is being made in the areas of education and training to better serve all participants in the construction industry, including owners, designers and contractors. Construction management has also become an acceptable and growing profession as it serves to address constructability issues through the sharing of information among all participants in the project. This paper offers a construction management (CM) approach to designing for construction safety by proposing a structured CM approach to information sharing and project collaboration for construction safety. The proposed structured CM approach has been developed based on the findings of a structured survey targeted to design and CM professionals in the construction industry.

Keywords: DFCS, Construction Management, OSHA

1. INTRODUCTION

Designing for construction safety entails addressing the safety of construction workers in the design of the permanent features of a project. The design defines the configuration and components of a facility and thereby influences, to a large extent, how the project will be constructed and the consequent safety hazards (Gambatese, 2000). For example, a decision would have to be made at the site concerning fall protection. This leaves open the possibility of a fall injury if inadequate fall protection is used, workers are not trained, or if fall protection is not used at all. If the designer specifies a 42 inch high parapet wall, not only does the design comply with the building code (safe for the public), the risk of a fall injury during the lifetime of the structure is eliminated because fall protection would not be required. Many other suggestions for how to design the permanent features of a project to facilitate safety during construction have been documented (Gambatese et al. 1997).

Studies by Whittington et al. (1992) and Suraji et al. (2001) reveal that a significant number of injury accidents originate from conditions upstream of the construction process during planning, scheduling, and design. Though the impact of the design on construction safety is evident and the potential benefits of its implementation are apparent, widespread application of this concept in the United States construction industry is currently lacking (Gambatese et al., 2005). Designing for safety has been proven to be a viable intervention in construction in the United States (Gambatese et al., 2005)

This paper offers a construction management (CM) approach to designing for construction safety by proposing a structured CM approach to information sharing and project collaboration for construction safety. The proposed structured CM approach has been developed based on the findings of a structured survey targeting design and CM professionals in the construction industry.

2. DESIGNING FOR CONSTRUCTION SAFETY – THE NEED

Designers are generally assumed to be responsible for the deign of a building or structure; that meets the local building codes, takes into account accepted engineering practices and is safe for the public. Although typical contract terms do not define designers as being responsible for the safety of construction workers, all designers should feel an ethical obligation to take action to prevent a serious injury to a construction worker if the hazard was imminent and obvious to them. As accepted by all, decisions made by designers affect the cost, quality and duration of a construction project. Similarly, construction safety can also be enhanced greatly by their prompt input. The quality management principle that quality must be “designed in” also applies to safety: safety must be designed into a project.

In addition, studies have shown that design professionals can have a significant influence on construction safety; 22% of 226 injuries that occurred from 2000-2002 in Oregon, WA and CA were linked with the design, 42% of 224 fatalities in the U.S. between 1990-2003 were linked with the design (Behm, “Linking Construction Fatalities to the Design for Construction Safety Concept”, 2005). In Europe, a 1991 study concluded that 60% of the fatal accidents resulted from decisions made before site work began (European Foundation for the Improvement of Living and Working Conditions). These statistics clearly suggest that design professionals can play their part in construction safety by incorporating design elements that provide safety for construction workers during construction and maintenance projects.

Recognizing the importance of the design to construction safety, the American Society of Civil Engineers (ASCE) states in its policy on construction site safety (Policy Statement Number 350) that engineers shall have responsibility for "recognizing that safety and constructability are important considerations when preparing construction plans and specifications."

Outside the United States, the European Union mandates consideration of safety in the design (CEC 1992). The United Kingdom's Construction (Design and Management) Regulations (HMSO 1994), established to comply with the EU Directive, place a duty on the designer to ensure that every designer should, while preparing or modifying a design which may be used in construction work in Great Britain, avoid foreseeable risks to the health and safety of any person likely to be affected by such construction work; and in so doing should give collective measures priority over individual measures (MacKenzie et al., 2000). Similarly, many other developed countries such as Australia (Bluff, 2003) and South Africa (Republic of South Africa, 2003) have already incorporated responsibilities for designers for construction safety. Lacking a regulatory mandate, as is the case in the United States, implementation of the concept in practice will likely depend on the benefits received from designing for safety compared to the effort and resources necessary for its implementation.

A requirement of incorporating safety into the design stage of a project to enhance construction worker safety has been proposed (Gambatese et al., 2005) as an additional measure in providing better construction worker safety and health and is commonly referred to as designing for construction safety (DFCS). This concept of thinking through the risks associated with various means and methods of construction, as dictated by the design, can produce positive results in both safety related claims and reduced project costs.

3. DESIGNING FOR CONSTRUCTION SAFETY – OSHA REGULATIONS

In a research study conducted by Gambatese, Hinze, and Behm (2005), design suggestions were developed that can ultimately be addressed in the design documents. Contained within the research findings are numerous constructability safety measures that can be undertaken, many of which have been developed from those directly exposed to hazardous construction work. OSHA has language within its regulations that refers to the engineer of record providing designs with construction worker safety in mind. Subparts L through X of the OSHA regulations have been identified as areas where the greatest influence can be placed to incorporate safety design modifications.

Examples of such suggestions are as follows; in Subpart M – Fall Protection 1926.501, Design windowsills to be 42 inches minimum above the floor level. Windowsills at this height will act as guardrails during construction. OSHA Subpart 1926.502 suggests the design of perimeter beams and beams above floor openings to support lifelines (minimum dead load of 5400 pounds.). It also states to design connection points along the beams for the lifelines. The contract drawings should note which beams are designed to support lifelines, the number of lifelines, and the locations along the beams.

Currently, most of OSHA's construction regulations require engineering controls in Subpart P (Excavation), Subpart L (Scaffolds), and Subpart R (Steel Erection) among others. These are a few areas that if addressed in the design stage can explicitly aid in construction worker safety through the OSHA regulations.

4. DESIGNING FOR CONSTRUCTION SAFETY – LEGAL CONCERNS

The traditional construction industry model has been split into two distinct fields, design and construction. As the industry moved from the master builder system into more specialty fields, definitions were developed in dealing with standards of practice, construction scope and defining areas of risk. Legislative proceedings were undertaken in the late 1980's to introduce bills in support of placing responsibility for safety on the design professional, along with the constructor through the use of a competent person on site to oversee worker safety. DFCS is not attempting to place blame on the designer but rather to bring to the forefront the ethical practice and the value of implementing construction worker safety through design efforts.

Designing for safety relies on the integration of construction process knowledge and the incorporation of proven methods into the design. Architects and engineers are not prepared to address this deficiency and lack proper training and fear exposure to legal proceedings as a result of injuries due to their designs.

Exposure to liability remains the greatest challenge in persuading designers to take on greater responsibility. Courts have found designers liable for the deaths of construction workers based on their prior knowledge of risks associated with different types of construction (Loulakis and Shean, 2005) . Ultimately contract language should reflect that designing for safety was a strong consideration for the project in question; however, safety remains the responsibility of everyone.

The American Institute of Architects rule 2.105 requires that architects take action when an employer or client makes a decision that may adversely affect the safety to the public, but this obligation is restricted to the completed facility. Similarly, the National Society of Professional Engineers clause holds the engineer responsible for the safety, health and welfare of the public in the performance of their professional duties. In summary court decisions have gone both ways and continue to be challenged.

5. DESIGNING FOR CONSTRUCTION SAFETY – A CONSTRUCTION MANAGEMENT APPROACH

Construction management can assure project success under various delivery methods. CM is distinct from both design and construction and well recognized as a specialized profession. Through the CM model, resources of various disciplines and backgrounds converge to provide construction leadership in the planning, design and construction phases. Due to project delivery constraints; timing, project capitalization, owner experience, and the complex nature of projects, the CM can serve as an agent to the owner and/or consultant in the pre-design and design phases.

Constructors in the CM model can greatly influence and contribute to DFCS through the flow of information as shown in the modified Figure 4. Project knowledge, risk assessment, design reviews, constructor input and a comprehensive management plan can provide the optimal mix of project safety designs. As will be discussed in the proposed CM model for DFCS, CM offers the best placement of safety assessment and identification in creating a successful and timely project.

In studies conducted by Szymberski (1997), the time/safety influence curve was developed to demonstrate that designer influence could be an integral part of construction safety. As shown, safety can be best controlled during the early stages of the design development when the influence is high, even as the project is being conceptualized, and diminishes throughout the project life cycle.

Regardless of the chosen contract form or project delivery utilized, design-bid-build (DBB), design-build (DB), or construction manager/general contractor (CM/GC) even greater influence can be achieved in the conceptual design phase through the incorporation of the experiences of construction management. The earlier that construction management is on board a greater influence can be placed on the effective influence on safety and vice versa. This concept holds true for all related professionals on the project, as the influence on safety decreases with project evolvement, as suggested by Szymberski. Fig. 1 represents the Time / Safety Influence Curve (Szymberski, 1997).

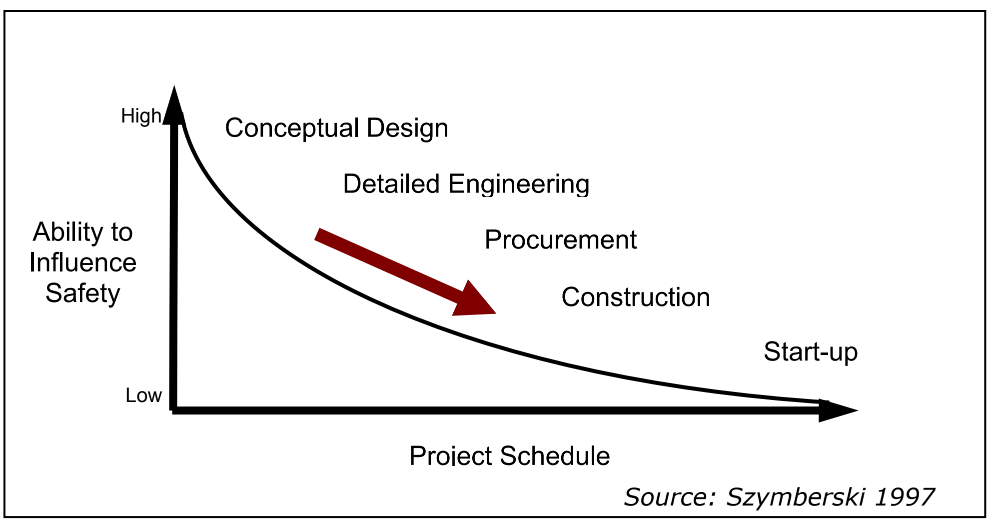

Fig. 1: Time / Safety Influence Curve (Szymberski, 1997)

There are practical reasons for each party participating in a construction project to encourage DFCS, in addition to ethical responsibilities. Subcontractors and general contractors that self-perform work have several practical reasons to encourage DFCS: it reduces accident rates, thereby reducing workers' compensation insurance rates, and increases project productivity. Benefits to owners from reducing the risk is that one or more construction accidents cause delays in project completion and hence loss of profitability. Owners incorporating Owner-Controlled Insurance Programs (OCIPs) get financial benefits from the lower accident rates that DFCS provides. Designers who perform DFCS can use this ability to market themselves as progressive, team-oriented professionals who will help to deliver a project with reduced liability and increased profitability. Designers who are part of design-build teams should benefit financially from the reduced accident rates experienced during construction.
In Burke's tripod (2006), the partners in construction management can be said to include a relationship conducive to construction worker safety as it relates to the contractual relationship between owner, designer and contractor (see Fig. 2). Suggestions on how this typical tripod can be modified to improve the information flow are discussed later in this paper (Fig. 3).

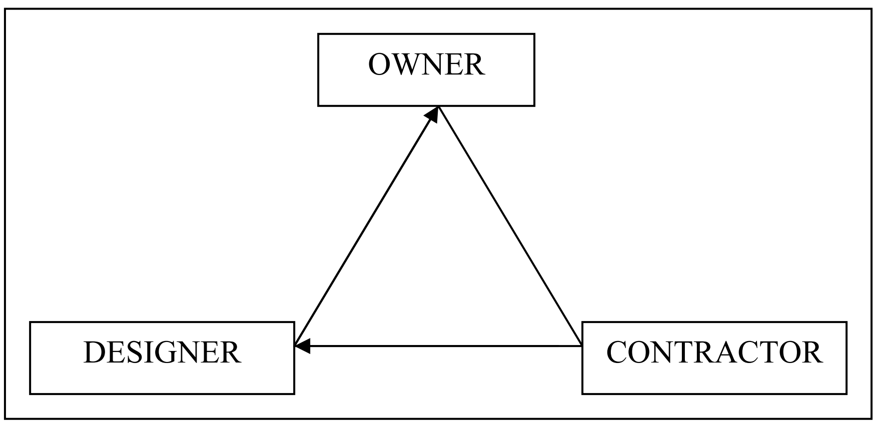

Fig. 2. The Tripod - The partners in Construction Management (Burke, 2006)

Extending the responsibility of construction worker safety to that of trade contractors, suppliers, and the construction management team overseeing construction, can reduce accident rates, thereby reducing workers' compensation insurance rates, and increase overall project productivity.

Safety is often viewed by management as being controllable; however there are those areas that are outside of the traditional concept of Total Safety Management (TSM). TSM relies on safety being the responsibility of everyone in the organization. As acknowledged by Dr. V.B. Burke, Professor and Director of Construction Management at Florida Atlantic University, Florida Institute of Safety and Construction, "TSM is an approach to safety of workers and other employees in the workplace that gives companies a sustainable competitive edge in the marketplace. This is accomplished by getting all the employees involved in establishing, enforcing, maintaining, and continually improving the safety of the work environment so that it is conducive to peak performance at all levels and all times."

Additionally, TSM may be viewed as a precursor to the development of DFCS in that it extends this responsibility to include the designer as part of the management team in designing with construction worker safety in mind.

6. RESEARCH METHODS

The purpose of this research study was to provide an approach to the topic of designing for safety by analyzing it from a construction management perspective so as to introduce a structured methodology to information sharing and project collaboration for construction safety. Drawing on the findings of previous research, examples of successful implementation of designing for safety, and regulations enacted outside the United States, the premise driving the research was that the practice of designing for safety is a viable means for enhancing construction site safety. Also, adopting a construction management approach to designing for construction safety can play a significant role in improving the safety and health of construction workers.

A survey was structured for design and construction management professionals with the objective of addressing the impact of safety design practices in the construction delivery stage of the project in an attempt to set design criteria and standards for construction safety. Taken into consideration were the following: years of design/construction management experience, years of construction experience, knowledge of designing for safety, knowledge of the implications of designing for safety on construction safety, and understanding of construction management project review (including constructability review, value engineering, design coordination, etc.). Data for survey development were collected from published research, Department of Labor, OSHA and from other published and non-published sources.

The types of design disciplines included in the research study were limited to architecture, civil engineering, structural engineering, mechanical engineering, and electrical engineering. These are the primary disciplines involved in the design of construction projects and, by both dollar value and hours expended, their work constitutes the majority of the design effort undertaken on many projects.

Design professionals are employed by design firms that concentrate on one or more design disciplines, and by design–build firms that undertake both the design and construction aspects of the work. A sample of prospective design firm, design–build firm, and designer respondents was created using both convenience and random sampling from local telephone directories, the Internet, web-based professional association directories, and personal contacts of the researchers. A total of 35 different design professionals (16 architects and 19 design engineers) in southern Florida (Miami, Fort Lauderdale, Broward and surrounding areas) were selected.

Construction management (CM) professionals are employed by owners for program management, project management, design review (constructability improvement, value engineering), design coordination, construction coordination and project implementation control; by design–build firms for overall project management; and by contractors for construction management. The role taken and authority assumed by a construction management professional is very much dependent on the hiring authority as well as the project delivery approach – design-bid-build, design-build, CM agency or CM at-Risk. A sample of prospective owner firms, design–build firms, CM firms and contracting firms (general contractors and CM contractors) was created using both convenience and random sampling from local telephone directories, the Internet, web-based professional association directories, and personal contacts of the researchers. A total of 20 construction management professionals in southern Florida (Miami, Fort Lauderdale, Broward and surrounding areas) were selected.

When selecting firms and design professionals for the study, consideration was given to firm type, size, and location to ensure a survey sample representative of the construction industry. In addition, firms that participate in projects in each of the various sectors of the construction industry (residential buildings, commercial buildings, engineering facilities, and industrial facilities) were included in the study sample.

The survey was sent to architects, engineers and construction management professionals in order to best determine the role each played in developing or implementing safety in design in the early stage of project development. The results were compiled and analyzed to develop a proposal for the construction management approach to DFCS.

The research team contacted the 35 design professionals and the 20 construction management professionals to request their participation in the survey on a voluntary basis. Criteria used to determine participation were: willingness and availability to participate in the study; experience as a professional construction manager and knowledge about safety in design. Out of the list of 55 design and construction management professionals contacted, 23 volunteered to be surveyed (14 design professionals and 9 construction management professionals) for a total response rate of 42.%. Considering the fact that it was a construction industry questionnaire, this response rate was considered encouraging. The questionnaire was sent to the 23 professionals and all responses were received within a period of one month.

The respondents had varied backgrounds representing a variety of disciplines, employment positions, and durations of work experience. Of the 23 survey responses there were four architects (17%), three structural engineers (13%), three civil engineers (13%), two mechanical engineers (9%), two electrical engineers (9%) and nine construction managers (39%). Of the fourteen design professionals surveyed, eight (57%) were employed by design firms and the remaining six (43%)were employed by design-build firms. Of the nine construction management professionals surveyed, three (34%) were employed by owner firms, two (22%) were employed by design-build firms, two (22%) were employed by construction management contractors and the remaining two (22%) were employed by general contractors.

The size of the firms represented by the respondents ranged from medium to large (based on their annual turnover and number of employees). The design experience of the design professionals who responded ranged from five to twenty six years (mean=18.5 years; median=21 years). In addition to their design experience, the respondents were asked how much construction experience they had accrued. Construction experience was defined as actually performing construction work, e.g., carpentry, roofing, plumbing, etc. The construction experience of the respondents ranged from two to ten years with a mean of 3.1 years.

The construction management experience of the respondents ranged from five to twenty eight years (mean=20.1 years; median=22 years). In addition to their construction management experience, the respondents were asked how much design coordination and review experience they possessed. Design coordination and review experience was defined as experience in constructability review, design coordination and value management. The design coordination and review experience of those who responded ranged from three to twenty three years with a mean of 5.7 years. Almost all of the construction managers had design coordination and review experience. Additionally, construction management professionals were also asked about their construction experience. Almost all of the construction managers had construction experience of more than three years.

7. RESULT HIGHLIGHTS

Of those having the most years of design experience, 23% considered safety in their design efforts and cited that design practice does not incorporate safety knowledge, resulting in their own initiatives in addressing worker safety through design, as with the use of a checklist. This is not uncommon as most designers stated that the responsibility for safety rested with the contractor and that of their subcontractors. Over 70% of responding architects, engineers and construction management staff viewed the contractor as having the greatest influence over project safety. Further implications arise out of concern for motivational factors in promoting designing for safety, designer's knowledge of concepts, available tools, specific redesign guidelines and ultimately liability exposure.

Approximately 63% of the participants have contributed to improving construction worker safety in some way or another. When asked if there was a formal process for this effort, many replied negatively and some expressed a desire to learn more. The concept being new is not well penetrated in the industry and professionals have either very little or no knowledge about it.

Of all participants, 90% claimed that they contributed to improving construction worker safety by utilizing OSHA's guidelines as a checklist for assistance with their design efforts and had incorporated a self-devised checklist indicating that there are no formal design for safety guidelines that can be followed. OSHA guidelines at the present are related to construction phase safety, thus indicating that even those who are affirmative that they consider safety are not well equipped.

Regarding concerns about designing for worker safety nearly 40% felt that the level of importance was not considered. That is, their management does not place due importance on design for worker safety.

When asked about the importance of management acceptance of safety concerns and training, less than 15% stated they were exposed to training or discussions about worker safety. This means there is very little importance placed on educating people about designing for safety.

All of the respondents had concerns with the legal implications involving failed safety designs but admitted that improved safety, quality and productivity can be achieved through DFCS. When asked if construction health and safety consultants were used in the project design phase, 9% responded with assent. It indicates that a majority of the projects do not incorporate the ideas of safety professionals (or construction management in other words) at the beginning of the project which could be quite beneficial to achieve overall safety for the project.

The best approach to introducing information flow to the design is through construction management as it monitors, inspects and is involved directly with all other constructors on the job site. Emphasis should be placed on the entire tripod if DFCS is to be employed. Regardless of the procurement method, relationships or the contracting parties, the owner may assume the liability for the designer's performance, or lack thereof. This places both the owner and designer at risk for designs not incorporating safety design practices. The revised tripod (see Fig. 3) reflects this change with the added benefit of shared information flow and CM involvement.

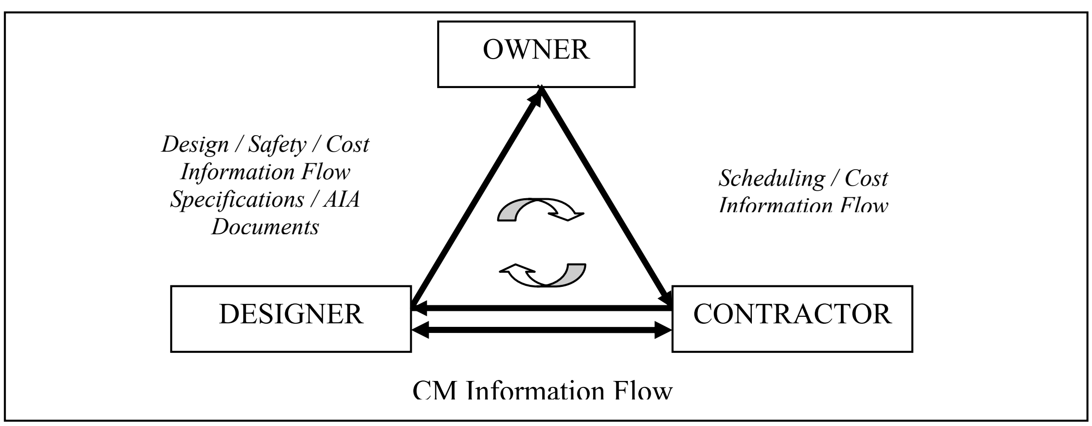

Fig. 3: Modified Tripod

As proposed in the CM constructability review process and by the flow of information in the modified tripod, CM can provide a very sensible and sustainable approach to DFCS.

8. PROPOSED MODEL FOR A CONSTRUCTION MANAGEMENT APPROACH TO DFCS

The Safety Decision Hierarchy model developed by Gambatese (2004) was used as a platform to develop a *CM model to DFCS* tool to serve the designer and constructor (contractor, consultants, trade contractors, construction management) in their evaluation of safety risk.

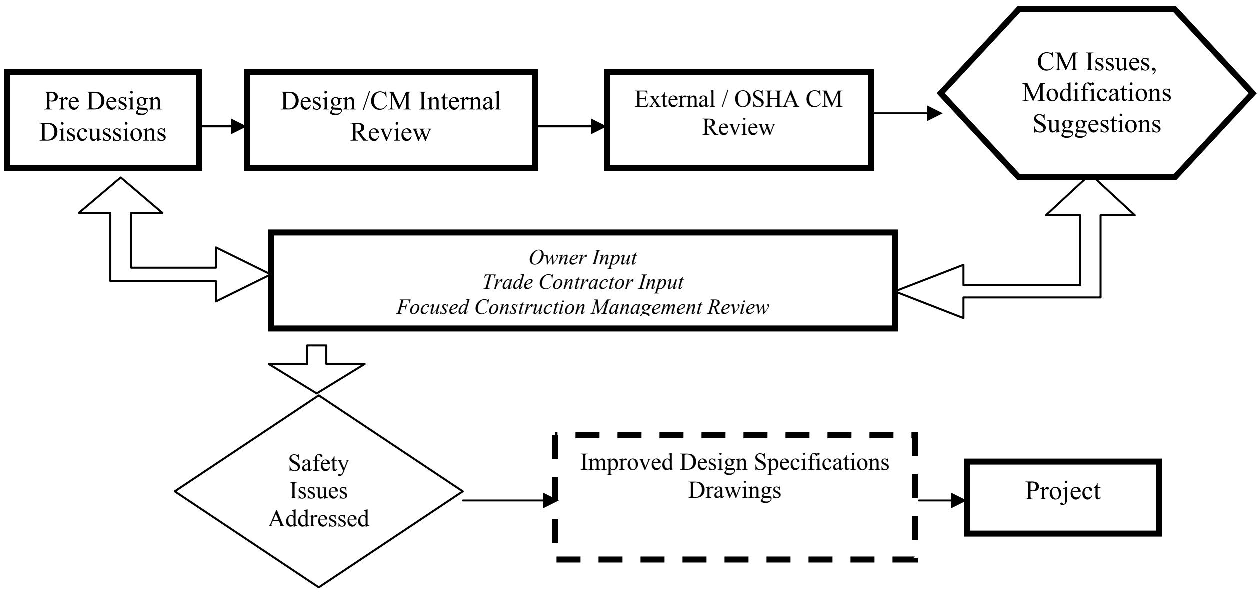

Fig. 4: Proposed Model for a Construction Management Approach to DFCS

The proposed model (Fig. 4) incorporates interaction between all parties involved in project delivery including construction management. Consistent with design phase reviews, designing for safety should address the documentation and construction management side of construction. Construction management is tasked often with the challenges of building a project that is based on flawed designs. This translates to constructors having to make field decisions that can also affect construction worker safety.

The *pre design discussion phase* establishes the standard by which safety expectations will be based. It includes the construction and operational information flow and can serve as a depository for the entire safety design process and associated tools.

The role of construction management is to evaluate the constructability of the project through impacts on scheduling, estimating, risk assessments, and safety concerns and finally project delivery. The CM can provide construction experience, project collaboration, and knowledge into the design phase and may provide alternatives to means and methods of construction. During the *design and internal review* portion of the model, trade contractors, subcontractors, and construction management provide input regarding overall safety concerns of the design as they will be the ones directly impacted. During the *External - OSHA Standards / CM phase,* drawings and specification are to be developed based on discussions and standards and are made part of the project construction documents. These documents will provide better details relating to safety enhanced details and notes.

Issues that arise out of the CM Issues / *Modification / Suggestions phase* are communicated back to the owner with supporting documentation of cost analysis and scheduling impacts. This information is obtained from the contractor, consultant, design build firms, and construction management, whose responsibility it will be to oversee project construction.

9. IMPLICATIONS AND CONCLUSIONS

In summary, this paper has explored DFCS, a growing trend in construction safety and its impact given the project delivery method chosen. Engineers, architects, owners and constructors must adopt a standard not centered exclusively on profits but rather on designer responsibility in the design of structures. This is achieved through enhanced means and methods and CM oversight. Regardless of the method used in evaluating the risk, it is often the input of the owner's goals and objectives, project cost, delivery method, construction practices, building codes, design resources, and capabilities, training and education that greatly impact project design and cost. CM is proposed to impact greatly, the successful outcome of projects by assessing construction worker exposure to risk. This proactive approach will reduce injuries, and reduce the cost of construction, which benefits all involved.

Through these efforts of enhanced OSHA regulations, designers and constructor collaboration, training and education, information sharing, risk engineering and CM oversight, there are no limitations of what can be achieved by the full integration of DFCS. The cost of all these factors will impact the project budget and affect methods of construction; however, it will also significantly enhance and improve the health and safety of construction workers.

10. RECOMMENDATIONS

Efforts made in the industry have greatly reduced or eliminated construction accidents by "engineering in" better safety measures through the design and planning phase. Designing for safety has the potential to greatly reduce, if not eliminate construction worker injuries and deaths.

Major universities are at the forefront of providing education and raising awareness for the values of DFCS and have provided numerous studies on the topic. Alliances are being formed by various organizations in addressing construction worker safety through design.

The Department of Labor, OSHA, American Society of Civil Engineers, National Institute for Occupational Safety and Health, Construction Management Association of America, American Society of Structural Engineers, among others have all met to share information on designing for safety. The current OSHA Alliance has created a workgroup to further discuss the topic of training design professionals to recognize and evaluate risk.

Additionally, proposed accreditation through the American Council for Construction Education (ACCE) should require semester hours to be earned in construction safety covering topics such as risk assessment, risk engineering and the use of design tools to assist in the redesign of safety efforts.

OSHA continues to provide leadership through its alliance and met in January and April of 2006 to further develop its case study on the topic. Continued efforts are said to include a 2 – 4 hour DFCS course and a 10-hour training program for engineers as well as efforts to attract others to this very ethical approach to construction safety.

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DEVELOPMENT OF A TASK-BASED SAFETY MODEL FOR CONSTRUCTION PROJECTS

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ABSTRACT

The United States construction industry was responsible for 1,243 work-related deaths and 415,000 non-fatal injuries and illnesses in 2005, making it one of the most dangerous industries to work for. As interests in design-build and other alternative project delivery methods are developing rapidly in recent years, one of the challenges is to leverage the integration of design and construction to achieve maximum accident reduction with a minimal resultant impact on project cost and schedule. Therefore, a new safety model is formulated based upon the relationships between construction tasks and accidents as observed from historical records. Both physical and non-physical attributes of project design are examined and quantified with respect to their contribution to safety. As the result, a safety model is applied to identify and assess hazardous conditions as the project design takes shape. Cost-effective approaches are able to be implemented at an early stage of project development to mitigate potential risks. This model can serve as a basis for the broader use of information technologies such as BIM that could further add value to project owners and the society.

Keywords: Construction Safety, Accident Rate, Project Design, Construction Task

1. INTRODUCTION

About 7.7 million workers are employed in the construction sector, accounting for 31% of goods-producing sector employment (which also includes manufacturing, and natural resources and mining) and 5.5% of total employment in the U.S. economy (BLS, 2007). In 2005, there were 1,243 recorded fatal injuries in construction, 31.7% of the total 5,734 occupational fatalities in that year (BLS, 2006a). The construction incidence rate of injuries and illnesses was 6.3 cases per 100 full-time workers, the highest among goods-producing industry sectors (BLS, 2006b). Between 2003 and 2005 the total number of fatalities in construction increased by 6% from 1,171 to 1,243 while the manufacturing sector experienced a 7% decrease.

This paper is organized as follows. First, a literature review summarizes several relevant research projects on the causal factors of construction accidents and the impact of design on safety. After establishing research objectives, both physical and non-physical attributes of project design are investigated and their impacts on accident occurrence are formulated. The result is a probabilistic model for estimating safety performance of a project based on its design characteristics. It's followed by discussions of mitigation strategies at component and system levels. In the end, conclusions are given along with suggestions for future work.

2. REVIEW OF RELEVANT LITERATURE

Abdelhamid and Everett (2000) evaluated root causes of construction accidents in the United States and suggested unsafe conditions resulted from (1) management action/inaction; (2) unsafe acts of workers and coworkers; (3) non-human related events; or (4) an unsafe condition that is a natural part of the initial construction site conditions. While it acknowledged the contribution of both management and labor to accident occurrence, this research didn't consider the impact of decisions made during project design phase on safety. Studies of construction accidents in the U.K. and the U.S. revealed that about one-third to one half of accidents could be linked to the project design (HSE, 2003; Behm, 2006). These studies provided not only the evidence that design has a significant impact on safety in the context of construction operations but also the motivation for developing best practices for design professionals to adopt.

"Design for Safety" or "Building Safety into Design" is a concept aimed at eliminating or minimizing hazards before design decisions are finalized. It has been widely adopted in chemical processing, air traffic control and other fields (Hasan et al., 2003; Kinnersley and Roelen, 2007; Drogoul et al., 2007). Partially in response to persistent ineffectiveness of conventional measures such as safety trainings and personal protection equipment, this concept begins drawing attentions in the construction industry and emerges as a viable means that leverages permanent features of a facility to improve worker's safety (Coble, Hinze and Haupt, 2000). Gambatese et al. (2005) used an example in which the architect could specify a parapet wall higher than 42-inches to provide fall protection for construction workers. This concept also encompasses better communication about safety hazards between disciplines (e.g. noting overhead power lines on contract plans by engineers). Gambatese et al. (1997) developed a "Design for Construction Safety Toolbox" to provide designers with a variety of suggestions that would improve safety. Nevertheless, Toole (2005) identified four sets of barriers that encumber designers from improving construction safety: lack of safety expertise, lack of understanding of construction processes, typical contract terms, and professional fees.

3. RESEARCH OBJECTIVES

The key to preventing accidents is identifying and eliminating potential hazards (Goetsch, 2002). Therefore, the objective of this research is to develop a systematic approach to identify safety risks and assess their contribution to accident occurrence. Because accidents are originated from the construction process which is largely dictated by project design, the hypothesis is that the causal relationship between attributes of project design and accident occurrence can be quantitatively formulated. To test this hypothesis, the relationship between physical attributes of a project's design (e.g. specified construction materials and geometric features) and accident occurrence is firstly characterized to determine how the construction of a building's architectural, structural and MEP components contribute to the formation of hazardous conditions. Secondly, the intangible attributes of a project (e.g. delivery method, project location, weather conditions, contractor past experience and safety record) are assessed in relation to their impact on safety. Based on these results, a probabilistic model is created, enabling users to systematically evaluate safety risk from a set of readily known project parameters. The rationale is that once hazards are identified, effective mitigation strategies can be devised and implemented for minimizing work-related injuries.

4. CHARACTERIZATION OF PHYSICAL ATTRIBUTES OF PROJECT DESIGN

Physical attributes of project design refer to the permanent features of a project as defined by architects and engineers on plans and specifications. They are wholly or partially responsible for creating certain conditions that ultimately lead to accidents. The procedure for modeling their contribution to hazard formation is shown in Figure 1.

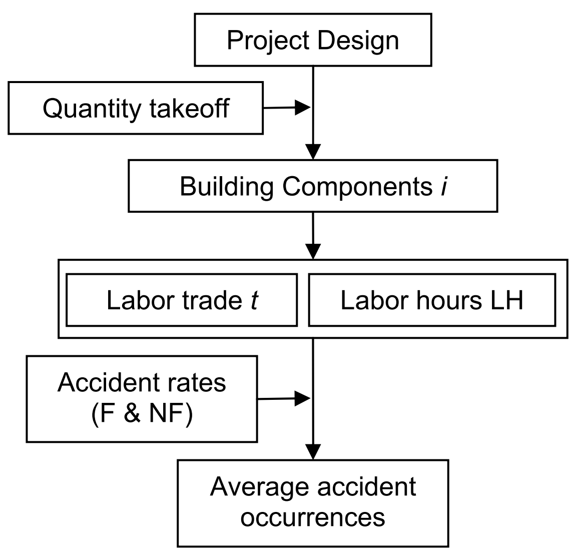

Figure 1: A task-based procedure for modeling contribution of physical attributes of project design to hazard

Firstly, a project is broken down into N discrete building components such as concrete footings and built-up roof using standard quantity takeoff technique. For each component *i*, specific trade(s) *t* are identified with required labor hours (LH). Then, average accident rates for a specific labor trade (t) are determined from the Department of Labor databases. For fatal injuries, rates are calculated per 100,000 FTEs (full-time equivalents defined as 2,000 working hours per year) while non-fatal injuries and illnesses rates are calculated per 100 FTEs. The total numbers of accidents and their characteristics are collected by the Census of Fatal Occupational Injuries (CFOI) and Survey of Occupational Injuries and Illnesses (SOII) of the Bureau of Labor Statistics and can be retrieved by industry and occupation. Fatal and nonfatal accident rates FR_t and NFR_t for trade *t* are then calculated as the total numbers of accidents divided by the numbers of full time employees in the latest year when data is available. Average numbers of fatal and nonfatal accidents for building component *i* are the product of average accident rates and length of exposures as given by Equations 1 and 2:

$$F_i = \sum_{t=1}^{T} (LH_{i,t} \times FR_t) \qquad \text{Eq. 1}$$

$$NF_i = \sum_{t=1}^{T} (LH_{i,t} \times NFR_t) \qquad \text{Eq. 2}$$

where F_i and NF_i are expected numbers of fatal and nonfatal accidents resulting from constructing building component *i*; FR_t and NFR_t are average fatal and nonfatal accident rates for trade *t* per working hour; $LH_{i,t}$ is the labor hours of trade *t* required for constructing building component *i*.

In this study, accident occurrences are modeled as random variables with a normal distribution. Its mean values are calculated by Equations 1 and 2. Direct estimation of standard deviations is difficult due to a lack of sufficient data collected by individual projects. Alternatively, standard deviations of fatal and nonfatal accidents in 50 state-wide averages are used to approximate SF_t and SNF_t for trade *t* by a multiplier of $\sqrt{50}$. The standard deviations of fatal and nonfatal accidents SDF_i and $SDNF_i$ for component *i* are determined by Equation 3 and 4:

$$SDF_i = \sqrt{\sum_{t=1}^{T} (LH_{i,t}^2 \times SF_t^2)} \qquad \text{Eq. 3}$$

$$SDNF_i = \sqrt{\sum_{t=1}^{T} (LH_{i,t}^2 \times SNF_t^2)} \qquad \text{Eq. 4}$$

After knowing mean and standard deviation of accident occurrence at the component level, the statistical profile of accident occurrence function for an entire project can be established by using Equations 5, 6, 7 and 8 given below.

$$Mean_F = \sum_{i=1}^{N} F_i \quad \text{Eq. 5}$$

$$SD_F = \sqrt{\sum_{i=1}^{N} (SDF_i)^2} \quad \text{Eq. 6}$$

$$Mean_{NF} = \sum_{i=1}^{N} NF_i \quad \text{Eq. 7}$$

$$SD_{NF} = \sqrt{\sum_{i=1}^{N} (SDNF_i)^2} \quad \text{Eq. 8}$$

5. CHARACTERIZATION OF NON-PHYSICAL ATTRIBUTES OF PROJECT DESIGN

Many attributes of project design other than abovementioned physical ones play a significant role in shaping the construction process and consequently affect likelihood of accidents. Therefore, the effect of these non-physical attributes on safety needs to be closely examined. With the baseline of accident occurrence being established in the preceding section using industry averages, this section focuses on developing multiplicative factors for non-physical attributes.

At first, possible non-physical attributes of project design are identified through literature review and a survey. The listing contains a large number of entries ranging from contract type, contractor's EMR, risk sharing mechanism, to average temperatures of project location. To simplify the calculation, only a limited number of them are selected based on their significance ranking.

The quantitative impact of K attributes on safety is estimated with a hybrid approach combining both statistical analysis and engineering judgment. It's assumed that non-physical attributes only alter mean values of accident occurrence functions. These attributes are grouped into two categories depending on whether they impact risk profile of a project (i.e. global factors GF such as prime contractor's EMR) or of certain building components (i.e. local factor LF such as steel subcontractor's safety record). Mean accident occurrences at the component level are recalculated by the following equations:

$$Mean'_F = \sum_{i=1}^{N} \left\{ \sum_{t=1}^{T} (LH_{i,t} \times FR_t) \prod_{p} LF_{p,t} \right\} \quad \text{Eq. 9}$$

$$Mean'_{NF} = \sum_{i=1}^{N} \left\{ \sum_{t=1}^{T} (LH_{i,t} \times NFR_t) \prod_{p} LF_{p,t} \right\} \quad \text{Eq. 10}$$

where Mean'$_F$ and Mean'$_{NF}$ are the adjusted average numbers of fatal and nonfatal accidents for a given project; $LF_{p,t}$ is local adjustment factor for trade t and attribute p. Global adjustment factors applied at the system level follow Equations 11 and 12:

$$Mean''_F = Mean'_F \prod_q GF_q \quad \text{Eq. 11}$$

$$Mean''_{NF} = Mean'_{NF} \prod_q GF_q \quad \text{Eq. 12}$$

where Mean''$_F$ and Mean''$_{NF}$ are the total numbers of fatal and nonfatal accidents after being adjusted by global factors GF_q for attribute q.

6. ESTIMATION OF SAFETY PERFORMANCE BASED ON CONSTRUCTION TASKS

With estimated statistical parameters of accident occurrences, this section devises a performance measure in an effort to establish a baseline cost of project design so that effectiveness of intervention measures can be assessed.

Costs of accidents to contracting companies can arise in many forms including medical expenses, loss of productivity on the short term and loss of business, and increase in insurance premium in the long term. Due to data availability, only medical cost C_M is considered hereafter. Average medical expenses per fatal and nonfatal accidents C_F and C_{NF} are determined through literature review. Since accident occurrences follow normal distribution and C_F/C_{NF} are constants, C_M shall follow a normal distribution and its mean and standard deviation are calculated by the equations below:

$$Mean_{C_M} = Mean''_F \times C_F + Mean''_{NF} \times C_{NF} \quad \text{Eq. 13}$$

$$SD_{C_M} = \sqrt{SD_F^2 \times C_F^2 + SD_{NF}^2 \times C_{NF}^2} \quad \text{Eq. 14}$$

Where $Mean_{CM}$ and SD_{CM} are mean value and standard deviation of medical cost; Mean''$_F$ and Mean''$_{NF}$ are adjusted mean values of fatal and nonfatal accident occurrences; SD_F and SD_{NF} are standard deviations of fatal and nonfatal accident occurrences.

7. DEVELOPMENT OF A DESIGN-FOR-SAFETY STRATEGY

After safety risks are identified and assessed, mitigation measures can be developed through design modification in an effort to eliminate or minimize them in an efficient and effective way. Implementation of system-level changes to existing design would have a global impact on the safety performance of a project. In some cases, changes specifically targeting certain high-risk components or trades may prove more cost-effective and feasible. Therefore, both types of changes are investigated and evaluated in this section to facilitate decision making by perspective users.

Mitigation measures to enhance construction safety at system level

System-level changes that have an impact on overall safety performance in project design have been known as global factors. The objective here is to categorize these factors and assess their relative performance in reducing fatal and nonfatal accident occurrences.

The preceding analysis provides estimates for every global adjustment factor GF_p for attribute *p*. A number of system-level attribute groups (AG) are defined, such as project delivery methods, contractor's qualifications, structure type and project location. Within each attribute group, there could be several design alternatives each of which is assigned to a GF value. For example, under the project delivery method group, three possible options are considered: design-bid-build (dbb), design-build (db), and construction management (cm) and their adjustment factors are GF_{dbb}, GF_{db}, and GF_{cm} respectively. Therefore, the impact of substituting design-bid-build method with design-build method would alter fatal and nonfatal accident occurrence estimates as follows:

$$Mean_F(db) = Mean_F(dbb)\frac{GF_{db}}{GF_{dbb}} \qquad \text{Eq. 15}$$

$$Mean_{NF}(db) = Mean_{NF}(dbb)\frac{GF_{db}}{GF_{dbb}} \qquad \text{Eq. 16}$$

where $Mean_F(db)$ and $Mean_F(dbb)$ are means of fatal accidents using db and dbb methods respectively; $Mean_{NF}(db)$ and $Mean_{NF}(dbb)$ are means of nonfatal accidents using db and dbb methods respectively. Therefore, the percentage of net changes (PNC) from dbb to db for both fatal (F) and nonfatal (NF) cases are given by the following equation:

$$PNC_{dbb\rightarrow db} = \frac{GF_{db}}{GF_{dbb}} - 1 \qquad \text{Eq. 17}$$

PNC is calculated for each pair of design alternatives with an attribute group in two directions. This multiplicative factor reflects the expected level of increase (or decrease) by adopting an alternative in lieu of the baseline design.

Design alternatives suited for addressing safety hazards at component level

Design modifications at component level can be an efficient way to mitigate safety risks by targeting components with large mean value of accident occurrence. It's aimed at providing users with a series of design alternatives to choose for common building elements and then quantify the level of accident reduction. The term "element" has different meanings from "component" in this study. Element refers to a part of building serving certain functions without specifications. For example, flooring is considered a building element while ceramic flooring in the 2^{nd} floor restroom is a building component. Differentiating these two terms is necessary for developing a set of generic design alternatives that are intended to be used on a broad basis.

Building elements common to building construction are identified by their functions, such as building envelope, roof, interior partition, floor of wet areas, etc. For each building element, there could be multiple design alternatives available. For example, interior partition can be made from CMU walls, steel-framed drywalls, wood-framed drywalls or removable panels. These alternatives are referred to as building components and their impact on construction safety have been assessed in the forms of F and NF (i.e. expected numbers of fatal and nonfatal accidents). If only fatal accident is considered, the expected risks of three alternative designs *a*, *b*, and *c* for the building element *G* can be calculated using Equation 1, which are denoted by $F^G{}_a$, $F^G{}_b$, and $F^G{}_c$. The net change in fatal accidents *NCF* from design *a* to *c* for *G* can be determined. Similarity, the net change in nonfatal accidents NCNF is given by Equations 18 and 19.

$$NCF^G_{a\to c} = F^G_a - F^G_c \qquad \text{Eq. 18}$$

$$NCNF^G_{a\to c} = NF^G_a - NF^G_c \qquad \text{Eq. 19}$$

NCF and *NCNF* are calculated for every pair of design alternatives of identified building elements.

Estimation of the impact of design alternatives on project cost

Design alternatives at both system and component levels compiled by two preceding tasks represent necessary building blocks for creating an inherently safer project design in construction. However, owners, designers or contractors would be unlikely to make any commitment towards design modifications without being ensured with a positive return for their investment. Therefore, this task is to perform the cost-benefit analysis for these design alternatives to help potential users make informed decisions.

On the benefit side, economic impact of accidents based on the base design has been estimated previously as $Mean_{CM}$. If one system level alternative is adopted, savings in medical costs is given by the following equation:

$$Mean_{CM} \times PNC_{Base\to Alt} = Mean_{CM} \times (\frac{GF_{Alt}}{GF_{Base}} - 1) \qquad GF_{Alt} < GF_{Base} \qquad \text{Eq. 20}$$

If one component-level alternative is adopted, saving in medical cost is given by Equation 21:

$$NCF^G_{Base\to Alt} \times C_F + NCNF^G_{Base\to Alt} \times C_{NF} = (F^G_{Base} - F^G_{Alt}) \times C_F + (NF^G_{Base} - NF^G_{Alt}) \times C_{NF}$$

$$F^G_{Alt} < F^G_{Base} \;\&\; NF^G_{Alt} < NF^G_{Base} \quad \text{Eq. 21}$$

Two types of costs are considered. Architects or engineers are compensated for their work on redesigning and such cost is determined by the scope and timing of design modifications. If project design is still in its early development stage, cost of making changes can be easily absorbed by scheduled releases. In contrast, making a late change requires much more time and resources. Three design stages are defined here: 30%, 50%, and 100% of design completion. Redesigning cost is estimated for each design alternative based on a 100% design completion. A reduction factor of 0.3 is multiplied when the revision work is performed at the 50% stage. No cost is considered before project design reaches a 30% level. The other type of costs is the construction cost of implementing design alternatives including material, labor and equipment costs. Unit costs are derived from from the Means Building Construction Cost Data 2006 Book (Means, 2005). These costs vary from project to project and have to be estimated on an individual basis.

8. CONCLUSIONS AND FUTURE WORK

This proposed research is aimed at devising a new approach to improve construction safety through design modification and optimization. By advancing our understanding of the interplay between design and safety, unsafe conditions can be better identified and mitigated in the early stage of project development lifecycle. It would enable owners, designers and contractors to view hazardous conditions as an intrinsic and manageable risk of construction process. Building safety into design can potentially prevent many accidents from occurring and therefore lead to an inherently safer working environment for tens of thousands of employees.

Future work will include the validation of the proposed model by comparing estimated and actual accident rates of a large sample of projects. In addition, the classification and contribution of non-physical attributes of project design could be further studied with feedbacks collected by surveying safety practitioners in the industry. Furthermore, the integration with Building Information Modeling (BIM) shall be explored so that the safety assessment process can be fully automated.

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CULTURE & ATTITUDES 4

SUPPORT WORK AND FORMWORK PERFORMANCE: BUILT ENVIRONMENT PRACTITIONERS' PERCEPTIONS

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ABSTRACT

Reinforced concrete construction entails substantial support work and formwork activities, which expose workers to inter alia, work at elevated heights, ergonomic hazards, and hazardous chemical substances. Furthermore, support work and formwork is required to support and or restrain substantial loads and forces, is dependent upon a range of resources, and is influenced and contributed to by a range of stakeholders. Consequently, the integration of design and construction, scientific designs, the implementation of documented Quality Management Systems (QMSs) and health and safety (H&S) programmes, and optimum appropriate education and training are essential.

A study conducted among delegates attending seminars in various metropoles in South Africa realised the following findings: the traditional project parameters of quality, time, and cost, are more important than H&S; a range of support work and formwork practices / aspects are perceived to be important, and the performance of the South African construction industry relative to support work and formwork is perceived to be poor as opposed to good.

Conclusions include that the industry does not adopt a formal structured approach to support work and formwork. Recommendations include: a range of practices / aspects should be focused upon and addressed in the temporary works section of project H&S plans; the implementation of QMSs in design and construction is imperative; and QMSs should be complemented by H&S Management Systems. Both management systems should link all the stages in the support work and formwork process.

Keywords: Support Work, Formwork, Health and Safety, Quality

1. INTRODUCTION

The Advisory Committee on Falsework (1975), which reviewed support work and formwork failures in the United Kingdom, illuminates the issues relative to support work in the introduction to their report. Each project is unique and there is considerable doubt about the actual loads that will occur. The need to dismantle support work after use introduces further problems. Hazards arise from the prevailing weather, unexpected site conditions, and from the non-availability of critical resources such as material. A further complication is the involvement of different contributors in the various processes. The design of the permanent works is invariably undertaken by consulting engineers, and the design of the support work by contractors. Support work components may be supplied by suppliers, supplemented by contractors, and be erected and dismantled by specialist subcontractors. Alternatively, specialist subcontractors may supply, erect, and dismantle support work. Such diverse contributions introduce difficulties of communication and a confusion of responsibilities, sometimes exacerbated by complicated contractual arrangements.

The Health & Safety Executive (HSE) (2003) states that the causes of many past failures of support work were foreseeable and could have been prevented by proper consideration when planning, erecting, loading, or dismantling the support work.

Given the documented impact of accidents, the influence of H&S on other project parameters, the need for a multi-stakeholder approach to H&S, and the number of slab and other collapses in South Africa in recent years, a study entitled 'Support work and formwork practices' was conducted. The objectives of the study were to determine the:

- Importance of practices / aspects relative to optimum support work and formwork;
- Performance of the South African construction industry relative to support work and formwork practices / aspects, and
- Importance of various project parameters.

2. REVIEW OF THE LITERATURE

Support Work and Formwork Problems

Irwin and Sibbald (1983) cite a number of common problem areas.

Inaccurate estimation of the magnitudes and combined actions of probable loadings represents an extremely common source of difficulty in support work design, and is often the root cause of failures.

When systems that were used on a previous job are re-used, an inspection should be made for rust cavitation, cracked elements, weld fatigue, bent crushed or buckled sections, and generally damaged units, all of which reduce the load-carrying capacity of the scheme.

Site supervision of the erection and dismantling is critical to ensure correct fabrication, component use, foundation provision, plumbing of towers, and verticals, and leveling of structures.

Wind loads are often as significant as vertical loads, particularly since schemes are designed to withstand primarily vertical loading. Special care should be exercised relative to free-standing support work and access scaffolds, especially in the absence of vertical loading or where there are eccentric vertical force actions.

Foundation checks should be conducted in all cases, and often it is necessary to provide a grillage even where the permanent structure foundations are available for a proportion of the support work structure.

The overall stability of a support work structure should be examined. This is important in the case of large systems, but equally so in the case of scaffolds, and portable inspection and maintenance towers.

Support Work and Formwork Failures

According to the Advisory Committee on Falsework (1975) there are a variety of causes for failures, but there are two common elements, namely technical error in design or construction leading to the collapse, and procedural inadequacies which allowed the faults to remain undetected and uncorrected. In general, no evidence of technical 'unknowns' were found, failures occurred because the known rules were not applied. However, the HSE (2003) cites lack of coordination between the various trades and suppliers of support work as a major cause of support work collapses.

The Advisory Committee on Falsework (1975) identified the following common technical faults:

- Insufficient allowance for horizontal loads and general lateral and longitudinal instability;
- Lack of appreciation of the possibility of progressive collapse;
- Overloading: inadequate or lack of design; adequate design, but actual loads differ from the design loads, and the manner in which the load is applied differs from the manner anticipated during design;
- Inadequate foundations;
- Lack of support to beams, and inadequate allowance for their deflection, particularly in the third dimension;
- Instability of grillages;
- Eccentricities and lack of fit during erection – tolerances not specified;
- Faulty setting out;
- Defective or inadequate materials, and
- Incorrect sequence of dismantling.

Procedural inadequacies include (The Advisory Committee on Falsework, 1975):

- Failure of communication: inadequate client briefing of designer; inadequate design drawings or drawings liable to be misunderstood, and lack of feedback to designers when site conditions were found to be different from those assumed, and
- Failure of inspection: the design was not checked by a competent authority, or the structure was not inspected after the erection.

Hadipriono (in Poon and Price, 1996) classifies the causes into enabling, triggering, and procedural. Enabling causes are defined as events that contribute to the deficiencies in the design and construction of the support work. These include inadequate: design; soil foundation; cross-bracing, and design / construction of permanent structure. Triggering causes are events that initiate support work collapses. Most of the causes are essentially the result of excessive loads exerted during construction. The loads are usually not expected or underestimated at the design stage, and hence they trigger a local failure, which propagates a major collapse. Examples include: strong winds; impact loads during concreting; vibration from equipment, and improper / premature removal of support work components. Procedural causes are procedural in nature and do not directly cause the support work to fail. However, the procedural errors are often hidden events that produce the enabling and trigger events. Furthermore, they are not easily extracted from failure reports due to a variety of reasons. Examples include: inadequate review of support work design / construction; lack of inspection of support work during concreting, and inadequate communication between parties involved.

Legislation

The Construction Regulations (South Africa, 2003) schedule a range of requirements relative to clients, designers, and contractors.

In terms of Regulation 4 'Clients,' clients are required to among other:

- prepare and provide the Principal Contractor (PC) with an H&S specification. The PC
- in turn is required to provide an H&S plan in response to the H&S specification;
- provide the PC with any information that may affect H&S;
- ensure that the PC implements and maintains H&S plan – conduct audits at least monthly;
- stop work not in accordance with the H&S plan;
- provide sufficient H&S information when changes are made to design and construction;
- ensure that PCs have made provision for the cost of H&S in their tenders;
- discuss the contents and approve the H&S plan, and
- appoint a PC that is competent and has the resources.

In terms of Regulation 9 'Structures,' designers shall, among other:

- make available all relevant information about the design such as: the soil investigation report; design loadings of the structure, and methods and sequence of construction;
- inform principal contractors of any known or anticipated dangers or hazards or special measures required for the safe execution of the works;
- modify the design or make use of substitute materials where the design necessitates the use of dangerous structural or other procedures or materials hazardous to H&S;
- consider ergonomics throughout all phases of projects;
- carry out sufficient inspections at appropriate times of the construction work involving the design of the relevant structure in order to ensure compliance with the design and a record of those inspections is to be kept on site, and
- stop any contractor from executing any construction work which is not in accordance with the relevant design.

In terms of Regulation 10 'Formwork and support work,' contractors shall among other, ensure that:

- all formwork and support work operations are supervised by a competent person who has been appointed in writing for that purpose;
- all formwork and support work structures are adequately designed, erected, supported, braced and maintained so that they will be capable of supporting all anticipated vertical and lateral loads that may be applied to them and also that no loads are imposed onto the structure that the structure is not designed to withstand;
- the designs of formwork and support work structures are executed with close reference to the structural design drawings and where any uncertainty exists, the structural designer should be consulted;
- all drawings pertaining to the design of formwork or support work structures are kept on the site and are available on request by an inspector, contractor, client, client's agent or employee;
- all equipment used in the formwork or support work structure are carefully examined and checked for suitability by a competent person, before being used;
- all formwork and support work structures are inspected by a competent person immediately before, during and after the placement of concrete or any other imposed load and thereafter on a daily basis until the formwork and support work structure has been removed and the results have been recorded in a register and made available on site;
- if, after erection, any formwork and support work structure is found to be damaged or weakened to such a degree that its integrity is affected, it shall be safely removed or reinforced immediately;
- adequate precautionary measures are taken in order to: secure any deck panels against displacement, and prevent any person from slipping on support work or formwork due the application of formwork or support work release agents;

- as far as is reasonably practicable, the health of any person is not affected through the use of solvents or oils or any other similar substances;
- upon casting concrete, the support work or formwork structure should be left in place until the concrete has acquired sufficient strength to support safely, not only its own weight, but also any imposed loads and not removed until authorisation has been given by the competent person;
- provision is made for safe access by means of secured ladders or staircases for all work to be carried out above the foundation bearing level;
- all employees required to erect, move or dismantle formwork and support work structures are provided with adequate training and instruction to perform these operations safely, and
- the foundation conditions are suitable to withstand the weight caused by the formwork and support work structure and any imposed loads such that the formwork and support work structure is stable.

In terms of Regulation 9 'Structures,' contractors shall ensure that:

- all reasonably practicable steps are taken to prevent the uncontrolled collapse of any new or existing structure or any part thereof, which may become unstable or is in a temporary state of weakness or instability due to the carrying out of construction work, and
- no structure or part of a structure is loaded in a manner which would render it unsafe.

Quality Management

Quality, which according to Crosby (1984) means conformance to requirements, amplifies the need for H&S, as conformance to requirements entails *inter alia*, conformance to national standards and other contractual requirements, legislation and, if applicable, ISO environmental, H&S, and quality management systems. The findings presented in the Investigation Report into the Injaka Bridge Collapse of 6 July 1998 (Department of Labour, 2002) reinforce and amplify the relationship between quality and H&S, and bear testimony to the implications of non-conformance to requirements and the lack of adequate quality and other management systems.

Design and Design Outputs

The client must provide the contractor with the exact details of the permanent structure, including the philosophy of the design and details of any particular method or sequence of construction, which must be used. Any particular environmental restraints should be specified and information regarding soil and other conditions provided (The Advisory Committee on Falsework, 1975).

The Advisory Committee on Falsework (1975) recommends that the contractor should then provide the designer of the support work and formwork with a brief evolved from the information provided by the client. The brief should refer to the materials and equipment that are or not available, and provide all the information needed to devise a complete plan of the method of construction of the permanent and temporary works.

A check list of all the information required should be maintained: foundation and soil conditions; local restrictions; restrictions on methods of construction; philosophy of permanent works design; dead loading; available materials; available equipment; special live loads and accepted tolerances (The Advisory Committee on Falsework, 1975). The designer can then check what information is not available, which will enable the initiation of a request for outstanding information. Furthermore, such a checklist complements a documented QMS.

Designs, particularly those that involve the assembly of several parts, should be checked by a competent person. This person may not necessarily be in the employ of the contractor organisation, but an independent person. It is also recommended that the designer of the permanent structure or the principal agent, check support work designs. A designer of a permanent structure is well acquainted with the site and its special problems, knows the details of the dead loads and the possible interactions between the permanent and temporary works. Liability is an issue and therefore the designer of the permanent structure or the principal agent will not 'approve' the design. Although the prime responsibility must remain with the designer of the support work, the support work design should be submitted to the designer of the permanent structure for comment. Acceptance could be indicated by: 'If you proceed on these lines I shall raise no objection'. Ultimately, the designer of the permanent structure or the principal agent is employed to look after the client's interests – a support work collapse, which may result in a delay, is not in the interests of the client (The Advisory Committee on Falsework, 1975).

Irwin and Sibbald (1983) identify the loads that a design should be cognisant of and include where applicable: dead; imposed; live in the form of people; construction plant and equipment; storage of materials; impact in the form of possible collisions with the support work; vibrations, and other.

Responsibilities Relative to Support Work and Formwork

Irwin and Sibbald (1983) advocate that responsibility for the following be allocated:

- Design brief;
- Concept of the design;
- Design, detailing and specification;
- Adequacy of the materials used;
- Management (control) of maintenance, erection, and dismantling;
- Checking of design, procurement and construction activities / operations, and
- Issuing of formal permission to load and dismantle.

The Advisory Committee on Falsework (1975) recommends that a Temporary Works Coordinator be appointed to oversee any support work related activity. Clearly, the issues are integration, coordination, systems, procedures, and protocol.

Realising Safe Support Work

The Advisory Committee on Falsework (1975) presented a range of technical recommendations, recommended procedures, and education and training recommendations. The categories of technical recommendations include: estimation of loads; identifiable horizontal forces; 3% horizontal load rule; lateral stability; bracing and lacing; longitudinal stability; selection of materials and equipment; proprietary equipment; tolerances; factors of safety, and research and development. The categories of recommended procedures include: choice of parties; the design brief; acceptance of falsework drawings; loading of falsework; general site procedures; Temporary Works Coordinator; summary, and responsibility and liability. Education and training recommendations include: professional training; course standards; CITB facilities; certification; incentives; time scale; financial arrangements; trade unions; need for a textbook of falsework technology, and summary.

The HSE (2003) refers to planning, design, materials, erection, loading, striking and dismantling, and training. Planning – all concerned should contribute towards the preparation of a design brief, which should serve as the starting point for subsequent decisions, design work, calculations, and drawings. Initial planning should address what needs to be supported, how it should be done, and how long the support work will be required. Design – all support work should be designed, which varies from the use of simple tables and graphs, to site-specific design and supporting drawings. Particular attention should be given to: stability requirements, lateral restraint and wind uplift on untied decking components; designing such that support work can be erected, inspected, and dismantled safely; selecting adequate foundations or providing information to ensure adequate foundations are used, and providing the information that the temporary works coordinator will need to manage the interface between the permanent structure and the support work safely. Materials – should be strong enough for and stable in use; damaged components should not be used, and different proprietary components should not be mixed. Erection – before erection begins, a risk assessment should be conducted, and safe work procedures and a method statement indicating how all the hazards will be managed should be developed. Support work should be stable at all stages of erection and should be regularly checked. Erectors should know: where to commence; whether the equipment supplied is the same as that ordered; the stages when checks and / or permits are required; and whether checks and permits have already been conducted and issued respectively. Loading - upon completion, all support work should be inspected and certified as ready for use. A written permit-to-load procedure is strongly recommended. The frequency of subsequent inspections will depend on the nature of the support work, but should enable any faults to be rectified promptly. Striking and dismantling – a sequence for dismantling should be determined and detailed; the temporary works coordinator should sanction the time of striking for each section of the support work, and the safety of workers from falling objects should be assured. Training – temporary works coordinators, supervisors and workers that erect, strike, and dismantle support work should be competent and trained in the H&S of support work.

Contributions to an Improvement in Support Work and Formwork

Many of the recommendations made by the Advisory Committee on Falsework (1975) will contribute to an improvement in support work and formwork. These include the following: the design of all support work regardless of scale; research relative to the actual loads experienced relative to support work; optimum communication between designers and others on and off site; inclusion of training in safe work procedures (SWPs) in support work and formwork technology and practice; instruction in the special features of support work in civil engineering and architecture education; the requirement of the design of support work to be included with the design of the permanent works as evidence of professional competence; the provision of short courses in support work for engineers and architects; training in support work for operatives and first line supervisors, the assessment of their performance and certification thereof; the development of a support work handbook and data sheets, and the development of a support work textbook.

3. RESEARCH

Sample Stratum and Response

The sample stratum consisted of sixty-four delegates attending three half-day support work and formwork seminars and two five-day Client Appointed H&S Agent Certificate Programmes presented by the authors. A survey questionnaire was circulated at the inception of each of the half-day seminars to avoid any possible influence of the respondents' responses as a result of the seminar contents. Sixty-one questionnaires were included in the analysis of the data, which equates to a response rate of 95.3 %. Although the sample stratum could be termed a 'captive audience', given the nature of the seminars and programmes, the respondents are likely to constitute the more committed built environment practitioners in terms of support work and formwork, and H&S.

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.

Findings

Table 1 indicates that the contractor, engineer, public sector client, and private sector client stakeholder groups predominate among respondents.

Table 1: Respondents' stakeholder group.

Discipline	(%)
Architect	3.3
Contractor	30.0
Engineer	20.0

Insurer	0.0
Project Manager	13.3
Private sector client	6.7
Public sector client	15.0
Quantity Surveyor	6.7
Other	13.3

Table 2 indicates the importance of five parameters in terms of percentage responses to a range of 1 (not important) to 5 (very important), and in terms of a mean score ranging between 1.00 and 5.00. It is notable that the mean scores are all above the midpoint score of 3.00, which indicates that in general the respondents can be deemed to perceive the parameters as important. However, given that the mean scores for the top four parameters, including project H&S, the partial subject of the study, are > 4.20 ≤ 5.00, the respondents can be deemed to perceive them to be between more than important to very important / very important. Given that the mean score for environment is > 3.40 ≤ 4.20, the respondents can be deemed to perceive it to be between important to more than important / more than important. It is significant that the traditional project parameters in the form of quality, time, and cost, are ranked in the first three. Furthermore, it is notable that the partial subject of the study, project H&S, has a mean score only 0.28 below that of another partial subject of the study, first ranked project quality – project quality is effectively only 8.4% more important than project H&S. This is a lesser percentage than that determined in a study conducted among construction project managers, which determined that project quality was effectively 14.2% more important than project H&S (Smallwood and Haupt, 2006). However, that study also determined that project time and project cost were effectively 24.8% and 23.1% more important than project H&S, which is not the case in the study reported on below. In fact the mean score of project cost is only 0.03 higher than that of project H&S.

Table 2: Importance of project parameters to respondents' organisations

Parameter	**Response (%)**						**Mean score**	**Rank**
	Unsure	**Not…………………………Very**						
		1	**2**	**3**	**4**	**5**		
Project quality	1.6	0.0	0.0	3.3	24.6	70.5	4.61	1
Project time	1.6	0.0	0.0	1.6	36.1	60.7	4.52	2
Project cost	3.3	1.6	0.0	4.9	31.1	59.0	4.36	3
Project H&S	1.6	0.0	3.3	8.2	32.8	54.1	4.33	4
Environment	1.6	0.0	8.2	23.0	31.1	36.1	3.90	5

Table 3 provides a comparison of the importance of practices/aspects relative to optimum support work and formwork with the rating of performance relative thereto in South African construction in terms of a mean score ranging between 1.00 and 5.00. In the case

of the importance of practices/aspects the mean score is based upon the percentage responses to a range of 1 (not important) to 5 (very important), and in the case of the rating of performance, the percentage responses to a range of very poor to excellent.
It is notable that the mean scores for fourteen of the sixteen factors/aspects are > 4.20 ≤ 5.00, which indicates that the respondents can be deemed to perceive them to be between more than important to very important / very important. Given that the mean scores for maintenance and testing of components are > 3.40 ≤ 4.20, the respondents can be deemed to perceive them to be between important to more than important / more than important. However, it should be noted that their mean scores are marginally below the cut point of 4.20.

Five of the sixteen ratings are above 3.00, which indicates that in general the South African construction industry is deemed more poor than good in terms of support work and formwork practices / aspects.

Only one mean score, namely QMS (Structural design) is > 3.40 ≤ 4.20, and thus can be deemed to be rated average good. The factors / aspects ranked second to fourteenth have mean scores > 2.60 ≤ 3.40, and thus can be deemed to be rated between poor to average / average. The factors / aspects ranked fifteenth and sixteenth have mean scores > 1.80 ≤ 2.60, and thus can be deemed to be rated between very poor to poor.

It is notable that the performance rating is lower than the degree of importance relative to all practices / aspects. Furthermore, on a scale of 1.00 to 5.00, the mean performance rating is 33.4% lower than the mean degree of importance of practices / aspects.

There is less than five absolute percent difference between the differences relative to the first and seventh ranked practices / aspects. Testing of components which has the highest difference, is necessary to assure that components are adequate. The Advisory Committee on Falsework (1975) identified defective or inadequate materials in terms of common technical faults in terms of the causes of support work failures. Furthermore, the Construction Regulations (Republic of South Africa, 2003) require that all equipment used in the support work structure are carefully examined and checked for suitability by a competent person before being used. Second ranked maintenance is important in that damaged or deteriorated components and materials can be identified and remedial work or scrapping precipitated. Third ranked safe work procedures (SWPs) are a requirement in terms of the Construction Regulations and are necessary to assure healthy and safe work and reduce risk as a result of related hazards. With respect to fourth ranked dedicated support work supervision, the Construction Regulations require that support work operations are carried out under the supervision of a competent person who has been appointed in writing for that purpose. Fifth ranked foundation is important as the support work bears thereon. The Construction Regulations require that the foundation conditions are suitable to withstand the weight of the support work and any imposed loads and that support work is stable. Furthermore, The Advisory Committee on Falsework (1975) identified inadequate foundations in terms of common technical faults as a cause of support work failures. Sixth ranked reconciliation of erected with design is an essential intervention in terms of quality management and a QMS. Furthermore, with respect to loading upon completion of the erection of support work, the HSE (2003) states that support work should be inspected and certified as ready for use. Seventh ranked back propping layouts are important as inappropriate striking can compromise the permanent structure. The Construction Regulations require that upon casting concrete, the support work should be left in place until the concrete has acquired sufficient strength to support safely, not only its own weight, but also any imposed loads and should not be removed until authorisation has been given by the appointed competent person. This implies that a structured approach should be adopted. Joint eighth ranked H&S Management System is important as such a system provides *inter alia*, the framework for all H&S related activities and interventions, including procedures. The other joint eighth ranked practice / aspect, periodic inspections, is explicitly addressed by the Construction Regulations - support work should be inspected by a competent person immediately before, during and after the placement of concrete or any other imposed load, and thereafter on a daily basis until the support work has been removed and the results have been recorded in a register and made available on site. Tenth ranked condition of components is similar to testing of components as it is necessary to assure that components are adequate. As previously stated, The Advisory Committee on Falsework (1975) identified defective or inadequate materials in terms of common technical faults in terms of the causes of support work failures. Furthermore, the Construction Regulations (Republic of South Africa, 2003) require that all equipment used in the support work structure are carefully examined and checked for suitability by a competent person before being used. Eleventh ranked project H&S plan is a requirement in terms of the Construction Regulations (Republic of South Africa, 2003). Such a plan should address *inter alia*, temporary works, including support work. Furthermore, H&S plans constitute the operational framework relative to projects in terms of an H&S Management System. The twelfth ranked QMS (Support work design) is important as there are a range of contributors involved in the process and of processes and factors to be considered. The range of common technical faults identified by The Advisory Committee on Falsework (1975) in terms of the causes of support work failures amplifies the importance of thirteenth ranked scientific support work design, *inter alia*, insufficient allowance for horizontal loads and general lateral and longitudinal instability, and overloading – inadequate or lack of design. Sound structural design, ranked fourteenth, is important as The Advisory Committee on Falsework (1975) identified insufficient allowance for horizontal loads and general lateral and longitudinal instability as causes of support work failures. Furthermore, the Construction Regulations require that support work structures *inter alia*, are adequately designed, so that they will be capable of supporting all anticipated vertical and lateral loads and also that no loads are imposed onto the structure it is not designed to withstand. Fifteenth ranked QMS (Construction), as QMS (Support work design) is important as there are a range of contributors involved in the construction process and of processes and factors to be considered including support work. Sixteenth ranked QMS (Structural design) is important as should the design of the permanent structure be inadequate, the permanent structure is likely to fail upon the support work and formwork striking it.

Table 3: Comparison of the importance of practices / aspects relative to optimum support work and formwork with the rating of performance relative thereto in South African construction.

Practices / Aspects	Importance		Rating		Difference	
	Mean score	Rank	Mean score	Rank	Neg %	Rank
Testing of components	4.11	16	2.43	16	40.8	1
Maintenance	4.18	15	2.52	15	39.6	2
Safe work procedures	4.41	6	2.71	13	38.5	3
Dedicated support work supervision	4.25	12	2.63	14	38.1	4
Foundation	4.55	2	2.85	8	37.4	5
Reconciliation of erected with design	4.30	8	2.71	12	36.9	6
Back propping layouts	4.25	13	2.72	11	36.1	7
H&S Management System	4.28	9	2.77	10	35.3	8=
Periodic inspections	4.41	7	2.85	7	35.3	8=
Condition of components	4.22	14	2.80	9	33.6	10
Project H&S plan	4.26	11	2.88	6	32.4	11
QMS (Support work design)	4.53	3	3.22	4	28.8	12
Scientific support work design	4.28	10	3.06	5	28.5	13
Sound structural design	4.57	1	3.35	2	26.6	14
QMS (Construction)	4.42	5	3.25	3	26.5	15
QMS (Structural design)	4.51	4	3.54	1	21.5	16
Mean	4.34		2.89		33.4	

4. CONCLUSIONS AND RECOMMENDATIONS

The traditional project parameters of quality, time, and cost, are more important than H&S relative to support work and formwork. However cost is only marginally more important which indicates that the delegates are likely to constitute practitioners that are intimately involved with support work processes and / or are the more committed in terms of H&S.

A range of support work and formwork practices / aspects which have been addressed by *inter alia*, The Advisory Committee on Falsework (1975), and the Construction Regulations (Republic of South Africa), are perceived to be important. Thus it can be concluded that the practices / aspects should be focused upon and addressed in the temporary works section of project H&S plans. Furthermore, the implementation of QMSs in design and construction is imperative. However, such QMSs should be complemented by H&S Management Systems. The QMSs and the H&S Management Systems should link all the stages in the support work and formwork process.

Based upon the ratings it can be concluded that overall, the performance of the South African construction industry relative to support work and formwork is perceived to be poor as opposed to good. Furthermore, the industry does not adopt a formal structured approach thereto – Quality and H&S Management Systems, scientific design, dedicated supervision, project H&S plans, reconciliation of support work with design, safe work procedures, inspections, maintenance, and testing.

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AFFECTS OF GLOBALISATION ON THE MANAGEMENT OF HEALTH AND SAFETY IN ENGINEERING AND CONSTRUCTION PROJECTS

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ABSTRACT

Improvements in communication, transport and growth of developing countries have collectively given rise to the term globalisation with much of the work of global organisations is being done in developing countries. Multinational engineering and construction organisations have sought to work with consistently high standards irrespective of the location where the work is undertaken or the make-up of the workforce available to them. A different approach to the management of health and safety is required and Loughborough University investigated this in their Constructing Global Safety project, identifying twelve key areas to be addressed: infrastructure; politics and security; vocational skills; language and literacy; workers and their families; weather; local practices; PPE and use of equipment. These areas were used to develop a questionnaire used in the Global Safety project to obtain views on how these impacted on site health and safety. The same questionnaire has subsequently been used in workshops and master classes delivered to health and safety professionals in Europe and the United Kingdom to further investigate these key areas.

This paper looks at the results of the post Global Safety project research and the areas of research (migrant workers, visual communications) that have opened up as a result of the initial project.

Keywords: Globalisation, Health & Safety, Corporate Governance

1. INTRODUCTION

Improvements in communication (e-mail, mobile technologies and the Internet) transport (budget air travel, development of road networks) and growth of developing countries have collectively given rise to the term globalisation. New information and transportation technologies have reduced transportation, telecommunication and computation costs. As a result, economic distances have shrunk and coordination problems have diminished (Venn-Groot and Nijkamp 1999). It is projected that by 2010, an average computer will have 10 million times the processing power of the machine available in 1975 (Yusuf 2001). Moreover, the world wide web took just 3 years from its launch in 1989 to reach a global audience of 50 million and Internet traffic is doubling every 100 days. By comparison it took the radio 37 years to reach a comparable audience and even television required 15 years (Coyle 2000).

Much of the work of global organisations is now done in developing countries and this has led to an increase in the construction of large facilities across the globe. Within this new environment, multinational engineering and construction organisations have sought to carry out their operations with consistently high standards irrespective of the location where the work is undertaken or the workforce available to them.

To meet these demands a different approach to the management of health and safety is required (Bust et al, 2006). Loughborough University investigated this in its Constructing Global Safety project, identifying, through a series of interviews and workshops with health and safety professionals with experience of working in developing countries, twelve key areas that they considered affected their management on construction and engineering projects: infrastructure; politics, security; vocational skills; language and literacy; workers and their families; weather; local practices; PPE and use of equipment.

2. QUESTIONNAIRE

Following the initial interviews and workshops on the Global Safety project a two page questionnaire was developed to be used on site visits and when subsequently interviewing health and safety professionals with experience in working in developing countries. The first page of the questionnaire contained 20 questions regarding experiences of working in developing countries. A division of the questions was embedded in the questionnaire with 5 sets of 4 questions on different categories. The categories were – Individual, Task, Equipment, and Organisation and Environment. An investigation of these categories is required in order to understand any work system and its affect on workers (Smith & Carajon-Sanfort 1989). The majority of the ‘Global Project group were project-based health, safety and environmental managers. A further study, using the same questionnaire, was completed at the European Construction Institute’s international conference in Delft, The Netherlands. These respondents were mainly senior project managers, consultants or board members.

3. RESULTS

At the end of the questionnaire a series of questions were added to obtain information about the respondents as shown in Table 1.

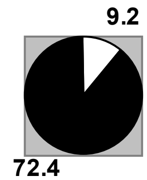
Table 1. Respondents profile from the two groups

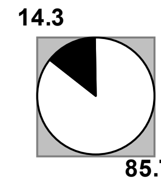
	Global Project Group	Delft Group
No. of respondents	87	21
Average age	48	54
Years in developing countries	11 ½	7 ¾
Main role	HSE managers	Project managers/ consultants
No of countries worked in	44	25

Global Project responses are shown on the **left** and Delft Conference responses appear on the **right.** Disagreement with the statement is shown in **Black, whereas** agreement is shown in **White**

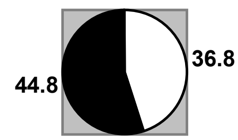
Questions relating to the individual

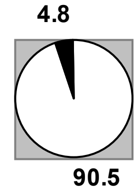
Skill levels of workers did not affect health and safety



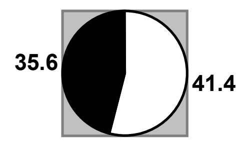


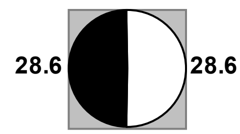
Workers' perceptions of risk were the same as in developed countries



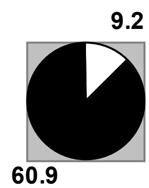


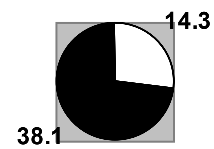
Workers general health did not affect their work on site





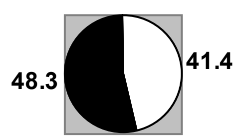
Women were able to carry out work without increasing risk to health and safety

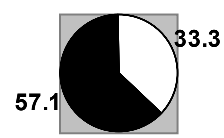




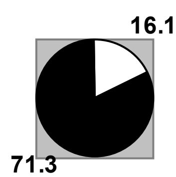
Questions relating to the task

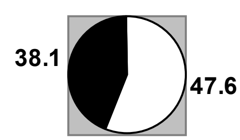
Working at height was carried out using local practices



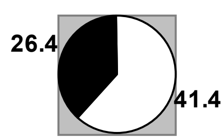


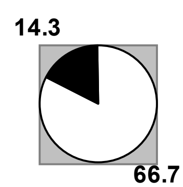
Lifting operations were carried out the same as in developed countries



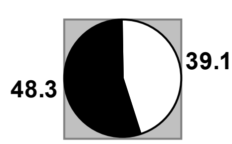


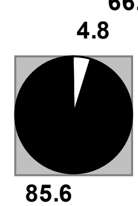
Traditional/local methods of work were not found to pose any health & safety problems





The amount of manual handling was greater than that in developed countries

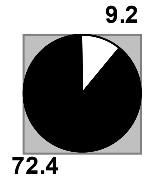


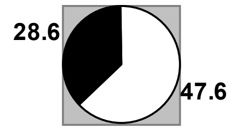


Questions relating to the equipment

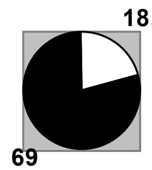
Global Project responses are shown on the **left** and Delft Conference responses appear on the **right.** Disagreement with the statement is shown in **Black, whereas** agreement is shown in **White**

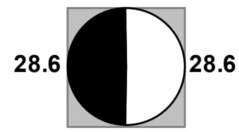
Construction vehicles were used in a safe manner



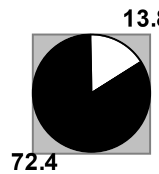


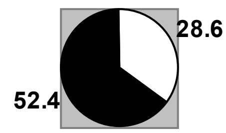
Workers were able to provide the standard of electrical work required



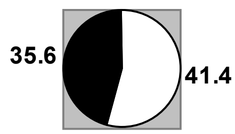


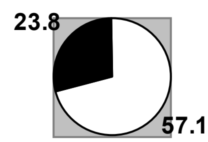
Worker use of power tools was satisfactory





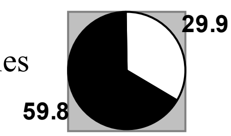
Workers were familiar with any computer-operated systems used

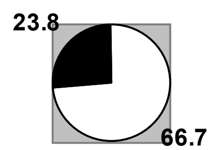




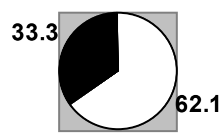
Questions relating to the organisation

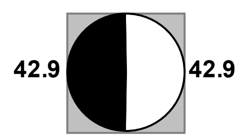
Health and safety priorities were the same as for those on projects in developed countries



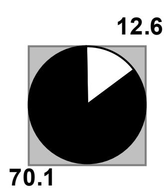


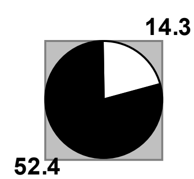
Equipment normally used in developed countries was not available



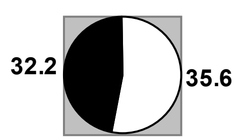


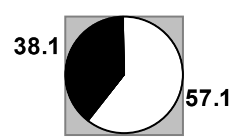
Workers were able to adopt shifts and working times proposed





The amount of health and safety training was greater than in developed countries

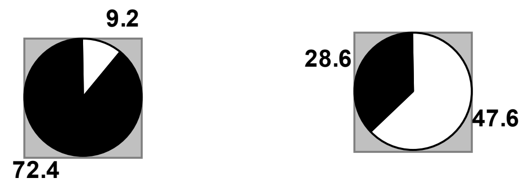




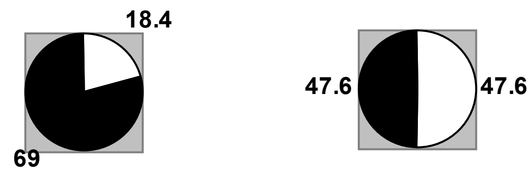
Questions relating to the environment

Global Project responses are shown on the **left** and Delft Conference responses appear on the **right.** Disagreement with the statement is shown in **Black, whereas** agreement is shown in **White**

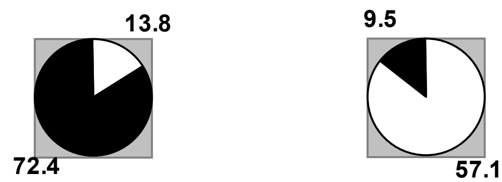
Workers families have a greater influence on how they work than in developed countries



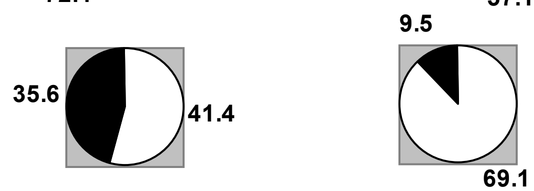
Language barriers were only a problem in the short term



The client was not supportive of health and safety initiatives



National and regional health and safety regulations were enforced by the authorities

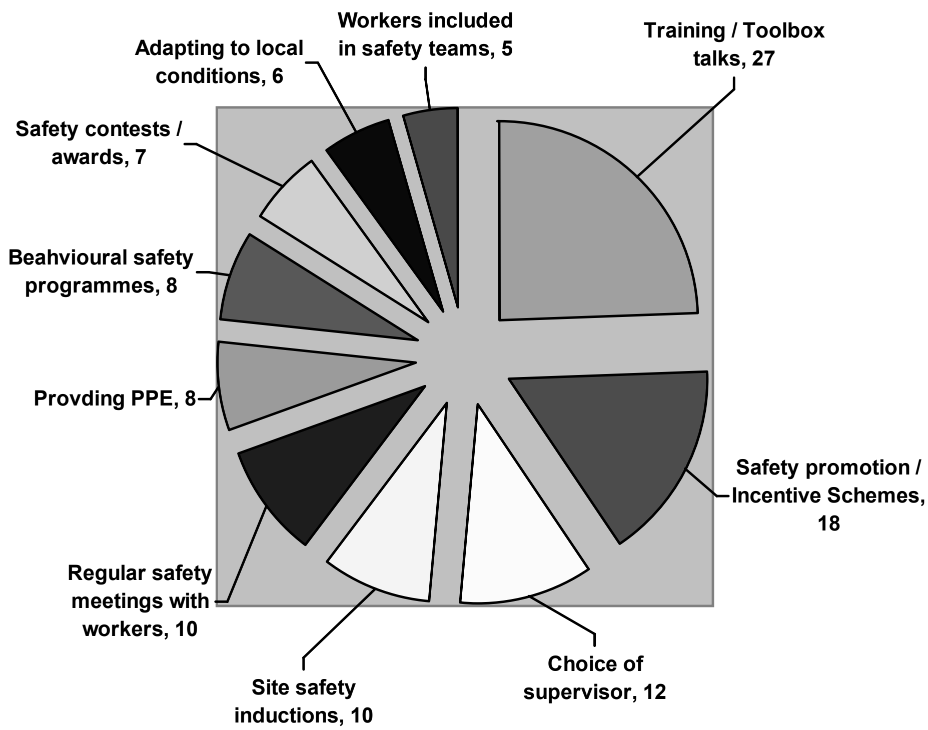


Summary of Responses to questions 1 to 20. The overall trends from the question responses are as follows:

- Individual – Disagreement between groups on two of the four questions
- Task – Disagreement on three of the four questions
- Equipment – Disagreement on all of the questions
- Organisation – Strong disagreement on one of the four questions
- Environment – Strong disagreement on one question and disagreement on one question

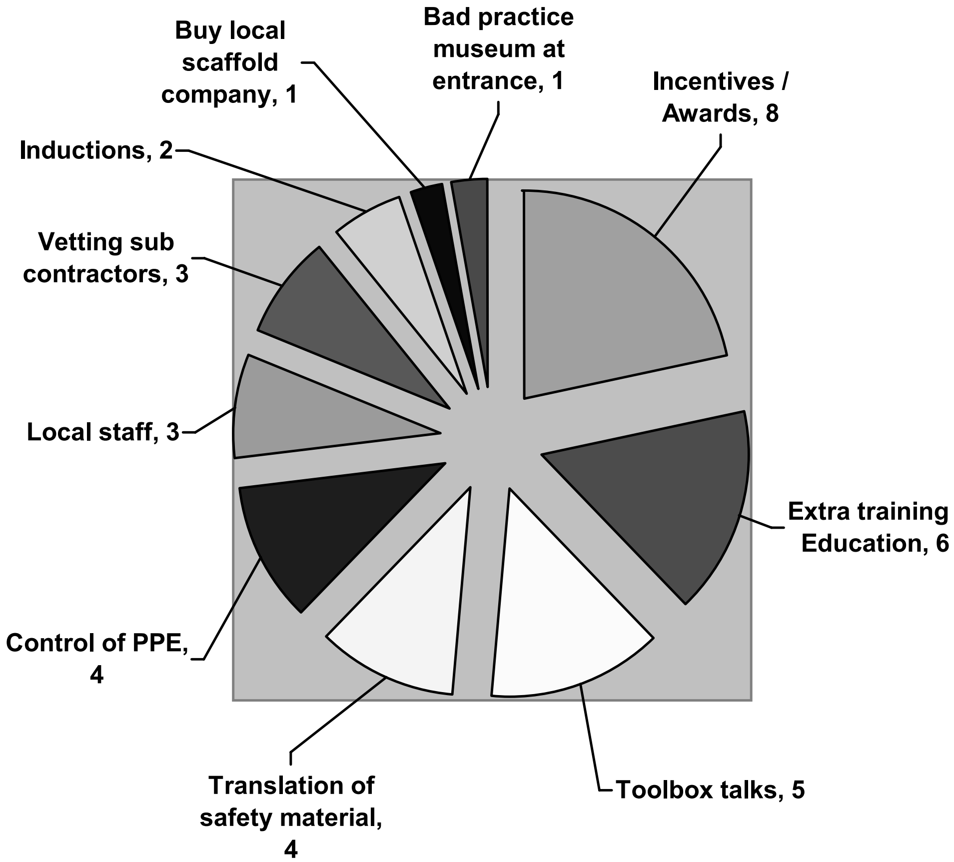
Questionnaire - Part Two Responses.

In the second part of the questionnaire the respondents were asked to describe any initiatives that were successful in overcoming barriers to implementing health and safety in the countries where they had worked. Their responses are shown in Figures 1 and 2.



Initiative category	Number of responses
Training/ toolbox talks	27
Safety promotion/incentive schemes	18
Choice of supervisor	12
Site safety inductions	10
Regular safety meeting with workers	10
Providing ‘good’ PPE	8
Behavioural safety programs	8
Safety contests/awards	7
Understand and adopt local conditions	6
Include workers/unions in safety team	5

Figure 1 - Initiatives that worked well – Global Project



Initiative category	Number of Responses
Incentives/Awards	8
Extra training/education	6
Toolbox talks	5
Translation of safety materials	4
Control of PPE	4
Local staff	3
Vetting sub contractors	3
Inductions	2
Buy local scaffold company	1
‘Bad-practice’ Museum at entrance	1

Figure 2 - Initiatives that worked well – Delft Conference

4. DISCUSSION

In order for the management of health and safety to be successful in an organisation, commitment to health and safety is required at all levels of management and throughout the workforce. From the Global Safety project, it was clear that this commitment existed but the results from the questionnaire cast doubt upon the understanding of the problems that exist in developing countries by those in higher levels of management who are remote from the projects.

Responses to the questionnaire from the two groups showed there to be disagreement on 12 of the 20 topics. This included polarised views on the subject of health and safety priorities and health and safety enforcement. A summary of the groups' views is given below.

Questions relating to the individual

The groups disagreed on two of the four subjects. The Delft group strongly believed that workers' perceptions of risk were the same in developing countries as that in developed countries while the Global group strongly disagreed with this. The Delft group strongly believed that skill levels did not affect health and safety and the Global group had no strong views on this.

Both groups strongly believed that women working on construction sites posed a risk to health and safe but when it came to the workers general health affecting their work on site, neither group had a strong view either way.

Questions relating to the task

On three of the four questions there were strong views by one group which were not held by the other group. The Delft group strongly believed that manual handling was the same as in developed countries while the Global group had no strong views. The Global group strongly believed that lifting operations were not carried out the same as in developed countries while the Delft group believed they were. The Delft group strongly believed that traditional or local methods posed no health and safety risk while the Global group had no strong views on this.

Questions relating to equipment

There was no agreement between the two groups on any of the questions relating to the use of equipment. The Global group had strong concerns over the use of construction vehicles, the standard of electrical work and the use of power tools. The Delft group had no strong views on any of these areas and thought that vehicles were used in a safe manner.

Questions relating to the organisation

There was general accord between groups on three of the four questions but strong disagreement on the fourth one. The Global group strongly disagreed that health and safety priorities were the same as for projects in developed countries while the Delft group strongly believed they were the same.

Both groups strongly believed that workers were not able to adopt the proposed shifts and working times.

Questions relating to the environment

The group disagreed on two of the questions. The Global group strongly disagreed that National and Regional health and safety regulations were enforced by the relevant authorities while the Delft group strongly believed that they were enforced. The Global group strongly disagreed that workers' families had a greater influence over them in developing countries while the Delft group believed they did have a greater influence.

Both groups strongly believed that the client in developing countries was not supportive of health and safety initiatives.

Initiatives that worked well

There was some agreement between the two groups with what initiatives worked well in developing countries. Both groups emphasised the importance of incentives, training and toolbox talks. Both groups referred to the importance of controlling personal protective equipment, site inductions and choice of supervisors.

From the lists of initiatives that worked well, safety incentives and awards were top among the more senior managers while they were further down the list for those currently working in developing countries. It is possible that, in a more competitive market, the health and safety managers are now unable to fund the same type of initiatives as in the earlier run projects.

Communication and awareness between managers

Research has shown that there can be differences in awareness between mangers at various levels of organizations. Executives closest to the top of the organisation are most aware of its strategy (Hambrick 1981). The questionnaire results would suggest that, in the case of working in developing countries, at levels closer to the top of a construction organisation the awareness of factors affecting health and safety on site decrease.

In the 'house of safety' analogy produced by Jorma Lappalainan (2006) the commitment, co-ordination and staffing for safety are shown as the basement (see Figure 3) or foundation of the safety system. These areas all depend on how the key issues will affect health and safety on the project, and how they are understood by the operational and overseeing managers.

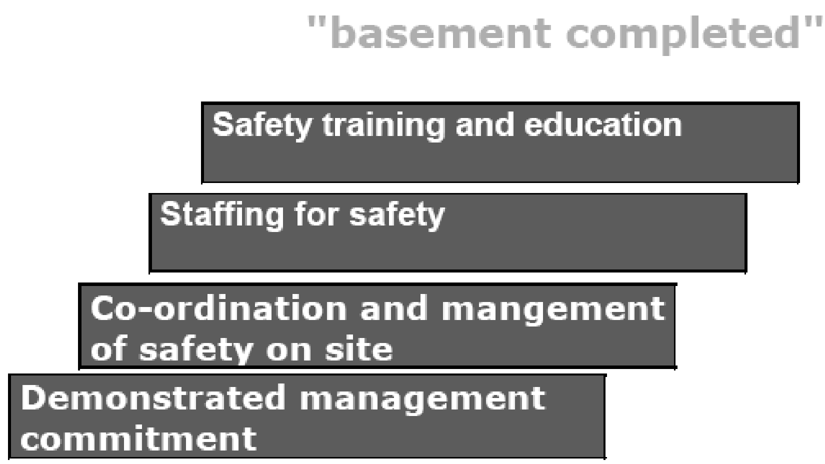


Figure 3 - Extract from the Lappalainan's House of Safety

These results alone are not sufficient to say that a problem exists that could impact the successful management of health and safety when working in developing countries. A more detailed investigation of the roles of different layers of management within these organisations would be required to show if a problem existed. It is better to assess how well information flows within the organisation rather than discover, after the event, that the warning messages from the safety manager were disappearing (Wagenaar and Hudson 1998)

While the above situation affects the management of health and safety as a whole, work has progressed on two areas of research affecting i) communication of health and safety information on site (Bust et al. 2007) and ii) the health, safety and welfare of migrant workers in the UK (Dainty et al. 2007)).

The first area was developed from discovering that the projects visited in developing countries used visual methods to overcome communication barriers associated with managing multicultural/multilingual workforces. The second area was also associated with the Global Safety projects, as migrant workers were used extensively on the projects visited in the United Arab Emirates and Qatar, together with a concern in the UK construction industry that the growth of the migrant workforce in recent years may have an adverse affect on health and safety.

5. CONCLUSIONS

The questionnaire results proved to be useful in confirming the majority of the concerns voiced by managers in the early workshops carried out. Later results from the Delft conference have identified a new concern – that there may be a difference in understanding between those carrying out management of health and safety in developing countries and those managers that may be overseeing this work.

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BEYOND COMPLIANCE: A COGNITIVE APPROACH TO CONSTRUCTION SAFETY

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ABSTRACT

Traditionally, strategies to improve construction safety have been based on a normative paradigm (compliance with prescribed safety rules). This approach has resulted in significant improvements, but it also has theoretical and practical limitations. The challenge for construction researchers and practitioners is to develop work systems that are at the same time more productive and more resilient. To this end, this paper proposes a cognitive approach to construction safety based on developments in several sectors. This approach considers safety as an emergent property of the production practices and the teamwork behaviors of the work crew. The cognitive perspective shifts the focus of accident prevention from conformance with prescribed behaviors to the task demands and capabilities, and the factors affecting them—such as task design, work distribution and workload, and the team processes that help crewmembers cope with the task demands. Based on this approach, the paper identifies new research directions for accident prevention.

Keywords: Cognitive approach, Task demands, Production practices, Team processes.

1. INTRODUCTION

In the U.S., construction accidents remain a significant economic and social problem, with over 400,000 injuries and 1,200 deaths annually (BLS 2007). Compared to the high risk sectors, construction involves frequent but relatively small scale accidents, with many and diverse hazard sources. Construction work involves a large number of work processes that need to adapt to the project-specific requirements and context. As a result, construction work processes are loosely-defined, unlike the well-defined procedures of the high-risk systems (such as aviation, nuclear and chemical plants). Furthermore, the complex, dynamic, and often unpredictable construction tasks and environments, combined with high production pressures and workload create high likelihood of errors.
With the continuous pressures for speed, productivity and competitiveness, the challenge for construction researchers and practitioners is to develop work systems that are simultaneously highly productive and highly reliable and can function safely and effectively in the dynamic, complex and competitive conditions of construction projects. This requires a more fundamental understanding of the workplace elements and processes that generate accidents, and new approaches to accident prevention and work.

This paper introduces a cognitive approach to construction accidents, and identifies strategies for accident prevention. The paper reviews developments in accident prevention in other sectors, and identifies several important factors that affect the likelihood of accidents, but have been neglected in the construction safety theory and practice. Based on the background, a cognitive perspective of construction accidents is developed and new improvement strategies are identified.

2. SAFETY RESEARCH PARADIGMS

Rasmussen (1997) identifies three paradigms in the evolution of research on accidents and occupational safety. The first paradigm focuses on normative, prescriptive theories concerning the way people ought to act. Efforts to prevent occupational accidents focus on task design and safe rules of conduct—they attempt to control behavior through normative instruction of the 'one best way,' selection and development of 'competent' personnel, and motivation and punishment. The current safety practices in the construction sector are grounded on this safety paradigm.

The second paradigm focuses on descriptive models of work behavior in terms of deviations from the normative, 'best way' of working—that is errors and biases. This paradigm guides efforts to control behavior by removing causes of errors. It includes studies of errors (Rigby 1970, Rasmussen et al.1981), management errors and resident pathogens (Reason 1990).

The third paradigm takes a cognitive approach to safety. The cognitive approach focuses on the interaction of the individual and the work system. It is concerned with the characteristics of the work system (the features of the task, tools and environment) that influence the individual decisions and actions and the possibility of errors (Rasmussen et al. 1994). From a cognitive perspective, an error is not a 'human failure' but a symptom of a problem in the work system (Dekker 2005).

This paradigm provides descriptive models of work behavior in terms of the behavior-shaping features of the work environment. Such models include the risk homeostasis theory (Wilde 1985), Rasmussen's (1997) model of migration to accidents (described below), and the Task-Capability Interface Model (Fuller 2005). The cognitive approach to safety attempts to prevent accidents by increasing the workers' ability to successfully adapt to the work environment. It aims at making visible the constraints and work affordances of the workplace (Flach et al. 1998).

Current strategies for construction accident prevention

The current safety practices in the construction sector are based on the normative approach. They focus on measures to control hazards, and means to control workers' behaviors so that they comply with prescribed safe practices. This approach emphasizes (1) management commitment and policies to prevent unsafe conditions and (2) workers' training and motivation to prevent unsafe behaviors. Safety programs—such as contractor's selection, training, inspections, motivation, enforcement, etc., as well as efforts towards safety culture, and behavior-based safety aim at increasing the workers' compliance with prescribed 'safe behaviors.'

Organizational factors associated with safety performance include top management's attitude towards safety (Levitt 1975), organizational culture (Molenaar et al. 2002), safety climate (Mohamed 2002), and the owner's role in safety (Huang and Hinze 2006). Individual factors focus on competency, attitudes, and behaviors and are addressed through training, retention, selection and motivation programs. Researchers have examined the role of design in construction safety (Hinze and Wiegand 1992, Gambatese 2003) and the importance of work method (Everett 1999) and proposed technological interventions to improve safety. More recently, Mitropoulos et all (2005) have highlighted the importance of errors that lead to loss of control and accidents.
These practices have contributed to the reduction of accidents, but also have significant theoretical and practical limitations as they do not account for the production factors that shape the work behaviors, they ignore the importance of production practices and teamwork on the likelihood of accidents, and they do not prevent or manage errors. The next section reviews safety research from several sectors and develops a new conceptualization of safety as an emergent property of the social and production system.

3. DEVELOPMENTS IN OTHER SECTORS

Migration to Accidents

Rasmussen's model of 'migration to accidents' (Rasmussen et al 1994) describes how the pressures for efficiency, and the tendency for least effort, cause the work behaviors to systematically migrate closer to the limit of loss of control. Figure 1 illustrates how safety programs attempt to counter the above pressures and prescribe 'safe behaviors' away from the boundary. However, the safety efforts need to be continuous as there is continuous tension between safety and production and in the short-term, such conflicts are usually resolved in favor of production, because production efforts have relatively certain outcomes and receive rapid and rewarding feedback (Reason 1990).

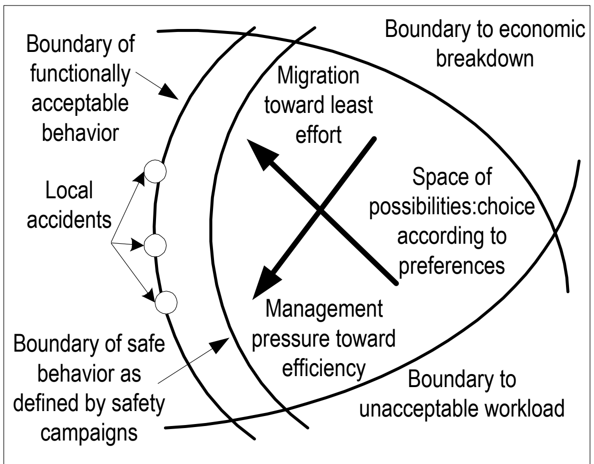

Figure 1. "Migration to Accidents" model of work behavior (Rasmussen et al 1994)

Efforts to improve safety through technical advancements (new methods, and improved safety features) tend to be ineffective because of human adaptation that compensates for safety improvements. Thus, the behavior migrates close to the new boundary of loss of control. This phenomenon of 'risk homeostasis' has been observed in transportation, navigation and traffic research and explains why technological safety improvements have not generated the expected improvements in safety (Wilde 1985, Taylor 1981, Fuller 2005). The adaptive human behaviors require that safety improvements to be directed toward the control of performance in interaction with the work environment, and effective error management to prevent loss of control. Furthermore, developments in decision making theory (Naturalistic Decision Making), increasingly consider the human interaction with the environment as a continuous dynamic control task, that does not involve conscious decision-making or risk-assessment—workers immersed in the dynamic flow of work do not make decisions based on careful situation analysis but on know-how, heuristics, and a perception of dynamic control (Rasmussen et al 1994).

The Task Demand-Capability Model

In traffic research, the risk homeostasis theory (Wilde 1985, Taylor 1981) proposed that drivers adapt their behavior to maintain an 'acceptable level of risk.' Recent research supports the argument that drivers adjust their behavior based not on the perceived 'risk of crash,' but on the perceived task difficulty. The Task-Capability Interface (TCI) model (Fuller 2005) proposes that drivers adjust their behavior (e.g., by changing their speed) to control the perceived task difficulty. The TCI model provides a new conceptualization of the driving task, the determinants of driver task difficulty, and the process by which collisions occur.

At the heart of the TCI model is the interface between (a) the demands of the driving task to achieve a safe outcome and (b) the capability applied during the task. When the Capability exceeds Task Demand, the driver has control of the situation. As Figure 2 shows, when Task Demands exceed Capability, the result is loss of control, which may result in a crash unless there is a compensatory action. Task Demands are determined by factors related to the vehicle, the road, the traffic conditions, the speed, and other tasks that the driver may perform (talking on a cell phone). The driver's speed has a central role in safety and is affected by the driver's goals (such as minimizing time to arrival), and motives inherent in the behavior of human beings when in movement, such as maintaining speed and conservation of effort. The capability applied during the task depends on the driver's competency (training and experience), the level of activation, and human factors (fatigue, etc.). Task Demand and Capability are not independent—changes in the perceived task demand, change the driver's level of activation and consequently the Capability. The level of Task Difficulty and Capability changes over time, as both the driving conditions (road, environment, traffic, speed) and the capability-related factors (fatigue, level of activation) change. To maintain control, it is essential that the driver has effective feedback to correctly assess and anticipate the task demands.

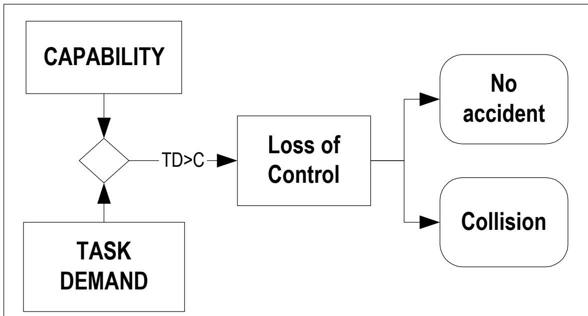

Figure 2. The TCI model

Effect of Production Practices

In contrast to the well-defined procedures of the high-risk systems, the loosely-defined construction work processes allow the work crews many degrees of freedom in how they organize and coordinate the work. As a result, construction crew practices determine largely how the actual work is structured and coordinated (such as task allocation, sequencing, workload and pace, work coordination, collaborative behavior, etc.) and consequently they shape the work situations that the workers face. For these reasons, crew coordination and communication are essential for effective and safe performance of construction crews. In terms of production factors, Hinze and Parker (1978) found that job pressures and crew competition are related to more injuries, and suggested that job practices are more important than safety policies in preventing accidents. Despite their importance, construction safety has ignored the effect of crew work practices on accident prevention.

Lean Production. Lean production practices are increasingly accepted in the construction sector, as an opportunity to reduce waste and add value in infrastructure projects. The Lean Construction Institute (LCI) developed the Last Planner system of production control (Ballard and Howell 1998) which provides a set of principles for assignment planning. The Last Planner emphasizes the quality of work assignments as the primary means to reduce variability and increase process speed and productivity. The effect of the Last Planner on safety has been investigated by one study in Denmark (Thomassen et al, 2003). The study found that crews using Last Planner had about 45% lower accident rate than crews in the same company performing similar work, who did not use the Last Planner system. However, the study did not investigate the mechanisms that generate this outcome.

Effect of the Social Environment

In a study of industrial accidents, Dwyer and Raftery (1991) found that accidents are produced by the social relations at work, and argued against the more traditional perspective that accidents are mainly produced by unsafe acts and conditions. Wright's (1986) study of accidents in the oil industry reached a similar conclusion, while trying to understand why contract employees had a disproportionately high rate of accidents compared to regular employees. Wright discovered that production pressures and a focus on work speed encouraged the development of shortcuts, which eventually became accepted as normal operating conditions. For regular employees who were familiar with the plant conditions and processes, this did not present a problem. The shortcuts were much more hazardous for contract employees who were not part of the informal network of communications in the plant and were unaware of the potential risks associated with the shortcuts. Other occupational safety research also found that social support from supervisor and coworkers reduces injuries (Iverson and Erwin 1997). In construction, Hinze and Gordon (1979) and Hinze (1981) reported that good working relationships with the foremen and other crew members were significantly related to reduced accidents.

Crew Resource Management (CRM) in Aviation

Reducing human error is a primary concern for commercial and military aviation. The analysis of aviation accidents conducted by NASA in the late 70's, resulted in the development of the CRM training system to increase the ability of the crew to collectively identify threats and manage errors (Helmreich et al. 1999). CRM emphasizes the non-technical skills and team processes (Klampfer et al 2001), such as crew briefings, contingency planning, workload management, cross-monitoring, communicating intentions, and asssertiveness. These behaviors, develop a shared mental model, facilitate effective workload management, and establish ways to collectively detect and correct errors. CRM has been implemented in sectors that require effective group interaction in complex environments, such as hospital operating teams (Helmreich and Schaefer 1994), emergency response teams (Morey et al. 2002), nuclear power operation centers, and offshore oil platforms (Flin 1997).

High Reliability Organizations

High Reliability theory investigated the characteristics and operating principles of organizations such as nuclear power plans and aircraft carriers (Rochlin et. al 1987, Weick and Sutcliffe 2001), which operate under extreme conditions, and perform complex processes with a surprising low rate of serious incidents. HROs use different organizational structures under different situations (centralized under normal conditions but decentralized under crisis), extensive training, and job rotation, while at the same time they create a homogeneous set of assumptions and decision premises which enable integration and coordination during crisis. Based on the previous background, the next section synthesizes a model of construction safety that is grounded on the cognitive perspective and considers the likelihood of accidents as a result of the production and teamwork practices of a team.

4. A COGNITIVE MODEL OF CONSTRUCTION SAFETY

The background provides the following foundations for the development of the cognitive model for construction safety:

- A construction task is conceptualized as a dynamic interaction between the worker and the elements of the task and the environment (the tools, materials, physical environment and other workers).
- During Task Interactions, the worker has a dual goal—to satisfy production goals and avoid injury.
- Accidents are a result of loss of control when Task Demands exceed Capabilities. Consequently, the likelihood of accidents during a construction operation depends on the Task-Capability Interface (TCI).

This conceptualization is a significant departure from normative models. From this perspective, an 'error' is defined not as a deviation from a prescribed procedure, but as a failure of the applied capability to match the demands of the task. Loss of control does

not necessarily result in injury—the consequences depend on the energy involved, the use of protective measures, and other situational factors.
Task Demands and Capabilities change during an operation as workers perform different tasks, task conditions change, and the workers' capabilities change (due to fatigue, disruptions, etc.).

The Work Practices and Team Processes of a work crew shape the quantity and quality of Task Interactions (Task Demands-Capabilities) and consequently the likelihood of accidents.
The TCI model provides a framework for relating the effect of work practices and team processes on the elements of the individual task and the likelihood of accidents.
Figure 3 illustrates that work practices and team processes affect the likelihood of accidents by affecting the tasks and task demands, the Tasks Interactions and the match between Task Demands and Capabilities. These factors determine both the likelihood of accidents and the productivity of an operation.

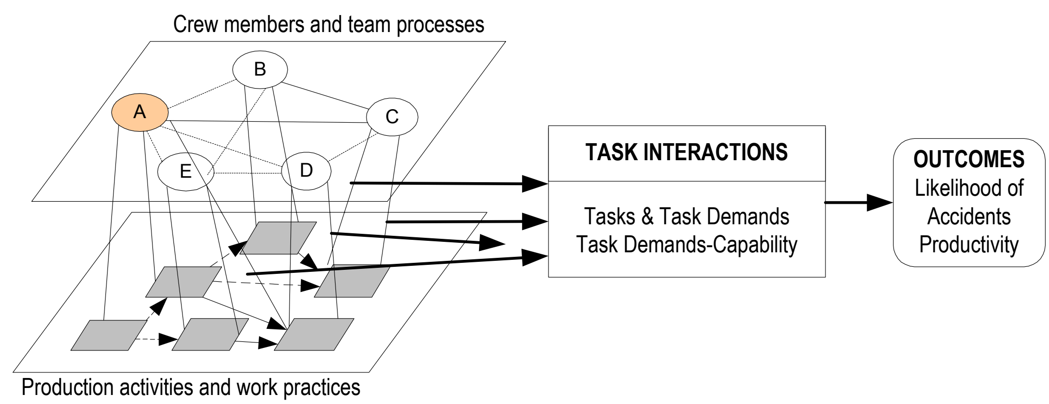

Figure 3. Influence of Work Practices and Team Processes on Task Interactions

5. CONCLUSIONS

This conceptualization shifts the focus from hazards and individual behaviors to the design of tasks (which determine the task difficulty and demands) and the teamwork processes used to execute the tasks. Safety research should focus on the following:

Task demands and errors. This research direction will increase understanding of the important features of the work system that increase the likelihood of errors and accidents.
Error proofing is an outcome based strategy to effectively manage errors. It blocks the error without removing the root causes of errors.
Production practices. This research direction will focus on understanding how the production variables and practices influence the task demands, the capability applied and the likelihood of accidents.
Teamwork practices. Development of teamwork strategies for construction crews is another potentially important strategy.

Task Demand and Errors

The TCI model conceptualizes accidents as a result of loss of control when Task Demands exceed Capabilities. This approach directs attention to the task demands, how they are generated, and how they are managed. This research direction focuses on identifying the "high risk" tasks (that is, the production tasks with the most frequent and/or severe injuries) and understand the characteristics of those tasks that make them error-prone and difficult to control. Such factors may include design features, task features, tool features and production factors that increase the task demands and the likelihood for errors. The long-term goal is to develop a systematic approach to analyze, redesign and error-proof the production task features (such as design features, task features, tools, etc.) to reduce the task demands and the likelihood for errors.

Error Proofing

The unique aspect of error-proofing is that it blocks undesired outcomes regardless of the causal factors, by making it impossible (or very difficult) for the operator to make the mistake Error proofing has dramatically reduced product defects in manufacturing (Shingo 1986), as it prevents the errors and their consequences. In construction, error proofing should address both the production errors that lead to defects and rework, and those errors that lead to injuries. This requires a culture of reporting errors, analyzing and learning from errors and accidents, and understanding the nature and type of errors that experienced and inexperienced personnel makes.

Production Practices

The production practices of the work crews determine largely how the actual work is divided and coordinated (such as task allocation, sequencing, workload and pace, work coordination, collaborative behavior, etc.). As a result, the production practices shape the work situations that the workers face (the task difficulty) as well as the worker's ability to cope with the task demands individually or collectively. For example, the use of the Last Planner System appears to significantly reduce accidents.

To develop highly productive and safe production systems it is critical to understand how the production practices affect the likelihood of accidents. Research needs to address the following questions and topics: What work practices at the crew level simultaneously support higher production and higher reliability? More specifically, what is the effect of task uncertainty, division of the work, workload management, quality control on the likelihood and accidents? What are the specific mechanisms by which these practices and processes affect the likelihood of accidents?

Teamwork Processes

As CRM indicated, effective team processes provide an important strategy for error management, and increase the crews' ability to cope with task demands, detect threats and avoid, trap and recover from errors. In construction, where exposures and errors are unavoidable, and the complexity and uncertainty of the task and environment increase the likelihood of errors, a team-based approach to error-management can provide an important strategy that complements current practices. This research direction has two goals: First, to identify the observable behaviors of effective teamwork (such as team planning, cross checking, etc.) that influence the likelihood of accidents during the construction operations, and second to identify the deeper determinants of effective teamwork (such as shared mental models, capabilities, etc.). Understanding the key teamwork behaviors will increase our ability to train crews for more effective teamwork. Together, these research directions will contribute to the development of work systems that are at the same time highly productive, safe and resilient.

6. ACKNOWLEDGEMENTS

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FRAMEWORK FOR CHANGE IN SAFETY CULTURE IN UK CONSTRUCTION

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ABSTRACT

This paper provides an evaluation of safety culture in the construction industry. Firstly, a brief overview of recent changes in accident statistics in UK construction is given. The concept of safety culture is discussed including an assessment of its main characteristics. The cultural changes which health and safety law has sought to bring about in construction are provided. These include top management commitment, employee involvement, training, co-ordination, communication, information sharing, forward planning, risk assessment and control. Research on safety culture in the aviation, mining, nuclear, and offshore sectors is assessed with a view to drawing important lessons for the construction industry. It is concluded that the safety climate or culture of an organisation can be assessed and a toolkit to assist in this process has been developed and published by the UK Health and Safety Executive. However, studies are required to develop this toolkit further to take account of the regulations, risks and management systems that are specific to the construction industry.

Keywords: Health and Safety Law, Accident Statistics, Safety Culture.

1. INTRODUCTION

Many construction workers are killed or injured every year as a result of construction operations. Others suffer ill health. The hazards are not restricted to those working on site. Children and members of the general public are also killed or injured due to inadequate control of construction activities. The construction industry's performance has improved over the years but the rates of death, serious injury and ill health are still too high. Accident rates today in the construction industry are one-quarter of those reported in the 1960s and half those reported in the 1970s. A construction site is a more dangerous workplace in comparison to other places of work. According to the Health and Safety Executive (HSE), those who spend their working lives on construction sites have a 1 in 300 chance of being killed at work (HSE, 1995).

There is still great potential to improve the health and safety record of the industry. The Egan report – a government sponsored review of the UK construction industry published in July 1998 (DETR, 1998) recognised this and argued the industry to provide decent and safe working conditions. Measured in terms of the number of reportable accidents per 100 000 employees in any given year, the report states that some leading clients and construction companies have achieved reductions in reportable accidents of 50-60% in two years or less. The report challenged construction companies to set targets to reduce the number of reportable accidents annually by 20% in addition to simultaneous improvements in other project performance measures (DETR, 1998). Cultural change throughout the organisation is recognised as one of the ingredients necessary to bring about these safety improvements. Ten years since publication of the Egan report, accident statistics reveal that the targets set in the report have not been achieved.

Safety culture may be considered as a sub-set of organisational culture. In this paper, the ten year targets set in the year 2000 to improve health and safety performance in UK Construction are firstly evaluated. The concept of safety culture is evaluated in this paper including an assessment of its key characteristics. The changes in safety culture which the UK legislative framework has sought to bring about are discussed. Finally, a review of research studies on safety culture in other high-risk industries such as nuclear, offshore, and the mining sectors is provided with a view to drawing important lessons for the construction industry.

2. ACCIDENT STATISTICS IN UK CONSTRUCTION

The UK Government and the HSE also recognised the potential to improve workplace health and safety. In July 2000, they set targets to improve the UK's health and safety record over a ten-year period. The targets set specifically for the construction sector are to (HSE, 2003):

- Reduce the incidence rate of fatalities and major injuries by 40% by 2004/05 and 66% by 2009/10.
- Reduce the incidence rate of cases of work-related ill-health by 20% by 2004/05 and 50% by 2009/10.
- Reduce the number of working days lost per 100,000 workers from work-related injury and ill health by 20% by 2004/05 and by 50% by 2009/10.

The HSE further recognised that cultural change in the industry is necessary to deliver these targets and that such improvements can only be achieved if all those involved in construction projects play their role.

There were 71 fatal injuries to workers in UK Construction in 2004/05, the same number as in 2003/04. The majority of these deaths (28 representing 39%) were due to falls from height. This means that in 2004/05, 32% of all work related deaths in the UK were in the construction industry. In 2000/01, there were 5.9 fatal accidents per 100,000 employees compared to 3.4 per 100,000 in 2004/05. This represents a decrease of 42% in the number of fatal injuries over this particular five year period. In the year 2006/07, there were 77 fatal injuries to workers in construction, a 28% increase on the previous year. Of these 77 fatalities, 50 were employees and 27 were self-employed, compared to 43 and 17 in 2005/6 respectively. In 2006/07, 32% of all worker deaths were in the construction industry. The rate of fatal injury to workers in construction rose to 3.7 per 100,000 workers, from 3.0 per 100,000 workers in 2005/6.

Since 1999/00 there has been a downward trend in the number of major injuries sustained by employees in the UK construction industry. In the period since 2000, there has been a steady drop in the number of major accidents. In 2000/01 there were 380.9 major accidents per 100,000 employees. This dropped to 299.4 per 100,000 in 2004/05. This represented a 21 percent improvement over this five-year period. Furthermore, the rate of major injury to employees decreased by 4% from 370.8 per 100,000 employees in 2006/07 to 295.4 in 2005/06. This continues the general downward trend seen since 1998/99, and is the lowest since the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations were introduced in 1996.

In 2006/07, the most common kind of accident was a slip or trip 988 (27%). As in previous years, falling from a height accounted for a high number of major injuries, 987 (27%). The next two most common kinds of accident were being hit by moving/falling objects (649) accounting for 17%, and being injured while handling, lifting or carrying (525) accounting for 14% of major injuries.

HSE statistics show that the number of workers that sustained non-fatal (includes major and over 3 day) injuries in construction decreased by 8% in the year 2006/7, from 935 to 861 per 100,000 and continuing the downward trend since 1999/2000.

The ten year health and safety targets for the UK construction industry were set in June/July 2000. Today in 2008, it is only two years away from 2010 and therefore an appropriate point to analyse statistics and evaluate whether these well intended goals and targets set by government and the industry will be achieved. The industry aimed to reduce the incident rate of fatalities and major injuries by 40% by 2004/05. The data above shows that the number of fatalities actually fell by 42% which was a good indicator that the goal of a 66% reduction by 2009/10 might well be achieved. Unfortunately, fatal accident rates in the two year period from 2005/06 to 2006/07 show an upward trend. Based on the Labour Force Survey (LFS), the rate of reportable non-fatal injury in construction was 1600 per 100 000 workers (1.6) in 2005/6 and is statistically higher than the average for all industries (1000 per 100,000 workers – 1.0%) (HSE, 2008).

Research carried out into accident rates has shown that small enterprises have a below average health and safety performance across all industries (HSE, 2006). Workplace size has a significant influence on trends in occupational injuries, with Small and Medium Enterprises (SMEs) accounting for proportionately higher rates for major injuries than larger enterprises (Nichols, 1995). Some of the reasons found for SME poor health and safety management performance are due to (Walters, 1998):

- limited resources
- limited knowledge of regulatory resources
- poor awareness of economic advantages of health and safety
- poor knowledge and understanding of safe working practices
- short-term economic pressure and competition
- inadequate enforcement and absence of preventive services.

It should also be noted that there is a dominance of very small companies in the UK Construction industry, with 93% of all registered construction companies employing less than 7 people. It is clearly partly because of this that the construction industry has a poor health and safety record.

3. SAFETY CULTURE

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. The culture on construction sites is inevitably a task culture where individuals may take risks and break rules and procedures to get the job done.

The factors which influence the type of culture in an organisation are (Handy, 1993):

- History of the organisation and its ownership,
- Size of the firm,
- Type of production technology,
- Objectives of the firm,
- The external business environment,
- and finally its people

There is general consensus that there is a difference between the terms organisational culture and organisational climate. 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 with trait-like properties and not easily changed. On the other hand, organisational climate can be viewed as a manifestation of organisational culture. If culture represents the more trait-like properties of personality, climate can be taken to be more of state-like properties of mood.

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 organisational climate is commonly conceived as a distinct configuration with limited dimensionality surveyed through self-completion questionnaires and that 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.

Although norms and values remain relatively stable, culture can be learned. That is why a lot of research effort has been directed towards understanding the influences, ingredients and consequences of culture. The overall objective is to understand these aspects and influence them so as to change the overall culture of the group or organisation.

A culture is a set of norms and beliefs. It is about both individuals and groups of people who share common values and attitudes. The common-sense view of a culture could be summed up in the phrase "the way we do things around here". The term "safety culture" was first introduced into common use in the nuclear industry following the Chernobyl nuclear accident in 1986. The reasons for the accident were proposed to be not only technical or individual human errors. It was suggested that management, organisation and attitudes also influence safety. In recent years, it has attracted considerable attention in the offshore industry following investigations into the 1988 Piper Alpha disaster in which 192 people died.18 Other high risk industries in which the concept of safety culture has been researched include tunnelling, mining and aviation.

On the concept of safety culture with specific reference to the construction industry, Anderson (1998) writes: "It is clearly a 'good thing'. Quite how it should be researched, evaluated and improved within the construction industry is, as yet unclear, but the gains that have been made elsewhere just cannot be ignored." A comprehensive definition of safety culture which has been widely adopted in research and other scientific publications is one proposed by The Advisory Committee on the Safety of Nuclear Installations (ACSNI). According to the ACSNI (1993), "the safety culture of an organisation is the product of the individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisations' health and safety management. Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficacy of preventive measures".

High standards of health and safety will be achievable if people can report errors and near misses. These are a source of vital information. A reporting culture and a learning culture in which people can admit and learn from such genuine mistakes without fear of blame or punishment requires also to establish a just culture in which employees are confident that they will be treated fairly if they report accidents and near misses. Obviously, wilful carelessness cannot be accepted. In any organisation, people should be disciplined or indeed prosecuted for wilful contribution to or creation of conditions in which accidents, injury or ill-health result.

4. CULTURAL CHANGES SOUGHT THROUGH LEGISLATION

The UK government commissioned the first comprehensive review of health and safety law in 1970. Results of this review were embodied in the Robens report which was published in 1972 and led to adoption of the Health and Safety at Work (HSW) Act 1974. The Robens report described in detail the shortcomings of workplace health and safety management as it had evolved in the UK. The HSW Act 1974 was designed to overcome these anomalies. The philosophy behind the HSW Act 1974 was to have an enabling piece of legislation which applies to virtually all workplaces but with regulations issued from time to time under Section 15 of the Act to cover specific high risk areas. Section 2 of the Act lays down general duties of employers to their employees. Section 3 lays down general duties of employers and the self-employed to persons other than their employees. Employees at work also have general duties laid down under Section 7 of the Act (HMSO, 2000). Detailed specifics of these duties are well known and will not be reproduced here. The HSE was formed under Section 10 of the Act to improve enforcement of health and safety law.

Senior management involvement and commitment to health and safety is required in the HSW Act 1974. Unless an organisation has less than 5 employees, under Section 2(3) of the Act, every employer is required to prepare a written statement of his general policy with respect to health and safety including the organisation and arrangements for carrying out that policy. The statement of the policy and any revisions must be brought to the notice of all his employees. Some authors have criticised this provision of law on the grounds that it merely requires an employer to prepare a safety policy but does not require it to be adequate.

The aim of the HSW Act 1974 was to promote proactive safety management and to a large extent self-regulation, a concept which was advocated in the Robens report. The philosophy embodied in the Act was that competent and committed employers in consultation with their employees would identify hazards, assess risks and implement preventive measures within a framework of law and standards developed with the participation of all the parties. The Robens report and the HSW Act 1974 therefore aimed to promote a positive organisational safety culture. Despite these general duties imposed on employers and employees, some old legislation still continued to exist on the statute book. The change in safety culture sought by the Robens report and indeed the HSW Act 1974 was thus at best uneven and clearly unachievable. The concept of risk assessment was also not explicit in Section 2 of the HSW Act 1974 but merely implied.

The Management of Health and Safety at Work Regulations 1999 require explicit assessment of health and safety risks. Regulation 3 of the Management Regulations 1999 requires all employers and the self-employed to assess risks to their employees and any others who may be affected by their work or conduct of their operations. Risk assessments must be suitable and sufficient. Preventive and protective measures must be applied following such risk assessments. The following principles of prevention are laid down in Regulation 4 and must be considered in designing protective and prevention measures. They are (Perry, 2003):

- If possible avoid risks altogether,
- Evaluate risks which cannot be avoided,
- Combat risks at source,
- Adapt the work to the requirements of the individual,
- Take advantage of technological progress,
- Replace the dangerous with the non-dangerous or less dangerous,

- Implement risk assessment measures as part of a coherent policy and approach that takes into account work organisation, working conditions, the environment and any social factors,
- Give priority to collective protective measures over individual protective measures,
- Provide appropriate instruction to employees and the self-employed to ensure they all understand what to do.

Guidance to the Management Regulations 1999 requires development of a positive health and safety culture within the organisation. Avoidance, prevention and reduction of risks are expected to be part of every organisation's approach to all its activities. This should be the case throughout the organisation and must be recognised as such from junior employees to senior management. Regulation 5 requires every employer to manage health and safety arrangements in very much the same way that other important aspects of the business such as profits or sales are managed. The regulation imposes a requirement on every employer organisation to plan, organise, control, monitor and review its health and safety preventive and protective measures.

The concept of risk assessment is the cornerstone of modern health and safety legislation. Several regulations relevant to the construction industry require explicit health and safety risk assessments. Repeal of old health and safety law is now almost complete. The HSW Act 1974, Management Regulations 1999 and other modern regulations passed under Section 15 of the Act offer the UK construction industry a chance to develop a safety culture of forward planning, organisation and control to manage health and safety risks. They offer organisations the opportunity to develop mechanisms of self-regulation within a statutory framework first envisaged in the Robens report.

Active employee involvement in management of health and safety is also required in law and provided for through the Safety Representatives and Safety Committee Regulations 1977. These regulations provide for the appointment of safety representatives from among the employees by recognised trade unions. The employer has a legal obligation to consult such representatives on matters of health and safety at work. Safety representatives have powers to investigate potential hazards and dangerous occurrences at work and causes of any accidents. They can investigate complaints by employees and make representations to the employer on health and safety matters. They can carry out inspections of the workplace provided they give written notice to the employer. Even in organisations without recognised trade unions, the employer is required under the Health and Safety (Consultation with Employees) Regulations 1996 to consult representatives of employee safety.

Modern health and safety law also aims to promote a culture of training and information sharing. For example, Regulation 13 of the Management Regulations 1999 requires all employees to be provided with adequate health and safety training. Such training should be provided on first recruitment to the job and on being exposed to new or increased risks. Changes in risk exposure may result from change of job responsibilities, introduction of new work equipment, technology or systems of work. Regulation 10 requires every employer to provide his employees with relevant and understandable information on risk assessments and preventive or control measures put in place by the employer. Other information which the employer must provide includes emergency evacuation procedures including fire evacuation, the identity of competent persons appointed by the employer to assist with overseeing such evacuations and any information on risks passed to the employer by other employers.

In the UK, there has recently been another major and recent change in health and safety law. The Construction (Design and Management) Regulations 2007 took effect on 6th April 2007. The CDM regulations 2007 are comprehensive and apply to all construction work. The declared objectives of the CDM Regulations 2007 are to:

- Improve overall planning and management of a project from the early stages
- To improve health and safety risk identification and management
- To eliminate unnecessary bureaucracy
- To target resources and effort where they are likely to maximise benefits in terms of health and safety performance.

For the benefit of readers who will be familiar with the CDM Regulations 1994, the key changes are these:

The Construction (Health, Safety and Welfare) Regulations 1996 have been repealed. Its provisions are now incorporated as part 4 of the CDM Regulations 2007. It should also be noted that provisions which were in the Construction (Health, Safety, and Welfare) Regulations 1996 relating to work at heights are incorporated in the Working at Heights Regulations 2005.

The CDM Regulations 1994 applied to all demolition and dismantling work regardless of the length of time or the number of people involved in carrying out the work. There are now no special provisions for demolition or dismantling work under the CDM Regulations 2007 other than to have a written plan of work before the demolition or dismantling begins (Regulation 29).

The CDM Regulations 1994 applied to all notifiable projects. They also applied to other construction work unless the work was expected to last less than 30 days and involve less than five people on site at any time. The five person rule does not exist in the CDM regulations 2007. The threshold for notification of a project to the HSE remains unchanged at 30 days or 500 person days. Where a project is notifiable, additional legal obligations specified in Part 3 of the CDM Regulations 2007 apply. For a project that is not notifiable, parts 2 and 4 of the CDM Regulations 2007 apply. Thus, the CDM regulations 2007 apply to all construction projects. There are no exemptions or disapplications. The only special case is domestic clients. Domestic clients do not have legal duties under CDM 2007.

Clients and contractors must tell those that they appoint how much time they have allowed to plan and prepare for construction work (mobilisation time).

In relation to project notification which is normally undertaken using Form F10, there is now an obligation to provide extra information. Specifically, the time allowed by the client to the principal contractor for planning and preparation for construction work must

be included in the information to the HSE. The name and address of any designer already engaged must also now be provided.
The Planning Supervisor role has been removed and replaced with a new duty holder of the CDM Co-ordinator.
Designers still have legal obligations to consider the hierarchy of risk control whenever they design a structure. There is however now an additional duty on designers to ensure that any workplace they design complies with the Workplace (Health, Safety and Welfare) Regulations 1992.
The Pretender Health and Safety Plan under the CDM Regulations 1994 Regulations has been removed and replaced by Pre-Construction Information in the new Regulations.
There are enhanced client duties to ensure that other duty holders have made adequate arrangements to ensure the health and safety of those working on the project including welfare facilities.
The provision for a Clients agent which was permissible in the CDM Regulations 1994 has been removed. Clients can still of course appoint consultants to act as their agents but must note that they still retain criminal liability.
A number of provisions which were implicit in the CDM regulations 1994 have been made explicit in the CDM Regulations 2007. For example, CDM Co-ordinators must prepare a health and safety file or update it if one exists. Under the CDM regulations 1994, the Planning Supervisor only had a legal obligation to ensure that this was done. By implication, this means that the Planning Supervisor could delegate or sub-contract the actual preparation of the file to another individual or company.
There is greater clarity regarding the criteria and procedures for assessment of competence of individuals and companies, contractors, designers, CDM Co-ordinators, etc.

The CDM regulations 2007 are designed to promote a culture of co-operation, communication and sharing of information, planning, organisation and control. Pre-Construction Information, the construction phase health and safety plan and the health and safety file are all designed to facilitate this. A fundamental requirement of CDM is the duty to undertake timely risk assessments, and to develop control solutions that provide continuing protection for every one potentially at risk. The systems approach to health and safety management introduced by CDM has the potential to produce health and safety benefits. The risk assessment process begins with the Client. Commissioning the following surveys would not be unreasonable:

- Asbestos survey
- Building Services survey
- Contaminated land survey
- Environmental noise survey
- Structural survey

Clients are expected to face extra costs if they are to comply with the CDM Regulations 2007. These costs depend on the size and complexity of the projects. The estimates costs according to the New Civil Engineer are as follows (NCE, 2007)

Project Size (Cost)	Costs of CDM 2007
Very large (£20m)	£30,000
Large (£10m)	£25,000
Medium (£5m)	£25,000
Small (£300,000)	£850
Very Small (£50,000)	£500

Perry (2003) lists some HSE criticisms of the construction phase health and safety plans. They are:

- Construction phase health and safety plans do not focus sufficiently on risk assessments

Site supervisors and managers have limited knowledge of health, safety and welfare requirements.

Site supervisors and managers are unaware of the contents of the construction phase health and safety plan.

Some sources of risk including site-wide activities are not taken into account in health and safety risks assessments,

Plans do not lay down in sufficient detail welfare provisions

The implications of tight schedules on project health and safety are rarely recognised in risk assessments

- Fire safety is often overlooked

5. SAFETY CULTURE IN OTHER HIGH-RISK INDUSTRIES

According to Laurence (2005), a positive safety culture requires:

- Higher management commitment to safety
- Open communication channels
- A stable, experienced workforce
- High quality housekeeping
- A safety emphasis on training
- Full-time safety personnel reporting to top management.

A positive safety culture provides a platform on which to build greater awareness, understanding, and compliance with safety rules and regulations. Although research by Laurence (2005) did not focus on safety culture in the mining industry per se, analysis of responses from 500 mineworkers on the development of more effective mine safety rules and regulations revealed that:

- Management and regulators should not continue to produce more and more safety rules and regulations to cover every aspect of mining because miners will not read nor comprehend this level of detail.

- Detailed prescriptive regulations, detailed safe work procedures, voluminous safety management plans will not influence activities or behaviour of a miner. The aim should be to develop a framework of fewer rules but of the highest quality.
- Achieving more effective rules and regulations is not the only answer to a safer workplace. Emphasis should be placed on ensuring that a positive safety culture exists and that communication channels are open and working well.

The Piper Alpha disaster led to a fundamental review of health and safety law in the offshore oil and gas processing sectors in the UK. A lot of research was also initiated although these efforts were initially focussed on improvements in technology and management systems. Cox and Cheyne (2000) take the view that further improvements in safety in the offshore sector may best be realised through enhanced efforts in the areas of human factors and through associated developments in health and safety.

Cox and Cheyne (2000) carried out extensive research on safety culture in the offshore industry and have developed, tested and validated a safety climate assessment toolkit. The key areas which can be "measured" using the model on a scale of 1 to 10 in relation to health and safety culture or climate are:

- Management commitment
- Communication
- Safety systems
- Work environment
- Supportive environment
- Involvement
- Co-operation
- Personal appreciation of risk
- Personal priorities
- Competence
- Management style

Use of such a toolkit brings a number of benefits. The first is that it can raise the profile of health and safety in the organisation. Secondly, it allows active monitoring of the health and safety culture in the firm. Thirdly, it provides an opportunity to discuss openly issues relating to health and safety culture and encourages participation of all workers in health and safety matters. Finally, the performance of the firm can also be benchmarked against the performance of similar firms in the sector.

In their international report, Sese' et al (2002) note that there has been a general improvement in occupational health and safety in Spain in the last ten years. This is mainly due to enacting the Law of Prevention of Labour Risks in 1995. This body of Spanish law also promotes the concept of proactive accident prevention and a positive safety culture. Despite the general improvement in safety, Spain still has the highest incident rate for nonfatal occupational accidents in the European Union and occupies third place for fatal accidents. The fatal incidence rate per 100,000 persons in employment is 5.5 in Spain compared to 1.6 in the UK. Sese' et al (2002) also report that behaviour based safety programs for enhancing safety behaviour are not widespread in Spain. Workplace behaviour in Spain is to a large extent governed by a culture of fulfilment of legal obligations mainly due to prosecutions for unsafe behaviour. There is no real intervention for reinforcement of safe work behaviour. It is recommended that a multi-disciplinary approach where human behaviour plays an important role is essential to improve health and safety performance in Spain.

Gurjeet and Gurvinder (2004) report findings of research based on a very extensive survey of businesses and individuals in the aviation industry in New Zealand. They reiterate the view that a positive safety culture will thrive where there is a senior management commitment to safety. Their study revealed that aircraft maintenance businesses considered positive safety practices and safety education as the two most important factors for ensuring safety. Furthermore, aircraft maintenance engineers considered positive safety practices, safety education, implementation of safety policies and procedures to be the most important aspects in ensuring safety in the aircraft maintenance system. They found that a positive safety sub-culture appeared to have emerged amongst aircraft maintenance engineers. This is a sub-culture of commitment to ensuring safety by strongly following standards, regulatory procedures and safety practices. This was a positive finding given that 12 percent of major aviation disasters are due to inspection maintenance inadequacy. The study also revealed that pilots considered luck to a significant contributor to safety. Overall they concluded that various sectors in the aviation industry need to do more to improve the prevailing safety culture.

Findings on a comprehensive study of safety culture in the nuclear industry are presented in Lee and Harrison (2000) and conclude that personnel safety surveys can be usefully applied to deliver a multi-perspective, comprehensive and economical assessment of the safety culture in an organisation and to explore the dynamic inter-relationships of its composition or parts. They also comment on the HSE's Health and Safety Climate Assessment Toolkit based on Guidance HSG65 entitled "Successful Health and Safety Management"21. This signifies official endorsement of health and safety climate or culture assessment by the UK regulatory body. It should however be noted that Guidance HSG65 provides generic guidance for planning, organisation and control of health and safety across all workplaces. Clearly, risks, safety problems and safety management will differ from sector to sector although there are bound to be similarities. This HSE Safety Climate Assessment Toolkit ought to be developed further so that it is customised for relevant sectors such as agriculture, construction, offshore oil extraction, manufacturing or service sectors to take account of the risks and management procedures and systems in different industries.

6. CONCLUSIONS

The concept of safety culture has been defined and discussed in this paper. It is the shared and learned knowledge, experiences and interpretations of safety which guide employees' attitudes and actions towards hazards, risks and their prevention. Safety culture is shaped by people working together in organisational structures and social relationships in the workplace. This paper has provided a brief review of accident statistics in UK construction. Although the long-term safety performance of the industry has improved in recent years, there is no evidence to show that the targets set for 2009/10 will be achieved. In fact, the rate of fatal injury to workers in construction rose to 3.7 per 100,000 workers in 2006/07 from 3.0 per 100,000 workers in 2005/06. Furthermore, the actual number of reported major injuries to employees rose slightly in 2006/07 to 3,711 compared to 3,706 in 2005/06

The Robens' committee report that led to enactment of the HSW Act 1974 in the UK aimed to promote a culture of self-regulation within a statutory framework. This was not achieved initially because of the presence of wide ranging legislation on the statute book. However progressive repeal of old legislation is now virtually complete. The substantive body of health and safety law is now the HSW Act 1974 supplemented by the various regulations made under Section 15 of the Act. The Management of Health and Safety at Work Regulations 1999 make explicit the provisions of the HSW Act 1974. The Act and the Management Regulations aim to promote a culture of planning, organisation and control of risks arising from workplace activities. They also aim to promote a culture of training, communication and information sharing.

There has been a recent and major change in health and safety law in the UK. The CDM regulations 2007 aim to promote a culture of good safety management with emphasis on avoidance, mitigation and management of construction health and safety risks. The philosophy is to involve everyone in the management process through proper planning and co-ordination of the phases of a construction project. The CDM Regulations 2007 aim to promote a culture of sharing and communicating information including keeping a proper record of information to promote health and safety during subsequent use, cleaning, maintenance and eventual demolition of the structure.

The construction industry could improve its health and safety performance further by improving its safety culture. This is in addition to developing a culture of generating, distributing and acquiring knowledge on hazard causation and control (a learning culture). All managers and employees must be motivated to willingly expend effort to minimise health and safety risks. Good health and safety management is the product of effective harmonisation of technical and managerial systems including human factors. If one of them is absent or poorly in evidence, the product of effective management and potential for improvement is severely undermined.

There has been a substantial amount of research into the concept of safety culture in the aviation, mining, nuclear, and offshore industries. The safety culture of an organisation can be measured or assessed and indeed improved over a period of time. This has been recognised by the Health and Safety Executive which has issued a Health and Safety Climate Assessment Toolkit. This toolkit is however based on generic HSE Guidance document HSG65 - successful management of health and safety. Further research is required to customise this Toolkit and develop it further to take account of specific legislation, hazards and management systems which are applicable to the construction industry.

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INVESTIGATING SAFETY AND PRODUCTIVITY ON CONSTRUCTION SITES

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ABSTRACT

Improving safety and productivity are major concerns throughout the construction industry. Many companies around the world are implementing safety management systems to provide a safe work environment at their construction sites. Nonetheless, efforts are lacking that document the need for simultaneously investigating safety and productivity considerations. The objective of this research is to investigate how to improve productivity and safety by integrating them on construction sites. To achieve the objective, a questionnaire survey was conducted on the construction sites of a leading construction company and its subcontractors in Hong Kong. In total, 1,800 hard-copy questionnaires were distributed and the response rate was 81 %, resulting in 1,454 valid questionnaires for analysis. By means of the statistical analysis, safety and productivity were investigated on 25 construction sites. The results showed that eleven of the fifteen significant findings pertained to safety, and four pertained to productivity. In general, the findings confirm that it is possible to improve productivity and safety simultaneously on construction sites. All measures were found to be correlated with both productivity and safety.

Keywords: Safety, Productivity, Construction Sites, Safety Management, T-test, Hong Kong

1. INTRODUCTION

Safety and productivity issues have gained vital importance in the competitive global environment. Organizations are under pressure to produce more with a reduced workforce and often with fewer resources. Koller (1989) illustrates a number of examples of improvements being made to workers' health, safety and wellbeing through good work design. Such practices might be examined to determine if they are adoptable for improving both productivity and safety on construction sites.

The construction industry is regarded as a dangerous industry due to the characteristics of decentralization and mobility (Fang et al., 2006) wherein employees are separated on construction projects, and they readily move among companies. Frequently, they make decisions on-site about the safe behaviors they deem important. Mohamed (2002) developed a research model based on the hypothesis that safe work behaviors were the consequences of the existing safety climate. Lingard and Rowlinson (1994) investigated construction site safety in Hong Kong through behavior-based safety. Advances in technology result in changes to working methods and patterns (Ahasan, 2002) which are compounded by the need to be competitive. Essentially, improving worker safety and productivity are major concerns in the construction industry. Shikdar and Sawaqed (2003) reported that some of the common problems faced by the oil industry are improper workplace designs, mismatch between worker abilities and job demands, adverse environments, poor human-machine system designs and inappropriate management programs. These problems apply equally to the construction industry. On-site hazards, poor workers' health, and injuries on construction sites, reduce productivity and increase costs.

In the past, safety performance and productivity were treated as separate and independent characteristics. Nonetheless, the International Labor Organization (ILO-OSH, 2001) guidelines summarize occupational safety and health as "decent work" which is safe work, and it is a positive factor for productivity and economic growth. These days, there is a tendency to shift the responsibility of safety from a separate safety organization or safety department to the management team (Choudhry et al., 2008). Safety officers are re-designated as safety advisors to reflect that the responsibility for safety lies firmly with the project director, project manager, and their line managers (Choudhry et al., 2008). The role of the safety advisors is to provide advice on actions to be taken in order to ensure a safer working environment. The whole purpose is to ensure that safety management has been integrated into project management.

Accidents do cause human suffering and economic losses. When the true costs of injuries are computed it becomes clear that compromising safety results in increased costs and decreased profits (Hinze, 2000). After understanding 'incurring the cost of injuries versus investing in safety' (Hinze, 2000) it is apparent why such slogans as "Safety Pays; Injuries Cost" and "It Pays To Be Safe" become part of the culture of companies that truly are committed to the well being of their employees.

These days, many construction companies around the world are implementing safety, health, and environmental management systems to reduce injuries, eliminate illness, and to provide a safe work environment on their construction sites (Choudhry et al., 2008). The International Labor Organization (ILO-OSH, 2001) and other researchers (Koehn et al., 1995; Koehn and Datta, 2003; Choudhry et al., 2008) have stressed the need for implementing a safety management system on construction projects. Countries, such as the United States and the United Kingdom, are implementing safety management systems for example the Occupational Safety and Health Administration Standards for the construction industry (OSHA, 2005), and the British Standards Institute's (BSI, 2000) safety management code, known as OHSAS 18001 (Occupational Health and Safety Assessment Series 18001).

Jaselskis et al. (1996) indicated that management commitment and involvement in safety was the most important issue for a satisfactory safety management program. In addition to the involvement of top management, the participation of foremen and workers is an important element of a safety management program (Lark, 1991). The literature review shows that very little research has been conducted to provide information simultaneously about productivity and safety on construction sites. Essentially, this study was carried out on the construction projects of a leading construction firm in the Hong Kong construction industry, hereinafter called, the "company" with the objective of investigating the direct and indirect effects of productivity and safety on the overall performance of the company and the industry as a whole. Specifically, the following objectives are identified:

1. To investigate employees' perceptions on productivity and safety which, on one hand, increase productivity and, on the other hand, improve safety;
2. To understand whether productivity and safety can be integrated and improved simultaneously on construction sites.

2. RESEARCH METHOD

This study took place in a large construction company based in Hong Kong with annual revenues of approximately US$1billion and employing more than 2,300 full-time staff. The information and data used in this paper were obtained from the survey conducted on 25 construction sites of this company. The Salminen and Saari (1995) questionnaire was adopted for this study, which consisted of 31 questions for improving productivity and safety. The questionnaire statements were modified to be applicable on construction sites because the questionnaire of Salminen and Saari (1995) was administered in the industrial sector. Additionally, based on the recommendations of the writers and the company personnel, four additional questions were included to make the questionnaire suitable for the construction sites in Hong Kong. The purpose of the questionnaire was to obtain the views of managers, supervisors, and workers for improving productivity and safety on construction sites.

The questionnaire in its final form consisted of 35 statements about productivity and safety issues at the organizational, group, and individual levels and consisted of two parts. The first part of the questionnaire related to general information about the respondents. The four added questions included the respondent's project name, name of the company, and ethnicity (Chinese or non-Chinese) of the respondent. Further questions included the respondent's role on the project, whether a worker, supervisor or a manager. The second part consisted of 31 items which asked the participants to respond to the statements using a five-point Likert-type (from 1 = "strongly disagree" to 5 = "strongly agree") scale. The questionnaire asked the participants to respond, on Likert-type scale, to each statement, simultaneously considering two major aspects, namely would "there be an increase in productivity if" and would "there be an improvement in safety if" followed by the question. Thus, questionnaires were used to investigate productivity and safety simultaneously on construction sites. Additionally, a cover letter and survey instructions were prepared to ensure that all employees understood that their responses would be anonymous. It is not possible to attach the questionnaire with this paper. (Note, if anyone is interested in the details of the questionnaire, they may contact the authors.) The questionnaires were prepared both in English and Chinese.

Twenty-five construction projects in Hong Kong were selected for the target sample. The questionnaire distribution targeted all employees working on the construction sites. To maximize the response rate on the projects, top management support of the company was sought. A total of 1,800 hard copy questionnaires were distributed. The response rate was 80.8% with 1,454 valid questionnaires being completed and returned.

Most of the responses (79.2%) were from subcontractor employees and 20.8% were directly employed by the company. In addition, 97.1% of the respondents were Chinese and 2.9% were non-Chinese employees. Among the respondents, 77.5% were workers, 16% were supervisors and 6.5% were managers. The ratio of questionnaires from managers, supervisors and workers was about 2:5:24 and the sample was quite representative of the total workforce working on the construction sites.

Statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS) software. A statistical t-test was carried out to check the population means responses to the issues raised in the questionnaire. The t-test results and correlation information of the variables are shown in Table 1.

3. RESULTS

The analysis examined the relationship of 31 variables (see Table 1) with both productivity and safety. The respondents rated each measure on a five-point scale so that values 1 and 2 described a low effect of a measure and values 4 and 5 a high effect. The respondents rated the value 3 if they felt that the measure had neither a low nor a high effect. The results will be described briefly.

The mean score on the factor (Q.1) "there shall be an increase in productivity if more skilled labor is employed" ($m = 3.96$) was significantly greater at the $p < 0.001$ level than the mean score on "there shall be an improvement in safety if more skilled labor is employed" ($m = 3.86$). The results also indicate that a significant correlation exists between these two variables ($r = 0.599$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.2) "there shall be an increase in productivity if operatives have better education and experience" ($m = 4.02$) did not differ significantly at the $p < 0.05$ level (note: $p = 0.480$) from the mean score on "there shall be an improvement in safety if operatives have better education and experience" ($m = 4.00$). The results also indicate that a significant correlation exists between these two variables ($r = 0.663$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.3) "there shall be an increase in productivity if operatives get help and advice easily" ($m = 3.79$) did not differ significantly at the $p < 0.05$ level (note: $p = 0.840$) than the mean score on "there shall be an improvement in safety if operatives get help and advice easily" ($m = 4.00$). The results also indicate that a significant correlation exists between these two variables ($r = 0.679$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.4) "there shall be an increase in productivity if more time and money are available for supervising" ($m = 3.82$) was significantly less at the $p < 0.001$ level than the mean score on "there shall be an improvement in safety if more time and money are available for supervising" ($m = 4.00$). The results also indicate that a significant correlation exists between these two variables ($r = 0.534$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.5) "there shall be an increase in productivity if there is improvement in safety knowledge of supervisors" ($m = 3.88$) was significantly less at the $p < 0.001$ level than the mean score on "there shall be an improvement in safety if there is improvement in safety knowledge of supervisors" ($m = 4.04$). The results also indicate that a significant correlation exists between these two variables ($r = 0.600$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.6) "there shall be an increase in productivity if there are better and frequent controls of site tasks" ($m = 3.89$) was slightly less at the $p < 0.05$ level (note: $p = 0.039$) than the mean score on "there shall be an improvement in safety if there are better and frequent controls of site tasks" ($m = 3.93$). The results also indicate that a significant correlation exists between these two variables ($r = 0.591$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.7) "there shall be an increase in productivity if there is better coordination between the work groups" ($m = 4.10$) was almost same at the $p < 0.05$ level (note: $p = 0.020$) than the mean score on "there shall be an improvement in safety if there is better coordination between the work groups" ($m = 4.05$). The results also indicate that a significant correlation exists between these two variables ($r = 0.613$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.8) "there shall be an increase in productivity if there are better personal relations between workmates" ($m = 4.05$) was slightly higher at the $p < 0.05$ level (note: $p = 0.008$) than the mean score on "there shall be an improvement in safety if there are better personal relations between workmates" ($m = 4.00$). The results also indicate that a significant correlation exists between these two variables ($r = 0.654$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.9) "there shall be an increase in productivity if supervisors discourage dangerous work habits" (m = 3.95) was significantly less at the $p < 0.001$ level than the mean score on "there shall be an improvement in safety if supervisors discourage dangerous work habits" (m = 4.14). The results indicate that a significant correlation exists between these two variables ($r = 0.519$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.10) "there shall be an increase in productivity if supervisors promotes safe work habits" (m = 3.91) was significantly less at the $p < 0.001$ level than the mean score on "there shall be an improvement in safety if supervisors promotes safe work habits" (m = 4.15). The results indicate that a significant correlation exists between these two variables ($r = 0.518$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.11) "there shall be an increase in productivity if safety inspections are intensified" (m = 3.80) was significantly less at the $p < 0.001$ level than the mean score on "there shall be an improvement in safety if safety inspections are intensified" (m = 4.08). The results indicate that a significant correlation exists between these two variables ($r = 0.475$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.12) "there shall be an increase in productivity if accident investigations are intensified" (m = 3.75) was significantly less at the $p < 0.001$ level than the mean score on "there shall be an improvement in safety if accident investigations are intensified" (m = 3.99). The results indicate that a significant correlation exists between these two variables ($r = 0.496$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.13) "there shall be an increase in productivity if there is strict adherence to the time schedule" (m = 3.85) was significantly greater at the $p < 0.001$ level than the mean score on "there shall be an improvement in safety if there is strict adherence to the time schedule" (m = 3.77). The results also indicate that a significant correlation exists between these two variables ($r = 0.580$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.14) "there shall be an increase in productivity if there is more emphasis on quality of work" (m = 3.86) was greater at the $p < 0.05$ level (note: $p = 0.025$) than the mean score on "there shall be an improvement in safety if there is more emphasis on quality of work" (m = 3.81). The results also indicate that a significant correlation exists between these two variables ($r = 0.588$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.15) "there shall be an increase in productivity if there is improvement of equipment and tools" (m = 4.09) was slightly different at the $p < 0.05$ level (note: $p = 0.05$) than the mean score on "there shall be an improvement in safety if there is improvement of equipment and tools" (m = 4.06). The results also indicate that a significant correlation exists between these two variables (r = 0.618, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.16) "there shall be an increase in productivity if there is an increase in the work pace" (m = 3.80) was significantly greater at the $p < 0.001$ level than the mean score on "there shall be an improvement in safety if there is an increase in the work pace" (m = 3.57). The results also indicate that a significant correlation exists between these two variables (r = 0.560, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.17) "there shall be an increase in productivity if longer time is allowed for work performance" (m = 3.63) did not differ significantly at the $p < 0.05$ level (note: p = 0.165) than the mean score on "there shall be an improvement in safety if longer time is allowed for work performance" (m = 3.66). The results also indicate that a significant correlation exists between these two variables (r = 0.618, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

Table 1. Variables that measured productivity and safety and correlations among them

Item		Mean (Productivity) There shall be an increase in productivity if	Mean (Safety) There shall be an improvement in safety if	T-test	Sig.	Correlation	Sig.
Q.1	More skilled labor is employed.	3.96	3.86	7.224	0.001	0.559	0.001
Q.2	Operatives have better education and experience.	4.02	4.00	0.707	0.480	0.663	0.001
Q.3	Operatives get help and advice easily	3.79	4.00	-0.199	0.840	0.679	0.001
Q.4	More time and money are available for supervising.	3.82	4.00	-8.139	0.001	0.534	0.001
Q.5	There is improvement in safety knowledge of supervisors.	3.88	4.04	-8.460	0.001	0.600	0.001
Q.6	There is better and frequent control of site	3.89	3.93	-2.071	0.039	0.591	0.001

Item		Mean (Productivity) There shall be an increase in productivity if	Mean (Safety) There shall be an improvement in safety if	T-test	Sig.	Correlation	Sig.
	tasks.						
Q.7	There is better coordination between the work groups.	4.10	4.05	2.337	0.020	0.613	0.001
Q.8	There are better personal relations between workmates.	4.05	4.00	2.640	0.008	0.654	0.001
Q.9	Supervisors discourage dangerous work habits.	3.95	4.14	-8.876	0.001	0.519	0.001
Q.10	Supervisors promotes safe work habits	3.91	4.15	-11.007	0.001	0.518	0.001
Q.11	There are intensified safety inspections.	3.80	4.08	-11.898	0.001	0.475	0.001
Q.12	There are intensified	3.75	3.99	-10.514	0.001	0.496	0.001

Item		Mean (Productivity) There shall be an increase in productivity if	Mean (Safety) There shall be an improvement in safety if	T-test	Sig.	Correlation	Sig.
	accident investigations.						
Q.13	There is strict adherence to time schedule.	3.85	3.77	3.846	0.001	0.580	0.001
Q.14	There is more emphasis on quality of work.	3.86	3.81	2.238	0.025	0.588	0.001
Q.15	There is improvement of equipment and tools.	4.09	4.06	1.959	0.050	0.618	0.001
Q.16	There is an increase in the work pace.	3.80	3.57	9.387	0.001	0.560	0.001
Q.17	Longer time is allowed for work performance.	3.63	3.66	-1.390	0.165	0.618	0.001
Q.18	There is flexibility of production plans in case	3.85	3.82	1.395	0.163	0.580	0.001

Item		Mean (Productivity) There shall be an increase in productivity if	Mean (Safety) There shall be an improvement in safety if	T-test	Sig.	Correlation	Sig.
	of unforeseen problems.						
Q.19	There are more safety measures for equipment.	3.97	4.11	-7.544	0.001	0.587	0.001
Q.20	There is improvement and more awareness of the use of equipment.	3.98	4.05	-4.943	0.001	0.791	0.001
Q.21	There is proper use of personal protective equipment (PPE).	3.88	4.05	-7.771	0.001	0.473	0.001
Q.22	There is better housekeeping.	3.97	4.04	-3.672	0.001	0.656	0.001
Q.23	Work sites are more spacious.	4.04	4.02	1.036	0.300	0.655	0.001
Q.24	There is better	3.99	3.98	0.608	0.543	0.646	0.001

Item		Mean (Productivity) There shall be an increase in productivity if	Mean (Safety) There shall be an improvement in safety if	T-test	Sig.	Correlation	Sig.
	flow of information between workers.						
Q.25	There is better flow of information about changes on-site.	3.96	3.94	1.126	0.260	0.723	0.001
Q.26	There is proper site work design for employees.	3.98	3.97	0.880	0.379	0.682	0.001
Q.27	There is no mismatch between employee abilities and job demands.	3.97	3.92	2.909	0.004	0658	0.001
Q.28	There is no adverse environment such as heat, noise, light	3.96	3.96	-0.190	0.849	0.691	0.001

Item		Mean (Productivity) There shall be an increase in productivity if	Mean (Safety) There shall be an improvement in safety if	T-test	Sig.	Correlation	Sig.
	and dust.						
Q.29	There is no high absenteeism or lost work days.	3.97	3.82	7.148	0.001	0.547	0.001
Q.30	There are no complaints of back pain, neck pain, hand or wrist pain, headache, stress and or dissatisfaction.	3.91	3.94	-1.414	0.158	0.708	0.001
Q.31	There is a hazard analysis and task analysis.	3.90	3.99	-5.216	0.001	0.660	0.001

The mean score on the factor (Q.18) “there shall be an increase in productivity if there is flexibility of production plans in case of unforeseen problems” ($m = 3.85$) did not differ significantly at the $p < 0.05$ level (note: $p = 0.165$) than the mean score on “there shall be an improvement in safety if there is flexibility of production plans in case of unforeseen problems” ($m = 3.82$). The results also indicate that a significant correlation exists between these two variables ($r = 0.580$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.
The mean score on the factor (Q.19) “there shall be an increase in productivity if there are more safety measures for equipment” ($m = 3.97$) was significantly less at the $p < 0.001$ level than the mean score on “there shall be an improvement in safety if there are more safety measures for equipment” ($m = 4.11$). The results indicate that a significant correlation exists between these two variables ($r = 0.587$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.20) “there shall be an increase in productivity if there is improvement and more awareness of the use of equipment” ($m = 3.98$) was significantly less at the $p < 0.001$ level than the mean score on “there shall be an improvement in safety if there is improvement and more awareness of the use of equipment” ($m = 4.05$). The results indicate that a significant correlation exists between these two variables ($r = 0.791$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.21) “there shall be an increase in productivity if there is proper use of personal protective equipment” ($m = 3.88$) was significantly less at the $p < 0.001$ level than the mean score on “there shall be an improvement in safety if there is proper use of personal protective equipment” ($m = 4.05$). The results indicate that a significant correlation exists between these two variables ($r = 0.473$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.22) “there shall be an increase in productivity if there is better house-keeping” ($m = 3.97$) was significantly less at the $p < 0.001$ level than the mean score on “there shall be an improvement in safety if there is better housekeeping” ($m = 4.04$). The results indicate that a significant correlation exists between these two variables ($r = 0.656$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.23) “there shall be an increase in productivity if work sites are more spacious” ($m = 4.04$) did not differ significantly at the $p < 0.05$ level (note: $p = 0.300$) from the mean score on “there shall be an improvement in safety if work sites are more spacious” ($m = 4.02$). The results also indicate that a significant correlation exists between these two variables ($r = 0.655$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.24) “there shall be an increase in productivity if there is better flow of information between workers” ($m = 3.99$) did not differ significantly at the $p < 0.05$ level (note: $p = 0.543$) from the mean score on “there shall be an improvement in safety if there is better flow of information between workers" ($m = 3.98$). The results also indicate that a significant correlation exists between these two variables ($r = 0.646$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.25) "there shall be an increase in productivity if there is better flow of information about changes on-site" ($m = 3.96$) did not differ significantly at the $p < 0.05$ level (note: $p = 0.260$) from the mean score on "there shall be an improvement in safety if there is better flow of information about changes on-site" ($m = 3.94$). The results also indicate that a significant correlation exists between these two variables ($r = 0.723$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.26) "there shall be an increase in productivity if there is proper site work design for employees" ($m = 3.98$) did not differ significantly at the $p < 0.05$ level (note: $p = 0.379$) from the mean score on "there shall be an improvement in safety if there is proper site work design for employees" ($m = 3.97$). The results also indicate that a significant correlation exists between these two variables ($r = 0.682$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.27) "there shall be an increase in productivity if there is no mismatch between employee abilities and job demands" ($m = 3.97$) was significantly greater at the $p < 0.05$ level (note: $p = 0.004$) than the mean score on "there shall be an improvement in safety if there is no mismatch between employee abilities and job demands" ($m = 3.92$). The results also indicate that a significant correlation exists between these two variables ($r = 0.658$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.28) "there shall be an increase in productivity if there is no adverse environment such as heat, noise, light and dust" ($m = 3.96$) did not differ significantly at the $p < 0.05$ level (note: $p = 0.849$) than the mean score on "there shall be an improvement in safety if there is no adverse environment such as heat, noise, light and dust" ($m = 3.96$). The results also indicate that a significant correlation exists between these two variables ($r = 0.691$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.29) "there shall be an increase in productivity if there is no high absenteeism or lost work days" ($m = 3.97$) was significantly greater at the $p < 0.001$ level than the mean score on "there shall be an improvement in safety if there is no high absenteeism or lost work days" ($m = 3.82$). The results also indicate that a significant correlation exists between these two variables ($r = 0.547$, $p < 0.001$) indicating those who score high on productivity tend to score high on safety.

The mean score on the factor (Q.30) "there shall be an increase in productivity if there are no complaints of back pain, neck pain, hand or wrist pain, headache, stress and or dissatisfaction" ($m = 3.91$) did not differ significantly at the $p < 0.05$ level (note: $p = 0.158$) from the mean score on "there shall be an improvement in safety if there are no complaints of back pain, neck pain, hand or wrist pain, headache, stress and or dissatisfaction” ($m = 3.94$). The results also indicate that a significant correlation exists between these two variables ($r = 0.708$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

The mean score on the factor (Q.31) “there shall be an increase in productivity if there is a hazard analysis and task analysis” ($m = 3.90$) was significantly less at the $p < 0.001$ level than the mean score on “there shall be an improvement in safety if there is a hazard analysis and task analysis” ($m = 3.99$). The results indicate that a significant correlation exists between these two variables ($r = 0.660$, $p < 0.001$) indicating those who score high on safety tend to score high on productivity.

From the results of the t-test, the five factors having the highest scores on providing the most improvement in productivity and safety are shown in Figure 1. For productivity, coordination between work groups and improvement of equipment and tools were rated at the highest levels. Better personal relations between workmates, more spacious work sites, and the use of more skilled labor were the next highest rates factors for improving productivity. For safety, the supervisors’ role of promoting safe work habits and discouraging dangerous work habits was rated at the highest level. Providing more safety measures for equipment, safety inspections, and improvement of equipment and tools were the next highest rated factors for improving safety. The respondents perceived that productivity and safety would increase with better coordination and with measures improving site work conditions. They perceived that it was possible to improve safety and productivity with measures that decreased work hazards. Finally, further research is planned to observe differences in the perceptions of managers, supervisors and workers and by conducting factor analysis for finding significant factors for improving both productivity and safety.

Productivity	Safety
Better coordination between the work groups	Supervisors promotes safe work habits
Improvement of equipment and tools	Supervisors discourage dangerous work habits
Better personal relations between workmates	More safety measures for equipment
More spacious work sites	Intensified safety inspections
More skilled labor	Improvement of equipment and tools

Figure 1. Measures rated as most effective for improving productivity and safety

4. CONCLUSION

While achieving the established objectives, this work determined the differences between respondents' perceptions of how the variable listed in the questionnaire would affect productivity and safety. Eleven of the fifteen statistically significant differences were in the direction of safety, and only four favored productivity. The factors stressed the actions of supervisors as a means to improve safety, as seven significant differences dealt with supervisors. These seven factors included: (1) more time and money are available for supervising, (2) improvement in safety knowledge of supervisors, (3) supervisors discourage dangerous work habits, (4) supervisors promotes safe work habits, (5) intensified safety inspections, (6) ensuring proper use of personal protective equipment, and (7) ensuring better housekeeping. The remaining four factors favoring safety were: (1) more safety measures for equipment, (2) intensified accident investigations, (3) improvement and more awareness of the use of equipment, and (4) hazard analysis and task analysis. Additionally, operatives easily getting help and advice, better and frequent control of site tasks, longer time allowed for work performance, and no adverse environment (e.g., heat, noise, light and dust) were perceived to be means with which to improve safety.

A faster work pace and strict adherence to time schedule were considered means to increase productivity; however, they were considered to have a lower influence on safety. Additionally, more skilled labor employed, operatives having better education and experience, better coordination between the work groups, better personal relations between workmates, emphasis on quality of work, flexibility of production plans in case of unforeseen problems, more spacious work sites, better flow of information between workers, better flow of information about changes on-site, proper site work design for employees, no mismatch between employee abilities and job demands, no high absenteeism or lost work days, and no adverse environment were thought to be means with which to significantly improve productivity.

Additionally, the five factors selected from the t-test providing the most improvement in productivity and safety were identified. The identified factors for productivity included better coordination between work groups, improvement of equipment and tools, better personal relations between workmates, spacious work sites, and use of more skilled labor. The five identified factors as the best means for improving safety included supervisors' promoting safe work habits, supervisors' discouraging dangerous work habits, more safety measures for equipment, safety inspections, and improvement of equipment and tools. Considering the relationship between productivity and safety, all thirty one measures were found to be significantly correlated with both improvements in productivity and safety.

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COMPETENCIES REQUIRED TO MANAGE CONSTRUCTION HEALTH AND SAFETY (H&S)

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ABSTRACT

The paper reports on an exploratory study conducted to determine the surface health and safety (H&S) competencies, namely knowledge and skills, that Site Managers, Site H&S Officers, and Client Appointed H&S Agents (CAH&SAs) require to manage construction H&S.

A postal study was conducted among a group of H&S better practice general contractors (GCs) to determine the importance of knowledge areas and skills. Eight composite knowledge areas and seven composite skills areas have been used to categorise the seventy-nine knowledge areas and fifty skills respectively. To date the study has been primarily a descriptive study.

In general the composite knowledge areas of OH&S, project administration, and design, are more important than the other five areas, and the composite skills of leadership, general management, planning, and interpersonal / developmental are more important than the other three skills.

The findings emanate from an exploratory survey, and therefore an expanded study should be conducted. However, the findings do emanate from an eminent sample stratum, and therefore provide a basis for the further research.

Construction Management programmes, which address the streams of economics, management, and science and technology, appear to be the most suitable programmes in terms of the development of the knowledge and skills required by the three occupations which are the subject of the study, particularly those which include a comprehensive subject or component in the form of H&S, and the subjects project management and theory of structures. Furthermore, a construction H&S association should be founded that promotes professionalism and leadership in construction H&S.

Keywords: Competencies, Construction, Health and Safety, Knowledge, Skills

1. INTRODUCTION

Competent is when a person is qualified to perform to a requisite standard of the processes of a job. However, competence means the condition or state of being competent – skill and standard of performance reached. Competency in turn, refers to the behaviour by which it is achieved (Singh, 2004). Therefore, competence describes what people can do whereas competency focuses on how they do it. The plural of each word indicates two different meanings. Competences refer to the range of skills, which are satisfactorily performed, while competencies refer to the behaviour adopted in competent performance.

Hogg (in Singh, 2004) elaborates on the characteristics of competencies as follows:

- Competencies are characteristics of a person;
- Competencies lead to the demonstration of skills and abilities;
- Competencies must lead to effective performance. Competency refers to behaviour, differentiating success from merely doing the job, and
- Competency embodies the capacity to transfer skills and abilities to from one area to another i.e. generic vis-à-vis functional competence.

Competencies are components of a job which are reflected in behaviours that are observable in a workplace, the common elements being (Singh, 2004):

- Knowledge;
- Skills;
- Abilities;
- Aptitudes;
- Personal suitability behaviour, and
- Impact on performance at work.

The criteria of performance are superior performance and effective performance, the issue being that only some competencies can predict performance. Thus competencies are divided into two categories (Singh, 2004):

- Surface or threshold: these are required to be minimally effective, namely knowledge and skills, and
- Core or differentiating: these distinguish superior from average performers, namely abilities, aptitudes, personal suitability behaviour, and impact on performance at work.

This paper addresses the surface H&S competencies Site Managers, Site H&S Officers, and Client Appointed H&S Agents (CAH&SAs) require to manage construction H&S. There are two reasons for the inclusion of these occupations is that Site Managers are responsible for the management of construction projects the physical construction process and activities, which includes H&S, as it is an integral aspect of the construction process and activities. During a study conducted by Smallwood (2006) H&S was ranked joint tenth out of seventy-eight subject areas at the Site Management level in terms of the mean frequency of the use of subject areas. Secondly, given the promulgation of the Construction Regulations, and the resultant occupations of H&S Officer, and CAH&SA,

the study investigated the importance of seventy-nine knowledge areas, and fifty skills relative to the occupations of Site Manager, Site H&S Officer, and CAH&SA.

2. RESEARCH

Sample stratum and methodology

Given the objectives of the study it was necessary to select a sample stratum consisting of contractors, which could be presumed to be committed to and which address H&S, and ergonomics related issues, and therefore best able to comment relative to knowledge and skills required to manage or advise regarding H&S. The sample stratum consisted of 26 general contractors (GCs), who had achieved first, second, or third positions in the Building Industries Federation South Africa (BIFSA) / Master Builders South Africa (MBSA) national H&S competition and, or BIFSA / MBSA 4 or 5-Star H&S gradings on one or more of their projects during the period 1995 to 2003 inclusive. 9 Responses were received and included in the analysis of the data, which equates to a response rate of 34.6%.

The questionnaire was based upon knowledge areas and skills included in a Practice of Construction Management study conducted by Smallwood (2006), which in turn were supplemented by further knowledge areas and skills deduced from the requirements of the Construction Regulations.

Findings

Table 1 indicates the importance of seventy-nine knowledge areas relative to the management of H&S in terms of a mean score ranging between 1.00 and 5.00, based upon percentage responses to a scale of 1 (not important) to 5 (very important) relative to the occupations Site Manager, Site H&S Officer, and CAH&SA, and a mean of the three occupations.

Eight composite knowledge areas have been used to categorise the seventy-nine knowledge areas for reasons of brevity and to enable comparisons between the occupations to be drawn: project administration; financial management; design; law; construction technology / technology; OH&S; planning, and management / management of parameters. This categorisation enabled the computation of composite knowledge area mean scores.

Although it is not readily apparent from the table due to the format, it is notable that seventy-five (94.9%) of the mean scores are above the midpoint score of 3.00, which indicates that in general the respondents can be deemed to perceive the knowledge areas as important. However, given that the mean scores for the top thirty-three (41.8%) knowledge areas are $> 4.20 \leq 5.00$, the respondents can be deemed to perceive them to be between more than important to very important / very important. Given that the mean scores for the knowledge areas ranked 34th to joint 69th (46.8%) are $> 3.40 \leq 4.20$, the respondents can be deemed to perceive them to be between important to more than important / more than important. Furthermore, the respondents can be deemed to perceive those knowledge areas ranked 71st to 79th to be between less than important to important / important – mean scores > 2.60 ≤ 3.40.

Table 1 Importance of knowledge areas relative to the management of H&S.

Knowledge area	Occupation							
	Site Manager (PC)		Site H&S Officer (PC)		Client Appointed H&S Agent		Mean	
	MS	Rank	MS	Rank	MS	Rank	MS	Rank
Project administration:								
Codes of practice / Standards	4.57	26=	4.57	12=	4.71	6=	4.62	10=
Contract administration	4.14	61=	3.71	47=	4.67	10	4.17	37
Contract documentation	4.29	53=	4.43	16=	4.29	19=	4.34	27
Professional practice	4.86	6=	4.29	21=	4.71	6=	4.62	10=
Composite	4.47	5	4.25	2	4.60	2	4.44	2
Financial management:								
Accountancy	3.57	77=	2.50	74=	3.00	72=	3.02	75
Cash flow forecasting	3.43	79	2.43	77=	3.00	72=	2.95	76=
Cost control	4.43	43=	3.14	67=	3.33	64=	3.63	65
Cost engineering	4.29	53=	3.00	69=	3.17	69=	3.49	68
Estimating	4.00	68=	2.17	79	2.67	77	2.95	76=
Financial management	4.29	53=	3.00	69=	3.00	72=	3.43	69=
Final accounts	4.14	61=	2.50	74=	2.83	75	3.16	73
Composite	4.02	8	2.68	8	3.00	8	3.23	8
Design:								
Design (Architectural)	4.57	26=	3.43	59=	4.29	19=	4.10	41
Design (Cantilever platforms)	4.71	17=	4.43	16=	4.14	28=	4.43	16=
Design (Engineering)	4.43	43=	3.50	58	3.86	40=	3.93	56
Design (Process)	4.29	53=	4.00	36=	3.86	40=	4.05	44=
Design (Influence of design on H&S)	4.43	43=	4.29	21=	4.57	11=	4.43	16=
Design (Influence of design on overall performance)	4.29	53=	4.17	31	4.43	17=	4.30	28
Design (Scaffolding)	4.86	6=	4.86	4=	4.57	11=	4.76	5=
Design (Support work)	4.86	6=	4.86	4=	4.57	11=	4.76	5=
Design (Temporary works)	4.86	6=	4.71	8=	4.29	19=	4.62	10=
Structural design	4.71	17=	4.29	21=	4.29	19=	4.43	16=
Drawing (Engineering / Geometric)	4.29	53=	3.29	62=	3.86	40=	3.81	60
Composite	4.57	4	4.17	3	4.25	3	4.33	3

Law:								
Commercial Law	4.57	26=	3.86	42=	4.00	35=	4.14	38=
Company Law	4.57	26=	3.57	55=	4.00	35=	4.05	44=
Labour Law	4.71	17=	4.14	32=	4.29	19=	4.38	23=
Composite	4.62	2	3.86	5	4.10	4	4.19	4
Construction technology / Technology:								
Information technology	4.14	61=	4.00	36=	3.86	40=	4.00	50=
Surveying (land)	4.14	61=	2.50	74=	2.20	79	2.95	76=
Materials	4.57	26=	3.57	55=	3.71	50=	3.95	54=
Mathematics	4.14	61=	3.29	62=	3.83	49	3.75	64
Measuring (quantities)	3.71	73=	2.71	72	3.17	69=	3.20	72
Methods (construction) - Building	4.86	6=	4.29	21=	4.14	28=	4.43	16=
Methods (construction) - Civil	4.86	6=	4.29	21=	4.14	28=	4.43	16=
Methods (construction) - Marine	4.67	25	3.83	46	3.67	53=	4.06	42=
Physics	4.20	60	3.60	53=	3.60	55	3.80	61
Specifications	4.71	17=	4.50	15	4.50	16	4.57	13=
Composite	4.40	7	3.66	7	3.68	6	3.91	7
OH&S:								
Environmental issues	4.43	43=	4.71	8=	4.86	2=	4.67	8=
Ergonomics (construction)	4.57	26=	4.57	12=	4.57	11=	4.57	13=
First aid	4.43	43=	4.86	4=	4.71	6=	4.67	8=
Occupational health	4.86	6=	5.00	1=	5.00	1	4.95	1
Occupational hygiene	4.86	6=	5.00	1=	4.86	2=	4.91	2=
Occupational medicine	4.14	61=	4.29	21=	4.17	24=	4.20	34
Occupational safety	4.86	6=	5.00	1=	4.86	2=	4.91	2=
Composite	4.59	3	4.78	1	4.72	1	4.70	1
Planning:								
Planning (Operational)	4.71	17=	3.86	42=	3.50	57=	4.02	47=
Planning (Programming)	4.71	17=	3.29	62=	3.50	57=	3.83	59
Planning (Strategic)	4.57	77=	3.43	59=	3.33	64=	3.78	62
Procedures	4.57	26=	4.33	61	4.17	24=	4.36	26
Composite	4.64	1	3.73	6	3.63	7	4.00	6
Management / Management of parameters:								
Benchmarking	4.50	42	3.60	53=	3.50	57=	3.87	57
Customer service	4.57	26=	4.00	36=	4.17	24=	4.25	31
Economics	3.71	73=	3.00	69=	3.14	71	3.28	71
Ethics	4.57	26=	4.14	32=	4.83	5	4.51	15
Facilities management	4.57	26=	4.29	21=	4.00	35=	4.29	29=
Human resources	4.43	43=	4.14	32=	3.57	56	4.05	44=
Industrial psychology	4.43	43=	4.43	16=	3.86	40=	4.24	32=
Industrial relations	4.43	43=	4.43	16=	3.86	40=	4.24	32=
International contracting	4.14	61=	4.14	32=	4.14	28=	4.14	38=

Management (business)	5.00	1=	3.71	47=	3.86	40=	4.19	35=
Marketing	3.71	73=	3.29	62=	3.67	53=	3.56	67
Materials management	4.71	17=	3.71	47=	3.50	57=	3.97	53
Negotiating	4.57	26=	3.86	42=	4.00	35=	4.14	38=
Plant and equipment management	4.86	6=	3.71	47=	3.50	57=	4.02	47=
Procurement	4.57	26=	3.67	52	3.33	64=	3.86	58
Productivity	4.86	6=	3.86	42=	3.29	67=	4.00	50=
Project management	4.57	26=	3.33	61	4.14	28=	4.01	49
Public relations	4.29	53=	3.57	55=	4.14	28=	4.00	50=
Purchasing	4.00	68=	2.43	77=	2.33	78	2.92	79
Quality management	4.57	26=	4.29	21=	4.00	35=	4.29	29=
Re-engineering	4.43	43=	3.14	67=	3.29	67=	3.62	66
Remuneration	3.71	73=	2.67	73	2.75	76	3.04	74
Research	3.57	77=	3.29	62=	3.43	63	3.43	69=
Risk management	5.00	1=	4.86	4=	4.71	6=	4.86	4
Service management	4.43	43=	4.00	36=	4.14	28=	4.19	35=
Sociology	3.86	72	3.71	47=	3.71	50=	3.76	63
Statistics	4.00	68=	4.00	36=	4.17	24=	4.06	42=
Subcontractor management	5.00	1=	4.29	21=	3.86	40=	4.38	23=
Total Quality Management	5.00	1=	4.57	12=	4.57	11=	4.71	7
Training	4.71	17=	4.71	8=	3.71	50=	4.38	23=
Value management	4.57	26=	4.29	21=	4.43	17=	4.43	16=
Worker participation	5.00	1=	4.71	8=	3.50	57=	4.40	22
Work study	4.00	68=	4.00	36=	3.86	40=	3.95	54=
Composite	4.43	6	3.87	4	3.79	5	4.03	5

Table 2 indicates the importance of the eight composite knowledge areas relative to the management of H&S in terms of a mean score ranging between 1.00 and 5.00, relative to the occupations of Site Manager, Site H&S Officer, and CAH&SA, and the mean of the three occupations.

It is notable that with the exception of financial management relative to the occupations of Site H&S Officer, and CAH&SA, all the mean scores are above the midpoint score of 3.00, which indicates that in general the composite knowledge areas can be deemed to be important.

In terms of the mean, OH&S predominates followed by project administration, and design. These are followed by a 'group' consisting of construction technology / technology, management / management of parameters, planning, and law, the absolute difference between fourth ranked construction technology / technology and seventh ranked law being 0.11. Financial management is ranked eighth.
In terms of Site Manager, planning, law, OH&S, design, project administration, management / management of parameters, and construction technology / technology predominate, followed by financial management, ranked eighth.

In terms of Site H&S Officer, OH&S predominates followed by project administration, design, management / management of parameters, law, planning, and construction technology / technology. There is an absolute difference of 0.98 between construction technology / technology and eighth ranked financial management.

In terms of CAH&SA, OH&S and project administration predominate, followed by design, law, management / management of parameters, construction technology / technology, and planning. There is an absolute difference of 0.63 between planning and eighth ranked financial management.

To summarise, in general the composite knowledge areas of OH&S, project administration, and design, are more important than the other areas.

Table 2 Importance of composite knowledge areas relative to the management of H&S.

Composite knowledge area	**Occupation**							
	Site Manager (PC)		**Site H&S Officer (PC)**		**Client Appointed H&S Agent**		**Mean**	
	MS	**Rank**	**MS**	**Rank**	**MS**	**Rank**	**MS**	**Rank**
Project administration	4.47	5	4.25	2	4.60	2	4.44	2
Financial management	4.02	8	2.68	8	3.00	8	3.23	8
Design	4.57	4	4.17	3	4.25	3	4.33	3
Law	4.62	2	3.86	5	4.10	4	4.10	4
Construction technology / Technology	4.40	7	3.66	7	3.68	6	3.91	7
OH&S	4.59	3	4.78	1	4.72	1	4.70	1
Planning	4.64	1	3.73	6	3.63	7	4.00	6
Management / Management of parameters	4.43	6	3.87	4	3.79	5	4.03	5
Occupation	4.47	1	3.88	3	3.97	2	4.09	

Table 3 indicates the importance of fifty skills relative to the management of H&S in terms of a mean score ranging between 1.00 and 5.00, based upon percentage responses to a scale of 1 (not important) to 5 (very important) in terms of the occupations Site Manager, Site H&S Officer, and CAH&SA, and a mean of the three occupations.

Seven composite skills areas have been used to categorise the fifty skills for reasons of brevity and to enable comparisons to be drawn between the occupations: interpersonal / development; general management; financial; leadership; negotiating; planning, and technical.

Although it is not readily apparent from the table due to the format, it is notable that all the mean scores are above the midpoint score of 3.00, which indicates that in general the respondents can be deemed to perceive the skills as important. However, given that the mean scores for the top twenty-two (44%) skills are > 4.20 ≤ 5.00, the respondents can be deemed to perceive them to be between more than important to very important / very important. Given that the mean scores for the skills ranked twenty-third to fourty-ninth (48%) are > 3.40 ≤ 4.20, the respondents can be deemed to perceive them to be between important to more than important / more than important. Furthermore, the respondents can be deemed to perceive the skill ranked fiftieth to be between less than important to important / important – a mean score > 2.60 ≤ 3.40.

Table 3 Importance of skills relative to the management of H&S.

Skill	**Occupation**							
	Site Manager (PC)		**Site H&S Officer (PC)**		**Client Appointed H&S Agent**		**Mean**	
	MS	**Rank**	**MS**	**Rank**	**MS**	**Rank**	**MS**	**Rank**
Interpersonal / Developmental:								
Communicating (Graphic)	4.00	40=	4.57	7=	4.29	8	4.29	15
Communicating (Oral)	4.43	23=	4.57	7=	4.43	6	4.48	4
Communicating (Written)	4.57	13=	4.57	7=	4.57	3=	4.57	2
Conceptual	4.14	32=	4.43	16=	4.20	9	4.26	17
Conflict resolution	4.57	13=	4.14	24=	4.33	7	4.35	13
Creative	4.00	40=	3.71	40=	3.00	45=	3.57	44
Initiating	4.80	6	4.17	23	3.40	36	4.12	25=
Interpersonal	4.57	13=	4.14	24=	4.00	15=	4.24	19=
Intuitive	4.33	29	3.67	42	3.60	30=	3.87	37
Social	4.00	40=	3.83	39	4.00	15=	3.94	36
Team building	4.86	1=	4.43	16=	4.00	15=	4.43	6=
Training	4.57	13=	4.57	7=	3.67	26=	4.27	16
Composite	4.40	4	4.23	4	3.96	1	4.20	4
General management:								
Administrative	4.14	32=	4.71	2=	4.71	1=	4.52	3
Controlling	4.43	23=	4.14	24=	4.17	10=	4.25	18
Coordinating	4.71	7=	4.29	18=	4.17	10=	4.39	9
Organising	4.57	13=	4.29	18=	3.14	42=	4.00	30=
Supervisory	4.71	7=	4.14	24=	3.50	34=	4.12	25=
Systems development	4.43	23=	4.29	18=	4.00	15=	4.24	19=
Composite	4.50	3	4.31	2	3.95	2	4.25	2
Financial:								
Costing	4.14	32=	3.43	44=	3.33	37=	3.63	43
Estimating	4.14	32=	3.00	48	3.33	37=	3.49	46
Financial	4.29	30=	3.14	46=	3.17	41	3.53	45

Composite	4.19	6	3.19	7	3.28	6	3.55	7
Leadership:								
Decision making	4.71	7=	4.14	24=	3.83	24=	4.23	22
Leadership	4.86	1=	4.29	18=	4.00	15=	4.38	10=
Motivating	4.57	13=	4.71	40=	4.00	15=	4.43	6=
Composite	4.71	1	4.38	1	3.94	3	4.35	1

Negotiating:								
Negotiating with clients	4.43	23=	4.29	18=	3.57	32=	4.10	27
Negotiating with material manufacturers	4.00	40=	3.86	34=	2.57	49=	3.48	47=
Negotiating with material suppliers	4.00	40=	3.86	34=	2.57	49=	3.48	47=
Negotiating with plant hire organisations	4.14	32=	4.14	24=	2.86	47	3.71	39=
Negotiating with subcontractors	4.71	7=	4.57	7=	3.14	42=	4.14	23
Negotiating with unions	4.57	13=	4.57	7=	3.14	42=	4.09	28
Negotiating with workers	4.86	1=	4.57	7=	3.29	39=	4.24	19=
Composite	4.39	5	4.27	3	3.02	7	3.89	6
Planning:								
Planning (Forecasting e.g. labour, weather)	4.57	13=	3.57	43	3.00	45=	3.71	39=
Planning (Programming)	4.86	1=	3.43	44=	3.60	30=	3.96	33=
Planning (Preparing generic method statements)	4.57	13=	4.71	2=	4.14	14	4.47	5
Planning (Preparing H&S method statements)	4.86	1=	4.86	1	4.57	3=	4.76	1
Planning (Preparing Site Layouts)	4.43	23=	3.86	34=	3.57	32=	3.95	35
Procedures development	4.43	23=	4.71	2=	4.00	15=	4.38	10=
Composite	4.62	2	4.19	5	3.81	5	4.21	3
Technical:								
Auditing	3.57	49	4.71	2=	4.71	1=	4.33	14
Computer	3.29	50	4.00	31=	4.17	10=	3.82	38
Design (support / formwork)	4.57	13=	4.57	7=	4.00	15=	4.38	10=
Measuring productivity	4.29	30=	3.14	46=	3.67	26=	3.70	41
Measuring quantities	4.14	32=	2.71	50	3.50	34=	3.45	49
Numerical (maths)	4.00	40=	3.71	40=	3.29	39=	3.67	42
Plan reading	4.71	7=	3.86	34=	3.67	26=	4.08	29
Report writing	4.14	32=	4.57	7=	4.57	3=	4.43	6=
Research	3.71	48	4.00	31=	4.17	10=	3.96	33=
Statistical	4.14	32=	4.14	24=	3.67	26=	3.98	32
Surveying (land)	3.86	47	2.86	49	2.67	48	3.13	50
Technical	4.71	7=	3.86	34=	3.83	24=	4.13	24

Work study	4.00	40=	4.00	31=	4.00	15=	4.00	30=
Composite	4.09	7	3.86	6	3.84	4	3.93	5

Table 4 indicates the importance of the seven composite skills relative to the management of H&S in terms of a mean score ranging between 1.00 and 5.00, relative to the occupations of Site Manager, Site H&S Officer, and
CAH&SA, and the mean of the three occupations.

It is notable that all the mean scores are above the midpoint score of 3.00, which indicates that in general the composite skills can be deemed to be important.

In terms of the mean, leadership, general management, planning, interpersonal / developmental predominate, followed by technical, negotiating, and financial.
In terms of Site Manager, leadership, planning, general management, interpersonal / developmental, and negotiating predominate, followed by financial and technical.
In terms of Site H&S Officer, leadership, general management, negotiating, interpersonal / development, and planning predominate, followed by technical and financial. There is an absolute difference of 0.67 between sixth ranked technical and seventh ranked financial.

In terms of CAH&SA, interpersonal / developmental, general management, leadership, technical, and planning predominate followed by financial and negotiating. There is an absolute difference of 0.79 between fifth ranked planning and seventh ranked negotiating.

To summarise, in general the composite skills of leadership, general management, planning, and interpersonal / developmental are more important than the other skills.

Table 4 Importance of composite skills relative to the management of H&S.

Composite skill	**Occupation**							
	Site Manager (PC)		**Site H&S Officer (PC)**		**Client Appointed H&S Agent**		**Mean**	
	MS	**Rank**	**MS**	**Rank**	**MS**	**Rank**	**MS**	**Rank**
Interpersonal / Developmental	4.40	4	4.23	4	3.96	1	4.20	4
General management	4.50	3	4.31	2	3.95	2	4.25	2
Financial	4.19	6	3.19	7	3.28	6	3.55	7
Leadership	4.71	1	4.38	1	3.94	3	4.35	1
Negotiating	4.39	5	4.27	3	3.02	7	3.89	6
Planning	4.62	2	4.19	5	3.81	5	4.21	3
Technical	4.09	7	3.86	6	3.84	4	3.93	5
Mean	4.41	1	4.06	2	3.69	3	4.06	

Table 5 indicates the degree of concurrence with a range of statements relative to the management of H&S in terms of percentage responses to a scale strongly disagree to strongly agree, and a mean score ranging between 1.00 and 5.00. In summary, respondents concur that H&S is an integral part of construction management, construction, and all activities, and that H&S is a line function and that site management take ownership of H&S. Furthermore, although 'H&S can be consulted into the construction process' it is merely sound construction management. There is also concurrence that in order to manage H&S, knowledge of design, the design process, procurement, construction, and the construction process is required.

Table 5 Extent of concurrence with statements.

Statement	**Response (%)**					**MS**
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	
H&S should be an integral part of all activities	0.0	0.0	0.0	0.0	100.0	5.00
H&S should be an integral part of construction	0.0	0.0	0.0	0.0	100.0	5.00
H&S should be an integral part of construction management	0.0	0.0	0.0	0.0	100.0	5.00
Site management should take ownership of H&S	0.0	0.0	0.0	0.0	100.0	5.00
H&S should be a line function	0.0	0.0	14.3	0.0	85.7	4.71
H&S can be 'consulted into the construction process'	0.0	0.0	0.0	28.6	57.1	4.67
In order to manage H&S requires knowledge of construction	0.0	0.0	0.0	57.1	42.9	4.43
In order to manage H&S requires knowledge of the construction process	0.0	0.0	0.0	0.0	28.6	4.29
H&S is merely sound construction management	0.0	16.7	0.0	33.3	50.0	4.17
In order to manage H&S requires knowledge of design	0.0	0.0	14.3	71.4	14.3	4.00
In order to manage H&S requires knowledge of the design process	0.0	0.0	28.6	57.1	14.3	3.86
In order to manage H&S requires knowledge of procurement	0.0	0.0	28.6	57.1	14.3	3.86

3. CONCLUSIONS

In general the composite knowledge areas of OH&S, project administration, design, are more important than the other areas. However, knowledge relative to the other areas, namely financial management, law, construction technology / technology, planning, and management / management of parameters, is also important.

In general the composite skills of leadership, general management, planning, and interpersonal / developmental are more important than the other skills. However, the other skills, namely financial, negotiating, and technical are also important.

The importance of the composite knowledge areas, the incumbent knowledge areas, the composite skills, and incumbent skills, has implications in terms of the acquisition of underpinning knowledge in built environment technology, design, construction management, and OH&S. The acquisition of the underpinning knowledge in turn has implications in terms of suitable tertiary education programmes. Construction Management programmes, which address the streams of economics, management, and science and technology, appear to be the most suitable programmes, particularly those which include a comprehensive subject or component in the form of OH&S, and the subjects project management and theory of structures. The subject project management being important due to the knowledge required relative to the management of design and / or design delivery, and the subject theory of structures being important due to the knowledge required relative to the design of temporary works.

Given the potential of the research, namely the informing regarding criteria for registration of H&S practitioners, and the development of courses and programs, then a more in depth study addressing a larger sample stratum, should be conducted. However, this recommendation does not detract from the relevance of the findings emanating from the exploratory phase of the study. The reason being that they emanate from contractors, which could be presumed to be committed to and which address H&S, and ergonomics related issues, and therefore best able to comment relative to knowledge and skills required to manage or advise regarding H&S.

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TRAINING

5

SAFETY AND HEALTH TRAINING FOR DEMOLITION AND RECONSTRUCTION ACTIVITIES

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ABSTRACT

In the fall semester of 2005, the Department of Building Construction Management at Purdue University offered the first course in Demolition and Reconstruction Management. This first college level course, offered in the newly created demolition and reconstruction management degree specialization, mirrors many of the general requirements of a traditional construction management (CM) curriculum. These include coverage of construction science, planning, regulation, estimating, safety, project management, and business management as they apply to projects that do not begin with a vacant site and a blank sheet of paper. During course development it became apparent that demolition and reconstruction activities present specialized safety considerations due to the high risk of accidents, injury, and potentially deleterious health effects presented by these activities. As contractors participate with increasing frequency in projects that involve existing built environments, there is a growing need for expansion of safety training provided to the traditional CM student. This paper examines areas of demolition and reconstruction related safety training that should be considered for inclusion in all CM programs.

Keywords: Demolition, Reconstruction, Hazardous Material, Infection-Control

1. INTRODUCTION

Construction management education in the United States during the twentieth century was fundamentally concerned with new work. This concentration was a logical response to the needs of the industry since the majority of work involved vacant sites and all new construction. In recent years, the construction organizations serving on Purdue University's Department of Building Construction Management's Construction Advisory Council have reported increasing activity that involves work on existing structures or infrastructure.

As the built environment within the United States ages, it is anticipated that opportunities in demolition and reconstruction will continue to expand. In a recent survey of owners responsible for facility construction and maintenance, FMI, a management consulting and investment banking firm to the building and construction industry, and the Construction Management Association of America (CMAA) outlined a set of seven challenges they believe will cause construction markets to change direction in the near future. The first challenge outlined indicated that "Aging infrastructure in nearly every market segment is at or beyond its current useful life…represent(ing) trillions of dollars in necessary spending over the next 10 to 20 years to upgrade and replace these assets" (D'Agostino et al., 2007). These asset upgrades include change in use, upgrade of mechanical or electrical systems, restoration of deteriorated building envelopes, repair of structural damage (or preventative upgrade such as seismic modifications), renovations to reduce serviceability problems, changes to satisfy government mandates, repair of original construction, and corrections to previous renovation errors.

The demolition industry through the National Demolition Association (NDA) has also expressed a desire to attract a college educated workforce and to advance professionalism within the demolition industry. It is believed that many misconceptions about the activities of demolition contractors are held by the general public, general contractors, and young construction management professionals. The most frequently cited misconceptions include the belief that demolition contractors primarily "blow-up" buildings, recycle very little, operate unsophisticated businesses, and can successfully complete demolition activities with little knowledge or experience (National Demolition Association, 2007). As a result, the National Demolition Association perceived a need for university construction management programs that include demolition in the undergraduate curriculum. The board of directors of the NDA has expressed a need for courses that will help the general contractors and construction managers of the future better manage the demolition process in addition to providing students with a background appropriate for employment in the demolition industry.

Through the encouragement of the National Demolition Association and the perceived need for an educational offering that includes the special requirements of reconstruction activities of all types, Purdue University has begun the development of a specialization in demolition and reconstruction management. During the development of the first course offerings in this specialization it became apparent that many safety and health issues in demolition and reconstruction should be presented. Some of the most prevalent of these concerns will be discussed in this paper for consideration as important topics for inclusion in all CM safety training.

2. DEMOLITION AND RECONSTRUCTION SAFETY

A brief description of demolition and reconstruction safety and health practices not commonly presented in collegiate CM programs follows.

Pre-job Planning and Hazard Identification

An engineering survey conducted by a qualified person is required by OSHA regulation (Occupational and Safety Administration, 2007). This survey allows the demolition contractor to fully evaluate the project, become aware of potential hazards, examine public and employee safety issues, and to collect data for planning the methods and materials to complete the job. Issues such as bracing and shoring, the need for temporary protective structures, dealing with environmental hazards and disposal, utility disconnects, fire protection, first aid services, and project site access are examined in detail during this survey. To appropriately manage the health and safety of their projects, construction managers charged with oversight of demolition activity as part of an overall construction project would be advised to obtain a copy of the demolition contractor's engineering survey and have a working knowledge of checklists used to perform similar surveys.

Handling of Hazardous Material

One of the most expansive sections of the OSHA safety and health standards deals with the handling of hazardous materials (Occupational and Safety Administration, 2007). The U.S. Environmental Protection Agency (EPA) also has comprehensive regulatory oversight of potentially hazardous materials encountered in demolition and reconstruction activities. Some of the most commonly encountered hazards are asbestos, lead, and Polychlorinated Biphenyls (PCB).

Asbestos Safety. Asbestos has been used extensively in construction. As a result, it is quite likely that it will be encountered during demolition and reconstruction activity. Because of the high potential for damage to the health of employees and the general public when asbestos becomes airborne, handling of this material is broadly regulated (Environmental Protection Agency, 1990). Construction managers should be knowledgeable of the regulations, planning requirements, protective practices, and required disposal procedures for asbestos.

Lead Safety. Lead is well known for use in plumbing and paint materials, but is also present in a wide variety of metal alloys encountered in the built environment. Lead is a material that is toxic to the human body and has significant impacts on the nervous system. Lead accumulates in the body, so exposure to even small quantities of lead through inhalation or ingestion will present acute effects through the cumulative effect of constant exposure. Employees should be monitored to assure that their exposure is below OSHA limits. Construction managers should be aware of appropriate work practices to minimize lead exposure, and have sufficient knowledge to monitor the use of personal protective equipment and hygiene practices to prevent lead poisoning.

PCB Safety. PCBs, used in the manufacture of many transformers and capacitors, have been determined to be a potent carcinogen. Although production of PCBs has been banned since 1979, the material is still in service in transformers and capacitors throughout the United States. The material is a potential health hazard to employees involved in demolition and reconstruction. In addition, it is a significant environmental hazard in that spills of PCB-based materials do not break down into harmless materials in the environment. Construction managers should be aware of these hazards and should have knowledge of proper handing and disposal of items containing PCBs.

Hazard Communication. Construction managers need to be aware of the unique material hazards present in demolition. In addition to assuring that the firms engaged in demolition activity on their projects have an appropriate hazard communication program, construction managers need to include these hazards in their own hazard communication program to inform all workers in the vicinity of demolition work of the potential for contact with hazardous material.

Personal Protective Equipment

Although personal protective equipment is not unique to demolition and construction, the nature of the work requires some specialized knowledge to assure proper equipment selection and use. The extensive use of torch cutting requires both proper eye protection and respiratory protection. The release of lead fumes when torch cutting painted steel requires proper respirator selection, medical evaluation of workers who use the respirators, and a respirator maintenance program. Fall protection equipment selection, use, and maintenance are also important components for construction manager knowledge since demolition and reconstruction activity frequently exposes workers to unique height risks. Safety nets, retractable lanyards, full body harnesses, and specialized anchoring systems may be required in addition to provisions for guard rails or other barrier type fall protection.

Safe Use of Hand Tools

Demolition and reconstruction frequently involves a form of material reuse called soft-stripping or non-structural deconstruction. Soft-stripping refers to the removal of specific building components that are determined to have a significant resale value. These components are removed prior to the demolition of the structure (Dept. of Housing and Urban Development, 2000). Common hand tools and manual labor are required for the removal and refurbishment of these materials. These tools are frequently used in a “forceful” manner, have sharp or abrasive surfaces, and are capable to significant human harm. Care must be taken to avoid the assumption that everyone knows how to use these tools. Construction managers should be able to select appropriate tools for the job, know how to use the tools in a safe manner, and assure that the tools are stored and maintained properly.

Safe Blasting Procedures

Although blasting is actually used in a rather small percentage of demolitions (National Demolition Association, 2007), explosives when used require careful planning, preparation, transportation, storage, and disposal. Safe blasting procedures are covered by a relatively large group of OSHA standards (Occupational and Safety Administration, 2007).

Safety When Working in Confined Spaces

Confined spaces in demolition and reconstruction include storage tanks, vaults, silos, utility tunnels, and vessels where natural movement is restricted, access is limited, and air supply may be limited. In addition, these confined spaces may present flammable, toxic, corrosive, or irritating work environments. Construction managers must be aware of these hazards and appropriate communications, ventilation, monitoring, and rescue planning procedures for work in confined spaces.

Safe Demolition of Pre-Stressed and Post-Tensioned Concrete

Many modern reinforced concrete structures utilize steel reinforcement placed under tension either during the placement of concrete or immediately after concrete placement. These pre-stressed or post-tensioned structures are now reaching an age where demolition may be required. Since the steel reinforcement is in tension at all times, the demolition process presents the potential for the release of violent or explosive forces. Construction managers should be aware of the potential for this potential forceful release of tension and must assure that appropriate engineering advice and planning is obtained prior to demolition of pre-stressed or post-tensioned concrete.

Debris Removal and Falling Debris

Removal of debris is a major component of demolition. The large quantity of material that must be moved from upper floors to the ground level presents the potential for impact damage to structures from falling debris, generation of potentially hazardous dust, danger to workers below debris removal activity from falling items, potentially unsafe cutting of floor openings for debris drop locations, and the improper use of debris chutes. OSHA regulations for demolition provide some guidance for construction managers in oversight of demolition debris removal operations (Occupational and Safety Administration, 2007).

Competent Person

OSHA regulation requires that a competent person continuously inspect the progress of a demolition project to detect potential hazards from weakened structures, inadequate shoring, lack of bracing, or other hazards from unexpected conditions (Occupational and Safety Administration, 2007). Since no employee should be allowed to work while an unsafe condition exists, construction managers should be aware of the authorized competent person and recognize that the designated competent person can and will stop work in the event they judge an unsafe condition to exist.

3. DEMOLITION AND RECONSTRUCTION PUBLIC HEALTH HAZARDS

Demolition and reconstruction activities have a high potential for impact on the health of the general public. These activities are commonly conducted in close proximity to occupied spaces, often in high-density urban settings. Consequently, the public is likely to be exposed to an assortment of dust and debris that results from the dismantling processes. Both airborne and waterborne contaminants released by demolition or reconstruction dismantling have the potential to expose large populations to significant health hazard.

Demolition and reconstruction also produces a significant quantity of debris. Handling and disposal of this debris have the potential to impose both short-term public health exposure and long-term environmental pollution. The following discussion presents a brief description of some of the public health hazards of demolition and reconstruction that construction managers should be aware of.

Dust Exposure

Dust is generated in large quantities during demolition activities. In most cases, dust control is provided by wetting down affected areas with a fire hose. This is an effective method for minimizing the nuisance of dust exposure for surrounding properties in most situations. Unfortunately some situations can expose special populations, such as the elderly and individuals with compromised immune systems, to health hazards that require greater care.

Figure 1 – Water Droplet Dust Control

Histoplasmosis is an infectious disease related to dust control. The disease is caused by spores of a fungus and can create a chronic lung disease that resembles tuberculosis. Although the disease is not contagious and cannot be transmitted from person to person, the spores are frequently found in areas frequented by birds and bats in buildings. Inhaled dust generated by demolition or reconstruction activity can become a vehicle for the transmission of the spores. Demolition workers should exercise care when working around bird or bat droppings. Individuals (especially children) with compromised immune systems are more susceptible to infection, making dust control activity in and around healthcare and childcare facilities of critical importance (Lenhart, et al., 2004). Figure 1 shows the use of dust control equipment that breaks the flow of water into small droplets, better able to capture dust particles and bring them safely to the surface of the ground. Nevertheless, on windy days the competent person assigned to site safety monitoring may need to discontinue operations until the wind subsides and dust control measures can be effective.

Inadvertent exposures to environmental pathogens such as aspergillus and legionella or airborne pathogens including mycobacterium tuberculosis and varicella-zoster virus can result from dust transfer during demolition and reconstruction activities in occupied health care facilities. Environmental infection-control strategies and airflow controls can effectively prevent these infections. After performing an infection control risk assessment (ICRA), the multi-disciplinary team formed to manage infection control during the construction activity creates a proactive plan of action. Infection-control measures typically include creating a negative air pressure condition within the spaces with undergoing demolition or construction activities (Figure 2) to prevent contaminated air from leaving these spaces through uncontrolled ventilation. Air removal from the construction areas is through HEPA filtration, preferably exhausted to the exterior (Sehulster & Chinn, 2003).

Figure 2 – Negative Air Pressure HEPA Filter

In addition to creating and monitoring negative air pressure in the construction zone, the infection-control plan will require extensive containment procedures. Containment procedures include sealing all connections with the ventilation system (Figure 3), installation of dust control partitions of either hard walls or plastic film barriers (Figure

4), controlled access to and from the construction area, and limitations on construction traffic through unaffected portions of the building.

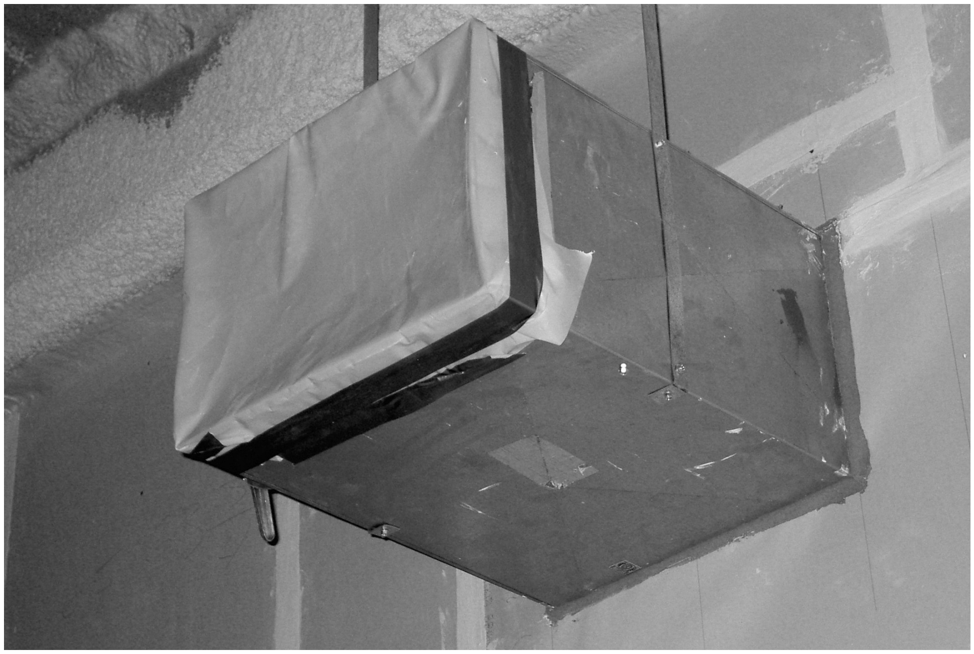

Figure 3 – Sealed Ductwork

Figure 4 – Dust Barrier at Door

Construction activities within a healthcare facility that are limited to a small area may not be confined by partitions that allow large zones of negative air pressure to be created. In these situations it is necessary to enclose a limited space utilizing a containment cart

(Figure 5) or plastic film barriers and a HEPA vacuum to create a limited area of negative pressure. These temporary containments can be installed for work requiring as little as an hour or two of construction or repair.

The examples given here demonstrate the need for dust control for infection-control purposes in conditions where severe public health conditions exist and enforcement is common within the facility. It is strongly suggested that similar dust control measures should be considered for any demolition or reconstruction activity within or adjacent to an occupied space. Not only would adoption of these measures prevent the spread of dust borne contaminants, but would minimize the nuisance and disruption created for the occupants.

Figure 5 – Containment Cart

Debris Disposal

A 1996 estimate concluded that the waste generated by demolition and renovation activities make up 92% of all construction and demolition waste generated in the United States. This represents 124,700,000 tons of debris generated (excluding waste resulting from roadway, bridge, and land clearing operations) or about 2.6 pounds per capita per day (Environmental Protection Agency, 1998). On the assumption that these materials are benign and present little in the way of hazardous material that can be leached into surrounding groundwater, a large quantity of this waste is disposed of in landfills that accept only construction and demolition (C&D) waste with minimal protection for the surrounding groundwater. Unfortunately products do exist in the demolition waste stream that contains small quantities of material which are hazardous to public health. These materials, when concentrated in a landfill, create a potential for environmental contamination through leaching of the hazards into the groundwater.

Listed below are some of the common products, along with the related hazardous material found in these products, which should be removed from the C&D waste stream through diversion to appropriate recycling programs or properly disposed of in a hazardous waste site:

- Fluorescent Light Bulbs – Mercury
- High Intensity Discharge Lamps – Mercury
- Thermostats - Mercury
- Silent Switches – Mercury
- Lighting Ballasts – PCBs, DHP, & DEHP
- Batteries – Lead, Mercury, & Cadmium
- Flashing & Pipes – Lead
- Treated Wood – Arsenic
- Refrigerants – CFCs
- Smoke Detectors – Radioactive Materials

Although the quantity of debris resulting from demolition activity that is diverted from landfills through recycling has been increasing, a recent survey of demolition contractors (Figure 6) shows that a large percentage of some demolition debris continues to be disposed of in a manner that has the potential to contaminate groundwater surrounding C&D landfills (Shaurette, 2006). One of these materials is wood. Although raw wood products do not contain hazardous material, contaminated wood (exposed to industrial contaminants or oils) and treated wood need greater scrutiny before disposal in a C&D landfill. A recent study of unlined C&D landfills in Florida confirmed that groundwater sampled from the soil surrounding 21 C&D landfills containing CCA-treated wood and CCA-treated wood ash exceeded the 5 mg/L regulatory level for total arsenic leaching. The authors concluded that CCA-treated wood and CCA-treated wood ash should be classified as a hazardous waste (Solo-Gabriele, et al., 2004).

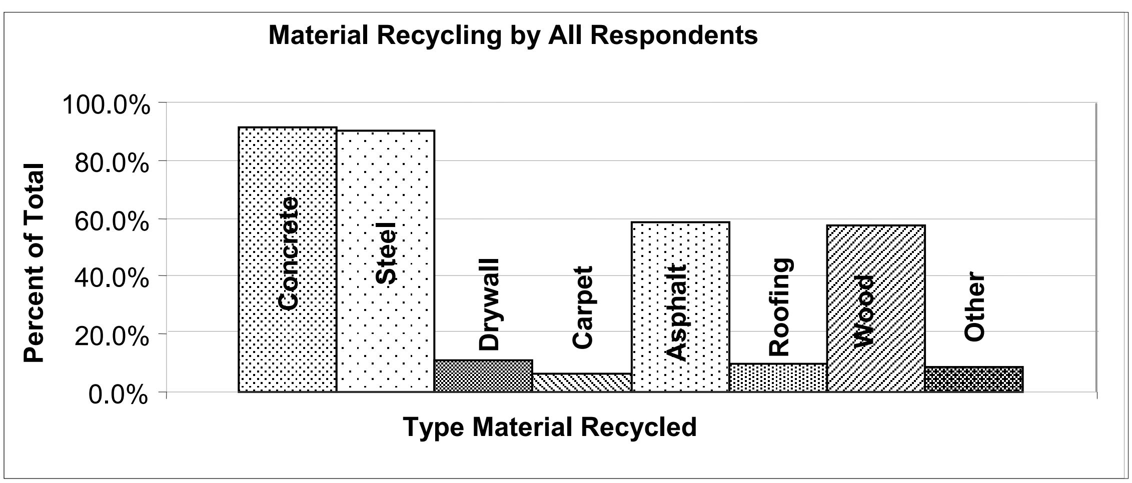

Figure 6 – Demolition Recycling Survey Results

4. INDUSTRY PARTICIPATION IN DEMOLITION SAFETY STANDARDS AND PRACTICE

Through the work of the membership and board of directors of NDA, the demolition industry has been proactive in the development and dissemination of health and safety training material. In May of 2005, NDA established an alliance with the U.S. Occupational and Safety Administration (OSHA) to jointly develop health and safety curricula, achieve outreach to the industry, and promote a national dialogue within the industry through forums, meetings and case studies. In October of 2007 NDA held its 13th Annual Safety/Management Training Summit, featuring a Demolition-Specific OSHA 10-Hour Training Certification (Clements, 2007).

NDA health and safety publications include, the *Demolition Safety Manual, Hazard Communications Program, Demolition Talks, Lead Safety in Construction, Lead in Demolition Work an Employer (Employee) Manual, Demolition Preparatory Operations, Skid Steer Safety Tips, Site Specific Safety Plan Guidelines,* as well as checklists for safety meetings, job-site safety hazard assessment, competent person designation, utility disconnect survey and follow-up. Safety videos are also available from NDA for general demolition safety training, lead safety awareness, and safe skid steer operation.

International recognition of the need for health and safety training for demolition is born out in a publication promoting safety training for young workers by the European Agency for Safety and Health at Work, a tripartite organization of European Union governments, employers, and workers representatives organized to promote occupational health and safety. One of the 25 practical examples selected from entries in the 7th annual Good Practice competition to support the dissemination of good practice information in workplaces in the twenty-seven Member States dealt with demolition safety (Kotzabasi, M., 2006).

5. CONCLUSION

With the aging of the build environment in the United States, demolition and reconstruction activity will continue to grow. As a result, a greater percentage of construction professionals will include theses activities as construction services they provide. Since demolition and reconstruction activities have unique safety and public health impacts, it is important that current construction management graduates have some exposure to safety practices and appropriate planning procedures required to protect both employees and the general public during demolition and reconstruction. The temptation exists to assume that new construction and reconstruction share sufficient materials and methods to treat them as synonymous in the educational environment. Much of the skill set required to perform the new work required in reconstruction is the same as new construction, nevertheless; the existence of hazardous materials, selective demolition work, frequent close proximity of other structures, and need to work in partially occupied spaces all demand additional safety and public health planning and implementation when dealing with demolition and reconstruction.

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ESTABLISHING GOALS FOR CONSTRUCTION SAFETY AND HEALTH TRAINING AND EDUCATION IN SUPPORT OF A NATIONAL OCCUPATIONAL RESEARCH AGENDA

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ABSTRACT

In 2006, the U.S. National Institute for Occupational Safety and Health (NIOSH) formed a Construction Sector Council to determine safety and health priorities in support of a National Occupational Research Agenda (NORA). The NORA Construction Sector Council is comprised of invited stakeholders and subject matter experts from government, academia, industry groups, organized labor, and private consulting. Through the council, priority topic areas were identified using a process of face-to-face discussions and multi-voting processes. Among eight topic areas identified, training issues were determined to be a priority area. A core Training Issues workgroup was formed and additional corresponding members were recruited based on expertise and interest throughout 2007. The mission of the workgroup has been to assess training needs, resources, and tools to address occupational safety and health hazards in the construction industry. The activities of the Training Issues workgroup have led to development of goals targeting gaps in current training and the resources which can best be applied to address them. Details of the resulting draft goals framework are presented, focusing on barriers as well as best practices and strategies for developing and delivering effective training and guidance to prevent illness and injury for construction workers.

Keywords: Construction, Education, Health, Research, Safety, Training

1. INTRODUCTION

Training is recognized as a key factor for addressing and preventing hazards in construction; yet, to be meaningful, training must be considered in the context of a comprehensive safety and health program that includes management commitment, employee participation, hazard identification and abatement, and program evaluation as well as the training program itself.

Challenges related to training include quality of training available, frequency of training, audience specific training materials (language and literacy-appropriate resources, trade or activity specific training), and evaluation of effectiveness (e.g., ability to evaluate the influence of training on safety behavior and culture versus teaching knowledge and skills). Training effectiveness research has shown that training can improve levels of knowledge and skills for workers, which can be a contributing factor in increasing awareness of hazards and recommended safe work practices in construction. However, additional research (including behavioral observation and evaluation) is needed to determine whether these precautions are exercised and to validate the true effectiveness of training as a contributing factor to avoiding hazards by utilizing recommended controls and taking appropriate precautions. Further evaluation is required to characterize the effectiveness of training, targeting outcomes such as increased use of recommended controls, personal protective equipment, and improved work practices.

Obstacles to use of training include time management issues, language barriers, failure to perceive hazards or a need for training, and additional costs. The persistence of hazards and associated injuries and fatalities could indicate that training is not the appropriate solution in some situations, or that training is ineffective, not frequent enough, not understood, or not consistent with expected practices on worksites. There exists a need for better characterization of the role that safety and health training plays in the construction industry, and how training is developed, delivered, and assimilated into construction practices.

2. METHODS

The NORA Construction Sector Council was formed in 2006, and is comprised of invited stakeholders and subject matter experts from government, academia, industry groups, organized labor, and private consulting. During its initial face-to-face meetings, the Construction Sector Council identified priority topic areas through a series of discussions and multi-voting processes. Among the resulting eight topic areas identified, training issues were determined to be a priority area for assessing research needs as well as the translation and dissemination of best practices for preventing hazards in construction through effective training. A core training issues workgroup was formed from volunteers on the Sector Council with interest and experience in this topic area. Additional corresponding members were recruited through the Sector Council in February 2007.

The mission of the NORA Construction Sector Council workgroup on Training Issues for Construction Safety and Health was to assess training needs, resources, and tools to address occupational safety and health hazards in the construction industry. The charge of the Training Issues workgroup was to provide leadership in the development of goals and priorities which identify gaps in current training and the resources which can best be applied to address them. Towards this end, the Training Issues workgroup sought to identify barriers as well as best practices and strategies for developing and delivering effective training and guidance to address construction-related hazards and prevent illness and injury for construction workers. These activities were performed through a series of facilitated discussions, including four face-to-face meetings and multiple teleconferences throughout a two-year period (2006 and 2007).

An overall strategic goal was established for the Training Issues topic:

> To increase the recognition and awareness of construction hazards and the means for controlling them through broad dissemination of quality training for construction workers, including non-English speaking workers.

Four intermediate goals dealing with specific aspects of training were also established to support the overall strategic goal. For the strategic goal and each intermediate goal, performance measures were specified for use in tracking progress towards meeting the goals. In addition, each of the intermediate goals has subgoals (12 total) to specify supporting activities which relate either to research or research–to–practice. The latter category (research–to–practice) refers to research translation, dissemination, or implementation of solutions derived from research.

The goals of the Construction Sector Council are established for a 10-year period according to the NORA schedule, beginning its second decade in late 2006/early 2007 and running through 2016/2017.

3. CHARACTERISTICS OF THE CONSTRUCTION INDUSTRY

Initial discussions of training issues factors and priorities for construction industry focused on determining characteristics of industry and the target audience. Employment in the construction industry is expected to grow at ~1.2% over the period from 2000 to 2010, creating 825,000 new wage and salary jobs (Berman, 2001; CPWR, 2002). Growth is projected to be higher in residential construction trades over that period (~9%), while growth in heavy construction employment (highway, bridge, and street construction) and special trades will be consistent with the industry average. Given the anticipated growth, demand for training for new construction workers is also expected to rise. Consequently, identification of relevant training materials and methods, appropriate delivery to target audiences, and evaluation of training effectiveness are several of the key issues facing the construction industry.

It was also determined that the construction industry is diverse, not only with respect to multiple and specialized trades, but also comprised of a broader audience of associated professions, organizations, and demographic groups. Among those groups likely to be impacted either as providers or users (intermediate customers) of training methods and materials are the following:

- Banking, mortgage, lending, insurance, and financing organizations
- Construction owners, users, and developers
- Architecture, engineering, and design firms
- Construction managers, supervisors, and workers
- Contractor, industry, and trade associations
- Training organizations and universities
- Federal, State, and local government

- Trade unions and organized labor groups
- Immigrant workers and worker centers
- Equipment rental, supply, and repair contractors

4. DRAFT GOALS FOR TRAINING ISSUES IN THE CONSTRUCTION INDUSTRY

The draft goals listed below were established by the Training Issues workgroup of the NORA Construction Sector Council and disseminated to a broader audience for review and comment in December 2007. Based on feedback from stakeholders and other reviewers, the goals may be revised accordingly.

Strategic Goal: Increase the recognition and awareness of construction hazards and the means for controlling them through broad dissemination of quality training for construction workers, including non-English speaking workers. (There are multiple occupational hazards associated with the construction industry which warrant attention, and priority areas identified by the NORA Construction Sector Council include falls, electrocution, struck-by hazards, noise and hearing loss, silica exposures and illnesses, welding fumes, and musculoskeletal disorders.)

Performance Measure: Demonstrate a minimum set of safety and health competencies required for all workers on construction sites to recognize hazards and the methods to control or avoid them through access to quality training and educational materials.

Intermediate Goal 1 – Perform a construction training needs analysis.

Performance measure -- Assess current state of training needs for at least 3-5 major construction trades within 3 years, and expand to include 3-5 more additional trades every year after over 10 years.

<u>Research Goal 1.1</u> – Identify existing and potential surveillance tools for tracking the use of training and its impact in construction trades. Use and organize existing databases, surveillance systems, and other information.

<u>Research Goal 1.2</u> – Harmonize training needs analysis to include intermediate and supporting goals from other NORA Construction Sector Council workgroups. Communicate with other NORA Construction Sector workgroups to identify, assess, and coordinate training needs and solutions as they relate to those workgroups' goals.

Intermediate Goal 2 – Survey current training programs, models, materials and best practices to identify the scope of training resources available.

Performance measure – Create an inventory or clearinghouse repository of model programs within 3 years that could serve as resources to other industry sectors for effective identification of training needs, and developing sector specific resources to address those needs. Maintain the repository by updating it at least annually.

Research Goal 2.1 – Identify programs used to provide training on safety and health core competencies. Develop and define a description of safety and health core competencies required for construction workers, construction trainers, and construction employers, and encourage identification or development of programs which meet these requirements.

Research Goal 2.2 – Identify existing quality training materials (e.g., toolbox talks, simple solutions, and industry and trade materials).

Research Goal 2.3 – Compile resources from peer-reviewed literature on construction safety and health training.

Research Goal 2.4 – Identify methods used to provide training for construction safety and health (e.g., each one teach one approaches, coaching worker-trainers).

Research Goal 2.5 – Identify methods of analysis and measures for effectiveness evaluation of training.

Intermediate Goal 3 – Develop new or improved training programs, models, materials, and methods.

Performance measures – Conduct baseline survey of construction safety and health toolbox talks available via electronic libraries initially within 3 years and conduct surveys periodically thereafter to determine availability of new materials. Demonstrate an increase in publication of peer reviewed literature on construction safety and health training.

Research Goal 3.1 – Develop, evaluate, and implement new materials and methods for delivering effective training on safety and health core competencies.

Research Goal 3.2 – Identify best methods of analysis and appropriate measures and indicators for effectiveness of training. Promote funding for training intervention effectiveness research.

Intermediate Goal 4 – Promote the dissemination and use of construction training best practices, materials, and methods.

Performance measure – Increase the number of construction workers provided with the core competencies for understanding construction hazards and their prevention.

Research/Research to Practice Goal 4.1 – Plan a national state-of-the-science conference on construction training issues, resources, and needs. (Options could include convening a dedicated national conference, participation in sister safety and health conferences, and piggy-backing onto existing safety and health conferences to focus on discussion of construction safety and health training issues.)

Research Goal 4.2 - Research and develop or refine approaches to institutionalize change. Examples might include: funding research and assisting with dissemination and use of results; publicizing practitioner success stories; using awards and other social marketing approaches.

Research to Practice Goal 4.3 - Improve training delivery and transfer of knowledge to small and self-employed construction contractors. Utilize or develop better surveillance tools to improve delivery systems for reaching smaller construction contractors (the majority of the industry).

Research to Practice Goal 4.4 - Increase communication with other construction safety and health researchers to integrate research findings into training programs. Encourage diffusion of research findings through multiple venues including web-based information sources, peer-reviewed literature, professional organizations, construction user groups, contractor associations, and construction worker unions.

5. CONCLUSIONS

Establishing these goals will help to guide efforts for understanding and enhancing the role of occupational safety and health training in construction. These goals are not static and will need to be revised periodically as performance measures indicate the level of success with which the objectives are met. In addition, training issues are viewed as one of multiple factors impacting safety and health in construction; as such, the training issues topic fits into a suite of topics (both outcomes and contributing factors) the NORA Construction Sector Council has determined to be priority areas for research and implementation of research findings (i.e., research–to–practice).

The impact of addressing challenges related to training, and conducting additional research and evaluation, will ultimately be judged against measures that translate into fewer injuries and fatalities by eliminating or mitigating hazards. A reduction in the occurrence of accidents and injuries will not only save lives and improve the quality of life for workers, it can also result in lower workers' compensation claims and other financial expenditures for contractors and owners of construction projects.

Disclaimer

The findings and conclusions in this paper have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

6. ACKNOWLEDGMENTS

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PROMOTION OF WORK ABILITY AND CONTINUATION OF WORKING CAREERS OF CONSTRUCTION WORKERS IN EASTERN FINLAND - AND WIDENING OF KNOWHOW THROUGH MODERN EDUCATION METHODS

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ABSTRACT

The mean age of construction workers in eastern Finland is high, and a considerable number of professionally skilled workers will retire within the next 10 years. Companies need tools to help them manage data on workers' knowhow, educational background, and additional training, and monitor absences due to sickness. Companies are willing to invest in ensuring the availability of a workforce, developing knowhow and learning by doing, and promoting well-being at work.
The aim of this study was to establish flexible and suitable models of operation which fit the needs of companies and, with which, it is possible to support long-term careers in construction.
Six workshops were organized, all of which were attended by representatives of management, supervisors of work and employees, an occupational health nurse from the occupational health care unit of the company, representatives of vocational education from the youth and adult sectors, and representatives of the industrial safety division. The information from the workshops was tested in the companies participating in the workshops. The topics included (i) a plan to promote the well-being for the company and the workers, (ii) a survey the knowhow needed at the company and individual levels, (iii) a survey of the guidance needed in the companies, (iv) assessment of the possibilities to advance knowhow and knowledge in occupational health care, (v) assessment of the possibilities for and advancement of networking, and (vi) measurement of the aforementioned actions.

Keywords: Construction Industry, Work Ability, Well-being, Training

1. BACKGROUND

The mean age of construction workers in eastern Finland is high, and a considerable number of professionally skilled workers will retire within the next 10 years. Companies need tools with which to manage data on workers' knowhow, educational background, and additional training and a system to monitor absences due to sickness. Companies are willing to invest in ensuring the availability of a workforce, developing knowhow and learning by doing, and promoting well-being at work.

2. AIM

The aim of this study was to establish flexible and suitable models of operation that fit the needs of companies, especially small and middle-size enterprises, in Eastern Finland, with which it would be possible to support long-term careers in construction and increase training to expand the capabilities of the construction workforce.

3. MATERIAL AND METHODS

Material

The pilot project started at the end of 2007 and lasted 6 months. Altogether nine companies (1500 workers) participated in the study. Three of the companies were branches of big Finnish enterprises. Two companies were prefabrication factories, one represented renovation, and the others built new facilities (apartment buildings or industrial premises). All of the companies were willing to develop the well-being of the workers at their workplaces.

Methods

In the beginning of the project, a seminar was organized to introduce the topic to all of the participants the topic and to help them internalize the factors behind well-being at work in the construction industry.

Six workshops were organized, all of which were attended by representatives of management, supervisors of work and employees, an occupational heath nurse from the occupational health care unit of the company, and representatives of vocational education from the youth and adult sectors. In addition, representatives of the industrial safety division were invited. The topics included (i) a plan promoting well-being at the company and individual level, (ii) a survey the knowhow needed at the company and individual level, (iii) a survey of the mentoring needed in the companies, (iv) assessment of the possibilities to advance the knowhow and knowledge of occupational health care, (v) assessment of the possibilities and advancement of networking, and (vi) measurement of the aforementioned actions.

The information from the workshops was tested in the companies that participated in the workshops. All of the contact persons in the companies received a summary of the workshops' results and their requested benefits, weak points, and suggestions for development from 3 to 10 representatives of management and supervisors of work and employees in the companies. These results were then presented in another workshop. Two days before the next workshop, the researchers sent an electronic questionnaire related to the experiences put forth in the summary. All of the responses were collected so that a book could be created to help all construction companies promote health and well-being among their staff.

During the project, experts in health promotion, health and safety, occupational health care, networking, training, and mentoring were available for the companies.

At the end of the study, a seminar will be organized to present and discuss the results of the project.

4. RESULTS

Participation was good. The attendance in the first seminar represented management, supervisors of work and employees, occupational health care units, and vocational educators from the youth and adult sectors. In addition, the industrial safety division took part in the project. In the workshops, the companies sent representatives of all personnel groups. The contact persons in the companies represented management.

The workshop participants were of the opinion that the workshops were successful because they were able to obtain more information about the possibilities to promote cooperation. Some of the companies did not know that they could get guidance and support from their occupational health care unit with respect to the follow-up of workers with prolonged incapacity to work.

The requested benefits, weak points, and suggestions for development from 3 to 10 representatives of management, work supervisors employees in the companies showed that the most important improvements should be focused on the work organization, development of the work environment and the work community (Fig. 1 and 2).

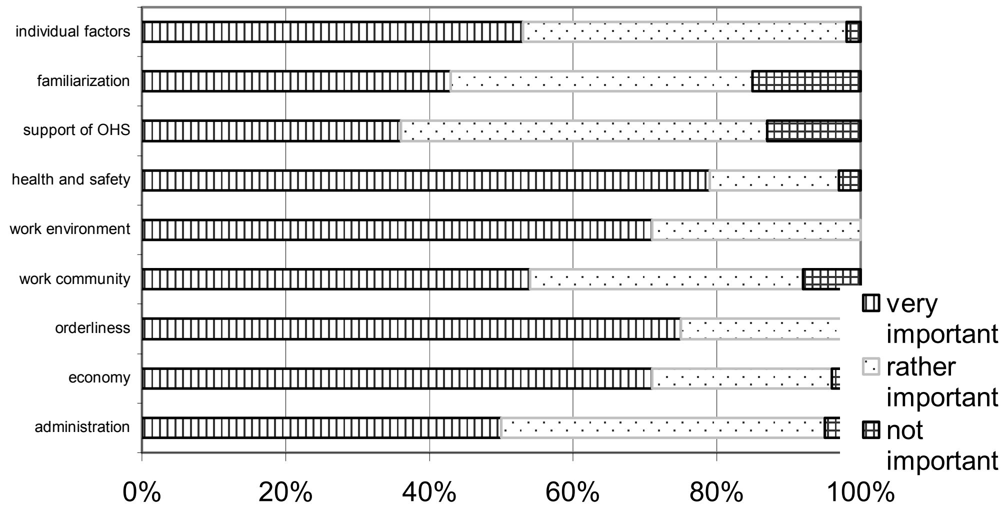

Figure 1. Importance of factors influencing work ability from the point of view of the enterprise.

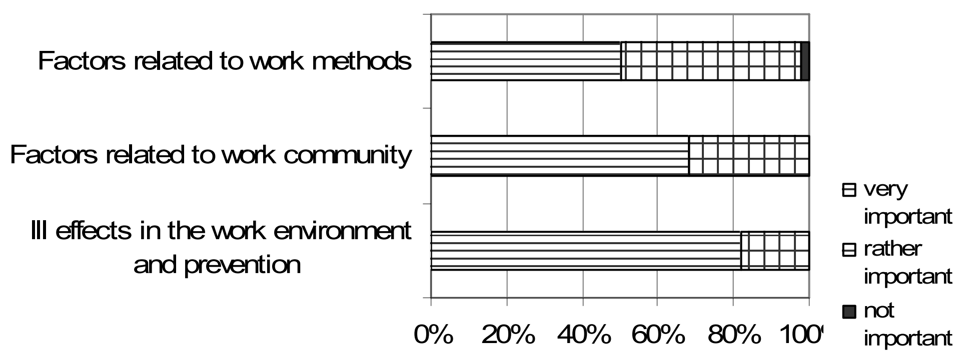

Figure 2. Importance of factors influencing work ability from the point of view of a worker.

More than half of the respondents rated the following aspects as being very important. (1) support from occupational health care with respect to exposures, workload and risk factors at work (53%), guidance on how to take care of one's own physical capacity and healthy life habits (68%). The mastery over workload through, e.g. (guidance in ergonomics, measures to master time) was considered rather important by 62% of the respondents. Familiarization and the guidance of work supervisors and workmates was rated as rather important by 53% of the respondents.

Altogether 85% of the respondents were ready to preserve or improve their own work ability, by: maintaining order and cleanliness in the work environment (94%) in order to prevent accidents, tying out new work habits and tools to decrease workload (100 %), recognizing all members of the work community (representing different ages, professions and cultures (88%), and taking part in education to develop knowledge and skills (74%). The industrial safety division planned a survey of musculoskeletal problems, and the knowledge on which the survey was based came from the workshops.

The occupational health care units were eager to participate in the workshops, where they could improve their services, deepen their knowledge of the companies in general, and discover new trends with respect to changes in the promotion of health, the prevention of illnesses, and the protection of workers.

The vocational education institutes received actual information to aid their further planning of the basic and high-level education offered in their construction sections. Although they already had plans in place, they were willing to tailor their courses to fit the needs of the companies and the construction industry.

5. DISCUSSION AND CONCLUSIONS

The companies needed support and encouragement in the beginning of the project. The promotion of work ability was well known, but widening it to the well-being at work was a new concept. Well-being at work was previously recognized, but no actions had been thus far organized.

In addition the occupational health care experts needed support, and they were enthusiastic about initiating their plans.

The members of industrial safety division welcomed the opportunity to act in the groups of the workshops.

The vocational education representatives received feedback from the companies regarding the content of education, and this feedback could be utilized in future plans.

At the end of the project, a model for well-being at work in the construction industry should be ready, and the developed methods will later be refined in a wider project aiming at the promotion of health, work ability, and well-being in the construction industry.

WORKER SAFETY TRAINING FOR DISASTER CLEAN-UP AND RECONSTRUCTION ACTIVITIES

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ABSTRACT

Natural disasters such as hurricanes and floods cause significant damage to buildings, creating significant confined space, fall, electrocution, caught-in/between and struck-by hazards. In addition, natural disasters generate significant quantities of hazardous debris. As a result, clean-up and reconstruction workers are at increased risk for illness and injuries.

In January 2008, a survey was administered to trade contractors that either had been involved or, would likely be involved in storm reconstruction in the hurricane-prone southeast U.S. Ninety percent of the survey respondents represented small to medium-sized contractors which are less likely to provide adequate safety training when compared to larger contracting firms. Contractors also indicated that 70% of their workforce consisted of non-union workers who likely had little or no formal apprenticeship training, including craft safety training. Furthermore, contractors reported that nearly half (45%) of their field workers primarily spoke a language other than English. These findings indicate that safety training for these workers is lacking and that traditional training methods may be ineffective for non-English speaking workers.

In response, researchers at the University of Florida obtained funding from the U.S. Occupational Health and Safety Administration (OSHA) to provide worker safety training for small to medium-sized contractors who would likely be engaged in disaster clean-up and reconstruction in the southeast U.S. This paper provides an overview of training that will enable workers to identify and mitigate safety hazards while performing clean-up and reconstruction activities following a natural disaster.

Keywords: Disaster, OSHA, Reconstruction, Safety, Training, Worker

1. INTRODUCTION

Section 5(a)(1) of the Occupational Safety and Health Act requires employers to *"furnish to each of his (or her) employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his (or her) employees"*. For post-disaster clean-up and reconstruction activities however, it is difficult to anticipate the myriad of possible physical, chemical and biological hazards to which a worker may be exposed. Hurricanes are powerful storms that can affect entire geographical regions. An unprecedented hurricane season in 2004 saw four major hurricanes with sustained winds ranging from 105-145mph at landfall, impact 60 of 67 counties in Florida within a span of six weeks (DHSMV, 2004). These storms left 152 people dead and caused more than $US 42B in damage. Hurricane Katrina less than a year later claimed the lives of 1,836 people in at least three states and caused more than $US 81.2B in damage.

Fig 1. Debris and damage to residential and commercial structures during Hurricane Ivan, Pensacola Beach, Florida, 2004 (Grosskopf, 2004).

Some workers are exposed to extreme hazards during hurricanes when performing or restoring emergency services; however, the vast **majority of disaster-related injuries and illnesses occur during clean-up and reconstruction** activities. These activities are even more hazardous in areas of flooding caused by coastal storm surge and inland flooding. Some of the specific hazards associated with hurricanes clean-up and reconstruction activities include:

- Electrocution from downed power lines or equipment failure
- Falls from heights
- Impacts from falling debris
- Exhaustion from working extended shifts in PPE
- Heat stress from overexertion and dehydration
- Illness from chemical and biological hazards
- Trauma from heavy and hand-held equipment

In January 2008, a survey was administered by the University of Florida to trade contractors in **OSHA regions 4 and 6** that either had been involved or, would likely be involved in storm reconstruction in the hurricane-prone southeast U.S. Over 100 contractors responding to the survey included those trades largely responsible for structural repair and weather-proofing of the building envelope. Nearly a third (29%) of respondents were roofing contractors (Fig 2). Given a list of OSHA Region 4 and 6 states, respondents reported having performed roughly half (45%) of their work in Florida (Fig 3).

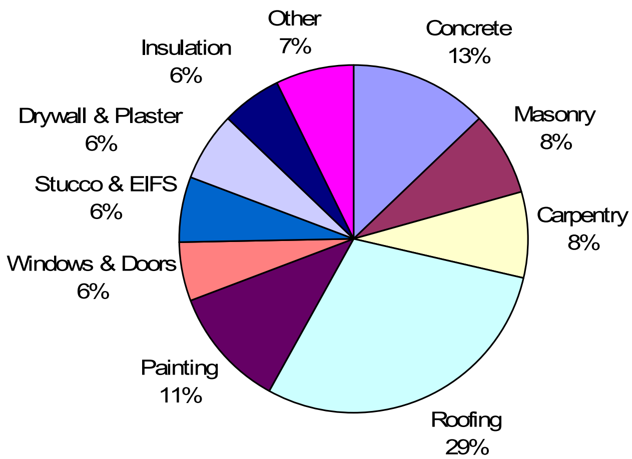


Fig 2. Respondents by trade.

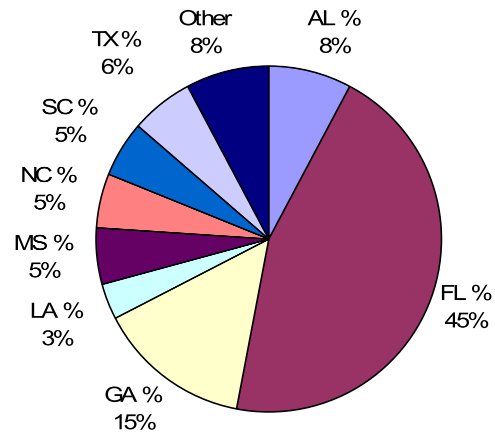
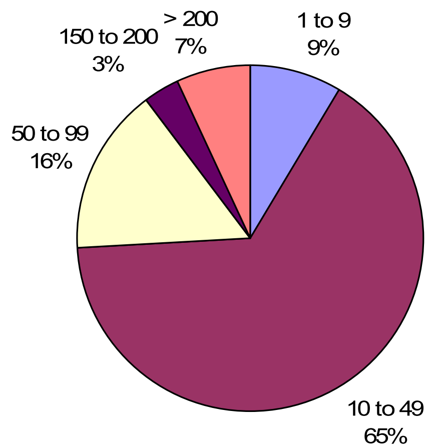


Fig 3. Respondents by U.S. state.

Next, contractors were asked how many field workers they employed and, their average length of employment. A majority of the contractors surveyed (65%) employed between 10 to 49 field workers. Twenty-six percent indicated they employed 50 or more employees (Fig 4), with 10% of these employing more than 150 workers (no respondents reported that they employed between 100 to 149 workers). Length of employment was near equally distributed (27-33%) between workers who had worked for their current employer less than one year, one to five years and, six to ten years (Fig 5).



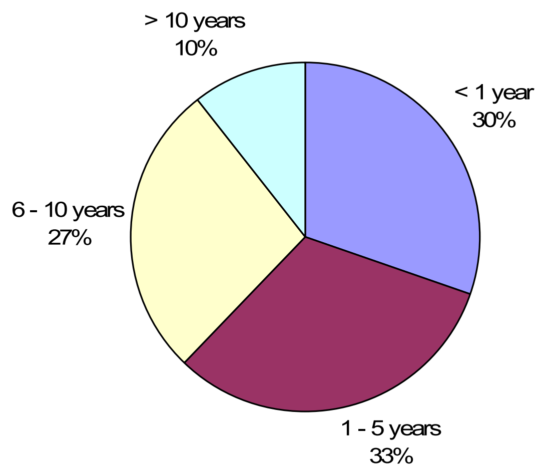
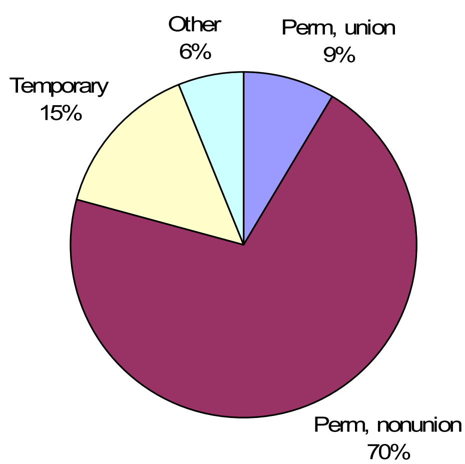


Fig 4. Respondents by number of field workers. **Fig 5. Average worker tenure.**

Contractors indicated that the majority (70%) of their field personnel were permanent hire, non-union workers. Approximately 15% of the workers were temporary hire or "day laborers" (Fig 6). When asked to describe the average education level of their field workers, contractors indicated that nearly all (92%) had general education. None of the respondents reported having field workers with any college or university level education (Fig 7).



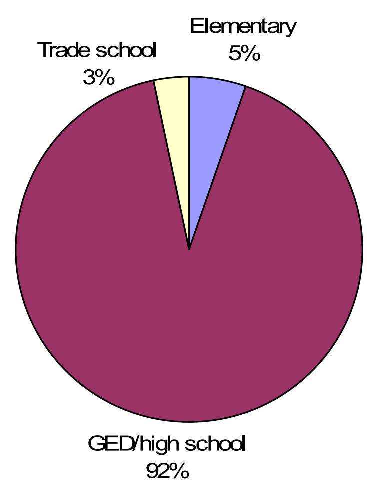


Fig 6. Permanent vs. temporary workforce. **Fig 7. Worker level of education.**

Contractors reported that on average, nearly half (45%) of their field workers spoke a language other than English (Fig 8). When asked how often safety training was provided to their field workers, more than half (57%) of contractors indicated that they offer training each week (Fig 9). Regardless of the frequency, nearly all respondents (89%)

reported that the duration of safety training was between 1 and 2 hours per session. On average, survey results conclude that each worker receives approximately 30-65 hours of safety training each year.

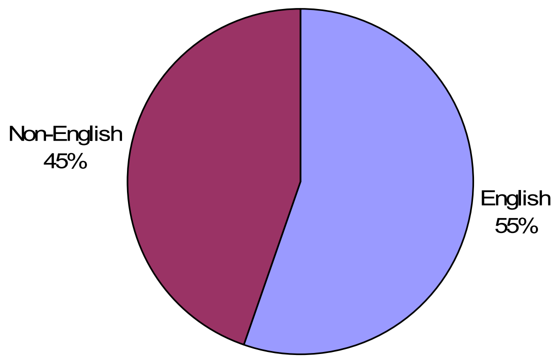


Fig 8. English vs. non-English speaking.

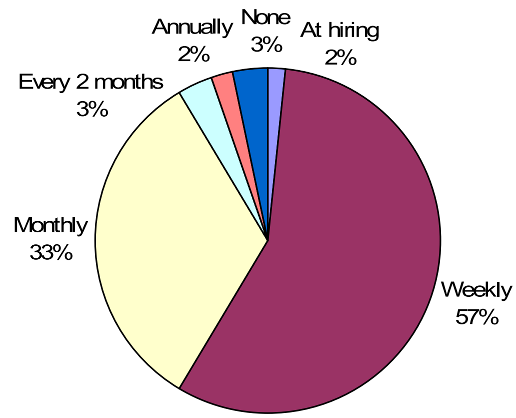


Fig 9. Frequency of safety training.

The intent of the survey was to determine the demographic composition of contractors and their field workers that either had been involved or, would likely be involved in hurricane reconstruction, and, the level of safety training provided to these at-risk workers. Survey results indicate that nearly all contractors performed work that would likely place workers in **"focus four" hazards** conditions, and specifically, in fall hazard conditions. The vast majority of the survey respondents (90%) represented small-to-medium sized contractors (less than 100 field workers) in the state of Florida (45%). Statistics from OSHA and the National Institute of Occupational Safety and Health (NIOSH) indicate that smaller to mid-sized firms are less likely to have the resources to provide adequate safety training when compared to larger contracting firms.

Contractors responding to the survey also indicated that on average, 70% of their workforce were non-union workers who likely had little or no formal apprenticeship training, including craft safety training. Furthermore, contractors reported that nearly half (45%) of their field workers primarily spoke a language other than English. Together, these findings indicate that safety training for workers tasked with hurricane reconstruction *may* be lacking and that traditional methods for providing safety training, especially among non-English speaking workers, *may* be ineffective.

In response, researchers at the University of Florida obtained funding from OSHA to provide worker safety training for small-to-medium sized contractors engaged, or, who would likely be engaged in disaster clean-up and reconstruction activities in the southeast and Gulf coast U.S. states (OSHA regions 4 and 6). In support of this grant and, as a teaching "tool" for future construction professionals, undergraduate students in construction safety classes at the University of Florida were assigned a project aimed at identifying unique hazards associated with hurricane clean-up and reconstruction activities and, methods to either avoid or mitigate these hazards. Specifically, students were divided into small groups of 2-3 persons each and asked to assume the identity of a small to medium-sized Florida contractor that self-performs hurricane clean-up and reconstruction services. Each student group was then asked to prepare a **job safety assessment (JSA)** to identify and mitigate likely physical, chemical and biological hazards associated with a specific type of clean-up and reconstruction activity. The following is an overview of available JSA and **OSHA training materials** supporting this effort {http://www.osha.gov/OshDoc/hurricaneRecovery.html}.

2. GENERAL HEALTH AND SAFETY

The primary safety goal for clean-up and reconstruction contractors is to **prepare in advance of a disaster** event for anticipated recovery activities and, to prevent work-related injuries and illnesses in the field once clean-up and reconstruction begins. First, a pre-deployment **medical screening** (e.g. physical) is necessary to evaluate a worker's fitness to perform potentially hazardous or stressful work safely. Additionally, a medical screening can be used to assess the worker's immunization status, particularly for work in areas affected by floodwater-borne pathogens. Pre-event medical screenings may also provide a "baseline" for assessing health effects in workers returning from disaster work. Natural disasters such as hurricanes can disrupt and even damage sewage systems and other basic sanitary services. **Immunizations** recommended for clean-up and reconstruction activities in the U.S. generally include common vaccinations for polio, measles, influenza, tetanus and diphtheria toxoid but, may also include hepatitis A and B, encephalitis, rabies and cholera. Natural disasters can also disrupt food and water supplies. Provisions for safe **drinking water and food** should be made in advance of a deployment to a disaster area. If a trusted source of potable water is not available, water should be bottled, boiled or disinfected. Food should be selected with care to reduce the risk of acquiring gastrointestinal illnesses or chemical poisoning. Workers should avoid using improvised surfaces (e.g., racks from damaged or abandoned refrigerators) for cooking food or for boiling water to avoid exposure to heavy metals.

Heat stress occurs when the body is unable to cool itself and is among the most common injuries in hurricane clean-up and reconstruction workers. Factors leading to heat stress include high temperature and humidity, direct sun or heat, limited air movement, physical exertion, poor physical condition and, some medications. Symptoms of **heat exhaustion**, a lesser form of heat stress, include headaches, dizziness, lightheadedness or fainting; weakness and moist skin; mood changes such as irritability or confusion; and, nausea or vomiting. Symptoms of **heat stroke**, a potentially fatal form of heat stress include dry, hot skin with no sweating; mental confusion or losing consciousness; and, seizures or convulsions. Methods to prevent heat stress include recognizing the signs and symptoms of heat-related illnesses; avoiding direct sun or other heat sources; using cooling fans or air-conditioning; resting regularly, drinking 1 cup (8oz) every 15 minutes; wearing lightweight, light colored, and loose-fitting clothes; and, avoiding alcohol, caffeinated drinks, or heavy meals. If a worker shows signs or symptoms of heat stress, call 911 (or a local emergency number) immediately; move the worker to a cool, shaded area; loosen or remove heavy clothing; provide cool drinking water; and, fan and mist the person with water. Related, severe **sunburn** can cause extreme discomfort and subsequent cataracts and **skin cancer**, including often fatal melanoma. Wraparound sunglasses that provide 100% ultraviolet (UV) ray protection should be worn for eye protection. A broad-spectrum UVA and UVB sunscreen and lip screen with at least SPF 15 should also be used.

Unlike construction activities during normal conditions, workplace hazards following a natural disaster such as a hurricane are much more difficult to anticipate and prepare for. At a minimum, all clean-up and reconstruction workers should be trained and equipped with basic **personal protective equipment** (PPE), including hand, foot, eye, fall, hearing and head protection well in advance of deployment to a disaster site. Workers should wear **hard hats** to prevent head injuries due to impact of falling or flying objects or from bumping into stationary objects. Hard hats should be maintained in good condition and routinely inspected for dents, cracks or deterioration. Hard hats showing evidence of excessive wear and tear, a heavy impact or electrical shock should be replaced. Use **eye protection** such as vented, impact resistant safety glasses or goggles when working around airborne particulates whether naturally occurring (windy conditions) or when generated by workers (grinding metal, sawing wood, etc.).

Workers should use **hearing protection** for the preservation of hearing in noisy environments (e.g., use of chain saws, high pressure water sprayers, portable generators, etc.). If a worker must shout over noise to be heard, earplugs, earmuffs or other hearing protection devices should be worn. Replace earplugs regularly. Wear appropriate hand protection, as **gloves,** when mixing, preparing, wiping, or spraying chemical products and when handling sharp or pointed materials. Gloves should fit snugly. Workers should wear gloves appropriate for the job or task (e.g. heavy-duty rubber gloves for concrete work, welding gloves for welding, insulated gloves and sleeves when exposed to electrical hazards, etc.). Always wear **foot protection** such as slip-resistant, watertight boots with a steel toe and insole to prevent punctures and cuts caused by various types of debris. **Protective clothing**, such as Tyvek suits, may be necessary to protect workers from contact with harmful substances.

Workers should wear **respiratory protection** when working in a hazardous atmosphere. Respirator use reduces exposures to airborne particles and microscopic organisms. The appropriate respirator will depend on the contaminant(s) to which workers may be exposed and the protection factor required. Required respirators must be **NIOSH-approved** and medical evaluation and training must be provided before use. Single-strap dust masks are usually not NIOSH-approved. They must not be used to protect from hazardous atmospheres. However, they may be useful in providing comfort from pollen or other allergens. Approved filtering facepieces or, **dust masks**, can be used for dust, mists, welding fumes, etc. They do not provide protection from gases or vapors.

Half-face respirators can be used for protection against most vapors, acid gases, dust or welding fumes. Cartridges/filters must match contaminant(s) and be changed periodically. **Full-face respirators** are more protective than half-face respirators when used for protection against most vapors, acid gases, dust or welding fumes. The faceshield protects the face and eyes from irritants and contaminants. Loose-fitting **powered-air-purifying respirators** (PAPR) offer breathing comfort from a battery-powered fan which pulls air through filters and delivers it into the face mask. They can be worn by most workers who have beards. A **self-contained breathing apparatus** (SCBA) is used for entry and escape from atmospheres that are considered immediately dangerous to life and health (IDLH) or oxygen deficient. The air from a SCBA system need not be filtered as the air is brought into the work environment.

Once on site, workers should establish a plan for contacting medical personnel in the event of an emergency. A preliminary **worksite inspection** should be conducted to verify structural stability before entering a severely damaged, flooded or formerly flooded building. During initial entry and assessment, use **battery-powered equipment** as flashlights and lanterns, rather than candles, gas lanterns, or torches for temporary lighting. Immediately **disconnect electrical power** and **natural gas** or propane tanks to avoid fire, electrical shock, or explosions. Do not begin clean-up or reconstruction activities in a wind damaged or flooded building until it has been examined and certified as safe for work by a registered professional engineer or architect. Use a wooden probe (e.g. stick or pole) to check flooded areas for pits, holes, and protruding objects before entering. Report any obvious hazards (downed power lines, gas leaks, etc.) to appropriate authorities. Use life-vests when engaged in activities that could result in deep water exposure. Use extreme caution when handling containers holding **unknown substances** or known **toxic substances**. Contact the **Environmental Protection Agency** (EPA) for information on disposal.

Workers should keep a safe distance from **downed power lines** or any object or water that is in contact with such lines. Treat all power lines as energized and beware of overhead and underground power lines when clearing debris. Extreme caution is necessary when moving ladders and other equipment near overhead power lines to avoid inadvertent contact. If damage to an electrical system is suspected, deactivate the electrical system in the building and follow **lockout /tagout** procedures before beginning work. Do not turn the power back on until all **electrical equipment** has been inspected by a qualified electrician. When using a generator, be sure that the main circuit breaker is open (off) and locked out prior to starting the generator to prevent accidental "backfeed" of electricity and help protect utility line workers from possible electrocution. Any electrical equipment, including extension cords, used in wet environments must be marked, as appropriate, for use in wet locations and must be undamaged. Be sure that all connections are out of water. All cord-connected, electrically-operated tools and equipment must be **grounded** or be **double-insulated**. Ground-fault circuit interrupters (**GFCIs**) must be used in all wet locations. Immediately evacuate any building that has a gas leak until the leak is controlled and the area ventilated. Be sure that an adequate number of **fire extinguishers** are available and re-evaluate the fire evacuation plan. Ensure all fire exits are clear of debris.

3. PHYSICAL HAZARDS

The top four causes of construction fatalities (e.g., **"focus four"** hazards) are falls, electrocutions, struck-by and caught-in/between accidents. Of these, **fall hazards** are the most common causes of fatalities in the construction industry. Falls and falling objects can result from unstable working surfaces, ladders that are not safely positioned, and misuse of fall protection equipment. Workers are also subject to falls or to the dangers of falling objects if sides and edges, floor holes, and wall openings are not protected. Falls will continue to be a major concern when performing post-disaster work on buildings. It is common for high winds and hurricanes to damage building roofs. Even if a roof is not entirely destroyed, any repair work will still entail work being performed at elevation. Workers must first assess the structural integrity of roofs and plan to safely navigate the roof prior to installation of temporary or permanent roofing.

In the U.S., fall protection must be provided for each employee on a walking or working surface with an unprotected side or edge. As a general rule in construction, if a worker is at a height of **six feet** or more, the worker must be protected. In general, fall accidents can be prevented by developing, implementing and sustaining a **fall protection program**. Workers must be given regular training on the fall protection program which should in turn be evaluated on a regular basis to insure the program's effectiveness. Contractors are required to assess the work site to determine if the walking and working surfaces have the strength and structural integrity to safely support workers, materials and equipment. Where protection is required, contractors must provide, train and supervise workers in proper installation, use and maintenance of fall protection systems appropriate for given situations.

Almost all sites have unprotected sides and edges, wall openings, or floor holes at some point during construction. Following a hurricane, openings, edges and holes created by wind or floodwater damage as well as unstable structures and falling debris cause significantly greater fall hazards. Contractors should identify all potential fall and **tripping hazards** before clean-up and reconstruction work starts. Use **guardrails**, **safety nets** or **fall arrest systems** and, wall opening and floor-hole **covers** whenever employees are exposed to a fall of 6 feet or more above a lower level. Floor covers should be labeled and capable of supporting **two-times the weight** of employees, equipment, and materials that may be imposed on the cover at any one time. Install and maintain **perimeter protection**. Practice good "**housekeeping"** by keeping electrical cords, welding leads and air hoses out of walkways or adjacent work areas.

Workers also risk falling if **portable ladders** are not safely positioned each time they are used. Falls from ladders can cause injuries ranging from sprains to death. Position portable ladders so the side rails extend at least **3 feet** above the landing. Secure side rails at the top to a rigid support and use a grab device when 3 foot extension is not possible. Make sure that the weight on the ladder will not cause it to slip off its support. Before each use, inspect ladders for cracked, broken, or defective components. Do not apply more weight on the ladder than it is designed to support. Never stand on the top rung/step of a ladder.

Electrical hazards exist in some form in nearly all construction occupations. However, the danger of **electrocution** multiplies for workers involved in cleanup and recovery efforts following hurricanes, floods and other natural disasters. The greatest danger exists around overhead powerlines that might be downed or damaged by high winds or floodwater. Those at risk include utility workers repairing **downed or damaged power lines** and, clean-up and reconstruction workers who may inadvertently come in contact with downed or damaged power lines and electrical equipment. Repairing downed or damaged power lines entails many of the same activities involved in installing, maintaining and removing overhead circuits. The key difference is that in emergency conditions there are unknown hazards and the potential for differing hazards as work progresses. Under these conditions, workers must be extra vigilant to prevent:

- Electrocution by downed power lines or objects in contact with fallen lines
- Electrocution from portable generator "backfeed"
- Falls from heights
- Being struck by or caught between falling poles, towers or tree limbs
- Burns from fires caused by energized line contact or equipment failure
- Being injured by equipment such as chain saws and chippers

Utility workers responding to downed power lines should first assess the hazards present to minimize the chances of exacerbating the situation. Ideally the lines involved should be de-energized, but this may not be possible in all situations. Even if electrical circuits are de-energized by the utility, improperly sized, installed, or operated **portable generators** can send power back to the electrical lines. This problem is called **"backfeed"** and can kill or seriously injure utility workers or workers in neighboring buildings.

During the initial site assessment, non-utility workers should be trained to recognize and establish a safe distance from low-hanging or downed power lines (and objects in contact with them) and report incidents to the responsible authority. Downed wires can **energize other objects**, including fences, water pipes, vegetation, buildings, telephone, CATV, fiber optic cables and other electric utilities. Even manhole castings and concrete reinforcement bars (rebar) can become energized by downed wires. Wind-blown objects such as canopies, aluminum roofs, siding, sheds, etc., can also be energized by downed wires. Only properly-trained electrical utility workers should approach and handle damaged power lines and debris in contact with them.

Although powerlines might be lying on the ground, they might still be energized. Electricity can spread outward through the ground in a circular pattern from the point of contact. Dangerous voltage differentials can be created by workers walking toward or away from a source of **stray voltage**. Maintain a safe distance away from power lines in contact with the ground. Never drive over downed power lines. Even if de-energized, downed lines can become entangled in equipment or vehicles. If contact is made with an energized power line while in a vehicle, remain calm and do not get out unless the vehicle is on fire. Warn other workers not to touch the vehicle, equipment or wire. Place a call to the local electric utility company and emergency services. If exiting the vehicle or equipment is necessary because of fire or other safety reasons, jump completely clear of the vehicle, making sure to avoid touching the vehicle and the ground at the same time. Land with both feet together and shuffle away in small steps to minimize the path of electric current and avoid electrical shock (e.g. **"step voltage"**). Balance is also to be maintained.

Before starting clean-up and reconstruction work, workers should **locate and identify all utilities**. Immediately disconnect electrical power and ensure that electrical systems remain safely de-energized by using proper **lockout/tagout** procedures. Never assume that any wire is, or, is not an electrical conductor. Never assume that any wire is safe to touch because it is insulated. Locate low-hanging power lines before operating any equipment or, if working at heights or handling long objects, including those not normally considered electrical conductors (e.g. wooden ladders or poles). Stay at least 10 feet away from overhead wires during cleanup and other activities, as a worker need not make direct contact with a high voltage line in order for electrical energy to transmit or **"arc"** to the object. Be especially alert to electrical hazards when working with ladders, scaffolds or other platforms. Do not operate portable **electric tools** unless they are **grounded** or **double-insulated**. Use ground-fault circuit interrupters for protection. Never operate electrical equipment while standing in water. Never repair electrical cords or equipment unless qualified and authorized. Have a qualified electrician inspect electrical equipment that has been wetted before energizing it. If working in damp locations, inspect electric cords and equipment to ensure that they are in good condition and free of defects. Always use caution when working near electricity.

Workers can also prevent **struck-by accidents** by avoiding areas where they are situated between moving and stationary objects and, by wearing high-visibility clothes near equipment and vehicles. Roadway traffic will be elevated when reconstruction work is performed as a result of many different contractors being involved in the reconstruction efforts of other damaged buildings and facilities. Vehicles and heavy equipment pose a serious threat of struck by accidents.

Caught in/between accidents consist of workers being pinned by debris, construction materials or equipment, being involved in trench cave-ins, or being involved in the movement and operation of heavy equipment. To avoid caught-in/between accidents, never enter an unprotected trench or excavation five feet or deeper without an adequate protective system in place. Make sure the trench or excavation is protected either by sloping, shoring, benching or trench shielding systems.

4. CHEMICAL AND BIOLOGICAL HAZARDS

Windstorm and flooding can cause the disruption of water purification and sewage disposal systems, overflowing of toxic waste sites, and displacement of chemicals previously stored above ground. Floodwaters may be contaminated by agricultural or industrial **chemicals** or by hazardous agents present at flooded hazardous waste sites. Although different chemicals cause different health effects, the signs and symptoms most frequently associated with chemical poisoning are headaches, skin rashes, dizziness, nausea, weakness, and fatigue.

Floodwater may also contain **infectious organisms**, including intestinal bacteria such as E. coli, salmonella, shigella; hepatitis A, typhoid and tetanus. The signs and symptoms experienced by the victims of waterborne microorganisms are similar, even though they are caused by different pathogens. These symptoms include nausea, vomiting, diarrhea, abdominal cramps, muscle aches, and fever. Most cases of sickness associated with flood conditions are brought about by ingesting contaminated food or water. Tetanus, however, can be acquired from contaminated soil or water entering broken areas of the skin, such as cuts, abrasions, burns or puncture wounds**.** Tetanus is an infectious disease that affects the nervous system and causes severe muscle spasms, known as “lockjaw”.

After a major hurricane, flood or other natural disaster, it is often difficult to maintain good **personal hygiene**. Good personal hygiene, and specifically proper hand hygiene, prevents disease transmission. First, if water is suspected of being contaminated, cleanup workers may need to wear special chemical resistant outer clothing, protective goggles, plastic or rubber gloves, rubber boots, and other protective clothing. Workers should wear thick, cut-resistant gloves made of waterproof material (nitrile or similar washable material) when working in contaminated floodwaters, handling contaminated debris, or handling human or animal remains. To avoid waterborne disease, workers should wash hands regularly with soap and clean, running water or, a waterless, alcohol-based hand rub, especially before work and meal breaks and after cleanup or decontamination work and toilet use. **First aid**, even for minor cuts and burns, is very important during flood cleanup. Immediately clean all open wounds and cuts with soap and clean water or, a waterless, alcohol-based hand rub. Most cuts, except minor scratches, will require treatment to prevent **tetanus**. Seek immediate medical attention if a wound becomes red, swollen, or if discharge is observed.

Workers should assume that any water in flooded or surrounding areas is not safe unless the local or state authorities have specifically declared it to be safe. Do not use contaminated water to wash and prepare food, brush teeth, wash dishes, or make ice. If no safe water supply is available for washing, use bottled water, water that has been boiled for at least ten minutes or chemically **disinfected drinking water**. To disinfect water for human consumption, use five drops of liquid household bleach to each gallon of water, 30 minutes prior to use. Water storage containers should be rinsed periodically with a household bleach solution.

It is preferable to use soap and clean water to **disinfect tools** and equipment because of the potential for a bleach-water solution to corrode metals. However, if only contaminated water is available, prepare a solution of ¼ cup household bleach per 1 gallon of water. Prepare fresh solutions daily, preferably just before use. Wipe objects with the bleach solution ten minutes prior to use and let air dry. Label containers used to disinfect tools and equipment “bleach disinfected water – DO NOT DRINK”. When handling bleach or other chemicals, carefully follow the product directions, wear eye, hand, and face protection as appropriate and, have clean water available for eyewash and other first aid treatments.

For **severe surface decontamination**, mix 1½ cups of liquid bleach per gallon of water and allow to stand for at least 30 minutes before use. Douse surfaces with heavy contamination and allow contact for 3 minutes. Wipe the contamination from the surface and douse the surface again using a hand wash solution concentrate. Wipe up any residual contamination. Exercise caution when using **cleaning agents** and chemical germicides (biocides) for disinfecting building surfaces contaminated by microorganisms and their bio-films. Use gloves and eye protection. All containers should be labeled "Bleach-disinfected water, DO NOT DRINK." Do not mix bleach with products containing ammonia. Do not immerse electrical or battery operated tools/equipment in solutions.

Molds are microscopic fungi found everywhere in the environment, indoors and outdoors. When present in large quantities, molds have the potential of causing adverse health effects, including allergenic symptoms and dermatitis (skin rash). Individuals with serious allergies, asthma, sinusitis or other lung diseases or, weakened immune systems (e.g., HIV and cancer patients) can develop serious secondary or "opportunistic" infections. Molds usually appear as colored "woolly" mats and can produce a foul, musty, earthy smell. Preventing mold growth can only be achieved by removing moisture within **48 hours** (or less) of first exposure.

To prevent or remediate mold, first identify and eliminate the source(s) of water or moisture penetration into the building. Remove water and excess moisture and ventilate the building as quickly as possible. Use fans to assist in the drying process. Clean wetted inorganic, impermeable materials and surfaces with a **10% bleach and water solution**, or, use a detergent and water solution for materials that may discolor or corrode when exposed to bleach. Do not mix bleach with other cleaning products that contain ammonia. Biocide use is to be considered only in combination with cleaning and removal, and should be considered only when drying will be too slow to prevent microbial growth where pathogenic organisms are present. Discard all wetted porous, organic materials (e.g. drywall, insulation, carpeting, furnishings, ceiling tiles, etc.), especially those in contact with floodwater. Make sure the working area is well ventilated and, ensure that the work area is sealed off from the rest of the building and maintained at negative pressure to reduce the spread of **mold spores**. Discard mold damaged materials in sealed plastic bags directly from the affected area to the outside if possible. Use respiratory protection (e.g. N-95 respirator) as well as hand and eye protection.

Heating, ventilation and air-conditioning (HVAC) systems contain cavities (e.g., ducts, air handlers, furnaces, boilers, fans) that are difficult to inspect, clean, and disinfect. Many of their components (e.g., ducts, pipes, air handling cabinets) are insulated inside or outside with fibrous material that gets wet easily and is difficult to clean. Systems that distribute air that is heated, cooled, or brought in from outdoors can also distribute contamination throughout the building served by that system. Any insulated ductwork saturated with water should be removed.

Atmospheric testing for **air quality in confined spaces** is required for two distinct purposes: evaluation of the hazards of the space and verification that acceptable conditions exist for entry into that space. A confined space is one that is large enough to enter and perform assigned work; however, it has limited or restricted ways to enter or exit the space and, is not designed to be occupied continuously by a worker. The atmosphere within a confined space must be tested using equipment that is designed to detect the chemicals or gases that may be present in harmful concentrations. Evaluation testing is done to determine what chemical hazards are or may become present in the space's atmosphere, and, identify what steps must be followed and what conditions must be met to ensure that atmospheric conditions are safe for a worker to enter the space.

Test results and decisions about what steps must be followed before entry must be evaluated by, or reviewed by, a **technically qualified professional** like an OSHA consultation service, a certified industrial hygienist, a registered safety engineer, or a certified safety professional. The technically qualified professional must consider all of the serious hazards in his/her evaluation or review. A confined space has one or more of the following features; it has or may contain a hazardous atmosphere; it contains a material that can engulf a person who enters; it has an inside design that could trap or asphyxiate a person who enters (inwardly converging walls, or a floor that slopes downward to a smaller section); or it has any other serious safety or health hazards. Test the atmosphere in the following order: (1) for **oxygen**, (2) for **combustible gases**, and then (3) for **toxic gases** and vapors. The testing results, the actual test concentrations, must be below the levels identified for safe entry.

Hydrogen sulfide (H_2S) is a colorless, flammable, extremely hazardous gas with a "rotten egg" smell. It occurs naturally in crude petroleum and natural gas, and can be produced by the breakdown of organic matter and human/animal wastes (e.g., sewage). It is heavier than air and can collect in low-lying and enclosed, poorly ventilated areas such as basements, manholes, sewer lines and underground telephone/electrical vaults. Hydrogen sulfide gas can be smelled at low levels, but with continuous low-level exposure or at higher concentrations, workers can lose their ability to smell the gas even though it is still present. Do not depend on sense of smell for indicating the continuing presence of this gas or for warning of hazardous concentrations.

Health effects vary with how long, and at what level, a worker is exposed. Asthmatics may be at greater risk. At low concentrations, hydrogen sulfide gas may cause irritation of eyes, nose, throat, or respiratory system; although these effects can be delayed. At high concentrations, hydrogen sulfide gas can cause shock, convulsions, difficulty with breathing, coma, and death; these effects can be extremely rapid (within a few breaths). Before entering areas with possible hydrogen sulfide, the air needs to be tested for the presence and concentration of hydrogen sulfide by a qualified person. This individual also determines if fire/explosion precautions are necessary. If gas is present, the space should be ventilated. If the gas cannot be removed, use appropriate respiratory protection and any other necessary personal protective equipment (PPE), rescue gear and communication equipment. Atmospheres containing high concentrations, **>100 ppm**, are considered immediately dangerous to life and health and self-contained breathing apparatus (**SCBA**) is required.

Carbon monoxide (CO) is a colorless, odorless, toxic gas which interferes with the oxygen-carrying capacity of blood. CO is non-irritating and can overcome persons without warning. People usually die from CO poisoning while using **gasoline powered tools and equipment** in buildings or semi-enclosed spaces without adequate ventilation. Severe carbon monoxide poisoning causes neurological damage, illness, coma and death. Symptoms of CO exposure include headaches, dizziness, drowsiness, nausea, vomiting and tightness across the chest. Common sources of CO exposure include gas-powered portable generators in buildings, concrete cutting saws, compressors, power trowels, floor buffers, space heaters, welding equipment and pumps. To avoid CO exposure, never use a generator indoors or in enclosed or partially enclosed spaces such as garages, crawl spaces, and basements. Open all windows and doors in enclosed spaces to prevent CO buildup. Generators should have 3 to 4 feet of clear space on all sides and above it to ensure adequate ventilation. Do not use a generator outdoors if placed near doors, windows or vents which could allow CO to enter and build up in occupied spaces. When using space heaters and stoves, ensure that they are in good working order to reduce CO buildup, and never use in enclosed spaces or indoors. Consider using tools powered by electricity or compressed air, if available. If a worker experiences symptoms of CO poisoning, they should immediately be moved to fresh air and provided medical attention.

Repair, renovation, and demolition operations of hurricane or flood-damaged buildings, especially older structures, can often generate airborne **asbestos**, a mineral fiber that causes chronic lung disease and cancer. Before it was widely known that inhalation of asbestos fibers causes several deadly diseases, including **asbestosis**, a progressive and often fatal lung disease, and other cancers, asbestos was used in a large number of building materials and other products because of its strength, flame resistance, and insulating properties. Asbestos was used in asbestos-cement pipe and sheeting, floor and roofing felts, drywall, floor tiles, spray-on ceiling coatings, and packing materials. When buildings containing these materials are renovated or demolished, or when the asbestos-containing materials themselves are disturbed, **minute fibers** may be released into the air. The fibers are so small that they often cannot be seen. The **permissible exposure limit** (PEL) for asbestos is **0.1 fiber/cm^3 of air** averaged over an 8-hour period. Access to locations where asbestos concentrations may be dangerously high should be restricted. Do not smoke, eat, or drink in asbestos regulated areas. Use warning signs and caution labels to identify and communicate the presence of hazards and hazardous materials.

Lead is a common hazardous element found at many construction sites. Lead exposure comes from inhaling fumes and dust, and, ingestion when hands are contaminated. Lead can be taken home with workers' clothes, skin, hair, tools and vehicles. Lead exposure may take place in demolition, salvage, removal, encapsulation, renovation and clean-up activities. Workers should use proper personal protective equipment (e.g., gloves, clothing and appropriate respirators). Wash hands and face after work and before eating. Never enter eating areas wearing contaminated protective equipment. Never wear clothes and shoes that were worn during lead exposure away from work. Launder clothing daily and use proper cleaning methods. Be alert to symptoms of lead exposure (e.g., severe abdominal pain, headaches, loss of motor coordination). Wear appropriate respirators as directed. Conduct a user seal check each time a respirator is donned. Understand the limitations and potential hazards of wearing respirators. Ensure adequate ventilation. When outdoors, stand upwind of any plume. Use dust collecting equipment when possible. Use lead-free materials and chemicals. Use wet methods to decrease dust. Use local exhaust ventilation for enclosed work areas.

Pools of standing or stagnant water become breeding grounds for mosquitoes, increasing the risk of encephalitis and West Nile (in the U.S.) and, malaria and dengue (in the tropics) or, other **mosquito-borne diseases**. Workers can reduce the risk of mosquito and other insect bites by wearing long-sleeved shirts, socks, long pants, and by using insect repellants containing **DEET** or **Picaridin**. Treat insect bites and stings with over-the-counter products that relieve pain and prevent infection. Avoid **fire ants**; their bites are painful and cause blisters; a pathway for secondary infections. Severe reactions to fire ant bites (chest pain, nausea, sweating, loss of breath, serious swelling or slurred speech) are potentially life threatening and require immediate medical treatment.

The presence of displaced wild or stray animals in populated areas increases the risk of diseases transmitted by **animal bites** as well as diseases carried by **fleas and ticks**. Dead and live animals can spread diseases such as **rat bite fever** and **rabies**. Avoid contact with wild or stray animals. Avoid contact with rats or rat-contaminated buildings. If contact cannot be avoided, wear protective gloves and wash hands regularly. Get rid of dead animals as soon as possible. If bitten/scratched, get medical attention immediately. Watch where placing hands and feet when removing debris. If possible, do not place fingers under debris. Wear heavy gloves. If a **snake** is discovered, step back and allow it to leave the area. Wear boots at least 10 inches high. Watch for snakes sunning on fallen trees, limbs or other debris. A snake's striking distance is about 1/2 the total length of the body. If bitten, note the color and shape of the snake's head to help with treatment. Keep bite victims still and calm to slow the spread of venom in case the snake is venomous. Seek medical attention as soon as possible. Do not cut the wound or attempt to remove the venom. Apply first aid; lay the victim down so that the bite is below the level of the heart, and cover the bite with a clean, dry dressing.

5. EQUIPMENT HAZARDS

Various types of exposure to equipment may be encountered when work is performed in a post-disaster environment. Examples of the types of equipment and possible concerns include the following:

Aerial lifts include boom-supported aerial platforms, such as cherry pickers or bucket trucks. The major causes of fatalities are falls, electrocutions, and collapses or tip-over. To avoid aerial lift accidents and injuries, ensure that workers who operate aerial lifts are properly trained in the safe use of the equipment. Maintain and operate elevating work platforms in accordance with the manufacturer's instructions. Never override hydraulic, mechanical, or electrical safety devices. Never move the equipment with workers in an elevated platform unless this is permitted by the manufacturer. Do not allow workers to position themselves between overhead hazards, such as joists and beams, and the rails of the basket, as movement of the lift could crush the worker(s). Maintain a minimum clearance of at least **10 feet** away from the nearest overhead power lines. Always treat power lines, wires and other conductors as energized, even if they are down or appear to be insulated. Use a **body harness** with a **lanyard** attached to the boom or basket to prevent the worker(s) from being ejected or pulled from the basket. Set the brakes, and use wheel chocks when on an incline. Use outriggers, if provided. Do not exceed the load limits of the equipment. Allow for the combined weight of the worker, tools, and materials.

Fatalities and serious injuries can occur if **cranes** are not inspected and used properly. Many fatalities can occur when the crane boom, load line or load contacts power lines and shorts electricity to ground. Other incidents happen when workers are struck by the load, are caught inside the swing radius or fail to assemble/disassemble the crane properly. Cranes are to be operated only by qualified and trained personnel. A designated competent person must inspect the crane and all crane controls before use. Be sure the crane is a level position and on a firm/stable surface. During assembly/disassembly, do not unlock or remove pins unless sections are blocked and secure (stable). Fully extend outriggers and barricade accessible areas inside the crane's swing radius. Watch for overhead electric power lines and maintain at least a **10-foot safe working clearance** from the lines. Inspect all rigging prior to use; do not wrap hoist lines around the load. Be sure to use the correct load chart for the crane's current configuration and setup, the load weight and lift path. Do not exceed the **load chart capacity** during lifts. Raise load a few inches, hold, verify capacity/balance, and test the brake system before delivering the load. Do not move loads over workers. Be sure to follow signals and manufacturer instructions while operating cranes.

Operating a **chain saw** is inherently hazardous. Potential injuries can be minimized by using proper personal protective equipment and safe operating procedures. Before starting a chain saw check controls, chain tension, and all bolts and handles to ensure that they are functioning properly and that they are adjusted according to the manufacturer's instructions. Make sure that the chain is always sharp and the lubrication reservoir is full. Start the saw on the ground or on another firm support. Drop starting is never allowed. Start the saw at least 10 feet from the fueling area, with the chain's brake engaged. When fueling a chain saw, use approved containers for transporting fuel to the saw. Dispense fuel at least 10 feet away from any sources of ignition when performing construction activities. Do not smoke during fueling. Use a funnel or a flexible hose when pouring fuel into the saw. Never attempt to fuel a running or hot saw. Clear away dirt, debris, small tree limbs and rocks from the saw's chain path. Look for nails, spikes or other metal in trees or wood before cutting. Shut off the saw or engage its **chain brake** when carrying the saw on rough or uneven terrain. Keep the hands on the saw's handles, and maintain secure footing while operating the saw. Proper personal protective equipment must be worn when operating the saw, which includes hand, foot, leg, eye, face, hearing and head protection. Do not wear loose-fitting clothing. Be careful that the trunk or tree limbs will not bind against the saw. Watch for branches under tension, they may spring out when cut. Gasoline-powered chain saws must be equipped with a protective device that minimizes chain saw **kickback**. Be cautious of saw kick-back. To avoid kick-back, do not saw with the tip. If equipped, keep tip guard in place.

Chipper machines cut tree limbs into small chips. Hazards arise when workers get too close to, or make contact with the chipper. Contact with chipper operating components (blades, discs or knives) may result in **amputation** or **death**. Workers may also be injured by material thrown from the machine. To minimize these hazards, use appropriate engineering and work practice controls, including worker training. Common hazards include workers making contact with or being pulled into the chipper; hearing loss; and face, eye, head or hand injuries. Never reach into a chipper while it is operating. Do not wear loose-fitting clothing around a chipper. Always follow the manufacturer's guidelines and safety instructions. Use earplugs, safety glasses, hard hats and gloves. Workers should be trained on the safe operation of chipper machines. Always supervise new workers assigned to chipper use to ensure that they work safely and never endanger themselves or others. Avoid contact with operating chipper components by guarding the in-feed and discharge ports, and preventing the opening of the access covers or doors until the drum or disc completely stops. Prevent detached trailer chippers from rolling or sliding on slopes by chocking the trailer wheels. Maintain a safe distance between chipper operations and other work/workers. When servicing and/or maintaining chipping equipment (i.e., "un-jamming") use a **lockout** system to ensure that the equipment is de-energized.

Portable generators are internal combustion engines used to generate electricity. They are useful when temporary or remote power is needed, and are commonly used during cleanup and recovery efforts following disasters. Major causes of injuries and fatalities from portable generators include shocks and **electrocution** to users from improper use and, shocks and electrocution to utility workers from improper connection to buildings (e.g. "**backfeed**"). Injuries and deaths can also be caused by fires initiated by improperly refueling the generator or inappropriately storing fuel and, **carbon monoxide** from a generator's exhaust. Many people have died from CO poisoning because their generators were not adequately ventilated. Generator placement should always be given careful consideration. If workers show symptoms of CO poisoning such as dizziness, headaches, nausea or tiredness, move them to fresh air immediately and seek medical attention.

In order to ensure the safe operation of portable generators, workers should inspect equipment for damaged or loose fuel lines as a result of transportation or handling. Keep the generator dry. Before refueling, shut down the generator and never store fuel indoors. Maintain and operate portable generators in accordance with the manufacturer's use and safety instructions. Never attach a portable generator directly to the electrical system of a building unless the generator has a properly installed with an open-transition **transfer switch**. Always plug electrical appliances and tools directly into the generator, using the appliance manufacturer's supplied cords. Use heavy-duty extension cords that contain a **grounding conductor** (3-wire flexible cord and 3-pronged cord connectors). Proper grounding and bonding are a means to prevent shocks and electrocutions. Use ground-fault circuit interrupters (**GFCIs**) as per the manufacturer's instructions. Do not connect a generator to a structure unless the generator has a properly installed transfer switch. Visually inspect the equipment before use, remove defective equipment from service and, mark or tag it as unsafe for use.

Portable and vehicle-mounted generators need not be grounded (connected to earth) as the frame may serve as the ground. The generator should supply only plug-connected equipment through receptacles mounted on the generator. The noncurrent-carrying metal parts of equipment (such as the fuel tank, the internal combustion engine, and the generator's housing) are bonded to the generator frame, and the equipment grounding conductor terminals (of the power receptacles that are a part of the generator) are bonded to the generator frame. Thus, rather than connecting to a grounding electrode system, such as a driven ground rod, the generator's frame replaces the grounding electrode. If these conditions do not exist, then a grounding electrode, such as a **ground rod**, is required. If the portable generator is providing electric power to a structure by connection via a transfer switch to a building, it must be connected to a grounding electrode system, such as a driven ground rod. The transfer switch must be approved for the use and installed in accordance with the manufacturer's installation instructions by a qualified electrician. Grounding requirements for generators connected via transfer switches are covered by Article 250 of the **National Electrical Code** (NEC).

Safe work practices for **potable electric tools** connected to portable generators include the use of properly rated cords. Replace underrated cords (and extension cords) with appropriately rated cords that use heavier gauge wires. Never use electrical tools or appliances with frayed cords, missing grounding prongs, or damaged or cracked housings. Use double-insulated tools and equipment distinctively marked as such, where possible. Use battery-operated tools, where possible. The integrity of the connection between the generator's frame and the equipment grounding terminals of power receptacles is important to the safe use of the equipment. The connection may be confirmed via testing by a competent electrician with the correct equipment. The **Ohmic resistance** should measure near zero and must not be intermittent, which would indicate a loose connection.

Falls from **portable ladders** (step, straight, combination and extension) are one of the leading causes of occupational fatalities and injuries. Read and follow all labels and markings on the ladder. Avoid **electrical hazards**; look for overhead power lines before handling a ladder. Avoid using a metal ladder near power lines or exposed energized electrical equipment. Always inspect the ladder prior to using it. If the ladder is damaged, it must be removed from service and tagged until repaired or discarded. Do not use a self-supporting ladder (e.g., stepladder) as a single ladder or in a partially closed position. Do not use the two top steps/rungs of a stepladder as a step/rung unless it was designed for that purpose. Always maintain **3-points contact** (two hands and a foot, or two feet and a hand) on the ladder when climbing. Keep the body near the middle of the step and always face the ladder while climbing and descending. Only use ladders and appropriate accessories (ladder levelers, jacks or hooks) for their designed purposes. Ladders must be free of any slippery material on the rungs, steps or feet.

Use a ladder only on a stable and level surface, unless it has been secured (top and bottom) to prevent displacement. Do not place a ladder on boxes, barrels or other unstable bases to obtain additional height. Do not move or shift a ladder while a person or equipment is on the ladder. An extension or straight ladder used to access an elevated surface must extend at least **3 feet** above the point of support. Do not stand on the three top rungs of a straight, single or extension ladder. The proper angle for setting up a ladder is to place its base a quarter of the working length of the ladder from the wall or other vertical surface. A ladder placed in any location where it can be displaced by other work activities must be secured to prevent displacement or a barricade must be erected to keep traffic away from the ladder. Be sure that all locks on an extension ladder are properly engaged. Do not exceed the maximum load rating of a ladder. Be aware of the ladder's load rating and of the weight it is supporting, including the weight of any tools or equipment.

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TECHNOLOGY

6

USING A BINARY PROBIT MODEL WITH RANDOM EFFECTS TO EVALUATE THE EFFECTIVENESS OF HIGH-VISIBILITY PERSONAL PROTECTIVE EQUIPMENT ON NIGHTTIME HIGHWAY OPERATIONS

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ABSTRACT

Nighttime construction has become an accepted procedure for roadway maintenance and construction operations although it presents visibility problems for motorists and workers. High-visibility garments are used to improve the visibility of roadway workers. This paper presents a methodology to compare the visibility of different high-visibility safety garments. The high-visibility garments were displayed in a simulated maintenance work zone on an interstate in Midwest USA. Videos were recorded using a camera which was mounted on a passenger car which passed through the work zone at the posted speed limit. These videos were then shown to drivers who compared the visibility of the garments of the construction workers. Statistical analysis was conducted to examine the impact of random effects by considering characteristics of the garments, drivers and site, etc. The study found that variables such as the mean of the retroreflectivity measurements of the garment and the frequency of the drivers encountering nighttime work zones were significant when choosing the most visible garment. The study provides insight regarding practices related to high-visibility garment, and can play a significant role in improving worker visibility on nighttime operations.

Keywords: Nighttime, Safety, Binary Probit, Personal Protective Equipment, High-visibility, Work Zone, Construction, Maintenance.

1. INTRODUCTION

Nighttime construction has become an accepted procedure for roadway maintenance and construction operations although it presents visibility problems for motorists and workers. Visibility is critical to workers and motorists on roadways. The sooner a driver detects a worker, the more likely a struck-by incident can be prevented (ANSI/ISEA 207-2006). High-visibility Personal Protective Equipment (PPE), which is composed of fluorescent background color and retroreflective material, is regularly used to improve the visibility of roadway workers.

In response to the importance of high-visibility garments, the International Safety Equipment Association (ISEA) and the American National Standard Institute (ANSI) published the American National Standard for High Visibility Safety Apparel and Headwear, known as ANSI/ISEA 107-2004. This publication provides recommendations for the use, design and testing of high-visibility apparel. ANSI/ISEA 107-2004 defines three performance classes (Class I, II and III) for high-visibility apparel, depending upon the minimum area of the different materials on the safety garment.

2. PRIOR STUDIES IN EVALUATING EFFECTIVENESS OF HIGH-VISIBILITY PPE

Typically, the effectiveness of high-visibility garments in the nighttime hours has been evaluated by determining the distance between the pedestrian and the point at which the driver recognizes the presence of a pedestrian. Previous research studies have evaluated the characteristics of safety vest luminescence using computer software and by obtaining the perspectives of human evaluators on their visibility. Table 1 summarizes prior studies that evaluated the effectiveness of high-visibility PPE. None of these studies were conducted in Indiana, nor have they incorporated in the assessment the combination of different high-visibility PPE, the perspective of drivers regarding visibility of different PPE and the features in a maintenance work zone. This study considers different types of safety garments (safety pants, safety vest and retroreflective bands) in a simulated maintenance work zone. Drivers compared the visibility of these garments. A statistical model was developed to predict which characteristics make garments more visible to drivers.

3. DATA COLLECTION

This study incorporates the perspective of drivers and the assessment of the visibility of different combinations of high-visibility PPE displayed in a maintenance work zone environment. A Binary Probit Model was developed to predict those characteristics which cause drivers to rate a garment as more visible. The following subsections provide further details.

Selection of Experimental Set-up

A simulated maintenance work zone located on interstate I-74 in southeast Indianapolis between Exits 96 and 99 was used. The cones at the work zone were placed at every other skip of the pavement markings. Figure 1 shows how the work zone was set up. A worker wore high-visibility garments and was videotaped in the active work zone area while performing two different tasks in two positions: position 1 and position 2. These two positions were found to be very common in nighttime work zones. Figure 2 shows workers in these positions on a maintenance project in downtown Indianapolis, Indiana.

Selection of PPE used in the Analysis

Fourteen different types of high-visibility PPE were considered in this study, including the high-visibility garment (Class II PPE) currently used by the Indiana Department of Transportation (INDOT),. All of the garments were yellow-green in color with white retroreflective material. The PPE evaluated in this study included weather-related garments (coats, raincoats and sweatshirts); however these garments were not included in the statistical analysis. Table 2 provides a listing of the key features of the garments considered in the Binary Probit model. Multiple coefficients of retroreflection (RA) measurements were taken for each high-visibility PPE using a retroreflectometer. Clothing assemblies were created by combining two or more high visibility items. The high-visibility PPE assemblies all meet the minimum requirements for Performance Classes 2 or 3 of the ANSI/ISEA 107-2004. Table 3 shows the assemblies that were evaluated in this study.

Table 1: Prior studies that evaluated the effectiveness of high-visibility PPE

Authors /Year	Key features of the Data Collection	Data collected and analysis performed	Key Findings
Luoma (1995)	• Studied the effects of retroreflector positioning on the recognition of pedestrians. • Considered four retroreflector positions at different locations and conditions.	Analysis of variance considering recognition distances, retroreflecto r positions and walking direction.	Pedestrians with retroreflectors at the major joints of their bodies had the greatest mean recognition distance (249m), followed by pedestrians with the material at the wrists and ankles (241m), torso (136), and no retroreflectors (35m).
Sayer and Mefford (2000)	• Examined the effect of color contrast in visibility during both the daytime and nighttime operations. • Experiment was conducted in a simulated work zone.	Pair wise comparison and Thurstonian scaling	• Combinations of color contrasts, within the vest and in contrast relative to the surroundings, affect the noticeability of the vest. • Stimuli having orange and yellow color were found to be more noticeable. • For nighttime, safety vests with higher luminance trim material were found to be more noticeable.
Sayer et al. (2002)	• Normal and color deficient drivers assessed the effects of color on the detection of pedestrians who were wearing different colors of retroreflective markings on the legs. • Drivers sitting in the driver's seat of a stationary automobile observed the pedestrian walking along the road.	Modeling of detection distances as a function of specific intensity of unit area and analysis of variance	The effect of the participants' ages was not significant; and for persons with normal color vision, the color of the retroreflective marking affected the distance at which the pedestrian was detected.

Arditi et al. (2003)	• Evaluated six safety vests in highway work zones by measuring their luminescence when they were displayed in a work zone. Involved the videotaping of the vests and considered the lighting intensities in the work zone, weather conditions, etc. • Factors evaluated by a group of subjects included the 360° visibility of these vests, their conspicuity against the background, etc.	A system was developed to perform a field test and calculate the luminance of the safety vests.	Two of the vests which were very similar and did not have the largest amount of retroreflective material were superior to the other vests.
Sayer and Mefford (2004a)	• Assessed the attributes of 18 retroreflective personal safety garments on pedestrian conspicuity at night by having drivers passing through a simulated work zone attempting to detect pedestrians. • The detection distances were found using the coordinates of the vehicle and the pedestrian, obtained using a differential global positioning system.	Analysis of variance considering detection distances, garment configuration, trim color, trim intensity, driver's age, etc.	• Class 3 jackets were significantly more conspicuous than both the Class 3 or Class 2 vests • Younger drivers detected a pedestrian at significantly greater distances than older drivers. • Gender and retroreflectivity were not significant. • The blaze orange color was found to be the most conspicuous of the retroreflective trim colors.
Sayer and Mefford (2004b)	• Assessed the effects of retroreflective arm treatments, pedestrian arm motion, scene complexity, and pedestrian orientation on the detection distances of older drivers. • Twenty-four drivers with a mean age of 68.8 years drove through a route and indicated to a researcher when they were confident of seeing a pedestrian	Analysis of variance considering detection distance, scene complexity, garment, orientation, etc.	• The garment and pedestrian orientation were not significant factors. • Both the scene complexity and arm motion had a significant effect on the results.
Hirasawa et al. (2006)	• Conducted an experiment in a simulated work zone to determine the most recognizable uniform colors (dark blue, red, yellow, and orange) as perceived by users during the winter and autumn seasons in the daytime and nighttime hours and at dusk. • Two lighting conditions were evaluated at nighttime:	Comparisons of the color recognition distance and worker	The most recognizable colors were yellow during daytime and orange at dusk and nighttime.

spotlighting and balloon lighting.	recognition distance.

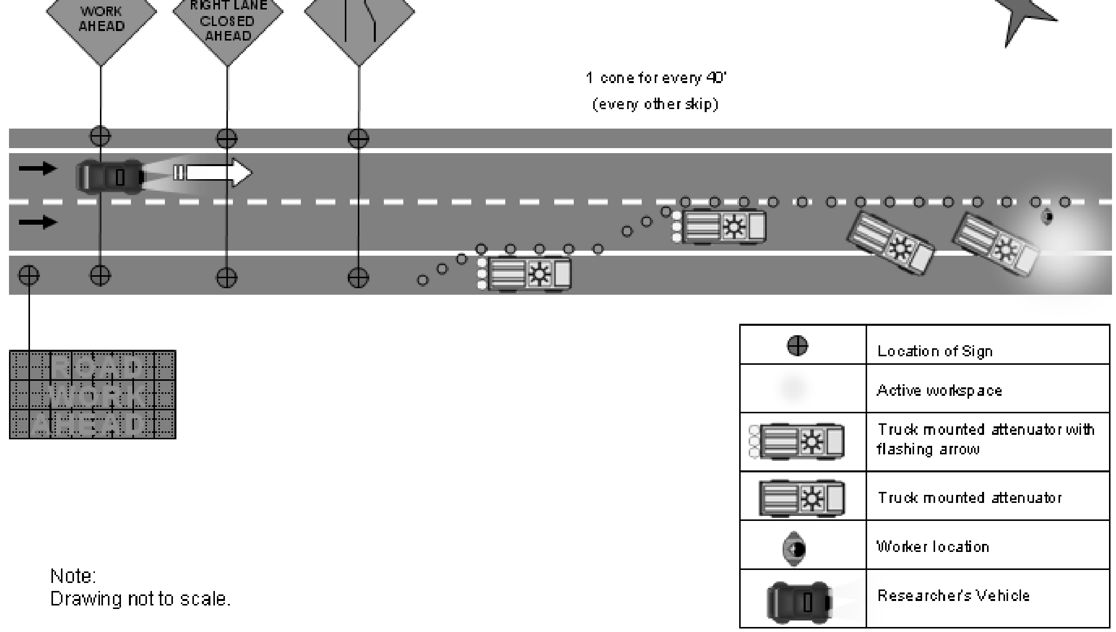

Figure 1: Test layout for data collection

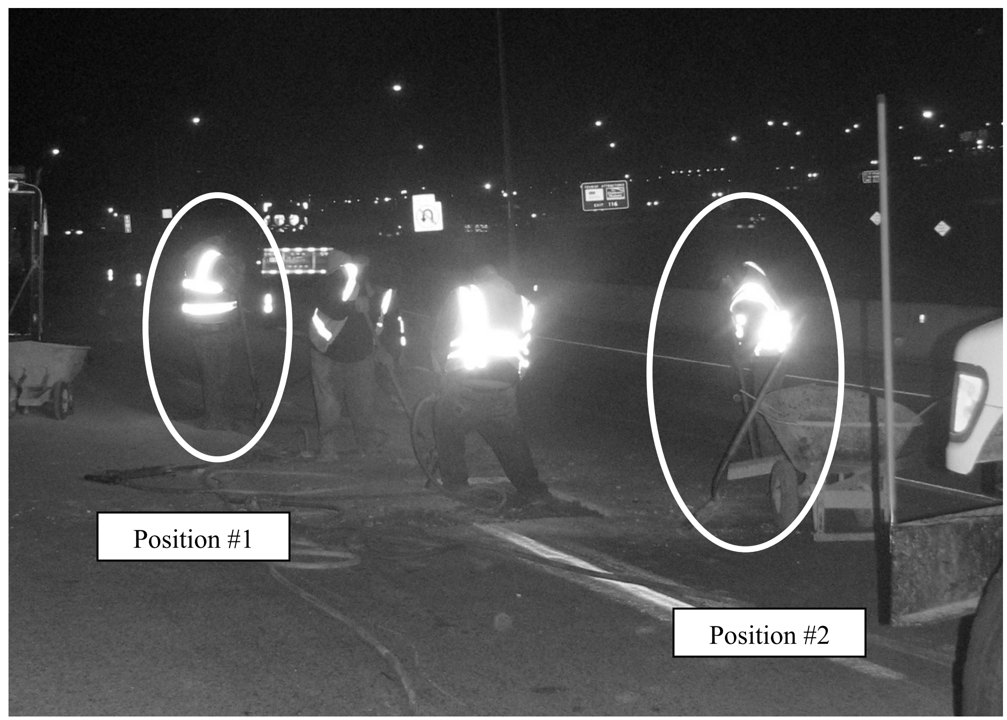

Figure 2: Photograph of positions used in testing (photo taken during site visit to a maintenance project, I-65 Downtown Indianapolis, on November 14, 2006)

Item	PPE	Performance Class	Amount of Retroreflective Material (in^2/front face)
1	INDOT Safety Vest	II	132
2	Short Sleeves Safety Vest	III	149
3	OccuLux Hi-Viz Breathable Safety Pants	E	96
4	High-visibility Headgear	Headwear	0
5	Arm and knee bands	-	42
6	Self-illuminated Vest	II	136
7	High Visibility T-shirt	II	101
8	Mesh Vest	II	112

Table 3: PPE assemblies evaluated

Assembly	High Visibility PPE Item												
	1	2	3	4	5	6	7	8	9	10	11	12	13
a **(INDOT)**	✓			✓									

C	✓		✓	✓				
D		✓	✓	✓				
E		✓		✓				
F				✓	✓		✓	
G				✓			✓	
H				✓		✓		
I				✓				✓

Special considerations in data collection

A video camera was mounted on the dashboard inside a passenger automobile. The research team passed multiple times through the open lane of the work zone and recorded the approach view of the worker. A total of 30 videos were developed – each video depicted each assembly in each worker position. The videos were recorded at 45 mph, which is the posted work zone speed limit on Indiana's interstates. The purpose of this set-up was to obtain an image similar to that seen by drivers while passing through the work zone. The position and angle of the camera were determined through initial trials in a controlled environment. The video camera was centered behind the automobile steering wheel and its shooting angle was parallel to the work zone.

Since lighting can be a significant factor in the conspicuity of high-visibility apparel, the amount of light in the active work zone was measured in candles and lux using an electronic light meter. During the test, the worker modeling the assemblies was told to take a light reading locating the light meter at the middle of the garment that was facing the traffic. The measures were taken to obtain a range of representative lighting levels in the work zone when the test automobile was passing at an average of approximately 1,000 feet and 180 feet before the testing assembly. The automobile driver, using a short wave radio, then informed the model worker when the automobile had reached the measurement point so the worker would know when to record the light intensity.

Use of surveys to compare the visibility of the garments

Surveys for drivers were developed to evaluate the videos. These surveys included questions about the characteristics of the driver, such as age and whether they wore contact lenses/glasses. In addition, pair-wise comparisons between the safety vest currently used by INDOT and a new assembly (*Assembly X*) to find which of the assemblies shown in two videos was more visible or if there was no difference in their visibilities. If the driver found a difference between the visibility of the garments, he/she would rate how large the difference was on a scale from one to five (1-small, 3-medium, and 5-large).

University, West Lafayette, Indiana. These students represented drivers who were likely to encounter work zones. Each video was approximately seven seconds long and showed the last portion of the work zone. Immediately after watching a pair of videos, the subjects were asked to compare the visibility of the high-visibility safety garments they had seen in the videos. The first video displayed on each comparison was the one showing the garment currently used by the Indiana Department of Transportation while the second video contained an *Assembly x*. Characteristics of the room in which the video screening was conducted and the location of the respondent in the room was recorded in order to determine if these factors had significant effects on the responses.

4. DATA ANALYSIS

A Binary Probit model with random effects was developed which considered the effects of the variables: (a) the drivers, (b) the assemblies, (c) the work site, and (e) the display room, on the selection of the more visible safety garment. The Binary Probit model considered two discrete outcomes: (1) "INDOT safety garment is more visible" and (2) "*Assembly X* is more visible". The basic principles of the Binary Probit model, the type of outcomes and the random effect component of the model are discussed in the following sections.

Use of Binary Probit Models

Following Washington et. al. (2003), the formulation for the Binary Probit model is derived from a simple linear function Z_{in} that determines discrete outcome i for observation n,

$$Z_{in} = \beta_i X_{in} + \varepsilon_{in} \tag{1}$$

where β_i is a vector of estimable parameters for discrete outcome i, and X_{in} is a vector of observable characteristics that determine discrete outcomes for observation n. These parameters determine the discrete response for the observation and in this case are related to the characteristics of the assembly, the driver, the video and the display room. The addition of the disturbance term ε_{in} emerges because of the possibility that for instance: (1) variables have been omitted, (2) the form of Eq. 1 may not be linear, or (3) variations in β_i are not accounted for (Washington et al. 2003).

If the probability of observation n to have a discrete outcome I is denoted by $P_n(i)$, with I being all possible outcomes for observation n, and ($i \in I$) then,

$$P_n(i) = P(Z_{in} \geq Z_{In}) \ \forall \ I \neq i . \tag{2}$$

Combining Eq. 1 and Eq. 2,

Eq. 3 is assumed to be normally distributed, resulting in Equation 4, which estimates the probability of outcome 1 occurring for observation n:

$$P_n(1) = P(\beta_1 X_{1n} - \beta_2 X_{2n} \geq \varepsilon_{2n} - \varepsilon_{1n}) \quad (4)$$

In this equation, ε_{1n} and ε_{2n} are normally distributed with mean = 0, variances σ^2_1 and σ^2_2 respectively, and the covariance is σ_{12}. When there are normally distributed variates, the addition or subtraction of two normal variates also produces a normally distributed variate (Washington et al. 2003). The parameter vector (β) is estimated using standard maximum likelihood methods. In the binary case with i = 1 or 2, the log-likelihood is,

$$LL = \sum_{n=1}^{N}\left(\delta_{1n} LN\Phi\left(\frac{\beta_1 X_{1n} - \beta_2 X_{2n}}{\sigma}\right) + (1-\delta_{1n}) LN\Phi\left(\frac{\beta_1 X_{1n} - \beta_2 X_{2n}}{\sigma}\right)\right) \quad (5)$$

Types of Outcomes and Random Effects Components

The two discrete outcomes considered in the analysis of the data were: (1) the INDOT safety garment is more visible and (2), *Assembly X* is more visible. However, each one of the drivers made multiple comparisons that will likely share unobserved effects and can result in the underestimation of the standard errors of the model's parameters. This can result in inflated *t* statistics, potentially misleading levels of significance, and potential biases in parameter estimates. These problems can be addressed with a random effects model which includes a normally distributed individual-specific error term (φ_i) to account for random error within each individual (Shafizadeh and Mannering 2006) in addition to the traditional disturbance term of each observation. In this case, Equation 1 becomes,

$$Z_{in} | \varphi_i = \beta_i X_{in} + \varepsilon_{in} + \sigma_\varphi \varphi_i \quad (6)$$

where φ_i is normally distributed with the mean zero and the variance one, and the term σ_φ is an estimable parameter. The development of an estimable model from this equation follows that from Equations 2 to 5 above. Please note that if σ_φ is not significantly different from zero, the random effects are not significant in the model; and if it is significantly different from zero, then the random effects are significant.

5. RESULTS OF THE STUDY AND IMPLICATIONS

The model developed predicts which assembly the driver would choose as the more visible (INDOT safety vest or *Assembly X*), given *Assembly X*-related characteristics, the characteristics of the drivers, and site-related characteristics. The observations of the drivers who did not find a difference in the visibility of the INDOT safety vest and *Assembly X* were not taken into account. Each driver made multiple comparisons and after eliminating the answers where the drivers believed there was no difference between the garments, the sample contained 325 observations. 46 of the respondents believed that

Assembly X was more visible.

Characteristics such as whether the driver wears glasses/contact lenses and how long they had been driving were not found to be significant. The descriptive statistics for the variables found to be significant in the Binary Probit model are presented in Table 4, and the estimation results for the model are presented in Table 5. The model provides information on how the characteristics of the assembly, driver, and site are associated with the perceived visibility of the garments. A positive sign in the coefficient means that an increase in the value of the variable or a value of 1 for the indicator variables will make *Assembly X* more likely to be chosen as the more visible PPE.

Table 4. Description of variables found to be significant in random effects Binary Probit. Model Estimations

Independent Variable	Symbol	Mean	Standard Deviation	Minimum /Maximum
Characteristics Related to Drivers				
Frequency driving at night (1 if daily or weekly, 0 otherwise)	*freqn*	0.92	.26	0/1
Characteristics Related to Assembly X				
Mean of retroreflectivity (cd/lx*m^2) of the main garment	*mmean*	448.75	38.77	410.3/554.4
Variance of retroreflectivity (cd/lx*m^2) of the main garment	*mvar*	119.60	198.71	31.50/679.40
Variance of retroreflectivity (cd/lx*m^2) of the secondary garment	*svar*	262.27	225.72	0/530
Characteristic Related to Site				

180 feet

Table 5. Random effects Binary Probit model of perceived visibility of high-visibility Garments

Independent Variable	Symbol	Estimated Coefficient	*t* statistic
Constant		-8.910	-2.620
Characteristics Related to Drivers			
Frequency driving at night (1 if daily or weekly, 0 otherwise)	*freqn*	2.190	1.248
Characteristics Related to Assembly X			
Mean of retroreflectivity (cd/lx*m^2) of the main garment	*mmean*	0.012	2.142
Variance of retroreflectivity (cd/lx*m^2) of the main garment	*mvar*	0.001	1.439
Variance of the retroreflectivity (cd/lx*m^2) of the secondary garment	*svar*	-0.003	-1.401
Characteristics related to site			
Amount of light at 180 feet	*light*	1.170	3.179
Model Parameters			
Random effect (Hausman test) parameter σ	φ_i	0.651	3.955
Number of observations	325		
Initial log-likelihood	-132.518		
Log likelihood at convergence	-67.540		
ρ^2	0.49		
Adjusted ρ^2	0.45		

*Dependent variable are zeros (INDOT safety vest) and ones (Assembly X).

The drivers made multiple comparisons that are likely to share unobserved effects. The significance of the random effects parameter (σ), with a t statistic of 3.955 indicates that the random effects element of the model is warranted.

INDOT safety vest as the most visible. This finding may indicate that a frequent driver may get used to seeing the INDOT safety garment in a work zone. A different garment may capture their attention more effectively, suggesting that high-visibility garments should be changed periodically.

The garment-related characteristics were also found to be significant. Higher values in the mean and variance of *Assembly X*'s retroreflectivity indicate that it is less likely for a driver to choose the INDOT safety vest as the more visible PPE. These findings suggest that garments with lower intensities and a lower variance of retroreflectivity cause the workers to blend into the work zone with inanimate objects, making them less visible to drivers.

However, lower values in the mean of the retroreflectivity of the secondary garment indicate that it is more likely that respondents will choose the INDOT safety vest as the more visible PPE. This finding may reflect that the combination of high retroreflectivity values in the primary and secondary garment is not effective, and differences in the retroreflective values are needed to make the worker more visible and detectable.

As expected, the lighting at the site was a very significant variable. The higher the intensity of light, the more likely it was that the driver did not choose the INDOT safety vest as the more visible garment. Changes in lighting can be produced by the headlights of passing vehicles and by changes in weather conditions. Greater amounts of lighting could mean that more vehicles are passing through the work zone at that time. This finding suggests that the *Assembly X* garment is more likely to be found more visible in nighttime work zones with higher light intensities and/or in work zones with higher traffic congestion.

6. CONCLUSIONS

The visibility of a roadwork worker during nighttime operations is crucial to ensure the safety of the worker and passing motorists. This paper describes a testing procedure to compare the visibility of different types of high-visibility PPE. The procedure begins with an assessment of different types of safety garments, and includes retroreflectivity values in the analysis and considers the characteristics of the work environment.

The paper describes the feasibility of using the Binary Probit model with random effects for determining the characteristics that influence, in a pair-wise comparison, the selection of a PPE garment as the more visible garment. Application of this statistical method can be used to further model an evaluation of the garments used by other DOTs. The statistical analysis identified the characteristics of the garments that could improve worker visibility. For example, a garment with higher retroreflectivity and higher variance in the retroreflectivity would be more likely to be seen than the currently used INDOT garment. In addition, if a secondary item (such as safety pants or retroreflective bands) is used, its retroreflectivity variance should be low. The results of this study also attention of drivers more effectively.

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SAFETY EXPERIENCE MANAGEMENT SYSTEM FOR ENGINEERS

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ABSTRACT

In order to reduce the training time for junior engineers participating in construction projects, it is helpful to provide these engineers with a learning platform to study and share the important construction safety-related knowledge and experience before and during project execution. With the assistance of web technology, the safety-related experiences acquired from past projects can be shared with the junior engineers. The framework and application of the safety e-Learning system for construction projects during the construction phase are presented and applied to an actual project. All training materials and experiences are obtained from past projects. Furthermore, the knowledge and experiences are managed and published as part of e-learning and knowledge management. All safety-related e-learning and experiences are edited by digital technology and the system is developed under a web-based platform programmed with Java Server Pages (JSP). The combined results of case studies demonstrate that the application of the Construction CAD-based Safety Experience Management (ConCSEM) system is an effective tool for sharing safety-related knowledge and experience, particularly when junior engineers do not have prior safety-related experience. The main contributions of the ConCSEM system include the following; (1) provide a safety experience management environment for junior engineers; (2) maintain and document past safety-related experiences from past projects; (3) reduce the cost and time of training and education. Finally, the efficiency of the proposed system is demonstrated through case examples.

Keywords: Safety Management; Web-based Application; Information Systems; Construction Project, Safety Training

It is very important for junior engineers to learn the important safety-related knowledge and experiences of experienced engineers on construction projects. With the assistance of web technology, junior engineers may acquire the safety-related knowledge and experiences directly from past projects, reducing the time and cost of training. By sharing previous safety-related knowledge and experiences, the safety-related tips and events in executing projects do not need to be trained over and over again. Safety-related experience management focuses on the acquisition and management of important safety-related issues and experience from experienced engineers. Useful safety-related experience can be recorded for different engineers and experts. Safety-related experience management in construction aims to effectively and systematically transfer and share safety-related experience among engineers. To enhance the quality of safety-related experience management gained by engineers involved in construction projects, this study proposes a CAD-based maps (CBM) approach to capturing and transferring safety-related experience management solutions in construction. Combined with web-based technology and CAD-based maps, this study proposes a web Construction CAD-based Safety Experience Management (ConCSEM) system enabling engineers to reuse safety-related knowledge and experience by exchanging and managing safety-related experience during the construction phase of a project. In the proposed ConCSEM system, the map-based experience exchange environment enables senior engineers to dynamically share their safety-related experience with other engineers in participating projects. Engineers are thus invited to exchange and share their safety-related experience. In a study of a Taiwan construction building project, survey (questionnaire) results indicated that the ConCSEM system integrated with a CAD-based experience maps approach is effective for e-learning and construction safety-related experience exchange and management.

2. PROBLEM STATEMENT

Most junior engineers learned the safety-related knowledge and experience directly through visiting construction sites and conversing with senior engineers or experts. The problem is that it usually takes a long time for them to understand the safety experience if they want to learn the process. Furthermore, it is not easy for them to find a proper instructor to learn from and talk to during the construction phase. However, few suitable platforms have been developed to assist engineers in illustrating and sharing their valuable experiences. Most safety-related problems, solutions, experiences and know-how are in the minds of individual engineers and experts during the construction phase of a project. Therefore, sharing and using previous safety-related tacit experiences from construction projects is the primary and significant challenge of this study.

3. RESEARCH OBJECTIVES

This study proposes a novel and practical methodology for capturing and representing the experience and project knowledge of engineers by utilizing a CAD-based Maps (CBM) experience and knowledge exchange and sharing service in the construction phase of a project (see Fig. 1). By integrating CAD-based Maps and web-based technology, engineers can obtain safety tips and benefit directly from the experiences of senior engineers, decreasing the time and cost of on-the-job training. By exchanging and sharing previous safety-related experiences among engineers, similar and related experiences in executing similar projects clarify safety-related knowledge and enable the exchange of knowledge through web-based experience management. The ConCSEM system services users, by requesting assistance from selected engineers or all engineers in the enterprise who have relevant safety-related experience, submit a problem description through CAD-based Maps. Moreover, senior and junior engineers can effectively and easily exchange experiences through CAD-based Maps regarding the specific aspect of the construction project in which they are participating.

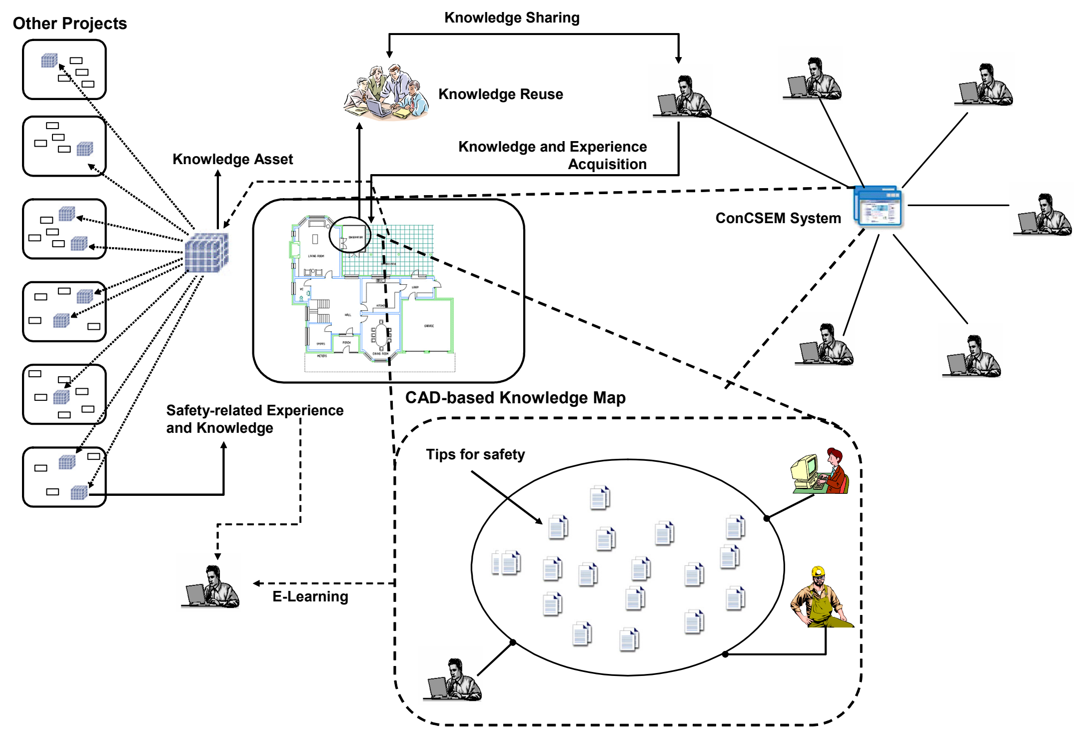

Figure 1 The framework of ConCSEM system

4. THE APPLICATION OF E-LEARNING AND EXPERIENCE MANAGEMENT IN SAFETY

Experience management deals with collecting, modeling, storing, reusing, evaluating and maintaining experiences (Bergmann, 2002). Implicit experience is generally undocumented or stored in a system database. To preserve implicit experience as corporate property, capturing the implicit experience and preserving it in the form of context-specific experience that is difficult to formalize, record or articulate; it is stored in the minds of people (Malhotra, 2000). Tacit experience is personal knowledge acquired through individual experience, which is shared and exchanged through direct, face-to-face contact (Malhotra, 2001). Explicit experience can be codified and transmitted in a systematic and formal language and can be obtained from documents, including reports, articles, manuals, patents, pictures, images and video (Malhotra, 2000; Tiwana, 2000).

How to exchange and share safety-related experience and knowledge for participating engineers became the main topic of research. In the Taiwan construction project case study, knowledge workers assist senior and junior engineers and experts to facilitate the collection of digital films regarding current and past projects. Senior engineers and experts provided their important safety tips and experiences through their discussions with knowledge workers. Knowledge workers transfer the tacit knowledge into explicit knowledge by interviewing senior engineers and experts. Furthermore, knowledge workers record the operation procedures using digital cameras and program the animation with Flash technology. Finally, junior engineers are encouraged to use the system for on-the-job safety training.

The primary advantages of using the ConCSEM system in construction are as follows: (1) reduce the percentage of accidents in construction; (2) support on-the-job-training safety education specific to the construction phase ; (3) provide a safety experience management environment for junior engineers; (4) maintain and manage effectively the past safety-related knowledge and experiences of experienced engineers and (5) reduce the cost and time of training and education.

Knowledge maps are knowledge management tools (Van den Berg and Popescu, 2005). A knowledge map includes the sources, flows, and points of knowledge within an organization (Liebowitz, 2005). A knowledge map has a significant role in implementing knowledge management. All captured knowledge can be summarized and abstracted through the knowledge map. The knowledge map also provides a blueprint for implementing a knowledge management system. Well-developed knowledge maps help users identify intellectual capital, socialize new members and enhance organizational learning (Wexler, 2001). A knowledge map (Wexler, 2001) is a consciously designed medium for communication between makers and users of knowledge by a graphical presentation of text, models, numbers or symbols. Knowledge mapping helps users to understand the relationships between knowledge stores and dynamics.

To apply experience management to new or other construction projects, the process and content of experience acquired from projects must be collected, recorded and saved effectively in the system. To assist participating engineers in illustrating and managing their own safety-related experience, CAD-based Mapping is presented to help engineers explore the safety-related experience they have acquired from past projects. The main objectives of this study are as follows: (1) enhance the illustration of captured safety-related experiences of engineers and experts related to construction projects using the based platform and maps for users to efficiently find applicable experience from experienced engineers. The ConCSEM system was applied in a selected case study of a Taiwan construction project to verify the proposed approach and demonstrate the value of sharing safety-related experience in the construction phase.

The proposed CAD-based Maps are specific approaches to construction experience management. Although knowledge and concept maps are not new in knowledge management, the proposed dynamic CAD-based Maps approach is a novel concept and specific to construction experience management. CAD-based Maps can be defined as a diagrammatic and graphic presentation of experience linking relationships between experience and events attributes. CAD-based maps have components and procedures based on construction project management and thus differ from existing knowledge maps. The proposed CAD-based maps consist of ten components. The ten components include experience number, people number, experience topic, experience layer, experience relationship, experience owner, experience diagram, experience packages, experience attribute, and similar experience. Procedures are presented for constructing CAD-based maps based on the experience management framework. The procedure consists of the following six primary phases: experience determination, experience extraction, experience attribute, experience linking, experience validation and experience sharing.

5. THE SYSTEM

The ConCSEM system is based on the Microsoft Windows 2003 operating system with the Internet Information Server (IIS) as the web server. The prototype is developed using Java Server Pages (JSP), which are easily incorporated with HTML and JavaScript technologies to transform an Internet browser into a user-friendly interface. Three search functions are supported in the system. The server of the ConCSEM system supports four distinct layers: interface, access, application and database layers; each has its own responsibilities. The interface layer defines administrative and end-user interfaces. Users can access information through web browsers such as Microsoft Internet Explorer or FireFox. Administrators can control and manage information via the web browser or by using a separate server interface. The access layer provides system security and restricted access, firewall services and system administration functions. The application layer defines various applications for collecting and managing information. These applications offer indexing, experience map editing, digital photo/video management functions, full text search, collaborative work and document management functions. The database layer consists of a primary SQL Server 2003 database and a backup database (also based on SQL Server 2003). All experience information in the ConCSEM system is centralized in a system database. Project participants may access some or all of these documents through the Internet according to their levels of access authorization. Any information/experience about the project can be obtained from and deposited into the system database only through a secure interface. The web and database servers are distributed on different computers, between which a firewall and virus scans can be built experienced engineers from the CAD-based Map to request assistance in providing previous experience or send the meeting problem directly to the ConCSEM system to request further assistance.

The proposed ConCSEM system consists of five main function modules. The five function modules include experience editing module, CAD-based maps editing module, experience sharing editing module, related-experience search module and experience management setup module.

6. FIELD TESTS AND RESULTS

During the field trials, verification and validation tests were performed to evaluate the system. The verification test was conducted by checking whether the safety e-learning system could perform tasks specified in the system analysis and design. The validation test involved asking selected case participants to use the system, who then provided feedback via questionnaire. The twenty respondents included one project manager with 10 years of experience; three senior engineers with 20 years of experience; five engineers with 10 years of experience; two junior engineers with 2 year of test experience; two knowledge workers with 5 years of experience, and one CKO (Chief Knowledge Officer) with 6 years of experience. The ConCSEM system was demonstrated to the respondents, who were then requested to express their opinions of the system via the questionnaire. The significant findings of the case study are summarized as follows; (1) the total number of gained safety-related experience units in the system was 113 experience units; (2) most senior engineers and experts considered recording and editing their safety-related experience to be too time consuming and (3) most engineers agreed that the ConCSEM system are helpful to enabling safety-related experience sharing and management in construction projects.

7. CONCLUSION

This study proposed a novel and practical methodology for capturing and representing the experience and project knowledge of engineers by utilizing a CAD-based Maps approach. Furthermore, this study developed a web ConCSEM system for engineers which provides dynamical experience exchange and management service for the reuse of domain knowledge and experience. CAD-based Maps divide experience into map units, thus forming an effective experience management tool in construction projects. Effective integration of web technology in ConCSEM system has been demonstrated in the case study in the Taiwan construction building project. The ConCSEM system enables engineers to exchange and share previous experience using CAD-based Maps to express their ideas and experience. Furthermore, the ConCSEM system enables users to request experience support and to exchange experience with selected engineers or all enterprise engineers by submitting problem descriptions through CAD-based Maps. Novice engineers directly accessing the system can effectively share and exchange experience construction phase of a project. In summary, the ConCSEM system can assist engineers in sharing their experience clearly.

The case study also highlights the need to enhance experience management and exchange platforms. However, the received feedback based on the application of the system are as follows; (1) the content of experience warehouse in the system is inadequate to support novice engineers in obtaining previously acquired safety-related experience in the early stages of a construction project; (2) most senior engineers and experts generally require substantial time and assistance to edit and record their experience and (3) most engineers agree that the ConCSEM system is more useful than other methods of obtaining previous experience. The use of ConCSEM system mainly deals with the assistance to provide engineers exchange important safety-related knowledge and experience easily and effectively. The questionnaire results indicate that the primary advantages of ConCSEM system in the case are as follows: (1) the ConCSEM system provide clear and dynamic representations, thus identifying the safety-related experience and knowledge of engineers relevant to the safety tips and events, (2) the CAD-based maps in ConCSEM system clearly illustrate safety-related experience and knowledge regarding the special in the current project and (3) users can find needed safety-related experience easily and effectively from available experienced engineers.

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E-LEARNING MANAGEMENT SYSTEM

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ABSTRACT

Construction safety learning management attempts to provide safety-related information to engineers and participants to reduce construction injuries and incidents. To address the issue of enhancing safety performance, this study presents a novel system called the Construction Safety-based E-learning Management (Con-SEM) System for application on construction projects. This paper will demonstrate that the Con-SEM System responds to newly-acquired safety-related information and efficiently enhances jobsite safety management in a construction project environment. Web-based technology can effectively enhance information sharing regarding construction safety learning management applications, and provides project-related safety information through the Internet. The Con-SEM system is applied to a selected case study involving a construction building in Taiwan to validate the proposed system and demonstrate the effectiveness of the safety learning and training during the construction phase. The main characteristic of the proposed Con-SEM system is that the system is extremely user friendly. The advantage of the Con-SEM system lies not only in improving construction safety-based information and learning efficiency for all engineers, but also in providing the latest safety-based information and experiences for general contractors in construction.

Keywords: Safety Management, Web-based Application, Information Systems, Construction Project

1. INTRODUCTION

It is essential that junior engineers understand the important safety-related operations and events of the construction process before participating in projects. However, training time and cost may make it difficult to access an actual training program in practice. In addition, there is the need to consider site safety and other issues if junior engineers are present at construction sites. With the assistance of e-learning, junior engineers may the safety tips and experiences in executing projects do not need to be trained over and over again. Furthermore, the junior engineers can understand how construction process safety works more quickly and easily by utilizing an e-learning platform.

The system is developed and implemented with an interactive e-learning platform using web-based technology and construction on-site safety education. The multimedia courseware provides junior engineers with animated illustrations specific to operation procedures using Flash technology. In addition, digital films record the all important construction operations. The animation helps the junior engineers understand the process easily and effectively. Furthermore, digital films with detailed explanations are recorded and clearly describe the progress and operation of the construction operations. In other words, junior engineers can access the animated illustrations and digital films for events in the system. Of course, those e-learning materials must be confirmed before being published in the system.

2. PROBLEM STATEMENT

It is important for junior engineers to go to the site to understand the manner in which buildings are constructed. Usually, junior engineers need time to be trained and experienced people to train them when they just arrive at the construction site during a specific phase in the construction process. Actually, most junior engineers understand the procedure directly through visits to construction sites and discussions with senior engineers or experts. The problem is that it usually takes a long time for them to understand the safety work experience if they want to learn the process. Furthermore, it is not easy for them to find a proper instructor to learn from and discuss with during the construction phase. Valuable knowledge and experience should be captured, stored, managed, and reused for other projects (Hart, 1992). The traditional methods for the exchange of safety-related knowledge and experience are ineffective because the safety-related knowledge and experience cannot be maintained and reused on other projects. Additionally, junior engineers do not know where to find this information. After completion of their projects, junior engineers have gained valuable safety-related knowledge and experience; however, they may not have the opportunity to share their insights with others. In practice, the problems mentioned above exist on most construction projects.

3. RESEARCH OBJECTIVES

The use of computerized delivery methods in continuing learning has become popular in recent years. One of the latest trends is in the use of web-based methods as a learning tool. Barron (1998) had attempted to classify and define the various modes of web-based delivery for learning and suggested that Web-based Training (WBT) is emerging as the preferred acronym in the industry. In fact, Web-based Introduction (WBI) and Web-based Training (WBT) are increasingly used in the academic world. Furthermore, the web permits the delivery of material through an attractive multimedia vehicle. In it is very convenient for them to utilize courseware from anywhere and at anytime.

The main purpose for conducting this research is to develop a Construction Safety-based E-learning Management (Con-SEM) System for junior engineers. Con-SEM system provides the exchange of safety knowledge and experience during the construction process. Figure 1 illustrates the concept of Con-SEM system. Therefore, how to prepare safety learning and knowledge for junior engineers becomes the main topic of research. In order to apply the concept to a real life example, the case study selected for this research was the Taiwan building project.. In the case study, knowledge workers assisted senior and experienced engineers and experts in the collection of digital films regarding current and past projects. Senior engineers and experts provided important safety-related tips and experience through interacitive discussions with the knowledge workers. Furthermore, the operation procedures were recorded using digital cameras and then animated with Flash technology. Finally, junior engineers were encouraged to use the system for on-the-job safety training.

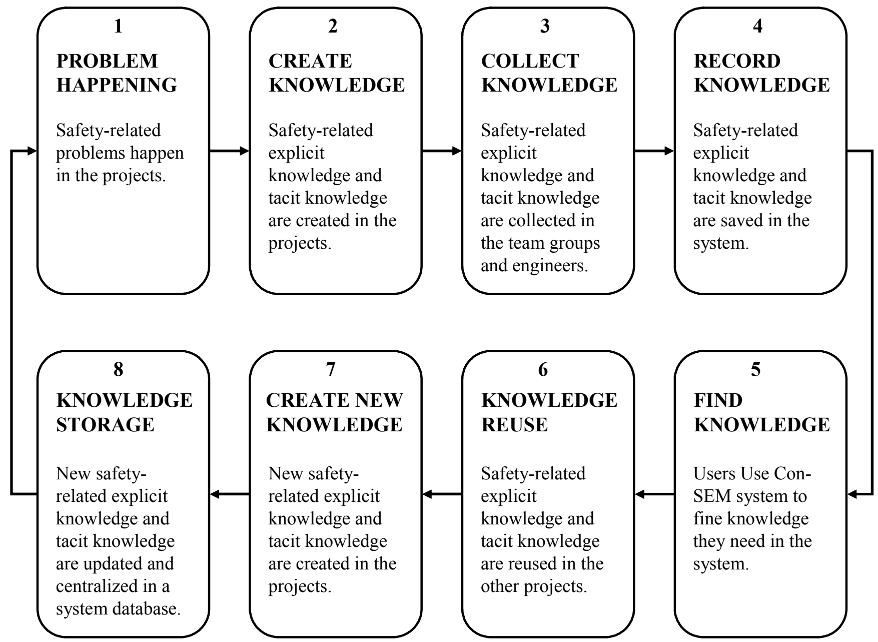

Figure 1 The concept of Con-SEM system

The knowledge management team in the company then identified a theme and a series of generic subject areas based on the discussion results. The advantages of the Con-SEM system included the following:

Supported on-the-job-training safety specific to the construction phase;
Provided safety learning environment for junior engineers;
Effectively maintained and managed the safety-related knowledge and experience from experienced engineers; and
Reduced the cost and time of safety-related training and learning.

Multimedia includes various types of media such as graphics, text, animations, audio and video (Miranda and Park 1998). In construction projects, most project-related problems, solutions, experiences, and know-how are recorded into multimedia-based content. Also, multimedia systems are particularly suited to interactive applications since they allow huge collections of visual media, text, and other data to be stored in a single digital document and accessed easily and quickly (Saad and Hancher 1998). Usually, implicit knowledge is not documented or stored in a system database. It is important to capture the implicit knowledge and make it available as explicit knowledge. In this study, tacit knowledge was collected, edited and recorded in useful interactive multimedia-based content that could be used during the construction process. There were two parts to this work. First, collection of the firms' safety related procedures and processes was conducted. Secondly, construction safety-related operations were animated using Flash technology. All procedures are shown below in Figure 2. The knowledge workers helped the senior engineers and experts to record the various construction processes and edited the descriptions by using input from senior engineers and experts. Next, knowledge workers programmed most of the animated illustrations of the important safety-related construction processes. This enabled junior engineers to quickly understand the construction safety-related procedures through e-learning environments.

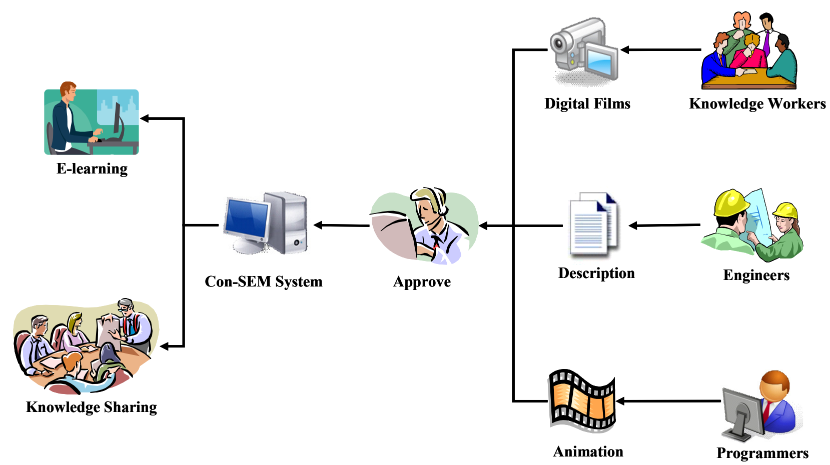

Figure 2 The framework of Con-SEM system .

The knowledge team in the company was responsible for preparing all materials in the Con-SEM system. Most of the materials in the Con-SEM system was collected at construction sites. Therefore, some of the knowledge workers assisted the senior engineers and experts by using digital video cameras to record films at the construction sites. Kknowledge workers also programmed animations modeled after discussions with the senior engineers in the office. Finally, knowledge workers placed those animations and digital films into the system based on their attributes.

All the animations were edited with FLASH technology, and the system was developed under a web-based platform programmed by JSP. The server of the Con-SEM system for safety provides four distinct types of layers: interface, access, application and database layers (see Fig. 3); each layer has its own distinct responsibilities. The interface layer defines administration and end-user interfaces suited to his/her work. The junior engineers can utilize the system through web browsers such as Microsoft Internet Explorer. Administrators can control and manage information through the web browser as well as a separate server interface. The access layer provides system security and restricted access, firewall services, and system administration functions. The application layer defines various applications for information collection and management. These applications provide indexing, full text searches, collaborative work functions and document management functions. The database layer consists of a primary SQL Server 2003 database and a backup database (also based on SQL Server 2003). Within the ConE-learning system, junior engineers may access the Internet to learn about all materials related to their requirements. By distributing the web and database servers on different computers, a firewall can be built between them to protect the system database against any foreign intrusion. The Con-SEM system for safety services described in this paper is made available to all the participants of the company through a specially designed portal, which also serves as a messaging (mail) server for the company (organization).

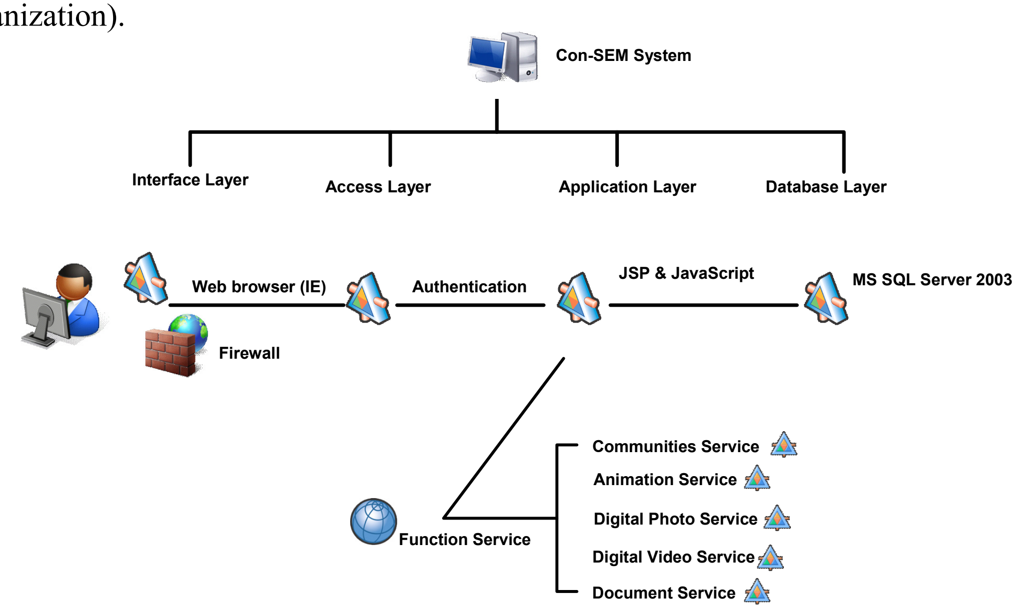

Figure 3 System architecture.

6. FIELD TESTS AND RESULTS

During the field trials, verification and validation tests were performed to evaluate the system. The verification test was conducted by checking whether the Con-SEM system could perform tasks specified in the system analysis and design. The validation test experience; two senior engineers with 20 years of experience; one engineer with 10 years of experience; two junior engineers with 1 year of experience and two knowledge workers with 5 years of experience. The significant findings of the case study are summarized as follows; (1) the total number of safety-related tips and experiences was 53; (2) most senior engineers and experts considered recording and editing their experiences to be too time consuming; (3) most engineers agreed that the Con-SEM system is helpful for enabling safety-related experience sharing and management in construction projects.

7. CONCLUSIONS

Multimedia can be any application that uses multiple types of media, such as graphics, text, animations, audio and video. The main purpose of this study presents a construction safety-based e-learning management system for junior engineers as an e-learning platform. The development of the Con-SEM system for safety employs the integration of web technology with a portal. This system has been outlined and illustrated through a case study of the Taiwan building project. The Con-SEM system takes full advantage of the interactive qualities of multimedia and the potential for collecting, storing and accessing a wide range of media applications. The Con-SEM system is advanced in the respect that it allows insight into the factors having impact on safety-related knowledge and experience for construction projects. This, in turn, will help senior engineers share safety-related knowledge with junior engineers to improve safety learning and management performance. Junior engineers can interact with the system so they can clearly and easily understand the safety-related knowledge and experience in which to involve projects effectively. In short, the Con-SEM system is able to assist junior engineers by providing accurate and important safety-related tips for safety experience reuse and reference. The integration of knowledge management and web e-learning technologies appear to be a promising way to improve junior engineers' learning curves.

The collection and animation of a firm's important safety-related construction tips and experiences allows junior engineers to understand and implement a great deal of safety-related knowledge and experience without the learning curve. The safety-related content of firms and animation in the system not only provides a variety of selected media, but also makes information from past projects readily available. Although effort is required to collect and transfer the safety knowledge into various types of explicit forms, the developed system will benefit construction safety learning and management by (1) providing an effective and efficient computerized environment to assist safety-related learning and management tasks, (2) providing explanations and an understanding of important safety processes construction, and (3) improving visual representation through animation with text. In the evaluation of the case study of the Taiwan building project, the results show that a Con-SEM system is an effective way to share safety-related knowledge for construction projects. Furthermore, animations were found to be the most attractive media to present construction methods, and according to questionnaire evaluations, firms found this to be the most useful e-tool.

management. The feedback based on the application of the system are as follows; (1) the content of safety-related tips and experience warehouse in the system is inadequate to support novice engineers in obtaining previously acquired safety-related experience in the early stages of a construction project; (2) most senior engineers and experts generally require substantial time and assistance to edit and record their safety-related experience and (3) most engineers agree that the Con-SEM system is more useful than other methods of obtaining previous safety-related experience.

The use of Con-SEM system mainly assists engineers in exchanging important safety-related knowledge and experience easily and effectively. The questionnaire results indicate that the primary advantages of ConE-learning system in the case are as follows: (1) the Con-SEM system provides clear and dynamic representations, (2) the animation films in Con-SEM system clearly illustrate safety-related experiences and knowledge, (3) users can find needed safety-related experience easily and effectively from available experienced engineers.

Based on the success of the first trial use of Con-SEM system for e-learning purpose, a new course called construction safety planning and management has been developed for the future. It will be an entirely problem-centered, computer-mediated course integrating IT skill with safety-related planning in construction.

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OPERATOR VISION AID

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ABSTRACT

The focus of this paper is the safety aspects of a tower-crane-mounted vision system that primarily enhances safety, improves productivity, and brings about direct and indirect cost savings. Operators of tower cranes enjoy a bird's eye view of the site, which undeniably contributes to work safety and efficiency. Yet their work often involves blind lifts, as well as other viewing difficulties, that impede full utilization of the potential inherent in the operator's location atop the crane. The development and implementation of the vision system are described, and a list of safety benefits drawn on the basis of feedback received from the field is presented. The paper is aimed at construction safety practitioners, who experience daily those situations that have prompted the development of the system, as well as at researchers who may benefit from the lessons learned with respect to the role of academia-industry cooperation in the introduction of innovative systems in construction.

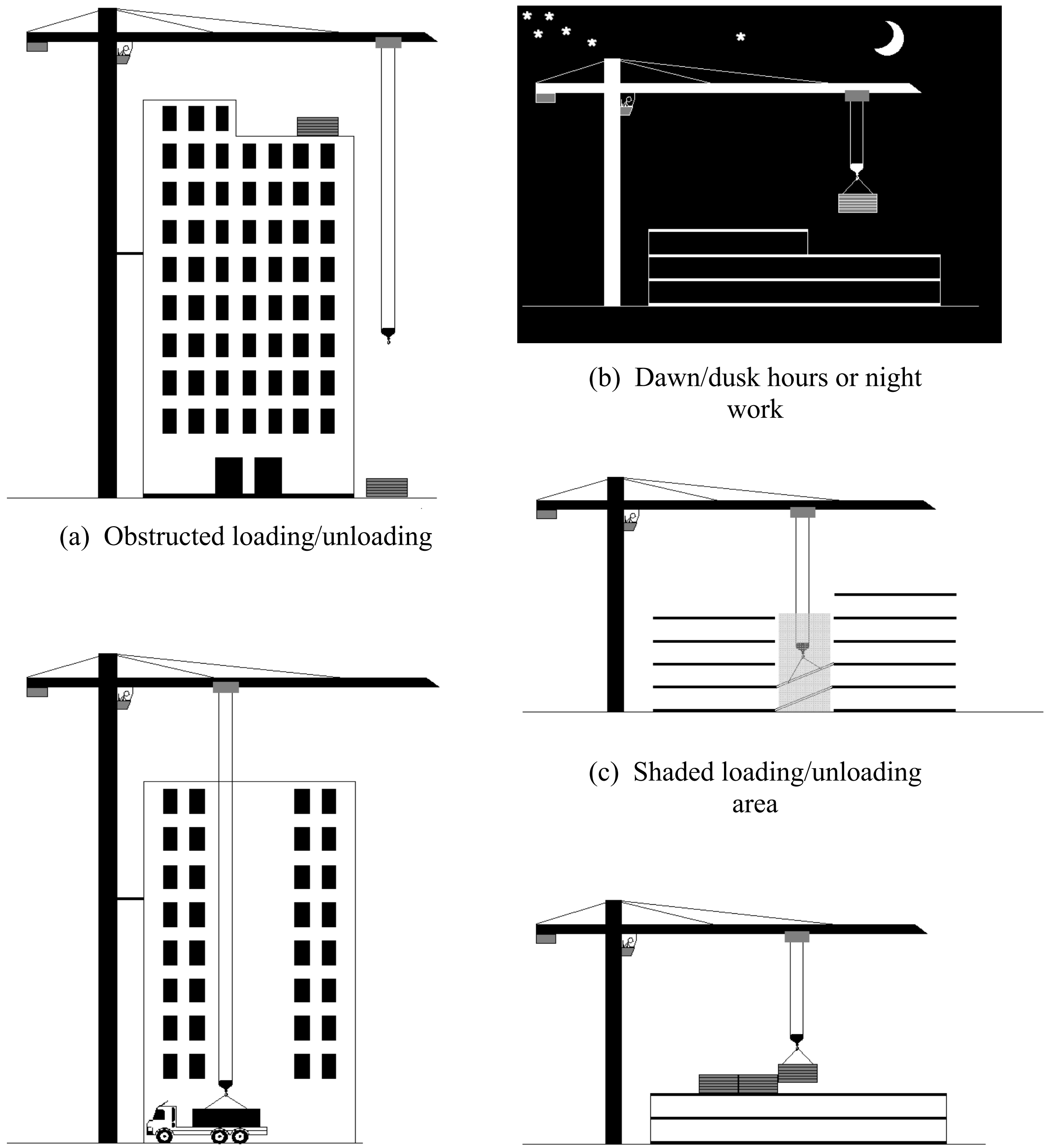
Keywords: Construction sites; Operator aid; Safety; Tower cranes; Visibility.

1. INTRODUCTION

One of the differences between tower and mobile cranes is the location of the operator cab: at ground level in mobile cranes, at the top of the crane in tower cranes. This difference grants the tower crane operator the advantage of a wide field of vision and a complete view of the site, which are helpful for safer rigging, craning, and unloading. Yet, several operational difficulties associated with the operator's vision are often unavoidable (Fig. 1):

- The obstruction from the operator's view of the loading area, unloading area, or travel path ("blind lift"). This problem exists, to some extent, on the vast majority of construction sites.
- Poor lighting conditions. This can be either semi-darkness at dawn and dusk or night work, which is only partially compensated for by artificial lighting.
- Moving the crane hook from broad daylight to shaded areas (e.g., elevator/stairway shaft). The human eye's capacity for quick adaptation to sudden changes of light intensities is challenged.
- An inconvenient angle of vision, which is created with the increase in ratio between the lifting radius and the vertical distance to the loading/unloading area (e.g., when handling heavy, oversized elements, such as precast concrete planks that require both precise positioning of the lifting hook over their center of gravity

operator eyes. This situation, which is always the case in high-rise construction, may also occur in lower structures, in which the crane is often assembled to its full height already at the beginning of construction.



(a) Obstructed loading/unloading

(b) Dawn/dusk hours or night work

(c) Shaded loading/unloading area

(e) Loading/unloading area at a great distance

(d) Loading/unloading area at inconvenient angle of vision

Figure 1 from Previous Page. Visibility Limitations

limitations have negative effects on both productivity and safety on site. Today's partial solution, as with mobile cranes, is commonly the use of signalpersons. But any means that can lessen the dependence on signalpersons is welcome: the cost of labor is high; the nature of tower crane service requires the simultaneous positioning of signalpersons at various locations; all too often signalpersons are undertrained; communication-related misunderstandings occasionally occur and language barriers sometimes exist; and responsibility for the lift is undesirably distributed (Häkkinen 1993; MacCollum 1993; Ross 1996; Neitzel et al. 2001; Shapira and Lyachin 2004).

This paper presents a crane-mounted camera system developed to counter these limitations and their resulting negative effects, and thereby taking full advantage of the potential of the crane operator's bird's eye view and control of the site. The paper describes the development of the system, its implementation and assimilation as an indispensable operator aid on numerous construction sites, and its safety-related benefits.

2. BACKGROUND

The basic concept of camera system aids is not new. Rear-mounted cameras to aid truck drivers have been in use for many years. Everett and Slocum (1993) developed Cranium, a *mobile*-crane mounted camera for improving productivity and safety. Rosenfeld (1995) listed video cameras among various safety and efficiency improvement devices that can be incorporated with computer-controlled tower cranes. *Cranes Today* magazine (Cranes Today 2000) reported that close to 1,600 crawler cranes in Japan were fitted with wired close-circuit television cameras as a safety feature. In Europe, Orlaco, a Dutch manufacturer of camera-monitor systems for land and sea vehicles, offers vision solutions for cranes. Finally, in his editorial on technology progress, Ian Vallely (2005), Editor for *Cranes Today*, lists cameras fitted on top of crane booms as the first of four examples given after maintaining, “there can be no compromise on crane safety equipment.”

Common to all these devices is the concept of providing the operator with a vision aid, which reduces the problem of concealed work areas, and consequently improves on-site productivity and safety. A camera is mounted onto the crane such that it constantly follows the load. The image is transmitted to a monitor located in the operator cab, and the operator can thus see work and hook-travel areas otherwise not within his or her line of sight.

The general advantages of such a system for *tower* cranes on building construction sites are obvious, while its cost is relatively low (and is likely to go further down in a more competitive market). Systems are also offered on a lease basis for a small fraction of the monthly site operation cost. However, up until the experience reported in the present paper, and in spite of these advantages and low costs, such systems have not found their way to a considerable number of sites employing tower cranes. This has been conspicuous mostly in Europe, the cradle of the tower crane culture, where a mere handful of these systems were used in the late 1990s. This, at a time during which tens of thousands of top-slewing tower cranes were in use throughout Europe (Shapira et al.

various safety devices listed. It was not until the end of 2005 that *Cranes Today* magazine (Howes 2005) was finally able to report on a somewhat increasing interest in tower-crane mounted cameras, although not in numbers that even compare to mobile-crane cameras of various types.

Given this state of affairs, the acquisition of dozens of systems as reported here over the past decade by construction companies in Israel and the change this has brought in work modes and crane operation on numerous construction sites, are exceptional and worth learning from: the product, its development and introduction into the market, as well as lessons learned through close field monitoring of its on-site service. Nearly 1,000 top-slewing tower cranes were used in Israel in recent years, an impressive number by any standard, and certainly relative to the country's population of seven million [compare with a similar number of tower cranes in the entire USA, with its population of 300 million (Shapira et al. 2007)]. Roughly 10% of these cranes are used on high-rise construction projects, the natural (though not only) market for tower crane cameras. Between 1999 and 2001, about half of those high-rise cranes were equipped with the vision system as described in this paper, virtually reaching the point of market saturation. This took place not only in an inherently conservative industry, but also during the peak years of a deep recession of the Israeli construction market, which quite understandably resulted in reluctance on the part of construction companies to invest funds in anything that did not appear to be essential.

3. DEVELOPMENT

Development of the vision system began ten years ago, in early 1998. A major construction project (1,100,000 sf, nine-story shopping and entertainment complex) simultaneously employing six tower cranes with a substantial extent of overlapping work envelopes was spotted as a suitable testing site for the development of a prototype. The camera R&D project was presented to the management of that construction project and gained its approval and willingness to cooperate. A 177-ft high tower crane was designated for the job. In addition to the high crane density situation, the work area (loading, unloading, and/or travel) was hidden from the sight of this crane's operators for a considerable part of the time. The crane was continuously busy throughout the entire workday, and occasionally worked during the night as well. At the time of the prospective testing the crane's work assignments were to include a variety of repetitive, duty-cycle lifts. All these parameters rendered this crane ideal for the testing of the camera in a real, constrained site environment.

On-site testing started with the installation of the first prototype in mid-1998. Eventually, two additional prototypes, each an improved version of the former, were installed and tested over the next months. During this period, numerous visits were made to the site by the R&D team, usually involving a climb up to the operator cab, which included observations, interviews with the operators and signalpersons, and a variety of technical operations to install, maintain, and run various checks on the system. Crane work was not

Initial results were encouraging, as were the conclusions derived from the various observations and interviews. Responses of the two crane operators after having used the system for just one day were rather enthusiastic. Primarily, they mentioned the help it provided under circumstances where the load was not within their sight (e.g., behind walls), in darkened areas (e.g., inside shafts), and when precise location of the hook above the center of the load was required. The two operators attested both to the sense of confidence the camera instilled in them and to the higher speed at which it enabled them to operate the crane. Even when still using signalperson guidance within full view of the work area, as mandated, the camera enabled them to see the signals more clearly, and in fast travel it added another angle of vision to help identify objects located beneath the moving load. Upon termination of the initial development at the test site, the crane operators would not hear of parting with the system and the monitor in the cab; they had gotten used to working with it and benefiting from it.

4. THE SYSTEM

In its current form, the system comprises two main modules (Fig. 2). The *Moving Unit* is installed on the trolley that travels along the horizontal crane jib. This unit includes a high-resolution auto-focus video camera that is permanently directed downwards at the work scene, with the lifting hook constantly located at the center of the image. The video image is processed and transmitted to the crane operator cab via wireless communication. The *Stationary Unit* is installed in the cab. It receives and decodes the video transmission, and displays it to the crane operator on a high-resolution color monitor. The operator can control the picture and navigate through different zoom modes as required.

The continuous video transmission is performed at a radio frequency of 2.4 GHz, while the moving unit is remotely controlled from the cab using radio signals in the form of 433 MHz pulses. Directional antennas are used on both the transmitter and the receiver for communication between the cab and the moving trolley. The transmitter's antenna concentrates the radio energy in the desired direction, while the directional antenna on the receiver picks up almost no disruptions ("noises") from undesirable directions.

12V rechargeable batteries, connected to solar panels that usually suffice to keep the batteries constantly charged, power the moving unit. The solar panels are mounted on the handrails of the trolley's service balcony (see Fig. 2 top left). As a backup alternative (rarely required, and usually only during the winter), the batteries can also be charged overnight using a 12V charger situated in the cab and a quick-connect cable. The primary function of this charger is to provide DC power supply to the stationary unit inside the cab, namely, the color monitor, the video decoder, and the remote control transmitter. The charger is fed directly from the cab's electric supply (100V–400V AC input), and is protected against electrical surges and spikes. The moving unit is also protected against over-charge and battery depletion. To save energy, if unused for an extended period, the entire system turns off automatically. The moving unit is housed in a sealed, weatherproof aluminum case, equipped with shock absorbers that damp trolley vibrations.

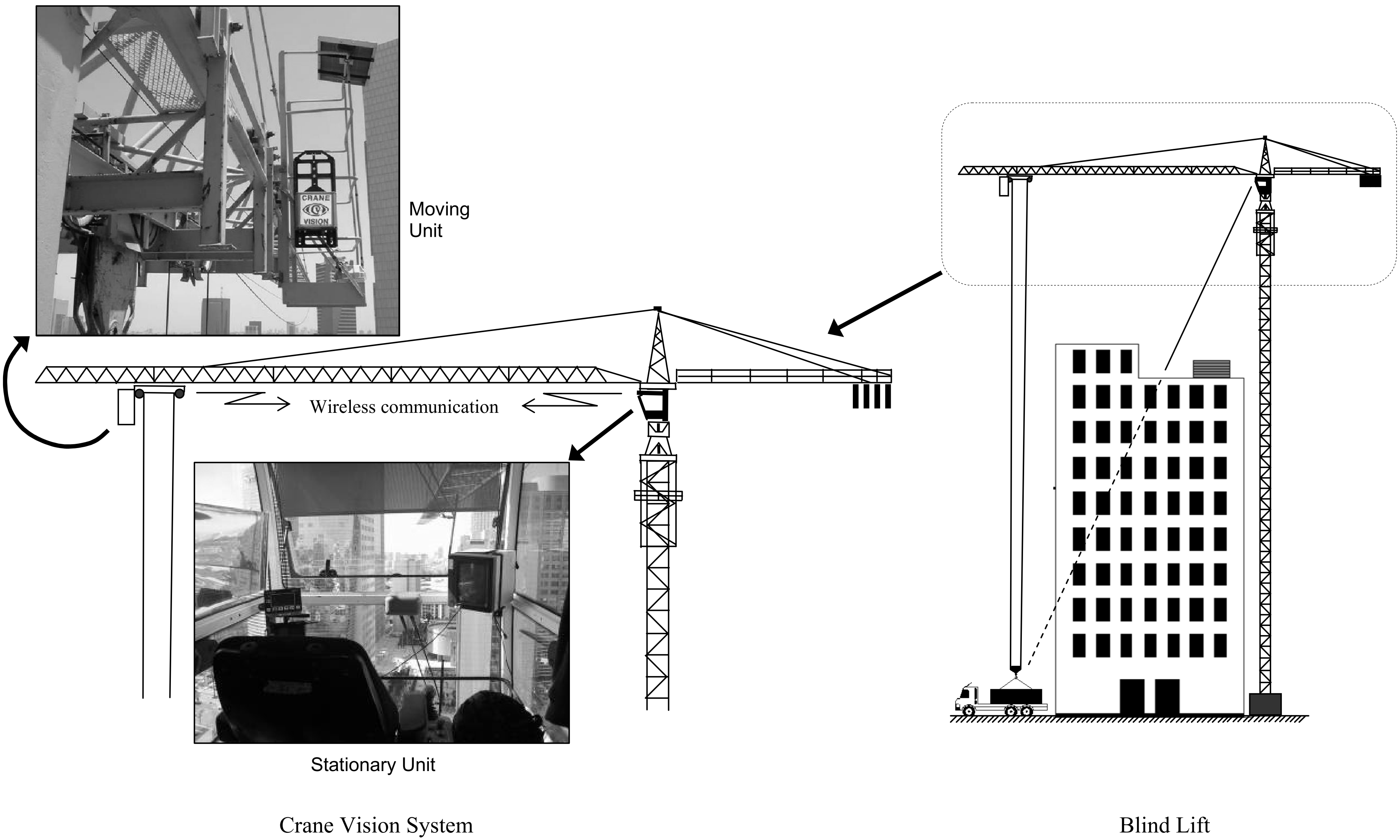


Figure 2. The Problem (Right) and its Solution (Left)

Throughout development and until the system reached its present final form, emphasis was placed on providing the operator with an aiding device that caters to the unique work environment of the construction site in general and within the operator cab in particular, as well as to the operator's modus operandi. Tower cranes enjoy a lifespan of 20 years and more (Rosenfeld and Shapira 1998; Shapira and Lyachin 2004). Most vision systems would therefore be mounted on used, and in many cases even old, cranes. These cranes commonly have tiny cabs and space is quite limited, a factor that must be carefully considered when deciding on the size of the monitor and its location. The location of operation buttons took into account the various other tasks of the operator, who must be facilitated, not impeded by the system. The modularity of the system and its mountability on any crane model were deemed rather important, as they mean a significant upgrade for a sizeable population of cranes. To that end, various alternatives were devised and field-tested with respect to the system's mounting location and brackets, until the present solution was reached. Another important consideration in that regard was the securing of unobstructed access by crane service personnel to their regular work posts. Other decisions made during development addressed options for power supply and recharging, various ergonomic aspects, and alternatives for the bi-directional radio transmissions between the trolley-mounted moving unit and the stationary unit inside the operator cab.

5. IMPLEMENTATION

The first commercial system was installed on a 558-ft high internal-climbing tower crane that served, along with another tower crane, in the construction of a 46-story hotel and residential complex in Tel Aviv. With the crane located inside the tower's shaft, all lifts originating or ending at ground level were blind lifts. The system was used continuously until completion of the project, 18 months later, when it was immediately reinstalled on another crane to continue its service on another company project.

As part of the cooperation between the construction company that built that Tel Aviv tower and the camera R&D team, equipment managers of other construction companies were welcome to visit the site and climb up the crane to see the system in operation. Before long, orders for several other systems were placed by other companies. One such order was for the 886-ft high external tower crane that helped build a nearby 69-story office and residential tower. A custom-made system, equipped with special zoom capabilities given the height of the crane, was installed and served uninterruptedly on this project for almost three years.

By late 2001, about 40 systems had been purchased and were employed by the leading construction companies in Israel, and several others were procured on a monthly rental basis (the ten largest construction companies in Israel use their own fleets of cranes, accounting for 30% of the country's 1,000 tower cranes). To date (early 2008), over 300 projects have been built with the aid of the vision system, including practically all the high-rise buildings constructed in the country during those years. On some of these projects, several systems were in use at the same time. Several companies acquired multiple systems, up to fourteen, a fact that further attests to the benefits perceived to be gained by the use of the system.

This success must be attributed mainly to the advantages offered by the system. Marketing was virtually non-existent (information about the system spread among construction circles mostly by word of mouth), and hence it cannot be considered a success factor.

Academia-industry cooperation must have played a major role during implementation, as it did during development and testing. Each unit installed was closely monitored by the R&D team. Regular visits were conducted to the sites. Scheduled meetings and interviews with site personnel covered not only the performance of the system but also a broad spectrum of productivity and safety-related issues. This monitoring activity was used to systematically gather testimonies, and a library of cases, problems, and camera-based solutions was established. Typical cases from various sites were also shared with all companies using the system.

In parallel to the close contacts with construction companies, the Chief Inspectorate of Israel's Ministry of Labor was also informed of this development from the beginning, and then kept posted. With the Inspectorate expressing encouragement, it was expected that when grading safety preparedness of construction sites, labor safety inspectors would award extra points to sites that employ the vision system. Reportedly, this has indeed been the case, at least with respect to several sites.

6. BENEFITS AND LIMITATIONS

The vision system was initially developed and implemented based on its potential to improve site productivity and safety. During implementation, however, when responses of users were systematically elicited and analyzed, it became clear that the system offers several additional benefits. For some users these other benefits were not less important than the general improvement in productivity and safety and in themselves justified the acquisition of the system.

Overall, the benefits offered by the system, related to safety and health, can be summarized as follows:

- Safety enhancement in general: By allowing the crane operator to continuously view the theater of work, the system prevents accidents and enhances work safety. Countless accidents or near misses result from problems in remote signaling or radio communication, when the operator has no line of sight with the load and receiving crew, and thus must rely completely and exclusively on a third party for guidance.
- Reduced wear of load cables: The vision system offers the operator a vertical vision angle not otherwise possible. This allows the operator fine maneuvering in the immediate proximity of the façade of the constructed building, yet without touching the building. A classic example is the installation of curtain walls, during which the cable often scrapes against existing slabs/beams. Not only do costly cables have to be replaced more frequently, but more importantly, it is also a safety concern.

- Avoiding direct cost damages: Overturning of craned pallets carrying various materials due to a rough landing or even a "soft" collision with another object, is not a rare occurrence. The cost of a lost load (e.g. high-quality exterior cladding marble boards) in one such mishap may be comparable to that of a single vision-system unit, let alone the safety hazard it poses.
- Working in the proximity of obstructions: With a side view only, it is usually difficult to assess the distance to obstructions, such as overhead power lines located within the crane's work envelope, and to maintain adequate clearance from them; the top view offered by the system's monitor allows exactly that. This is true also with respect to the jib or cable of a second, lower overlapping crane.
- Night work: The camera lenses are much more sensitive than the human eye. The vision system can use regular surface light, which is adequate for workers but not for the remote crane operator, in order to display a bright image of the hook and its vicinity on the monitor in the cab. This is also true for dawn and dusk hours during certain times of the year, as well as for heavily overcast or rainy days.
- Monitoring the rigging of loads: Using the vision system (particularly by zooming in), the operator can supervise the rigging of the load prior to lifting and ensure it is done properly. Crane operators reported that for the first time in their career they have on hand an instrument that allows them to refuse the execution of a lift if they are unsatisfied with the rigging. This is a crucial safety issue; incorrect rigging accounts for a considerable percentage of crane accidents.
- Controlling sway and swing: Many accidents occur due to the swaying/swinging motion of the load. Competent operators usually know how to minimize this problem, either a priori or after it has started. However, a downward view was found to be of great help, particularly for lifts made near the façade of the building. A typical example is the lifting of pipes, reinforcement bars, formwork joists, or other long elements that cantilever considerably from their slinging point, and which may hit the façade or any element—permanent (balconies) or temporary (work platforms)—protruding from it.
- Unloading large-size loads from trucks: These can be tricky lifts. The operator attempts to direct the hook towards the center of the longitudinal dimension of the load (e.g. hollow-core precast slab units). To avoid rapid, uncontrollable motion of the load toward the "horse" once the cables have been stretched out and the load lifted, the hook is usually directed such that the opposite motion occurs. This way or another, this constitutes a safety concern. With its downward view, the camera system allows accurate and time-saving positioning of the hook at the center of the load. A similar case is the lifting of an oversized element from within a crowded storage area.
- Ergonomics: Operators frequently find themselves leaning out of the cab's window (Fig. 3), often for prolonged periods of time, to get a better view of the load, particularly at a vertical angle. With the ability to watch the image on the monitor, work convenience is improved, as are work efficiency and safety. The operator is spared the physical effort and fatigue of getting up and bending, all the while keeping hands on the wheels and operating the crane; the operator eyes are similarly subjected to less strain.

Two limitations were observed in the course of implementation and discussions with prospective users. The first of these had to do with a philosophy toward the issue of responsibility during blind lifts that was adopted by a mere few, and which stood in complete contrast to the general notion of all others. Those few maintained that, while the crane operator was the one generally in charge of lifting, the responsibility during blind lifts shifts entirely to the signalperson. In line with this approach, any device that aids the operator in turning a blind lift into a non-blind one, such as the vision system, is problematic, since it partially restores responsibility to the operator.

Figure 3. Operator Leaning out of the Window for Better View

The other limitation observed was the two-dimensional nature of the image displayed on the monitor; this image lacks the visual depth perception rendered by human eyes. Factually correct, this limitation has virtually no meaning when the operator and the work arena are distanced (when human sight anyhow lacks depth), let alone in blind lifts, when there is no alternative to the two-dimensional image. In fact, crane operators reported how the system helped them assess the load's vertical distance from the ground: when zooming in while approaching the ground, they were able to follow on the monitor how the load and its shadow gradually converge until finally merging upon contact of the load with the ground.

It should be made clear that the vision system was by no means devised as a substitute for the operator's eyes but rather to provide an additional visual dimension, whenever needed. Indeed, "devices used in place of competence and good judgment on the part of the crane operator contribute to accidents" (Alterman 1998). Incompetent operators do, however, pose a great problem, both in terms of safety and productivity, even before the issue of any device is debated, while competent operators know better than to rely on a false sense of confidence that may be instilled through the use of safety devices.

7. CONCLUSION

The vision system described in this paper has the capacity to change the mode of operating tower cranes in general, and in particular on high-rise construction projects experiencing a great deal of blind lifts. The operator has an additional vision dimension that enables an *uninterrupted* view of otherwise obstructed work areas and travel paths, a *close* view of otherwise distant areas and blurred objects, a *top v*iew of otherwise potentially misleading side/angled-view areas/objects, and a *bright* view of otherwise dark areas and shadowed objects. It fortifies the operator's sense of confidence, reduces the risk to all lift personnel and workers in the vicinity of the crane work, and contributes to the safety of the entire construction site. Apart from being primarily a safety enhancement device, the system brings about better utilization of scarce crane time through shorter cycle times, and subsequently cost savings. These and other benefits were observed on the numerous sites that have used the system, both in routine work and in individual difficult situations.

For the R&D team, the ultimate test of this endeavor was its acceptance and adoption by construction companies. The innate reluctance of the conservative construction industry to adopt changes, compounded by prolonged years of deep economic recession in the potential markets, created a great challenge. This challenge was overcome mainly by a great deal of academia-industry cooperation.

This system and the effort that yielded it were not an isolated, one-time endeavor. They should be seen as one of many cooperative projects aiding site work and the construction industry in general on the part of academia, marrying the advantages offered by both for the benefit of a synergic outcome. Further development of safety enhancement devices is called for. As has been the experience in the current case, these devices are also likely to contribute to work efficiency and to bring about cost savings. In parallel to cooperating with construction industries, regulation authorities should be approached on the issue of possibly mandating the use of a vision system on certain projects. A proposition has to be made that includes quantitative measures to objectively evaluate dynamic conditions such as height of crane and proportion of blind lifts on prospective sites.

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ROAD/WORK ZONES

7

A ROAD SAFETY AUDIT ON A FREEWAY PROJECT IN CHINA

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ABSTRACT

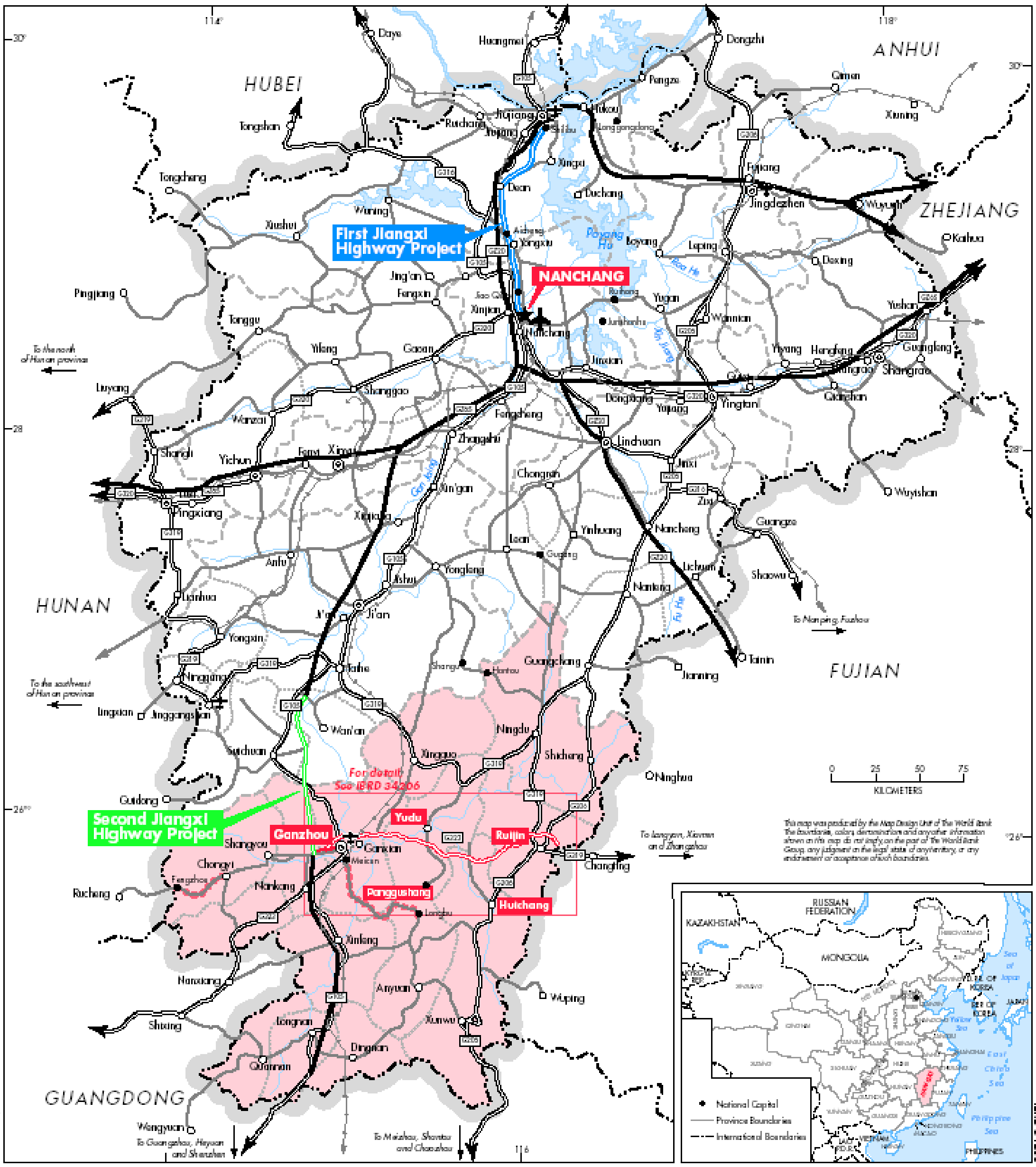
Due to China's rapidly developing economy, nationwide highway construction in China has been adding about 4,000 kilometers of freeways each year to its system. The efficiency and mobility of the movements of people and goods have been greatly improved. However, the number and severity of traffic incidents have also increased as an inevitable byproduct of the highway system expansion. One of the effective ways of improving highway safety is a process of examining a highway project before, during, or after its construction. This process is called road safety audit. A road safety audit is a formal process, conducted by a team of qualified, properly trained, and experienced traffic safety, highway design, and other related professionals, to identify the potential problems in roadway safety. A road safety audit focuses only on safety issues and provides suggestions of remedial actions to improve the road safety based on the audit team's experience and knowledge. This paper discusses a road safety audit performed on a freeway project in China. The performed road safety audit identified the potential problems with the freeway project and provided recommendations for addressing these problems. It is emphasized in this paper that there could be potential safety problems with a highway even if the highway was designed and constructed in a total compliance with the requirements and specifications.

Keywords: Freeway, Safety, Road Safety Audit, Tunnels, Bridges, Interchange

1. INTRODUCTION

Due to China's rapidly developing economy, nationwide highway construction in China has been adding about 4,000 kilometers of freeways each year to its system. China's highway system has been playing an essential role in the country's rapid economic growth and considerable improvement of living standards. The efficiency and mobility of the movements of people and goods have been greatly improved. However, the number and severity of traffic incidents have also increased as an inevitable byproduct of the highway system expansion. This paper discusses a road safety audit performed on a freeway project in China. The freeway project is a section of the Xiamen-Chendu freeway. The Xiamen-Chendu freeway connects Xiamen (the capital city of Fujian province) and Chengdu (the capital city of Sichuan province). The section for safety audit is the Ruijin-Ganzhou Freeway (RGE), which is located within Jiangxi province as a part of the Xiamen-Chendu freeway. The RGE begins at Yunshi-Shan of Ruijin City and ends at Zhanggong of Ganzhou City with a total length of approximately 117 km. Map 1 shows the location of the freeway.

The feasibility study of the RGE project was completed in 2005. The environmental impact assessment, economic impact analysis, and relocation analysis had been undertaken accordingly. The preliminary design of the RGE was completed and approved by the authorities. The construction of the RGE is scheduled for approximately three years from 2006 to 2009. The total construction cost is estimated to be $627 million. The RGE project consists of 78 bridges, 7 tunnels, 6 interchanges, 49 grade separations such as overpasses and underpasses, 137 drainage culverts, 185 pedestrians, 6 toll plazas, 2 service areas, 3 parking lots, and 1 main operation center. The RGE project will produce 11.8 million m^3 of earthworks and 11.7 million m^3 of stone-works. The total pavement area is 2686587 m^2. It has 5.5 km of interconnecting roads, and various drainage, traffic control and safety facilities.



Map 1. The Geographical Location of the RGE (Source: the World Bank)

Along with the efficiency and mobility provided, freeways in Jiangxi also have a high fatality rate, high accident severity, and huge property losses. It is estimated that the annual average number of fatality accident victims is greater than 300 on the freeway system. The direct annual cost is estimated more than RMB 30 million ($4 million), without considering the traffic delay costs. In particular, the Jiangxi highway agency has identified the following potential improvements associated with traffic safety:

- The freeway system consists of many tunnels. While those tunnels have not experienced major accidents, the highway agency recognizes the potential dangers. It is desired to develop an effective tunnel safety management plan.

- The highway agency recognizes that the existing highway design does not adequately address the needs of some road users. For example, the presence of long vertical curves in the existing freeways does not take into account the dynamic behaviors of trucks.
- Effort is needed to improve the location of traffic signs and pavement markings so as to provide drivers with clear and consistent information and warning.
- Improvement is needed to enhance roadside safety design.

To improve highway safety, the Jiangxi highway agency decided to conduct a road safety audit (RSA) on the design of the RGE. A road safety audit is a formal examination or process, conducted by a team of qualified, properly trained, and experienced traffic safety, highway design, and other related professionals, to identify the issues that may cause potential collisions. A road safety audit has proved to be an effective practice for enhancing road safety and it is most cost-effective when it is employed in the design phase. It is a proactive strategy rather than an interactive response. The road safety audit provides independent assessment and recommendations that should be considered by the client or the designer. A road safety audit focuses only on safety issues and provides opinions on the safety issues from the perspective of the potential road users based on the audit team's experience and knowledge. It does not directly address those issues of conformity to the design standards and specifications. It is not intended to re-design the project. It takes into account the human factors, combinations of design features, unusual design situations, and occurrence of unexpected circumstances that cannot be adequately addressed in the context of design process. The road safety audit presents the issues of concern, but not necessarily the solutions to the identified safety issues.

2. THE SAFETY AUDIT PROCESS

To conduct the road safety audit, an audit team consisting of six members was formed. The team members were selected based on their experience and qualification related to highway operations and safety. The expertise of the team members are listed below:

- Team member 1: extensive experience in the general areas of freeway construction, design, and operation.
- Team member 2: pavement surface characteristics.
- Team member 3: traffic safety, automobile engineering, human factors.
- Team member 4: traffic safety, pavement safety characteristics.
- Team member 5: traffic engineering, bridge/tunnel safety, interchange/access.
- Team member 6: traffic signs, pavement marking, alignment, roadside safety.

The audit was conducted mainly in the offices but in conjunction with site visits to the existing freeways in Jiangxi province. The audit process consisted of the following:

Obtaining Project Information

The background information on the RGE was obtained from the Jiangxi Provincial Communications Department. The data and documentation include:

- Feasibility study report
- Design documents
  Part I – Overview
  Part II – Layout
  Part III - Alignment
  Part IV – Subgrade, Pavements, and Drainage
  Part V – Bridges and Culverts
  Part VI – Tunnels
  Part VII – Interchanges
  Part VIII – Traffic Control and Ancillary Facilities
- Traffic data
- Collision data

The audit team briefly reviewed the above documents and data before the kick-off meeting, so as to obtain a first insight into the RGE project and identify the further information and clarification needed.

Holding a Kick-Off Meeting

A kick-off meeting was held for the road safety audit. At the meeting, the team identified a list of additional documentation and data needed to conduct the road safety audit. The safety issues in previous highway projects were discussed. The audit team discussed the essential areas on which the audit should focus on. A site visit on an existing freeway was deemed necessary because of the similarities between the existing and the designed freeways. A checklist was developed by the audit team for reviewing the data and documentation collected for the audit.

Assessing Data and Documents

The audit was conducted in accordance with the Guidelines for a Safety Audit of Highway published by the China's Ministry of Communications (2004). The audit team also took into account the procedures, manuals, and guidelines published or reported by other countries (UKDOT 1993, Austroads 2002, TAC 2001, Wilson and Lipinski 2004, and ADB 2003) to utilize the worldwide experiences and latest techniques associated with the road safety audit. As mentioned earlier, the audit team conducted a preliminary review of the design documents and data before the kick-off meeting. After the kick-off meeting, each individual audit member assessed the design documents by focusing on their areas of expertise. After a site visit to an existing freeway during a sunny period and a rainy period, respectively, the audit team met to conduct a group review of the documents and data, and to finalize the major concerns identified during the reviewing and assessing process.

Site Visit

A site visit to the selected freeway was conducted in addition to the review of design documents. This was because some potential safety problems were observed on the selected freeway and the new highway was designed in accordance with the similar standards. It was reasoned that by identifying safety problems the new highway design could be modified accordingly to eliminate these problems in the design phrase rather than after construction.

Wrapping-Up the Audit

The audit results and recommendations were summarized and documented in a road safety audit report for the highway agency to take necessary remedy actions.

3. FINDINGS OF THE ROAD SAFETY AUDIT

Operating Speed Consistency

Freeways are designed to provide for a high level of efficiency with a high safety level and to carry large traffic volumes at high speeds. In order to improve safety, it is significant to examine the consistency of the design. Design consistency can be defined as the conformance of a highway's geometric and operational features with driver expectancy (Parker 1997, Fitzpatrick, et. al. 2003). Operating speed consistency is to avoid abrupt changes in operating speeds on adjoining segments, in particular on sharp curves or steep grades or a combination of both, and therefore to provide similar sections or smooth transition. The requirements for operating speed consistency are:

- Good consistency: operating speed difference < 10 km/h
- Fair consistency: operating speed difference = 10 – 20 km/h
- Poor consistency: operating speed difference > 20 km/h

The operating speeds were calculated by using a set of established equations. The results indicated that the speed differences fall within a range of 5 km/h to 12.5 km/h. Therefore, the operating speed consistency can approximately be ranked as good.

Design and Operating Speed Consistency

Design speed is the speed employed to design highway geometrics such as vertical and horizontal curves, super-elevation, stopping distance, and so forth. Operating speed is the observed speed at which drivers are operating their vehicles during free-flow conditions. The 85th percentile of the distribution of observed speeds is used as the measure of the anticipated operating speed. In general, the design speed should be determined in terms of the highway functional class, land use, topography, and operating speed. In order to enhance safety, it is also recommended that the consistency between design and operating speeds be examined in the same segment.

It was found that the anticipated operating speeds varied from 103 km/h to 117 km/h. Since the design speed was 100 km/h, the consistency between design and operating speeds could be ranked as fair to good. It was desirable for the designers to adjust the geometric features in some identified segments with speed differences greater than 10 km/h. It should be pointed out that the operating speeds were estimated in terms of passenger cars. It was observed by the audit team that truck overloading and irregular loading were fairly common in the country. It was a concern that the speed consistency for trucks might be a problem on long grade sections. The sections with long grade were identified for possible modifications to better accommodate truck traffic.

Stopping Sight Distance on Horizontal Curves

Median planting, as shown in Figure 1, is typical for freeways across China, because such planting not only helps beautify the freeway, but also serves as an anti-glare screen. This practice, however, will adversely affect the available stopping sight distance for the driving lane on the outside of the horizontal curve when the median is narrow, the radius is small, and the planting is higher than driver's eyes.

Figure 1. Plants in a Freeway Median

Using the estimated operating speed, it was computed that in order to satisfy a required stopping sight distance of 153.70 m (The Ministry of Communications 2003), the radius of the horizontal curve with median planting must be greater than 1122 m. That is to say all mainline horizontal curves with radii less than 1122 m would not be able to satisfy the minimum stopping sight distance requirement if there are plants in the median. Therefore , the audit team recommended that the design team inspect the stopping sight distances for the left lane on the outside of horizontal curves with radii less than 1122 m.

Safety Concerns on Bridges

In the design documents, the amount of bridge rails and guardrails for each bridge were specified. The audit team observed on existing freeways in China that guardrails were extensively used on the roadway because the road is almost entirely built on an embankment. However, it was noticed that the guardrails on the bridged approach sections were not connected to the bridge rails on many existing freeways. Figure 2 is a photo of a typical layout of roadway guardrails and bridge rails. There exists a gap between the concrete bridge rail end and the guardrail end. The gap poses a potential danger for drivers because vehicles might hit the concrete end directly resulting in severe consequences. Therefore, AASHTO Roadside Design Guide (AASHTO 2002) specifies that guardrails must be connected to the bridge rails with transition guardrails to improve road safety. Transition guardrails gradually increase the rigidity of the guardrail so that at the connection to the bridge rail the rigidity of the guardrail is similar to that of the bridge rail. Based on the observations on the existing freeways in Jiangxi as well as in other parts of China, it is expected that guardrails would be similarly installed on the roadsides of the RGE. According to the AASHTO Highway Safety Design and Operations Guide (AASHTO 1997), research has found that crashes are seven times more likely to be fatal when the vehicle pockets or penetrates through, under, or over the barrier at the connections to a bridge end. Therefore, transitions should be provided between roadside guardrails and bridge rails. The audit team recommended that appropriate connections be installed between guardrails and bridge rails on the RGE to improve road safety.

Figure 2. Space between Bridge Rail and Guardrail

Overloaded trucks were common on freeways in China. Figure 3 shows a picture of an overloaded truck on a bridge. It would be expected that the RGE would have the same problems unless regulations were effectively enforced. Overloaded trucks are especially risky with respect to bridges because the extra load could cause damages to bridge structures. Goods on the overloaded trucks generally were not packed in a safe manner. This would increase the possibility of truck overturns on bridges. Furthermore, overloaded trucks would affect the travel speeds of traffic streams. As traffic principles indicate, an inconsistent travel speed of a traffic stream is a major factor of vehicle crashes. Although it is mostly an enforcement problem, not a design or construction problem, the audit team would like to call attention to the potential risks of overloaded trucks for road and bridge safety.

Safety Issues in Tunnels

Similar to bridges, overloaded trucks are also a concern for tunnel safety. In addition, trucks with oversized loads, as the one shown in Fig. 4, should also be a concern for tunnels because tunnels have limited horizontal and vertical clearances. Overloaded and oversized trucks should be effectively regulated to minimize the chances of accidents within tunnels.

Figure 3. Overloaded Truck on Bridge

Figure 4. A Truck with Oversized Load

It was observed that on existing freeways some vehicles changed lanes to pass other vehicles within tunnels. Because of limited space, any accident inside a tunnel could cause severe consequences to the tunnel structure as well as to the highway system. Changing lanes inside tunnels must be prohibited to minimize the probability of crashes. To achieve this, signs should be designed and posted before each tunnel to warn drivers not to change lanes or pass other vehicles inside the tunnel.

Lighting is important for traffic safety of tunnels, especially for the safety of long tunnels. It was observed that for unknown reasons only some of the lights were turned on in the tunnels on the freeway shown in Figure 5. Actions should be taken for the RGE tunnel to assure that all lights are lighted during operation unless the design requirements indicate to use portion of the lighting fixtures.

Figure 5. Only Some Lights Are on in the Tunnel

Safety Issues at Interchanges

There will be six interchanges in the RGE project. The design documents for interchanges were examined by the audit team to verify their appropriateness in terms of road safety. To minimize the effect of adjacent interchanges on traffic flow and safety, the distances between adjacent interchanges should be greater than 3 km. The distances between the adjacent designed interchanges are all more than 10 km so that the traffic flow of an interchange will not be directly affected by the vehicle maneuvers at other interchanges. That is, the spacing between the interchanges will not be a problem related to traffic safety.

The audit team reviewed the geometrics on the design documents related to interchanges. Sight distances to the exit and gore areas are satisfactorily designed. Sight distances to the entry and merge areas are also satisfactorily designed. The lengths and cross-sections of auxiliary lanes meet the standards. There are no problems with the lane continuity of the interchanges. The ramp geometrics and cross-sections do not reveal any inadequate or inappropriate designs.

The types of the designed interchanges are similar so that the patterns of the exit and entry ramps are not different to drivers. The consistency of the exit and entry patterns among the interchanges is important for road safety. With the consistent ramp patterns the drivers do not need to spend extra time to understand the new patterns and to execute new driving maneuvers while passing a different interchange. Based on the vertical and horizontal geometrics of the intersections, the operating speeds were found to satisfy the speed consistency requirements.

In the design documents, it is specified to plant grasses and trees in the enclosed areas between the intersecting roadways and the ramps. While grasses are essential to control soil erosion, trees in the enclosed areas may pose potential safety risks. First, trees near roadway may become dangerous obstacles for off-course vehicles. Second, trees may block drivers' views for the vehicles on the mainline and on the ramp to see each other before merging. Therefore, trees may create unsafe driving conditions for vehicles at interchanges, especially for the merging vehicles. To minimize any possible hazard to drivers, it is recommended that trees not be planted in the enclosed areas between the intersecting roadways and the ramps. Grasses should be planted as designed. As an option, flowers could be planted in addition to grasses.

Based on the field visit to the existing freeways and the observations of other freeways in China, the following additional issues should be considered for the interchanges in the RGE projects.

- In some of the ramp gore areas, crash cushions were utilized as barrier end protection as shown in Figure 6. However, some problems were observed with the use of crash cushions. First, the number of crash cushions seemed to be insufficient as compared to the crash cushions used in the USA. The number of crash cushions should be determined according to standards such as the AASHTO Roadside Design Guide (AASHTO 2002). Second, the sizes (height and diameter) of the crash cushions seemed to be smaller than the sizes of those used in the USA.

Figure 6. Crash Cushions in an Interchange Gore Area

Third, the crash cushions were not covered with lids as illustrated in Figure 7. This may result in an increase, decrease, or change of the content inside the cushions and thus the cushions may not function as intended. Normally, the crash cushions should be filled with sand and should be free of other materials. However, as can be seen in Figure 7, the crash cushions contained many unintended materials. Based on these observations, the audit team concluded that it would be a worthy and positive effort for further enhancing road safety if the use of crash cushions in the RGE project would follow either China's established standards or the AASHTO Roadside Design Guide (AASHTO 2002).

Figure 7. Crash Cushions without Cover

- As a common practice in China, guardrails are extensively used in freeway roadsides and in many cases curbs are typically installed with guardrails. Figure 8 shows a typical case of curbs used along with guardrails in the median on a freeway. However, as specified in the Standards used in the USA (AASHTO 2002 and INDOT 2006), roadways with a design speed greater than 70 km/h should be designed without curbs. The use of curbs with a roadside barrier, such as guardrails, is discouraged in the USA, because it has been found that curbs offer no safety benefits on high-speed roadways. It is believed that curbs on high-speed roadways will increase the risks for vehicles to overturn after impact. In a system with curbs and guardrails, an off-course vehicle would hit the curb first and then the vehicle would be in the process of overturning when hitting the guardrail. Thus, the vehicle would most likely impact the guardrail at an angle and a position that would be more harmful to the vehicle.
- Bridge piers are the most important component of a bridge structure. It is essential for the freeway system that the piers of interchange bridges be adequately protected. Figure 9 is an example of pier protection. The curbs under the bridge would cause vehicles to overturn and thus would increase the chances of a vehicle fire. Consequently, vehicle burning could result in more damages to the bridge piers and other structure components. Therefore, curbs should not be used for pier protection. Instead, guardrails or crash cushions can be placed to protect bridge piers. However, guardrails and crash cushions must be appropriately designed and placed to adequately protect bridge piers.

Figure 8. Curbs and Guardrails in the Median

Figure 9. Curbs under an Interchange Bridge

4. SUMMARY AND CONCLUSIONS

The road safety audit on the designed freeway was successfully performed. The audit team not only reviewed the design documents, but also visited existing freeways to identify potential safety problems in the design. Through the road safety audit, the following safety concerns were identified:

- The design's estimated speed consistency was satisfactory in terms of passenger cars. However, because truck overloading and irregular loading were common in the country, the speed consistency for trucks could be a concern on sections with long grades.
- Median planting is not recommended for segments with narrow median and small horizontal curve radii, because plants may adversely influence the stopping sight distance on the outside lanes of the horizontal curves.
- Truck overloading and irregular loading were a common phenomenon in the country. It is a great challenge to take into account this phenomenon in the freeway design.
- The use of curbs on freeways is not recommended because wheel contact with a curb may cause a vehicle to overturn and become airborne. If used, the design should provide specific requirements and safety analysis.
- Appropriate transitions should be provided between roadside guardrails and bridge rails. The audit team recommended that appropriate connections be installed between guardrails and bridge rails to eliminate gaps and improve road safety.

- Actions should be taken to assure that all lights are lighted during operation in tunnels unless the design requirements indicate to use only portions of the lighting fixtures.
- To minimize any possible hazard to drivers, it was recommended that trees not be planted in the enclosed areas between the intersecting roadways and the ramps. Grasses should be planted as designed. As an option, flowers could be planted in addition to grasses.
- The guardrail ends at ramp gore areas should protected using crash cushions. The design of crash cushions should be undertaken to determine the appropriate number and size of crash cushions. The cushions should be covered.

In the process of conducting the road safety audit, the audit team was impressed and motivated by the emphasis of Jiangxi Provincial Communications Department on the traffic safety and the strong support from Jiangxi Provincial High-Class Highway Administration Bureau. The team spirit of the audit team members also played an important role in completing the audit successfully. The audit team deemed the road safety audit on the design necessary and important. Necessary actions should be taken accordingly to improve the design and to mitigate the potential safety problems in future operations.

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MULTI-LEVEL SAFETY CLIMATES: AN INVESTIGATION INTO THE HEALTH AND SAFETY OF WORKGROUPS IN ROAD CONSTRUCTION

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ABSTRACT

In construction projects, occupational health and safety (OHS) competes with traditional bottom line issues, such as costs and time, and is sometimes overlooked in the interests of competing pressures. Even when formal policies stating organizational commitment to OHS and comprehensive OHS procedures have been developed, unsafe work practices continue to occur. Research indicates that safety climate mediates the relationship between management practices and OHS performance, suggesting that workers observe management behaviour, develop shared perceptions of the relative importance of OHS and behave accordingly. However, in complex and highly decentralised environments, this simplistic theory is complicated by the fact that work is undertaken in semi-autonomous teams who may have little opportunity to observe the activities of management. Construction operations are decentralised with work conducted on sites remote from the corporate office, in which OHS policies and procedures are made. This geographical dispersion is likely to increase the impact of group-level safety climate relative to that of the organisation. It is possible that a strong organization-wide OHS climate does not even develop in this context because workers' interactions with co-workers and their immediate supervisors are more important determinants of their safety attitudes. A safety climate survey was undertaken in a large regional area of one state-based road authority, in Australia. Nineteen workgroups participated in the survey.

Keywords: Safety, Climate, Workgroups, Supervisor, Multi-level

1. INTRODUCTION

Construction is one of Australia's highest risk industries (NOHSC, 2005). In 2002 – 2003 people working in the construction industry were more than twice as likely to be killed at work as the average worker in all Australian industries. Further, 2005 figures indicate that construction is Australia's third most dangerous industry, surpassed only by transport and storage, and agriculture (Fraser, 2007). The incidence of compensated claims for the industry is almost three times the national average for all industries (NOHSC, 2005).

This paper describes the first stages of a research project investigating group and organizational level climates within construction organizations (two private sector contracting organizations and one public sector road administration agency). For the purposes of this paper, data from two organizations, one of which was used to conduct a pilot study, is analysed to determine whether group-level safety climate is a valid concept in Australian industry. This analysis is achieved by exploring whether workgroups within a single organization demonstrate their own unique safety climates (as distinct from the organizational safety climate) and to what extent there is variation between the workgroup climates existing within a single organization.

2. SAFETY CLIMATE

The Concept of Safety Climate

Organizational climate has been identified as a set of coherent perceptions and expectations employees have about their work environment. In particular, climate perceptions are formed based on a variety of cues present in the work environment concerning reward-outcome contingencies, which are widely believed to shape workers' behaviour (Dedobbeleer and Beland, 1991). Safety climate is a subset of organizational climate and has been measured in various industrial sectors, including construction (Dedobbeleer and Beland, 1991, Gillen et al, 2002), manufacturing (Brown and Holmes, 1986, Zohar 1980; Griffin and Neal 2000), road administration (Niskanen, 1994), wood processing (Varonen and Mattila, 2000) and airport ground handling (Diaz and Cabrera, 1997). For a review of safety climate literature, see Flin et al. (2000).

Much of the research has demonstrated a link between safety climate and safety outcomes (Zohar 1980; Diaz and Cabrera 1997; Varonen and Mattila 2000). These studies suggest that safety climate can predict incident occurrence, and also be used to discriminate between organizations with good or bad safety performance. Safety climate has also been found to mediate the transfer of knowledge learned in safety training into behaviour in the workplace (Smith-Crowe et al. 2003).

Multi-level safety climates

Most safety climate studies have focused on workers' perceptions of organizational level issues, for example the status of specialist safety staff, resources allocated to safety, top management commitment and the quantity and usefulness of safety training. However, modern organizations are large and complex and thus the notion of a single uniform safety climate seems overly simplistic (Lingard, Blismas & Wakefield, 2005).

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 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. Thus, 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).

Zohar's results support a multi-level safety climate model, in which workers are influenced by their perceptions of expected behaviours at both an organizational and workgroup level. Zohar (2000) also reports that workgroup safety climate scores predict the safety performance of workgroups in the months following the climate assessment, i.e. those workgroups with more positive safety climates experience fewer incidents. In particular, Zohar 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.

Construction work is highly decentralized with productive work undertaken at sites remote from the corporate office. This geographical dispersion is likely to increase the behavioural influence of group climates relative to organizational climates (Patterson et al 1996). 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). Construction work is also 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.

3. RESEARCH METHODS

Participants

Data collected from two organizations is reported in this paper. First, a pilot study was undertaken at a national logistics company to determine the reliability and validity of a questionnaire survey for measuring group and organizational safety climates. Four hundred and thirty-eight completed questionnaires were returned and analysed.

Second, data were collected from the employees within a regional construction and maintenance works district of a large, state-based road administration authority. Four work centres' make up the works district. A standard work centre consists of a number of work crews. Each work crew has a Team Leader, reporting to a Works Supervisor. It is not unusual for a Works Supervisor to oversee multiple work crews. An example of a typical work centre is shown in Figure 1.

Due to the geographical area covered by the works district, work is highly decentralized with construction and maintenance work undertaken at sites remote from the work centres', or satellite corporate offices, of the road administration organization.

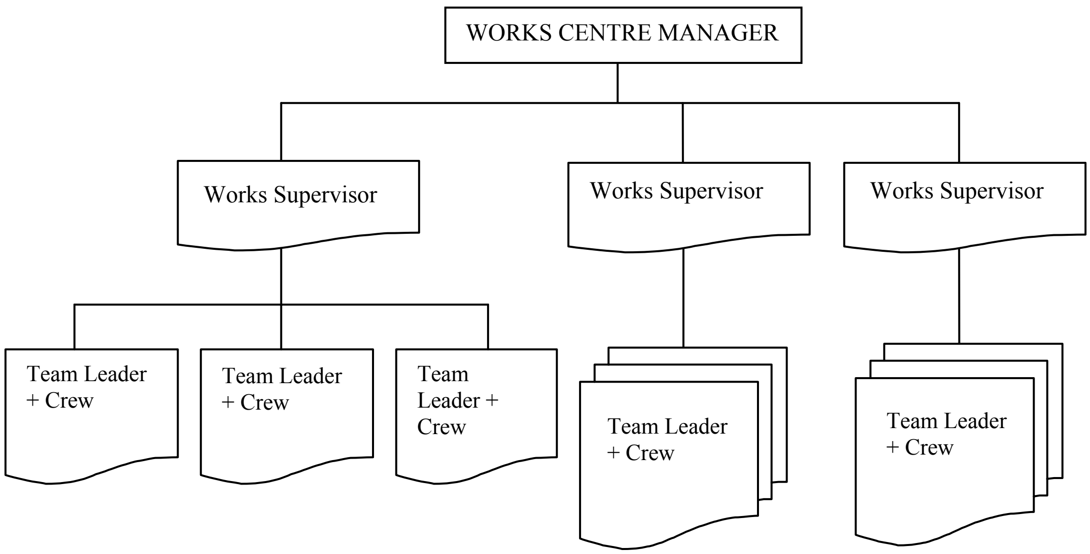

Figure 1: Typical Work Centre Organisational Chart

Questionnaires were administered during work hours. A member of the research team visited worksites, distributing and collecting the surveys in person. Prospective respondents were advised that completion of the questionnaire was voluntary and confidentiality and anonymity were assured. Workers not available or on site during the survey administration were invited to completed the questionnaire at a later date. Completed surveys were put in self-sealed envelopes and returned directly to the research team, via the site Safety Coordinator.

Data collection

A questionnaire was developed to measure group and organizational safety climate perceptions of Australian construction industry workers. Whilst previous research has identified commonly measured safety dimensions, such as risk, competence, etc (Flin et al, 2000), an examination of previously established safety climate instruments revealed variability in dimensions measured and the actual items used to measure each dimension. The Australian questionnaire comprised of 85 items (questions) drawn from a number of previously used surveys.

The questionnaire consisted of three parts. Part 1 of the questionnaire was made up of 39 items designed to measure the organizational safety climate and consisted of statements such as “The organization really cares about the health and safety of people who work here”, “Management provides enough safety education programs” and “Management officially encourage open communication but in reality most people know not to 'upset the apple cart' or 'rock the boat'” (reverse scored). Completion of Part 1 was requested of both workers and their supervisors.

Parts 2 and 3 of the questionnaire (46 items) were designed to measure perceptions of the safety attitudes and behaviour of respondents’ supervisors and co-workers. These parts of the questionnaire were only administered to non-supervisory workers. The combination of the two parts permitted an analysis of the existence of group safety climates with each organization. Part 2 (About Your Supervisor) utilised a scale previously developed and validated by Zohar (2000), measuring supervisory attitudes and behaviours towards safety. Example items are “Whenever pressure builds up, my supervisor wants us to work faster, rather than by the safe work procedures” (reverse scored), and “My immediate supervisor often talks to me about health and safety.” Part 3 focused on safety expectations and behaviour of co-workers (About Your Team). A scale developed by Burt, Sepie, & McFadden (2006), to measure considerate and responsible employee (CARE) behaviour was included in Part 3. The CARE scale measures the extent to which workers perceive that their co-workers actively look out for the safety of other workers in their work group. Example items are “Workers should avoid creating hazards for co-workers,” and “Workers should assist each other with tasks to ensure safety.”

All items contained within the survey were measured on a five point scale ranging from 5 (strongly agree) to 1 (strongly disagree).

Data analysis

The data collected was analysed using various statistical procedures. As organizational and group-level safety climates are multi-dimensional the structure of the data was first explored using a principal components factor analysis followed by a varimax rotation. Items were deemed to load on a given factor where their loading was 0.50 or greater (Hair et al, 1995). To determine if all the items falling into a single factor measured the same underlying construct, Cronbach’s alpha was performed. Factors with an alpha >0.70 were considered internally consistent. One way analysis of variance (ANOVA) was used to test for homogeneity in the safety climate perceptions of workers in different workgroups within the organization. If workgroup safety climate is a valid concept, it would be expected that perceptions of the organizational climate would be consistent between workers within single workgroups but that perceptions of group level climate factors would differ significantly between workgroups. Finally, to determine the level of agreement between members of a single workgroup enabling the measurement of the cohesiveness of team safety attitudes, a procedure developed by James et al (1984). f $r_{wg(j)} \geq 0.70$, then group consensus was deemed to exist about a particular aspect of workplace safety.

4. RESULTS

The Sample Group

To ensure that there was a sufficient number of respondents per workgroup to provide a reliable 'view' of the workgroups' safety climate, teams with less than 3 members were excluded from the workgroup safety climate analysis.

The pilot study provided a total of 423 completed surveys, breaking down into 396 surveys from non-supervisory employees and 27 surveys for supervisors. Missing data did not present any issues with aggregate amounts per question being <3%. All worker surveys were used in the factor analysis. Twenty-seven worker surveys failed to record their workgroup. These surveys were eliminated from any further analysis. The case-to-variable ratio of 5:1, met the minimum requirement for principal components analysis suggested by Gorsuch (1983).

There were 101 completed surveys received from the road administration agency. Of these, 30 respondents were supervisors, while the remaining 71 were workers, representative of 22 separate crews. The mean workgroup size was 4, with a standard deviation of 1.32. Seven workgroups were eliminated from the analysis because they had fewer than three members, leaving a total of 15 workgroups. Table 1 shows the number of members within a group. A review was conducted of missing data, indicating that there was less than 3% missing. Any missing values identified were replaced with the calculated mean. A case-to-variable ratio of less than 1:1 was achieved, necessitating the data to be pooled with the pilot study data for meaningful principal components factor analysis.

	Crew Numbers
Workgroup 1	4
Workgroup 2	2
Workgroup 3	4
Workgroup 4	4
Workgroup 5	4
Workgroup 6	7
Workgroup 7	1
Workgroup 8	4
Workgroup 9	4
Workgroup 10	4
Workgroup 11	5
Workgroup 12	3
Workgroup 13	4
Workgroup 14	4
Workgroup 15	4
Workgroup 16	6
Workgroup 17	4

Table 1: The road construction agency's crew numbers

Factor Analysis

Following a principal components factor analysis (with Varimax rotation), any items that either double-loaded (indicating conceptual overlap) or that failed to load with other items (i.e. splintered) were removed from the dataset.

In the pilot study (N=423) a forced two factor model of organisational safety climate explained 47% of the variance. Based on the common theme of the questions the 2 factors were named *Management Commitment* and *Priority of Safety*. Twenty statements loaded on the *Management Commitment* factor and reflected perceptions about the level of proactive management involvement, managers' safety related communication and enforcement of safety programmes. A total of nine statements made up *Priority of Safety* and referred to the degree to which employees perceived pressure to complete work and the prioritization of safety against other outcomes. The item loadings for the questions contained in Part 2 of the questionnaire (N=396) for the logistics organization confirmed the Zohar's two-dimensional model of group climate, The two factors, *Supervisor Action* and *Supervisor Expectation*, explained 54.6% of the variance. *Supervisor Action,* relates to supervisory reactions to subordinates' safety conduct (i.e. positive or negative feedback) and the manner in which they follow through with their feedback by either emphasizing, or diminishing the importance of safety. *Supervisory Expectation* refers to workers' perceptions of their supervisors' safety-related expectations. Part three of the questionnaire required a forced two factor model, explaining 36% variance. Sixteen questions from Burt et al.'s (2006) CARE scale loaded on the first factor, which was renamed *Co-workers' Ideal Safety*. This factor contains items relating to co-workers' behaviours which, if performed, would increase workgroup safety. Ten items loaded on the second factor which was named *Co-workers' Actual Safety.* Items loading on this factor described employees' perceptions of the actual (as opposed to ideal) safety behaviours and attitudes of co-workers within their workgroups. Cronbach's Alphas for all six factors, resulted in reliability scores > 0.8 (See Table 3), and these factors were deemed to have acceptable internal consistency reliability.

Data collected from the road administration agency was subjected to the same factor analysis process as that of the logistics organization. However, the emerging factor structure was not easily interpretable. The splintering of factors was possibly due to the lower sample size and subject-to-item ratio in the road administration organization (See Lingard & Rowlinson, 2006). In order to analyse the data, the factor structure derived from the pilot study with the logistics company was assumed. Cronbach's alpha tests were conducted to determine the internal reliability of factors assuming the factor structure derived from the logistics company. The internal reliability scores, as seen in Table 3 resulted in α=0.8 for five of the six factors. An insufficient score of α<0.8 for Supervisor Action led to further examination of the road administration organisation's data. A review of a parallel analysis and the scree plot for the items contained in Part 2 of the questionnaire showed a single component (as opposed to a two-dimensional supervisory model. Thus, *Supervisor Expectation* and *Supervisor Action* were combined yielding a single factor reliability score, of α=0.853. Therefore final factor structure for the road administration agency resulted in five principal components, *Management*

Commitment, Priority of Safety, Co-workers' Actual Safety, Co-workers' Ideal Safety and Supervisory Actions, the result of the amalgamation of Supervisor Expectation and Action.

	Logistics Organisation α	**Road Administration Organisation α**
Factor 1: *Management Commitment*	0.941	0.897
Factor 2: *Priority of Safety*	0.872	0.848
Factor 3: *Supervisor Expectation*	0.941	0.897
Factor 4: *Supervisor Action*	0.830	0.669*
Factor 5: *Co-workers' Actual Safety*	0.851	0.819
Factor 6: *Co-workers' Ideal Safety*	0.918	0.870
New Single Factor: *Supervisory Action* (Road administration Organisation only)		0.853

** Cronbach's Alpha score less than the accepted score of > 0.80*

Table 3: Cronbach's Alpha scores for factors

Within group consensus

To determine the level of agreement between members of the same workgroup, indicating team cohesiveness in their perceptions of safety, the $r_{wg(j)}$ statistic was calculated using a formula developed by James et al (1984). Within-group agreement is deemed sufficient if $r_{wg(j)} \geq 70$. Assuming a uniform null distribution, the results of the road administration agency's data indicate a high level of within-group homogeneity, meaning that members within the same workgroup agreed and had a consistent view about safety issues being raised. The *Co-workers' Actual Safety* and *Co-workers' Ideal Safety* factors yielded a median score of 0.95 and 0.98 respectively. *Supervisory Actions* also revealed a high within group homogeneity, with a median score of 0.97.

Between group differences

In order to compare the attitudes and perceptions of members of different workgroups, a one-way analysis of variance (ANOVA) was conducted. The mean score for each factor was identified, i.e. *Co-workers' Actual Safety, Co-workers' Ideal Safety, Supervisory Actions, Management Commitment and Priority of Safety*. If the significance value in the ANOVA table is ≤ 0.05 a significant difference between groups is deemed to exist.

There was a statistically significant difference between workgroups at the $p<0.05$ level for *Co-workers' Actual Safety* ($F(14, 49) = 3.19$, $p = 0.001$). The effect size, calculated using eta squared was 0.47. The results for *Co-workers' Ideal Safety*, ($F(14, 49) = 1.12$, $p = 0.369$) indicated no significant differences between groups. Workgroups showed statistically significant variance in perceptions of *Supervisory Actions* ($F(14, 49) = 2.105$, $p = 0.028$), with an eta squared score of 0.38. These results indicate that those surveyed have a consistent view about co-workers' attitudes and behaviours, that, if performed would increase safety. However, members of different workgroups' opinions differed in their assessments of co-workers' actual safety behaviour and supervisory actions.

Organisation-level safety perceptions were assessed at a workgroup level and also the perceptions of supervisors and non-supervisory workers were compared. A one way analysis of variance indicated that, at a workgroup level, there is no statistical significance in the way workgroups consider *Management Commitment,* ($F(14, 50) = 1.78$, $p = 0.07$). However, members of different workgroups viewed the priority the organisation placed on safety (*Priority of Safety*) significantly differently ($F(14,50) = 2.44$, $p = 0.01$), with an eta square score of 0.41.

An independent-samples t-test was conducted to compare the *Management Commitment* and *Priority of Safety* mean scores for non-supervisory workers and supervisors. There was no significant difference between supervisors and non-supervisory workers perceptions of either of the organizational safety climate factors.

Bi-variate correlation analysis

In order to determine the nature and strength of linkages between variables measured, bi-variate correlation analysis were conducted. The relationship between *Co-workers' Actual Safety, Co-worker's Ideal Safety* and *Supervisory Actions* was explored using Pearson product-moment correlation coefficients. The results of this analysis are presented in Table 4.

		Number in Crew	MgtCommit	Priority of Safety	Supervisory Action	Co-workers' Actual Safety	Co-workers Ideal Safety
Number in Crew	Pearson Correlation	1		.			.
	Sig. (2-tailed)			.	.	.	.
	N	65					
MgtCommit	Pearson Correlation	.018	1	.	.	.	.
	Sig. (2-tailed)	.887		.	.	.	.
	N	65	99				
Priority of Safety	Pearson Correlation	.186	.684**	1	.	.	.
	Sig. (2-tailed)	.138	.000		.	.	.
	N	65	99	99			
SupervisoryAction	Pearson Correlation	-.097	.497**	.426**	1	.	.
	Sig. (2-tailed)	.442	.000	.000		.	.
	N	65	69	69	69		
Co-workers' Actual Safety	Pearson Correlation	-.252*	.409**	.409**	.471**	1	
	Sig. (2-tailed)	.043	.000	.000	.000		.
	N	65	69	69	69	69	
Co-workers' Ideal Safety	Pearson Correlation	.126	.310**	.273*	.321**	-.023	1
	Sig. (2-tailed)	.316	.010	.023	.007	.854	
	N	65	69	69	69	69	69

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4: Correlation Matrix

Supervisory Actions showed a strong, positive relationship with all of the other variables, with *Management Commitment* (r =0.497*, p*=0.00), *Priority of Safety* (r=0.426, p=0.00), *Co-workers' Ideal Safety* (r=0.321, p=0.007) and *Co-workers' Actual Safety* (r=0.471, p=0.00).

Priority of Safety also showed a strong, positive correlations with *Management Commitment* (r=0.684, p=0.00), *Supervisory Action* (r=0.426, p=0.00) and *Co-workers' Actual Safety* (r=0.409, p=0.00). There was a positive relationship between *Priority of Safety* and *Co-workers' Ideal Safety* (r=0.273, p=0.023) though the relationship was not as strong as the other variables.

Co-workers' Actual Safety was not significantly correlated with *Co-workers' Ideal Safety*

A significant negative relationship was found to exist between *Co-workers' Actual Safety* and the number of members within a workgroup (r=-.252, p=.043)

5. DISCUSSION

The results indicate a high level of within-group consensus in relations to *Supervisory actions*, *Co-workers' Actual* and *Co-workers' Ideal* safety behaviour, meaning that members within the same workgroup agreed and had similar views about group-level safety issues. This outcome provides some evidence that group-level safety climates exist within the road administration agency. That is, group members develop shared perceptions of supervisors and co-workers' safety-related behaviour.

The analyses of variance also confirmed that mean scores for group and organizational level safety climate variables differed significantly between workgroups within the agency, providing further evidence for the existence of distinct workgroup safety climates within the organization. At a group-climate level, significant differences were found in the way members of different workgroups perceived supervisory behaviours and actions (*Supervisory Actions*). This indicates that some supervisors are perceived to place greater emphasis on safety and behave in a more consistent manner when dealing with safety issues than other supervisors within the road administration agency.

There was also significant between-group variance in the way workers perceived the safety behaviours and attitudes of their co-workers within their workgroups (*Co-workers' Actual Safety*). The data indicated that some workgroups had greater confidence in their co-workers, demonstrating co-worker concern for safety, whilst other workgroups failed to have the same degree of trust and support between group members. *Co-workers' Ideal Safety* related to workers' attitudes regarding behaviours which, if performed, would increase co-workers' safety. All workgroups had a consistent view about *Co-workers' Ideal Safety*, indicating a shared view within and between workgroups about how co-workers should behave in relation to safety within a work team.

Perceptions of organisation-level safety climate factors were also found to differ between members of different workgroups. In particular between group differences in views about how safety is prioritised by the road administration agency were significant. This suggests the absence of shared understanding of safety, a key component of organizational safety culture, within the organization (Prussia 2003). No differences were found between the perceptions of supervisory compared to non-supervisory personnel, again indicating that group-level variables might be more important determinants of safety perceptions than organizational level variables.

Strong positive relationships were found to exist between *Management Commitment*, *Priority of Safety*, *Supervisory Actions* and *Co-workers Actual Safety*. The relationship between *Co-workers' Ideal Safety* and *Priority of Safety* was not as strong as it was with *Management Commitment* or *Supervisory Action*, and failed to have any significant relationship with *Co-workers Actual Safety*. This finding, along with the strong positive relationships found between *Supervisory Actions*, *Priority of Safety* and *Co-workers' Actual Safety*, indicates a hierarchical link between workers' perceptions of the importance placed upon safety within the organization, the safety actions of supervisors and safety supportive behaviour between co-workers within workgroups. This supports the work of Simard & Marchand, which indicated that macro-level safety management activities within organizations are indirectly related to workers' safety behaviour through their impact upon supervisory actions (Simard & Marchand, 1994; 1995; 1997).

A negative relationship was also found between the number of members within a workgroup and the group members' perception of *Co-workers' Actual Safety* behaviour. Thus, as a workgroup increases in size, group members perceive their co-workers to be less supportive of the safety of other members within the group.

Members of different workgroups shared a consistent view about the ideal safety behaviours of co-workers, i.e. what co-workers should do to support the safety of others in their workgroup. The perception of ideal co-worker behaviour in relation to safety is independent of perceptions about the actual safety behaviours demonstrated by co-workers, priorities of the organization and the actions of supervisors. This indicates a consistent opinion of how co-workers should behave in relation to the safety of their workmates.

The results support the notion that group-level safety climates exist within the road construction agency. These findings are similar to Zohar (2000) and Findley et al (2006), who found differences in the safety climates among worker groups. Within the Australian road construction agency, members of different workgroups develop shared within-group perceptions of safety. At the same time, between group differences in perceptions of safety were significant.

The strength and quality (i.e. supportive or unsupportive of safety) of group level climates is reported to influence workgroups' safety performance through shaping members' safety behaviour (Zohar 2002a). The existence of variation between workgroup safety climate (driven by supervisor and co-workers' actual behaviour) can therefore support or undermine organizational safety management efforts. Strategies to develop supervisors and co-workers' safety leadership behaviour, to foster strong and supportive group safety climates and promote consistency in the safety climates between workgroups within an organization can contribute to better organizational performance in safety and help to bridge the gap between policy statements and practice (Zohar 2002b, Zohar & Luria 2004).

6. CONCLUSIONS

The results of the research confirm the existence of group-level safety climate within the Australian construction industry. This research offers support that workgroup climates are perceived as distinct from those of the organisation. First, the results have shown that workgroup members develop uniform perceptions concerning safety within their own teams; second, these perceptions vary between workgroups, resulting in significantly different safety climate perceptions between members of different workgroups (i.e. between group variance); and third, the safety climate perceptions displayed at a workgroup level differ from perceptions of the organisational safety climate. The existence of distinct workgroup safety climates provides one theoretical explanation for why some organizational workgroups consistently perform better in OHS than others (despite having very similar risk exposures), and suggests that interventions designed to develop strong and positive group-level safety climates could benefit the Australian construction industry.

7. LIMITATIONS

The research had some limitations. First, the pilot study was conducted within a non-construction (logistics) organization. Owing to the fact that the road administration agency employed a smaller workforce than the logistics company, results of the principal components factor analysis for the construction organization was unstable. The safety climate factor structure produced from the pilot study (logistics organization) was therefore assumed to be valid for the road administration agency. Cronbach's alphas suggest that the factors generated had acceptable internal consistency reliability; however, there is a need to confirm this factor structure when data are collected from the two private sector construction contracting organizations.

A second limitation relates to a lack of objective safety performance data for the workgroups. This data could not be easily retrieved for fine-grained workgroup level analysis. Thus it was not possible to examine whether group level safety climate variables (such as *Supervisory Action* and *Co-workers' Actual Safety*) is significantly related to safety outcomes, such as incidents and injuries.

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EMERGING PRO-ACTIVE SAFETY TECHNOLOGIES FOR CONSTRUCTION WORK ZONES

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ABSTRACT

For more than 13 years the U.S. construction industry has experienced over 1,000 fatalities annually. Construction incidents account for more than 21% of all workforce fatalities (BLS 2006). This fatality rate is three times higher than the average of all other industries, with the result that construction is one of the deadliest industries to work for. The focus of this paper is to reduce the incidence rate of construction site injuries and fatalities by making workforce and equipment operators more aware of the physical state of their environment around them and by alerting them to potentially dangerous situations before incidents occur. This paper will review automated technologies that perform site recording and analysis, using sensors distributed on people and on machines. A framework will be introduced of how the level of safety during construction operations involving large equipment such as excavation, earth moving, and paving machines can be improved. Preliminary research results comparing the advantages and limitations of emerging technologies such as Vision and Three-Dimensional (3D) Range Cameras, Radio-Frequency Identification (RFID), and Ultra Wideband (UWB) will be presented. A discussion follows on potential applications and implementation barriers, and what data types need to be collected and processed using sensor systems to make work zones safer.

Keywords: Human Factor Analysis, Safety, Sensing, Pro-active, Real-time, Work Zones

1. INTRODUCTION

In the period from 1995 to 2002, 802 workers in the construction industry were fatally injured when struck by a vehicle or mobile equipment. Nearly half of all fatalities (387) occurred in the road construction sector. 258 deaths were caused by the following construction vehicle types: Dump truck (41%), grading/surfacing machine (14.3%), excavation machine (6.5%), semi-truck (6%), other truck (14%), other machine (10.4%), and other vehicle/source (7.7%) (NIOSH 2007). These statistics are alarming, since many passive safety tools (e.g., precautions and interventions such as jersey barriers and Internal Traffic Control Plans (ITCP)) and active safety tools (e.g., Proximity Warning

Systems (PWS)) exist and protect road construction workers from being struck by passenger vehicles.

In a review of scientific literature and relevant Fatality Assessment and Control Evaluation (FACE) investigations, safety data analysis demonstrate that “road construction workers were as likely to be struck by a construction vehicle (48% of cases) as by a passing motorist” (Pratt et al. 2001). Contributing factors include: Lack of knowledge about specific risk factors, insufficient evaluation and adaptation of intervention technologies and newly developed approaches used in other industries, lack of adequate guidelines, particularly for controlling vehicle and worker movements inside the work zone, and lack of educational and training resources for non-English speaking workers. For these reasons, research objectives have been identified to coordinate vehicle/equipment movement inside the work zone and to develop measures for preventing workers-on-foot from being struck by motor vehicles and equipment:

- Focus on blind areas around construction vehicles and equipment, e.g., area around a vehicle or piece of construction equipment that is not visible to the operators, either by direct line-of-sight or indirectly by use of internal and external mirrors.
- Limit exposure of workers-on-foot to construction traffic.
- Reduce hazards for equipment operators, e.g., running over people, materials, striking other equipment and vehicles, rollovers, and contact with utilities.
- Develop exposure monitoring system(s), e.g., evaluation of speed controls, night work.
- Evaluate injury prevention measures.

It is commonly known that the overall safety culture of a company depends on the executive commitment, a formal and informal safety system, operation personnel, and safety best practices and methods in place to prevent mishaps. Accident investigations integrated with the science of human behavior and the identification of specific contributing factors involved demonstrate a significant lack of real data that often prevents valid assessment of human error causes. In advance of human factors, investigators receiving training in the science of human behavior before joining an investigating team, it might become essential to assist existing practices in place with the following methodology (Garret and Teizer 2008):

- Use of existing and emerging technology as neutral data collection tool designed within a human error analysis process.
- Automate validation, and interpretation of employee baseline capabilities to assess supervisors’ or workers’ behaviors, in addition to cognitive skills, in areas of critical thinking, leadership, and problem solving.
- Develop pro-active technology for real-time hazard warning.
- Improve training, educational tools, and methods within a framework of human error principles.

As a result of today's practices, this research tries collecting unrecorded data, processing and analyzing data, visualizing information to all stakeholders (workers, supervisors, management, etc.), and implementing new knowledge into the training procedure. It is envisioned that the product of this research will become a powerful tool in the education of today's and future workforce that ultimately reduces injuries and fatalities to zero.

2. BACKGROUND REVIEW

The use of semi-automated and automated real-time project safety control in construction is not an illusionary vision any more. As far as the availability of technologies for measuring project performance indicators is concerned, a number of advanced technologies that are appropriate for onsite measurement are maturing, their accuracy and integrity are improving, and their costs are declining (Deng et al. 2001). Among them are: Global Positioning Systems (GPS), Laser Detection and Ranging (LADAR), Vision Camera, Audio Technology, Radio Detection and Ranging (RADAR), Radio Frequency Identification (RFID), and Ultra Wideband (UWB). These sensing technologies are reviewed in Table 1 (*see next page*) for their potential use in construction safety (Navon and Sacks 2007):

Global Positioning System (GPS) is a widely used technology for position and navigation in construction. For dynamic positioning two measurement principles exist. (1) In the differential mode (DGPS), range measurements are taken using two receivers. One receiver locates the base, a stationary point of known position. The deviation between the measured and actual position of the base is roughly equal to the measurement error at a second receiver of unknown position. The error is used to correct the position computed by the latter, thus allowing accuracies below one meter (Peyret et al. 2000). (2) Kinematic GPS happens in post processing or real-time (Real-time Kinematic GPS). RTK GPS uses all raw measurement including measurements of the signal carrier phases. 3D vectors between the two receivers result in centimeter accuracy. (3) Since GPS requires line-of-sight of the transmitting signals between the receiver and the satellites, indoor local positioning systems, aka. "Indoor GPS", adds the flexibility to locate resources (personnel, machines, material) in covered spaces (Van-Diggelen 2002). Although Indoor GPS initially solves the commonly known problem of GPS, additional installation of indoor instruments can become very complex and can make this approach cost inefficient. GPS overall provides reliable position data at sub-meter accuracy and is mostly used in outdoor environments for machine navigation and utilization.

Table 1. Characterization of Technologies for Real-time Location Tracking

Tracking Technology	Global Positioning System	Laser Detection and Ranging	Color and Intensity Camera	Audio	Radio Detection and Ranging	Radio Frequency Identification	Ultra Wideband
Acronym	GPS	LADAR	Vision	Ultrasound	RADAR	RFID	UWB
Application:							
• Site Progress	Yes	Yes	Yes				Yes
• Personnel	Yes		Yes		Yes	Yes	Yes
• Equipment	Yes		Yes	Yes	Yes	Yes	Yes
• Material		Yes	Yes			Yes	Yes
Principle/Tag	Active	Reflectorless	Reflectorless	Reflectorless	Reflectorless	Active, Passive	Active
Size of Tag	Large	None	None	None	None	Small	Small
Signal Update	Medium	Low	High	High	High	Low	High
Location Data	Yes	Yes			Yes		Yes
Proximity Data	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Accuracy	cm to m	cm	cm to m	m	m	cm to m	cm
Purchase Cost	High	Very High	Low	Medium	High	Medium/Low	High/Medium
Maintenance	Medium	High	Low	High	High	High	High
Range	High	High	Medium	Short	High	Medium/Short	High
Day vs. Night	Day & Night	Day & Night	Day only	Day & Night	Day & Night	Day & Night	Day & Night
Indoor vs. Outdoor	Outdoor (Indoor)	Indoor & Outdoor	Outdoor	Indoor & Outdoor	Indoor & Outdoor	Indoor or Outdoor	Indoor & Outdoor
Main Barriers	Size, Cost, Accuracy, Availability of Signals	Line-of-Sight, Cost	Line-of-Sight, Requires Illumination	Noise, Range, Accuracy	Noise, Accuracy, Cost, Safety	Cost, Noise, Distance, No direct location data	Cost, Emerging Technology, Multipath

Laser Detection and Ranging (LADAR) in its many variations has become an increasingly popular assessment technique to survey complex three-dimensional (3D) environments in a rapid manner. LADAR instruments work after the time-of-flight or phase based measurement principle and can reach several hundred meters to measure dense range point clouds. Cheok et al. (2000), Akinci et al. (2006), and Bosche et al. (2006), and others have performed research on stationary laser scanners to track material quantities, detect defects in as-builts, or build 3D models from dense range point clouds. 3D Range Image Camera (aka. Flash LADAR) have a similar operating principle as laser scanners and collect distance information to each pixel in a scene. In addition, 3D Range Imaging Cameras work at high range frame update rates (up to 50Hz per range frame shot). Both technologies require line-of-sight, but since they emit a spectrum of safe laser and near-infrared wave front into the scene, they may operate during day and night, which makes these technologies the favorable method when natural illumination is not present. Construction research on 3D Range Imaging Cameras has been conducted by Lytle et al. (2005), Teizer et al. (2007a), and others who demonstrated obstacle detection and tracking in real-time (at range image update rates of more than 30Hz). Increasing range, declining cost, and increasing reliability can make LADARs become an attractive tool for construction management and control purposes, e.g. construction changes in layout, obstacle detection and avoidance, and others.

Video and Audio Technologies. Using video cameras combined with intelligent computer vision data processing allows real-time wide angle monitoring of construction sites (Deng et al. 2001). Until today, many data processing algorithms exist that can convert raw color or intensity data into meaningful information (Brilakis 2006). Since the construction environment is a rather complex environment comprised of many obstacles, cameras with limited field-of-view due to the line-of-sight problem may find restricted use in tracking applications. Generally, raw image data needs to be carefully post processed to achieve successful results. Robust automated pattern recognition, data filtering, and segmentation techniques working under such complex conditions (dust, dirt, rain, and illumination) are under development, but can offer a very cost-effective monitoring approach. Although cost-efficiency and accuracy may be sufficient, ambient conditions and line-of-sight remain a critical factor ultimately limiting the range of applications of video and imaging technology. Audio technologies, e.g. ultrasound or sonar, are often error prone due to noisy measurements and operate at very short ranges, e.g. back-up alarms on cars.

Radio Detection and Ranging (RADAR) technology is a favorable approach in fully automated environments or off-shore where harm resulting from strong radio waves have acceptable or no effect on humans. Although existing obstacle detection systems in commercial applications exist, such systems include additional redundant information when using GPS, LADAR, or acoustic data.

Radio Frequency Identification (RFID) tagging solves the problem of existing barcode technology that requires line-of-sight and close distance of the receiver (emitting and receiving signal) to the tag (storing data). RFID is a technology that automatically reads and writes limited data packages on passive (no battery, shorter distances) and active (with battery, longer distances) tags using radio signals that are emitted and received by antennas. Potential application areas in construction are material tracking, labor control, and monitoring construction progress (Jaselskies 2003). In safety, RFID tags can play a significant role to tag hazardous areas and warn workers before entry, or when tracking the location of personnel. The biggest barrier of RFID technology is that its raw data format only permits collecting proximity data rather than the direct three-dimensional location data. Using a more complex approach of signal strength, or combining RFID with other technology, e.g. GPS technology, it can provide location data (Song 2007). Other wireless micro-electro mechanical systems (MEMS) exist, that can monitor the weight of materials loaded on a crane and detect movement of personnel, replacing existing load and strain gauges, and accelerometers (MicroStrain, 2004).

Ultra Wideband (UWB) technology is an emerging technology that might have answers for real-time locating systems. The origin of UWB technology dates back to the early 1960s when research experimented with the time-domain of electromagnetic-wave propagation (Bennett and Ross 1978). Until 1994, the majority of the work was performed under US government programs. Since 1994, after rulings of the Federal Communications Commission (FCC), research on UWB technology has shown to possess unique advantages for precision localization applications. The use of short pulse radio frequency (RF) waveforms provides inherent precision for time difference of arrival measurements, as well immunity to multipath effects in indoor and outdoor applications, at the same time (Fontana 2004, Teizer et al. 2007b).

In summary, all of above technologies will eventually have some merit to an increasingly intelligent construction site. Real-time pro-active technology for safety monitoring and warning systems must be able to respond to the following criteria:

- Accuracy and Update Rate: Technology must offer better than existing solutions. An error in any dimension must be less than 1m in various complex environments at update rates of greater than 30Hz, contributing to feedback that is more rapid and accurate than existing approaches in work zone safety.
- Size and Cost: Depending on the application, the system needs to be affordable, small, and preferably offer a full range of operation (cost between US$0.1 to US$10, flat, and a few grams per tag).
- Ease of use and cost: Fixed installation of any hardware and antennas should require less setup time and maintenance. Running cost should be minimal.
- Legality: Standards and regulations in each country differ and need to be developed and followed.
- Safety: Technology must work at any location and time and may not harm people.
- Interoperability: Communication to other technologies must be likely, e.g. handhelds, but should not interfere and needs to co-habit with other signals indoors and outdoors.
- Ambient Environment, Range, Line-of-Sight, and Multipath: To be practical in construction, signals must be useable over 150m between fixed and potentially mobile receivers, and need to work in object cluttered environments, e.g. concrete walls and steel. Technology must work well when natural illumination is low, obstructions are present, and the likelihood of signal multipath is high.

3. FRAMEWORK FOR PRO-ACTIVE WORK ZONE SAFETY

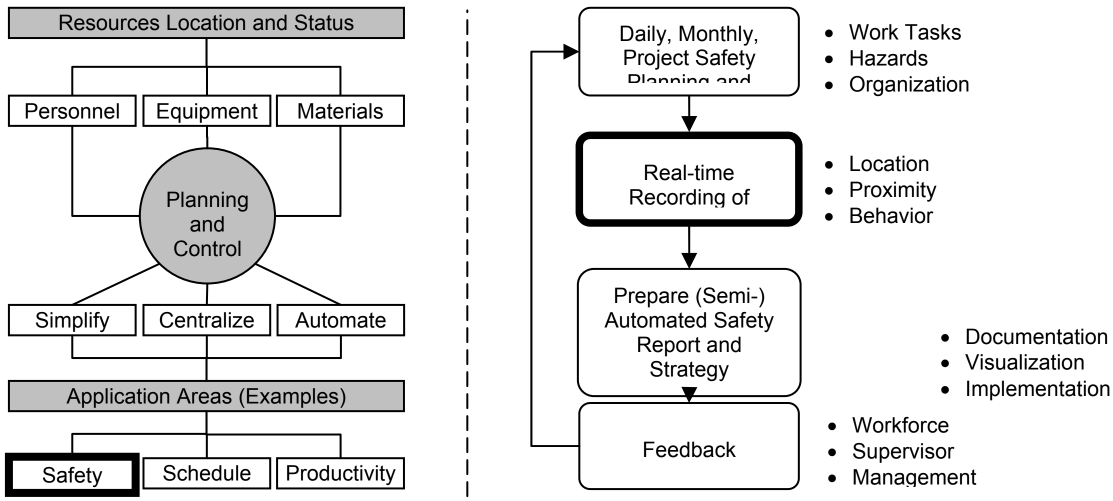

Figure 1. Simplified Job Site Monitoring and Real-time Work Zone Safety Framework

Innovative technology allows tracking resource location and status of construction resources (personnel, equipment, and material) to plan and control ongoing operations. A major goal in many industries is to simplify, centralize, and automate as many operational tasks as possible if safety, quality, and other key criteria for project success benefit. Existing safety programs can largely benefit from pro-active work zone safety technologies, since these allow real-time work site data recording, and in combination with data processing techniques, can create valuable information for report and strategic safety planning. Feedback can be provided to all organizational levels (management, supervisor, worker), and can happen at any time, e.g. in real-time to warn workers from close-by hazards, on a daily basis during routinely scheduled safety briefings, and in monthly project safety reviews for analysis on behavioral and team performance. Figure 1 illustrates a framework for a pro-active work zone safety system that implements above strategic thoughts for short, mid, or long term planning of an organizational safety culture.

4. PRELIMINARY RESULTS OF PROMISING PRO-ACTIVE SAFETY TECHNOLOGIES

4.1 Surveillance and Detection

The possibility of detecting and tracking workforce on construction jobsites using video and 3D Range Imaging Cameras exists for many years. The principal objective of this research is to test and demonstrate the feasibility of tracking workers from statically placed and dynamically moving cameras. An assessment of the algorithms with regards to computational complexity and real-time performance has been performed. Figure 2 and 3 illustrate preliminary results of techniques to monitor workforce on construction job sites. Major difficulties associated with tracking on a construction site was the significant amount of visual clutter, the changing photometric visual content throughout the course of a day, and the presence of occluding and moving obstacles. The detection of workers within the field of view of the camera involved two techniques: (1) based on distinguishing features such as photometric information (color of safety vest) and/or shape, and (2) based on consistent motion flow vectors. While the former method is computationally preferred over the second method, it can fail when a worker fails to wear a safety vest or a distinguishable shirt. However, the second method is capable of segmentation only when a worker is in motion. The tracking of workers, once detected, can be done using a variety of techniques. The three underlying methods tested were (1) mean-shift, (2) knowledge-based segmentation, and (3) active contours. Whereas the mean-shift algorithm can only track the overall position of the worker, the knowledge-based segmentation and active contours methods can also track the shape of the worker under the appropriate imaging conditions. Typical construction site videos were processed using the proposed algorithms and analyzed to determine the most appropriate detection and tracking method for the video presented. The algorithms were compared against ground-truth in order to compare the methods against a known baseline. As a result, tracking the location of workers using video or 3D Range Imaging Cameras was successful, but still requires research to make data processing algorithms robust.

Figure 2. Dynamic Video Camera Tracking of Workers' Shape and Centroid using Feature Detection Algorithm (Teizer and Vela 2008a)

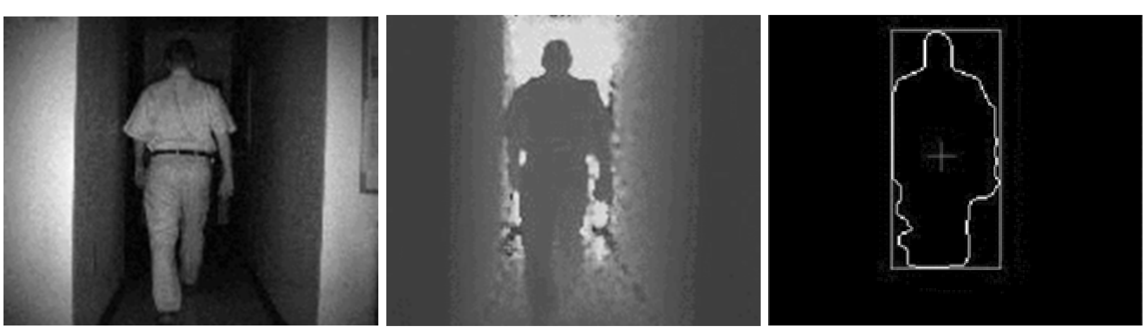

Figure 3. Object Detection and Tracking using Hidden Markov Models based on 3D Range Imaging Camera (from left: intensity, range, processed data) (Teizer et al. 2007a)

4.2 Warning Devices

The display system from sensor and processing unit to the human remains a critical and final link between the measuring system and the user. To make any sensor data that has been processed to information useful in practical applications, the mechanism of a warning device, e.g. visual, vibration, or acoustic, needs to be easy to understand and work at any given time, otherwise the function of the warning process is compromised. In existing human factors studies, the human's sensory capabilities and cognitive characteristics both need to be addressed in the display system selection (Murray et. al. 2000). Pro-active emerging sensing technologies offer potential assistance in collecting and evaluating data of hazardous environments in real-time. Furthermore, display technologies and performance capabilities are easier to evaluate in the context of their intended application. Consideration of the following issues can narrow the search for candidate systems, and can prevent needless frustration during system use:

- Environment: Will the display be operated in sunlight or at night?
- Application: Will the display present alphanumeric data, video images, graphics, or some combination, or use audio, vibration, or a combination of some or all?
- Task scenario: Are portability, handheld operation, or group viewing required?
- System characteristics: Weight, volume, power, maintenance, cost, etc.

Figure 4. Conventional Tagging Approach and Smart ID on Helmets

As a result from a literature review, a study in simulated front and side, uni- and multimodal collision avoidance system environments, indicated that warning signals that were simultaneously issued to the user in audio and visual format achieved the shortest response time across all ages (Kramer et al. 2007). Figure 4 illustrates a few examples that follow this thought using Radio Frequency Identification (RFID) Technology being developed in the Real-time Automated Project Information Decision Systems (RAPIDS) laboratory at the Georgia Institute of Technology.

4.3 Safety Education and Learning through Visualization

Tracking construction resources over larger distances more efficiently and potentially identifying them at the same time requires tagging the resources. Ultra Wideband (UWB) sensing has a particular advantage compared to RFID sensing, since it gives accurate three-dimensional (3D) indoor and outdoor location values in real-time. Since GPS requires satellite or base station connection is mostly limited to outdoor applications. UWB's main limitation at this point is a necessary measurement infrastructure. Once set in place the measurement infrastructure (antennas) can stay for at least the project duration. An integrated system of tagging a resource with UWB tags can help locate and eventually warn workers before entering hazardous areas.

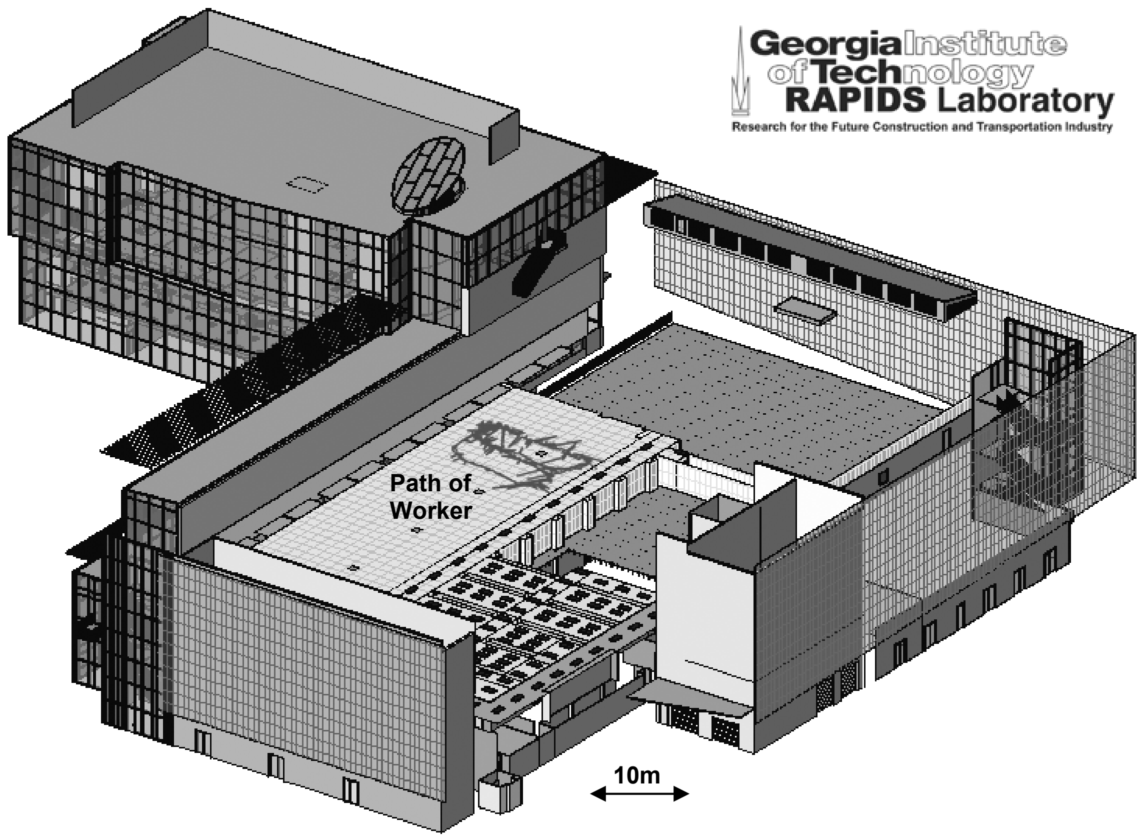

Figure 5. Ultra Wideband (UWB), Three-Dimensional Tracking Worker's Path in and Location Visualization integrated in Building Information Model (BIM)

In addition to tracking the safety performance, UWB offers the same capability as RFID for material tracking or supply chain monitoring. This would allow tracking all resources on site and control and ensuring safety among the many subcontractors that come on site. In high-rise projects, for example, real-time tracking construction resources and progress can become a new tool in construction and project management. Decision making at all levels (workforce, field manager, project manager) would be enabled by sensing technology that records location and movement of construction resources at different time intervals, in three-dimensional space, at all times, safely, and at low cost and maintenance (Teizer et al. 2007b, 2008b). Figure 5 illustrates that tracking the location of a worker's trajectory and visualizing the path inside a Building Information Model (BIM) can add another level to enhance safety to the next level in education and training. It furthermore allows recording, investigating, and correcting unsafe behaviors. Improving overall site productivity can ultimately lead to reduced work hours and minimize the duration workers are exposed to a potentially harmful environment.

5. POTENTIAL APPLICATION AREAS AND EXISTING BARRIERS

Potential application areas in pro-active work zone safety technologies are in: Enhanced Training and Education, Operator management assistance systems, lane departing warning, adaptive cruise control, communication to vehicles and operators, collision detection, collision avoidance (intervening/control), collision alertness monitoring and warning (alerting the driver), proximity sensing, back-up alarm, warning, and sensing, stability control/rollover warning, virtual safety geo-fencing, resource tracking of workers, equipment, and materials, in-vehicle event recorders (“Black Boxes”), tire pressure monitoring, navigation system, improve training courses and manuals, provide more accurate risk management to clients, and many more.

A critical element in the success of pro-active safety technologies is to make the construction industry aware of the need of sponsoring experimental data collection. Only the industries’ assistance of mid to long term studies can help validate the safe and useful use of emerging technology. Other major barriers exist and need to be addressed and solved, including: regulations on surveillance, ownership of data, “Right of privacy”, lack of cooperation/non-acceptance, lack of understanding the technology and benefits, time to implement, cost to implement, accuracy, support from management, union or other association.

6. CONCLUSION

This paper has introduced the problem of work zone safety monitoring in the construction industry and its lack of collecting and monitoring continuous data for safety analysis and accident prevention. The presented work has demonstrated that a standalone or joint approach of using existing and emerging technologies such as Global Positioning System (GPS), Radio Frequency Identification (RFID), Laser and 3D Range Image Scanning, and Ultra Wideband (UWB) comes each with a variety of benefits and limitations. Accurately tracking and monitoring construction resources (workforce, equipment, and materials) and activities in real-time, in indoor and outdoor situations concurrently, is made possible using technology such as Ultra Wideband. Preliminary research efforts conducted in the Real-time Automated Project Information Decision Systems (RAPIDS) Laboratory at the Georgia Institute of Technology have shown some of the benefits of using emerging technologies in construction work zone safety. Application areas in safety and implementation barriers were discussed. An outlook for the construction industry in form of a real-time pro-active work zone safety framework was presented assuming pro-active safety technologies as a competitive advantage rather than as a threat to the construction industry or workers. Emerging technologies that assist in solving existing needs for real-time working applications such as work zone safety, job site monitoring, and resource tracking may offer a high return on the investment. Further research is needed to explore the full potential of the technologies in construction safety and other application areas. Investigations are pending and are currently under research in the RAPIDS Laboratory.

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CAUSES AND ANALYSIS OF ACCIDENTS 8

UNDERLYING CAUSES OF ACCIDENTS INVOLVING FALLS FROM ELEVATION IN BUILDING REPAIR AND MAINTENANCE WORKS

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ABSTRACT

The construction industry has been identified as one of the most hazardous industries. A distinctive characteristic of Hong Kong is the large number of high-rise buildings; however, many high-rise buildings in the old districts are in desperate need of maintenance due to deterioration. In order to protect the living conditions, there is an increasing demand for the repair and proper maintenance of existing housing stocks. Unfortunately, most research focuses on new construction with the repair and maintenance sector often being neglected. Of all the construction-related injuries, fall accidents are the leading cause of death and thus provoking great concern among industrial practitioners in Hong Kong. There is an urgent need to investigate the causes of fall accidents and to make recommendations to avoid recurrence of similar accidents.

Based on the accident statistics obtained from the Labour Department (LD) of the HKSAR Government over the last five years (2000-2004), this paper examines the underlying causes of accidents involving falls from elevation in building repair and maintenance works. The nature of the accidents was analyzed according to the demographic characteristics of the victims, e.g. age and gender. Situations and locations with high risk, and seasonal distributions of accidents were identified. With a better understanding of the underlying causes of fall accidents, effective means can be developed to avoid the recurrence of similar accidents.

Keywords: Construction Safety, Fall Accidents, Hong Kong, Repair and Maintenance, Statistical Data

1. INTRODUCTION

On a global scale, the construction industry is recognized as being one of the most hazardous industries. This is also true of the construction industry in Hong Kong, so the Government of Hong Kong SAR has been working towards improving construction safety. As a result, the number of accidents in the construction industry has been decreasing rapidly from 11,925 in 2000 to 3,833 in 2004 (Fig. 1). The accident rate per

1000 workers also fell from 150 in 2000 to 60 in 2004 (Labour Department, 2005). This demonstrates that Hong Kong has achieved remarkable safety performance improvements in construction safety.

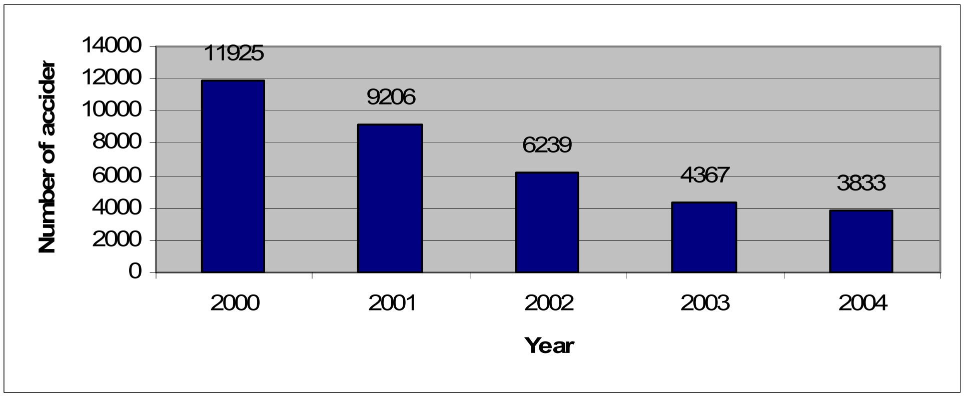

Fig. 1 Industrial accidents in the construction industry during 2000-2004 (Labour Department, 2005)

Hong Kong is characterized with high-rise buildings, and many of these high-rise buildings in the old districts are in desperate need for maintenance due to deterioration. An increasing demand on repair and proper maintenance of the existing high-rise housing stocks has aroused the attention of the construction industry on fall accidents. In fact, 'fall of person from height' accidents were one of the most frequent types of accidents from 2000 to 2004 (Labour Department, 2005). Such accident types also contributed to the highest number of fatal cases within the said period, which prompts an urgent need for the current study (Fig. 2).

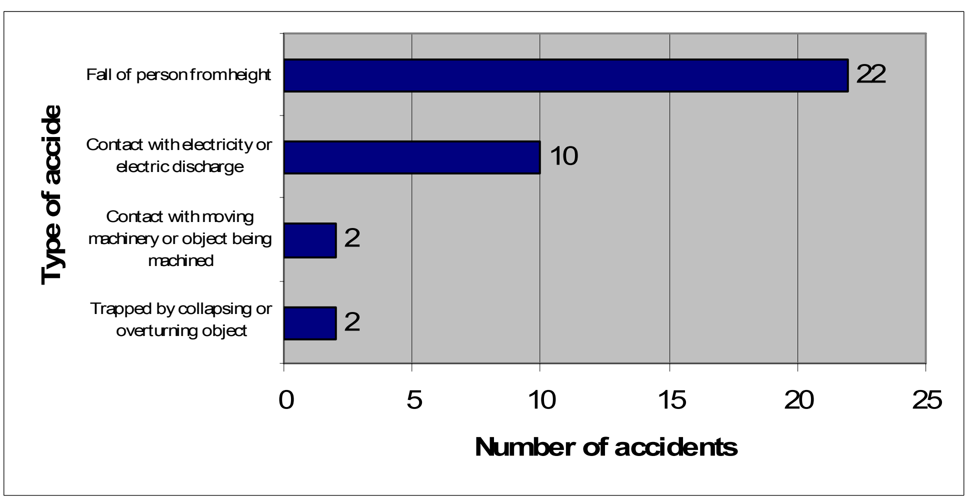

Fig. 2 Top four types of fatal accidents in repair and maintenance works during 2000-2004 (Labour Department, 2005)

This paper provides some findings of a collaborative research study between the Construction Industry Institute – Hong Kong (CII-HK) and The Hong Kong Polytechnic University entitled 'Construction Safety involving Working at Height for Residential Building Repair and Maintenance' (Chan et al., 2006a). The study aim was to improve construction safety and reduce fall accidents when maintaining residential housing stock. The main objectives were to identify situations where working at height externally is necessary, investigate the causes of fall accidents and suggest recommendation on reducing fall accidents. The current paper examines the causes of fall accidents in building repair and maintenance works. Based on the accident statistics from the Labour Department (LD) of the HKSAR Government over the last five years (2000-2004), this paper investigates the underlying causes of accidents involving falls from elevation on building repair and maintenance works. A literature review on the principal locations of fall accidents, causes of accidents and the preventive measures of fall accidents will firstly be introduced. The attributes recorded by the Labour Department will then be outlined. The nature of accidents will also be analyzed according to the demographic details of the victims, e.g. age and gender. In addition, situations and locations with high risk, and seasonal distributions of accidents will be identified and reported in the paper, followed by recommendations to avoid recurrence of similar accidents.

2. REVIEW ON THE PRINCIPAL LOCATIONS OF FALL ACCIDENTS

Falls from elevation on construction projects are a major problem and the prevention of accidents involving falls from height remains a high priority for the construction industry (Glasgow Caledonian University, 2005). There are a number of locations where fall accidents are most likely to take place.

A fall is used to imply a loss of equilibrium and control, including subsequent recovery by the subject (Ertas *et al*., 1990). In general, fall injuries can be classified as occurring from an elevated work surface (ladders, scaffolds, roofs, buildings, stairs, vehicles, floor openings, etc.) or from the same level (Cattledge *et al*., 1996). Moreover, nonfatal falls from elevation present a significant problem for individuals employed in the construction industry. Working at height is either carried out from the permanent structure or from some form of additional access equipment. This could either be permanently attached or dedicated to the structure, such as permanent gantries, suspended cradles, ladders or walkways. In some cases, they may be temporarily installed for the work, such as scaffolds, mobile elevating work platforms, suspended platforms or ladders (Malcolm, 2000). In some buildings, work at height is required to deal with natural deterioration.

Hinze and Russell (1995) identified the most common fall locations listed in order of occurrences as follows: (1) off roof, (2) collapse of scaffolding, (3) off scaffolding, (4) collapse of structure, (5) through floor opening, (6) off ladder, (7) off structure, (8) through roof opening, (9) off edge of open floor, (10) off beam support. They also attributed fall accidents to some external forces, such as the collapse of a support system, getting struck by an object, falling through an unknown or unprotected opening, and so on. The classifications are similar to those of Construction Worker Research Group

(1998), and Huang and Hinze (2003), who associated falls with workers on roofs, scaffolds, ladders, edges of structures, beam supports and floors with openings. Moreover, Agnew and Suruda (1993) found that most fall injuries occurred with the use of a ladder as a work platform. Cohen and Lin (1991) pointed out that falls from ladders are second only to stairway falls as the most frequent source of injury involving falls from elevation.

3. PRINCIPAL CAUSES OF FALL ACCIDENTS AND THE FALL PREVENTIVE MEASURES

Chan et al. (2006b) analysed the causes of fall injuries from three main perspectives, namely unsafe conditions, management inactions and human-related factors. Some unsafe conditions were identified by Toole (2002) as the root causes of construction accidents, such as unsafe site conditions, lack of proper training, deficient enforcement of safety, insufficient provision of safety equipment, unsafe methods or sequencing, workers not using provided safety equipment, poor attitude toward safety, and isolated and sudden deviation from prescribed behavior. Other improper management actions may also lead to fall accidents. Huang and Hinze (2003) pointed out that the inadequate or inappropriate use of fall protection equipment and inoperative safety equipment can contribute to more than 30% of the falls. Abdelhamid and Everett (2000) attributed the causes of fall accidents to human-related factors. They observed that some workers would proceed with a work activity even after the existing unsafe condition was pointed out to them. The workers may also perform unsafe work regardless of initial conditions of the work environment.

Prevention is always better than cure. Results showed that 33% of the fatalities in construction were caused by falls (Hinze *et al*., 1998). In the UK, Glasgow Caledonian University (2005) conducted a comprehensive study on fall prevention and arrest equipment available to the construction industry. Some common precautionary measures include purlin trolley systems, safety decking, fall arrest mats, safety netting, cable and track-based fall arrest systems, and the National Access and Scaffolding Confederation (NASC)'s fall arrest equipment in erecting, altering and dismantling scaffold. The principles of the 'hierarchy of risk control' were introduced, which are important when selecting appropriate safety equipment for working at elevation. The order of preference for the above precautionary measures should be prevention, such as the use of guardrails, purlin trolleys and safety decking, followed by the mitigation of any consequences of an accident. Moreover, the risk of a fall must be designed out and the selection of fall protection equipment should be carefully considered prior to opting for a particular system.

Other researchers, such as Cattledge et al. (1996) suggested that most fatal fall injuries can be prevented through the use of proper personal fall protective equipment, such as lifelines, lanyards and employee training in fall prevention. The suitable safety measures such as working platform, guard-rails, toe-boards, safe access, and safe egress should be provided to prevent fall accidents (Agnew and Suruda, 1993). Gillen et al. (1997) further suggested some simple hazard control measures in the common fall locations, e.g., perimeter protection for roofs and floor edges, correct ladder placement and anchorage, guarding of floor openings, comprehensive housekeeping activities, inspection and maintenance of ladders and aerial lifts, and proper scaffold erection and modified work practices. Huang and Hinze (2003) also pointed out that the current personal fall arrest systems (PFAS) can effectively protect workers after they fall from an elevation.

The review of literature provides a comprehensive examination of the causes of construction fall accidents and the fall preventive measures utilized in recent years. In order to identify the key issues in the local context, empirical data have been collected from the Labour Department of the Hong Kong SAR Government.

4. IDENTIFICATION OF KEY ISSUES FROM THE STATISTICAL DATA OF LABOUR DEPARTMENT

The statistical information provided in the Labour Department date presents information on all construction accidents in Hong Kong that occurred between 2000 and 2004. Nine key issues were identified for injury analysis, including:

1. Age distribution
2. Sex distribution
3. Month distribution
4. Employers, self-employed and illegal workers
5. Type of work performed at the time of the accident
6. Body part injured
7. Nature of injury

Age distribution

Statistics show that most injuries in the construction industry from 2000 to 2004 were sustained by workers in the age group 40-44 (Labour Department, 2005). This trend is the same for repair and maintenance works as shown in Fig. 3 and can be explained by a number of reasons. Firstly, the median age group working in the construction industry is 40-44; therefore it is not surprising to see most accidents occur in this age group. Secondly, this age group marks a natural break in developing Presbyopia[1], which is not a disease as such, but a condition that affects everyone at a certain age, noticeably between the ages of 40-50 (Wikipedia, online).

[1] "presbyteros" is the eye's diminished ability to focus that occurs with ageing.

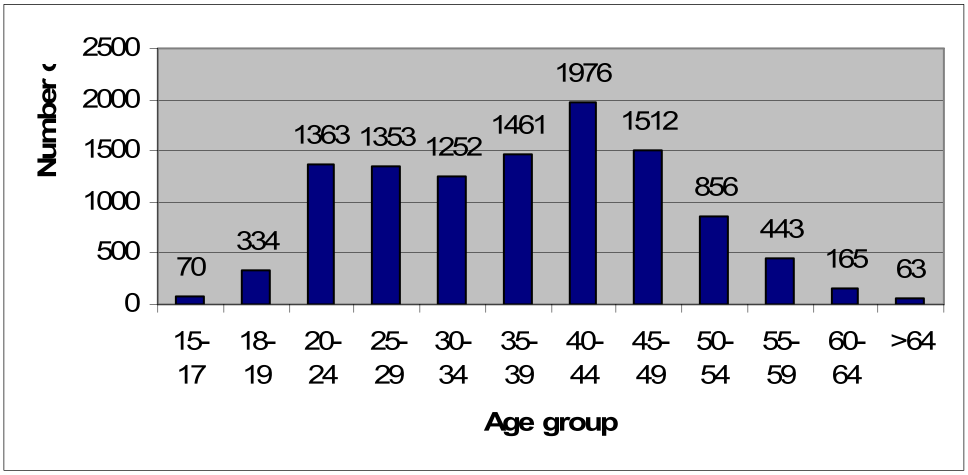

Fig. 3 Injuries in repair and maintenance works during 2000-2004 analyzed by age group (Labour Department, 2005)

Fatal accidents in the construction industry also included workers in the age group 40-44. But in repair and maintenance works, most fatal accidents occurred to workers in the age group 30-34 as shown in Fig. 4. It is likely that a large proportion of repair and maintenance workers are younger than workers of the construction industry in general. As repair and maintenance jobs are often unstable and involve high risk, workers, especially the younger ones, are attracted to these jobs as they often pay better and quicker since these jobs are generally shorter in duration.

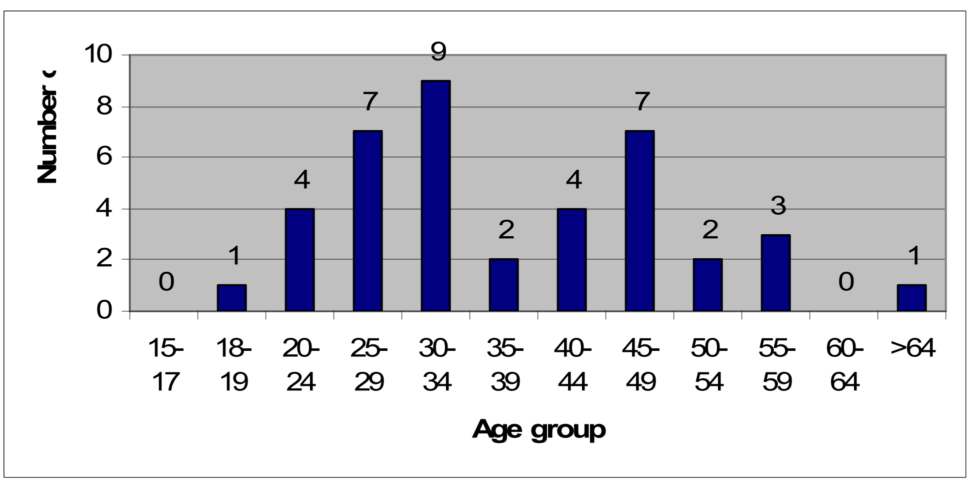

Fig. 4 Fatal accidents in repair and maintenance works during 2000-2004 analysed by age group (Labour Department, 2005)

Sex distribution

Not surprisingly, the majority of accidents occurred to male workers instead of female workers (Fig. 5). From 2000 to 2004, 10,660 male workers were injured compared to

188 female workers. The rate at which women workers are injured is less than 2% of the total accidents in repair and maintenance works. It is known that the construction industry is a male dominated industry; hence the findings are expected. Moreover, all fatal accidents recorded for repair and maintenance works occurred exclusively to male workers (Labour Department, 2005).

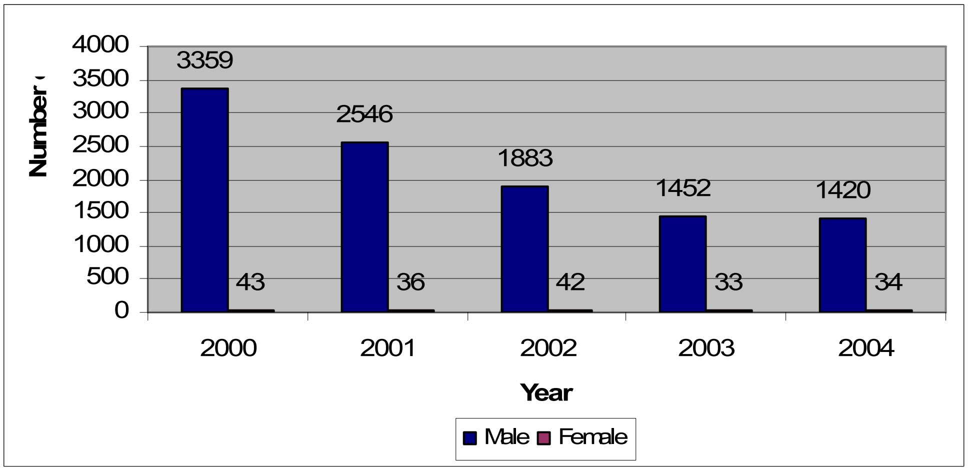

Fig. 5 Injuries in repair and maintenance works during 2000-2004 analyzed by sex (Labour Department, 2005)

Month distribution

Fig. 6 shows the average distribution of accidents over the months during 2000 and 2004. The distribution shows a trend that over the summer months accidents increase.

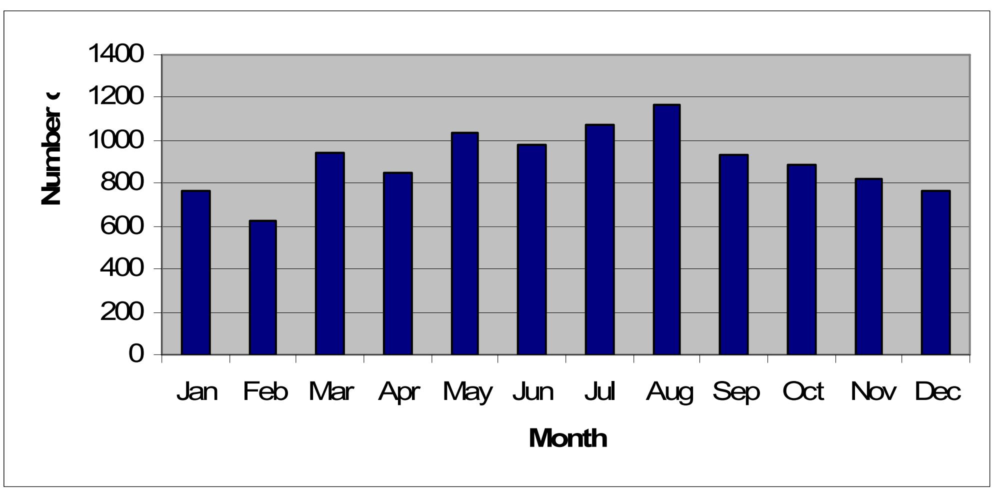

Fig. 6 Injuries in repair and maintenance works during 2000-2004 analysed by month (Labour Department, 2005)

Similarly for fatal accidents a similar behaviour can be observed as shown in Fig. 7.

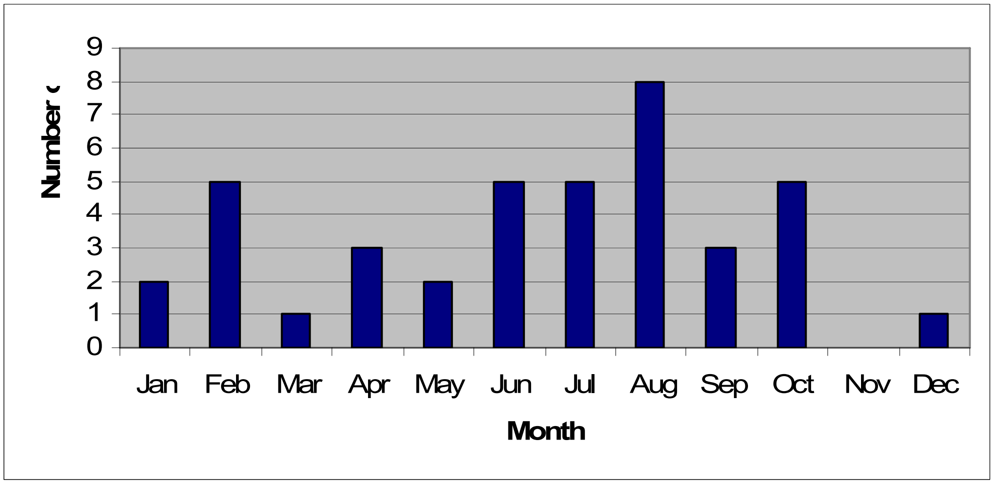

Fig. 7 Fatal accidents in repair and maintenance works during 2000-2004 analyzed by month (Labour Department, 2005)

The possible reason that both non-fatal and fatal accidents occur during the summer months is probably due to several reasons. Summer weather in Hong Kong can reach high temperatures of 35-37°C and the relative humidity regularly approaches 100%. Under these conditions, occupations that require working outdoors can be immensely uncomfortable. Hence it is likely that under these circumstances workers will feel more frustrated and their bodies do not adapt to the heat and humidity very well, causing them to neglect safety precautions and to be more careless resulting in a higher frequency of accidents. In addition, it is likely that workers work for longer hours during the summer days as daylight lasts for a few more hours compared to winter days. Construction projects rely heavily on the speed of work to maximize profits. Therefore, contractors often have their employees working longer hours when possible. As a result, it is likely that workers may be injured more easily after they have been working for extended periods and experience fatigue which increases the chance of accidents.

Employers, self-employed and illegal workers

Accidents involving employers, the self employed and illegal workers are sometimes excluded from published statistics. There are records of these individual when fatal incidents occur as these result in the involvement of the police who generally investigate these accidents. The non-fatal accidents involving these groups of people are frequently not reported, leaving no documented evidence for future evaluation. Fig. 8 shows the number of fatal accidents which occurred when performing repair and maintenance work, including those involving employers, the self employed and illegal workers.

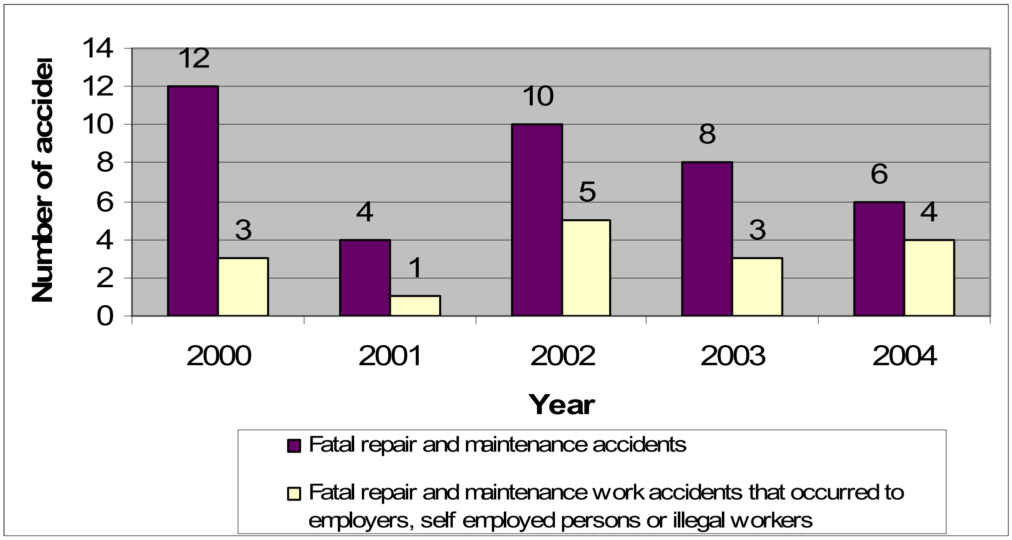

Fig. 8 A comparison of all fatal repair and maintenance work accidents of employees and fatal repair and maintenance work accidents that occurred to employers, self-employed persons or illegal workers during 2000-2004 (Labour Department, 2005)

The statistics show that employers, self-employed persons or illegal workers represent up to two thirds of the total fatal accidents that occurred during repair and maintenance works. The findings show that these groups of people are very much prone to accidents and that more precautions should be implemented to ensure their safety. It is likely that employers and the self-employed take more risks to complete projects faster and they may fail to use safety precautions as a means to increase profits. In addition their safety knowledge and safety equipment is often not sufficient when compared with contractors who employ people with safety expertise to supervise, monitor and design the works. For illegal workers it is likely that they possess little or no knowledge of construction safety as they probably did not even work in the same industry before arriving in Hong Kong. Moreover, safety standards vary from country to country, resulting in work practices that might be acceptable elsewhere but not in Hong Kong. Workers who work illegally often live under unstable economic conditions and therefore they are willing to work for low wages. At very low wages it is likely that safety measures have not been included. In general, a large proportion of accidents in repair and maintenance works occur to employers, the self-employed and illegal workers. These groups of people are more difficult to monitor and control; hence accidents are more likely to occur. This type of fatal accidents is not reported to the Labour Department under the Employees' Compensation Ordinance. Nonetheless, there have been established channels for fatal and serious accidents to be reported to the Labour Department by Police and Fire Services Department. All these accidents were thoroughly investigated with appropriate action taken afterwards.

Type of work performed during accident

Fig. 9 shows the top five types of work associated with accidents in repair and maintenance work. The statistics show that material handling was the most frequent with 1,588 accidents and was closely followed by manual work and electrical wiring. In addition, water pipe fitting and lift/escalator fitting were also among the top five types of work performed. These findings are not surprising as these chores are common on construction sites. The more common types of work being performed are expected to be associated with higher probabilities of accidents.

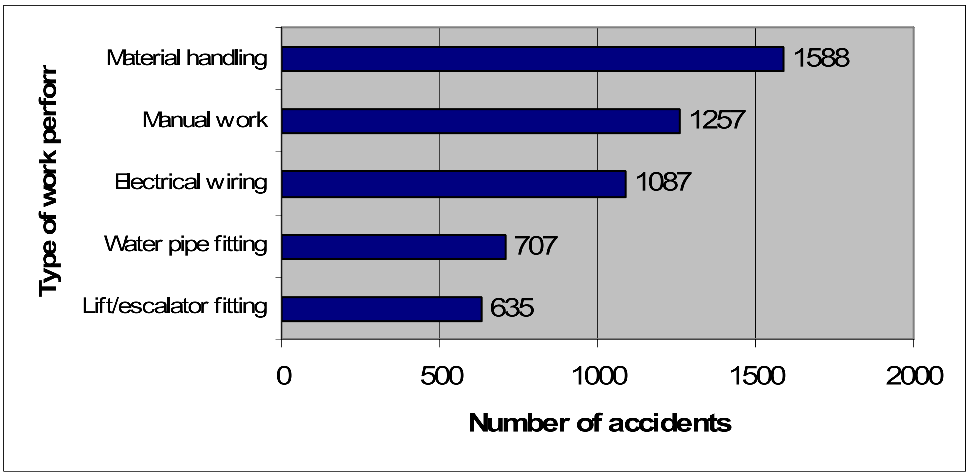

Fig. 9 Top five types of work performed when injuries occurred in repair and maintenance works during 2000-2004 (Labour Department, 2005)

Fig. 10 shows the top five types of work being performed when fatal accidents occur in repair and maintenance work. The results are slightly different from those shown in Fig 9. Demolition work is the most deadly in repair and maintenance work, probably because much work involves heavy machinery and working at height. The working conditions of demolition work are generally more unstable and unpredictable; hence the likelihood of accidents is aggravated. Electrical wiring, manual work, bamboo scaffolding and lift/escalator fitting were also among the top five types of work causing fatal accidents in repair and maintenance work. The order of the top five types of work performed when fatal and non-fatal accidents occur in repair and maintenance work are very similar to tho;se for fatal accidents only. Of the types of work performed, demolition work caused the highest number of fatal accidents during 2000-2004 in repair and maintenance work. More precautions and planning appear to be appropriate prior to undertaking demolition work.

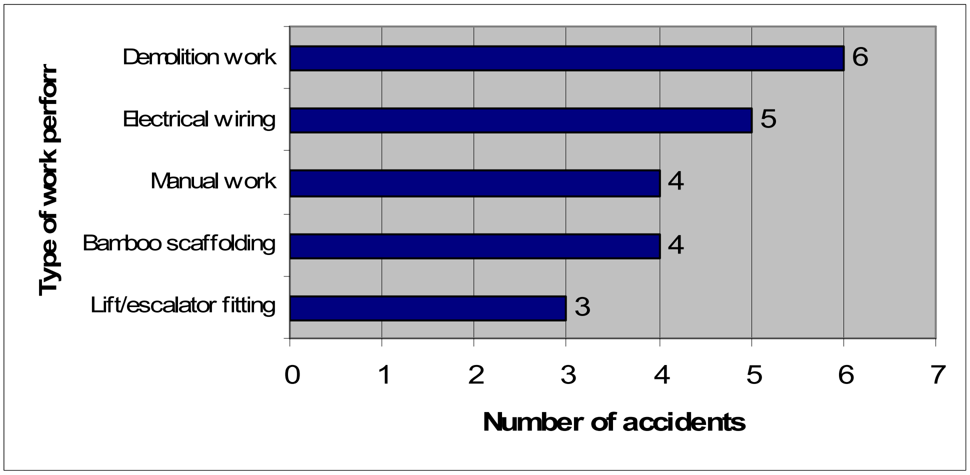

Fig. 10 Top five types of work performed when fatal accidents occur in repair and maintenance works during 2000-2004 (Labour Department, 2005)

Body part injured

Most workers hurt their fingers in the repair and maintenance works accidents (Fig. 11). Other body parts frequently injured included hand/palm, eye, foot and multiple locations. Again, similar to the discussion for type of work performed, it is obvious that the body part exposed and used most is the part that will be injured more often. Statistics for the top five body parts injured in all construction accidents are very similar in ranking. For accidents in the construction industry, and repair and maintenance work, the body parts injured from fatal accidents were multiple locations followed by skull/scalp (Labour Department, 2005). Therefore, more efforts should be expended to prevent falls from height which is the common cause of multiple injuries. Head protection is also important to protect the skull/scalp. In fact, findings are logical as fatal accidents are likely to be caused by injury to multiple locations or skull/scalp, and not just limited to the fingers.

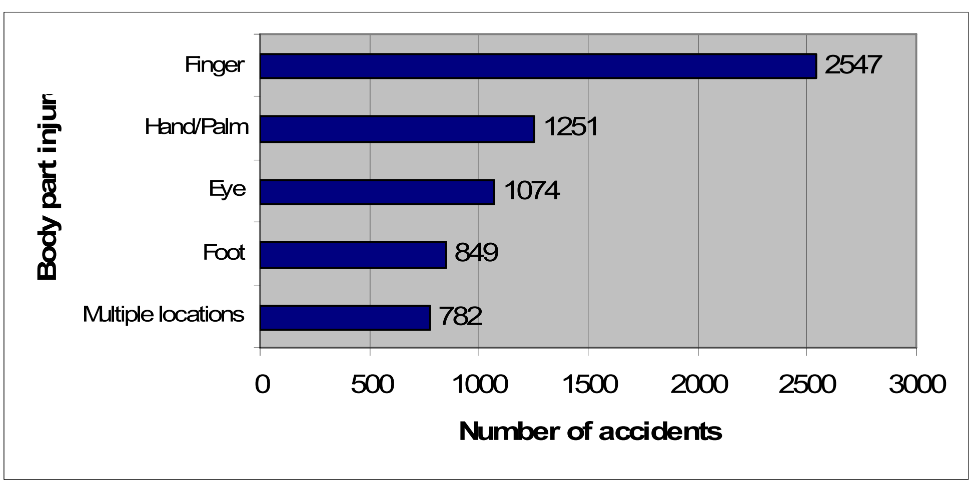

Fig. 11 Top five body parts injured in repair and maintenance works accidents during 2000-2004 (Labour Department, 2005)

Nature of injury

The top five nature of injuries of accidents in the construction industry, and in repair and maintenance works during 2000 to 2004 are the same. As shown in Fig. 12 most accidents in repair and maintenance work resulted in contusions and bruises, 462 such injuries among the 1,383 which represent one-third of all the accidents in repair and maintenance work. The second nature of injury was fracture with 422 accidents, which is also approximately a third of all the accidents in repair and maintenance work. Other nature of injury accidents in the top five included sprain and strain, multiple injuries, and lacerations or cuts. For accidents in the construction industry, and repair and maintenance works, multiple injuries were recorded in most fatal accidents followed by contusions and bruises (Labour Department, 2005). This finding is very similar to the one found for body part injured. It was realized that multiple locations, which are often caused by fall from height accidents, lead to the highest number of fatal accidents.

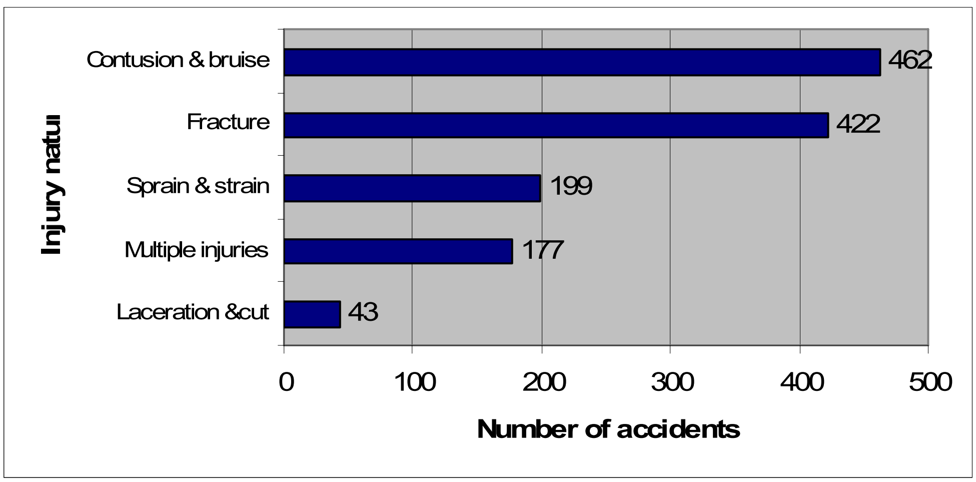

Fig. 12 Top five injury types in repair and maintenance works during 2000-2004 (Labour Department, 2005)

5. RECOMMENDATIONS TO AVOID RECURRENCE OF SIMILAR ACCIDENTS

A number of key issues were identified from the statistical data of the Labour Department to examine the underlying causes for accidents involving falls of workers from elevation in building repair and maintenance projects.

Most accidents in the construction industry occur to workers in the age group 40-44. However, in repair and maintenance work, most fatal accidents were sustained by workers in the age group 30-34. Therefore, more work needs to be carried out to re-educate the experienced workers, ensuring that they remain alert and safe at all times, as well as to ensure that they receive up-to-date information on safe work practices. Repair and maintenance projects are generally short in duration, but they should also be carried out under strict safety procedures comparable to those of large new construction projects.

Since all fatal accidents recorded for repair and maintenance work occur to male workers, information should be targeted particularly to male workers. The distribution shows a trend that over the summer months, accidents increase. Therefore, proper precautions should be taken to make sure that safety awareness is maintained. The increase of inspections and monitoring should also be considered. In addition, it is vital that, for all times of the year, workers get sufficient rest and they are not strained to work inappropriate long hours.

The statistics show that employers, self-employed persons or illegal workers represent up to two thirds of the fatal accidents that occurred when performing repair and maintenance work. Therefore, more work should be carried out to provide those categories of workers with sufficient technical support and safety information. Construction sites should also be monitored regularly to prevent the employment of illegal workers and employers of illegal workers. Both employer and the illegal worker should be penalized heavily if there are illegal activities on site. Demolition work results in the highest number of fatal accidents. Carefully drafted work plans should be developed before undertaking demolition work. Regardless of the type of work performed, safe practices should be employed when working at height. Extra attention should be given to work that is performed frequently. The body parts injured from fatal accidents were multiple locations followed by skull/scalp. Multiple injuries were identified as the main nature of injury for most fatal accidents followed by contusions and bruises. Therefore focus should be placed on preventing these injuries by improving safety practices when performing work at elevation, including the use of personal protective equipment.

6. CONCLUSIONS

Statistics show that Hong Kong has achieved an enviable safety record in recent years. Unfortunately, an unacceptable number of accidents still occur that result from falls of workers from elevation. The statistics showed that fatal fall accidents represented approximately half of all fall accidents. The findings cry out for more work to be done in the area of falls from height safety and especially in the area of repair and maintenance work.

In general, the statistical information has been extremely useful in providing information on common failures, acts and circumstances resulting in accidents in repair and maintenance works. When the underlying causes of fall accidents are identified, recommendations can be made to provide workers with continuous training to improve their safety attitudes and work practices and hence reducing the occurrence of unsafe acts or procedures. As bamboo truss-out scaffold is known to be one of the most severe safety hazards in residential building repair and maintenance projects, authorities should consider introducing a mandatory licensing system for workers using the bamboo truss-out scaffold system. With this information, practical solutions to eliminate falls from height accidents in repair and maintenance works can be achieved. With a better understanding of the underlying causes for these accidents, advancements have been made in developing effective means to avoid the recurrence of similar accidents.

7. ACKNOWLEDGEMENTS

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PROJECT LIFESAVER: REDUCING ACCIDENT AND INSURANCE COSTS

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ABSTRACT

Project Lifesaver (PLS) was developed by the American Contractors Insurance Group (ACIG) as a corporate-wide initiative to assist its members (exclusively construction companies) in reducing insurance losses across all lines of business. Project Lifesaver was designed and five (5) key objectives were identified and implemented throughout each contractor member of ACIG. The overall goal of PLS was to reduce the frequency and severity of losses. This goal was to be achieved over a two-year policy span. The expected losses by the contractor members were estimated to be nearly $50,000,000 for workers' compensation, general liability, and auto liability. The membership goal was to reduce losses by 40 percent, which equates to $20,000,000 in loss cost-reduction over the two-year policy span. The actual cost reduction that was achieved was $21,287,511 between the 2002-03 and 2004-05 policy years. This paper will detail and document the processes, methodology, and activities that were required to achieve the cost reduction goal.

Keywords: Project Lifesaver, Controlled Insurance Program, Contractor Action Plan, Indemnity cases

1. BACKGROUND

American Contractors Insurance Group (ACIG) is a Bermuda-based captive insurance company originally formed in 1981 by three construction companies that had "had it" with the unpredictable cost and coverage swings from the traditional property and casualty insurance markets available to contractors. ACIG's mission statement is to save lives, prevent injuries, and reduce the overall cost of insurance for its members. The business profile of the active members consists of sixteen (16) general contractors, eleven (11) industrial contractors, and ten (10) street and road (civil) contractors. For policy year 2005-06, the membership's operations scorecard consisted of over $9.0 billion in construction revenue, $1,049,000,000 in payrolls, 61,217,305 manhours worked, and $125,000,000 in pay-in premiums. Lines of business written included workers' compensation, general liability, and auto liability.

In policy year 2003-04, ACIG sought to lessen construction site losses. According to Lew & Overholt (2006), coordination among all parties regarding allocation of insurance costs should be a priority of the management teams to ensure that a project runs smoothly.

In policy year 2003-04, American Contractors Insurance Group instituted a corporate-wide initiative titled Project Lifesaver (PLS) to assist its members in reducing losses across all lines of business. The expected losses by its contractor members were estimated to be $49,330,005 for workers' compensation, general liability, and auto liability. The ACIG executive committee was briefed on a comprehensive strategy for targeted loss reduction. A baseline metric was established for the 2002-03 policy period and goals were developed for the members.

In conjunction with Project Lifesaver, ACIG implemented a Contractor Controlled Insurance Program (CCIP) with some of their general contractors in the group. The CCIP was structured to address a number of insurance issues commonplace in the industry. These include lack of completed operations coverage, shrinking additional insured protection, states' statutes of repose, quality of work, and safety concerns (Lew & Overholt, 1999). ACIG will be measuring the CCIP safety results, and compare them to all of the other members' results once these projects are completed.

2. INTRODUCTION

In the development of Project Lifesaver, five (5) key objectives were identified and implemented. The overall goal of PLS was to reduce the frequency and severity of losses. The five (5) key objectives were:

1. Contractor Ranking based upon objective rating of indemnity case rates. Number of injuries multiplied by 200,000 manhours divided by manhours worked. A 2-year average indemnity case rate was utilized.
2. Best practices review sessions.
3. Face-to-face Project Lifesaver meetings with CEO/COO and their management teams.
4. Contractor Action Plans that identify goals and objectives.
5. Conducting a benchmarking safety survey for safety-related activities.

The overall membership goal was to reduce overall losses by 40 percent, which equates to $20,000,000 in loss cost reduction. The overall goal was to be achieved over a 2-year policy span.

Two of the key drivers in construction safety loss reduction are the safety programs and processes that a contractor has in place, and measuring the effectiveness of these programs. From the previous year's CEO management team meeting, ACIG produced a Contractor Action Plan (CAP) to ensure that each one of its members remained focused on safety awareness and loss reduction in their companies (see Appendix). These action plans have proven very beneficial in keeping the contractors focused on safety, and on learning from past losses.

3. DEFINITIONS

The following terms are unique to the insurance industry and to the ACIG membership. To ensure consistency throughout the Project Lifesaver tenure, the following key terms and acronyms were used to educate the contractor on how the various benchmarks and reduction-in-accidents costs are calculated.

Project Lifesaver. Loss reduction initiative established by ACIG in policy year 2002-03.

ACIG Executive Committee. Consists of eleven members of the ACIG membership and includes the three (3) founding members, five (5) of the largest premium payers, and three (3) rotating members serving a term of two years.

Incurred But Not Reported (IBNR) Losses. An estimate of the amount of an insurer's (or self-insurer's) liability for claim-generating events that have taken place but have not yet been reported to the insurer or self-insurer. The sum of IBNR losses, plus incurred losses, provides an estimate of the insurer's eventual liabilities for losses during a given period.

Incurred But Not Enough (IBNE). Loss reserves that allow for an increase to an existing reserve because there was "not enough reported." This is also called incurred but not enough reserved (IBNER) or reserved but not enough (RBNE).

Indemnity Case Rate. Frequency benchmark rate used to measure safety results. Formula driven by the number of indemnity claims x 200,000 man-hours, divided by man-hours worked. This equates to an OSHA lost time accident frequency rate.

PLS Reportable. The Number of claims that have been paid in-house by the member; known as Self-Pays, and not reported to the insurance company.

Bureau of Labor Statistics (BLS). The principal fact-finding agency for the Federal Government in the broad field of labor economics and statistics (BLS, 2005).

National Council Compensation Insurance (NCCI). The oldest and largest provider of workers' compensation and employee injury data and statistics in the nation (NCCI, 2005).

4. CONTRACTOR ACTION PLAN (CAP)

Project Lifesaver was continued past the project year 2003-04. During the 2006 Project Lifesaver meetings, a Contractor Action Plan (CAP) was developed to assist each contractor member in focusing on key objectives and milestones to further evaluate the PLS loss-prevention program, and marshal the necessary tools and resources for reducing their losses and their cost of insurance.

5. PROJECT LIFESAVER TIMELINE

The following is the timeline that the American Contractors Insurance Group followed to execute Project Lifesaver:

April 2003	Expected losses for 2003-04 were projected by the annual underwriting process to be in excess of $49,000,000.
May 2003	Executive committee was briefed on strategy to initiate a comprehensive loss reduction initiative.
August 2003	Baseline metrics for the 2002/03 policy period were established, and goals were developed.
October 2003	Plans for the PLS initiative were approved by the executive committee and presented to the members.
December 2003	Round 1 of PLS meetings.
3rd quarter 2004	Round 2 of PLS meetings.
3rd quarter 2005	Round 3 of PLS meetings.
3rd quarter 2006	Round 4 of PLS meetings.

For comparison purposes, ACIG uses as one of the key benchmarks in indemnity case frequency reduction, national safety statistics as published by the Bureau of Labor Statistics. The following paragraphs describe the key statistics that provided benchmarking for the PLS project.

Occupational Safety and Health Administration (OSHA), Secretary of Labor, released a statement on October 20, 2006, that the rate of workplace injuries and illnesses in the private industry declined in 2005 for the third consecutive year.

Nonfatal workplace injuries and illnesses occurred at a rate of 4.6 cases per 100 equivalent full-time workers among private industry employers in 2005, according to the Survey of Occupational Injuries and Illnesses by the Bureau of Labor Statistics (BLS), US Department of Labor. (OSHA, 2005a) This was a decline from the rate of 4.8 cases per 100 equivalent full-time workers reported by the BLS for 2004. The reduced rate resulted from a total of 4.2 million nonfatal injuries and illnesses in private industry workplaces during 2005, relatively unchanged compared to 2004, and a 2 percent increase in the number of hours worked. Incidence rates for injuries and illnesses combined, declined significantly in 2005 for most case types, with the exception of cases with days away from work.

Table 1 outlines the OSHA lost-workday injury and illness rates by specific Standard Industrial Code (SIC) for each construction industry segment. The data is generated from the Survey of Occupational Injuries and Illnesses by the Bureau of Labor Statistics (BLS) annually and is collected from 176,000 private industry establishments. The case rates are recorded and conform to the definition guidelines as published by OSHA.

Table 1.
Lost-workday cases, incident rates

Explanation\ year	2000	2001	2002	2003*
Total	4.1	4.0	3.8	3.4
With days away from work	3.2	3.0	2.8	2.4
SIC 15	3.9	3.5	3.2	2.9
SIC 15 With days away from work	3.1	2.6	2.3	2.2
SIC 16	3.7	4.0	3.4	3.2
SIC 16 With days away from work	2.7	2.9	2.4	2.1
SIC 17	4.3	4.1	4.1	3.6
SIC 17 With days away from work	3.4	3.2	3.0	2.6

Notes: Most current BLS data available. Incident Rate = Number of injuries and illnesses x 200,000. Total hours worked by all employees during period covered. (OSHA, 2005b).

6. PLS REPORTABLES

This category of claims includes indemnity cases, and cases with medical expenses greater than $3,415 (reported during 2002-03), $3,757* (2003-04), $4,132 (2004-05), and $4,545 (2005-06). This data may also include cases not previously reported to ACIG which meet the same criteria. A benchmark of $5,000 was established and indexed backwards based on medical inflation. The National Council of Compensation Insurance (NCCI) produced the annual Statistical Bulletin where the annual trend of medical cost inflation during 1999-2001 is 12.2 percent. *The $3,757 is the threshold number used to measure any medical claim a contractor incurred. $5,000 as the threshold and then indexed backwards 10% every year. In other words, for policy year 2003-04 any claim exceeding $3,757 in value had to reported to ACIG. If a contractor had any claim below that threshold, they did not have to report it.

7. CONTRACTOR RANKING OF WORKERS' COMPENSATION INDEMNITY CASE RATES

This ranking is based on the two-year weighted-average loss rate for PLS reportables, which were previously described. This loss rate is equated to the OSHA lost time accident rate. ACIG utilizes as one of their benchmarks, the ranking of contractor members against the workers' compensation indemnity case rate. Contractor members are ranked against all other members and against their peer group members. The peer groups are general contractors, industrial, and civil contractors. The range of rates was from 0.0 to 4.31 (determined by the same formula as the OSHA lost time rate) for all members. (ACIG, 2005)

8. CONTRACTOR ACTION PLAN

A copy of the Contractor Action Plan (CAP) template was sent electronically in a separate correspondence in order to ensure that it would be completed and returned to ACIG at least 5 days prior to the PLS meeting.

Project Lifesaver Results

The following tables represent Project Lifesaver results and the reduction made by the contractor members regarding frequency and severity of accidents.

The following number of WC indemnity cases have occurred over the last four policy years. The reduction of cases is one benchmark on how ACIG evaluates their efforts and overall results.

Policy Year: 2002/03	431
Policy Year: 2003/04	374
Policy Year: 2004/05	355
Policy Year: 2005/06	338

Table 2 outlines the overall ACIG group of contractors' (37 members) workers' compensation indemnity case rates. These case rates are the number of indemnity cases showing an indemnity payment or reserve in the ACIG claims system. The ACIG case rates shown below are equivalent to the OSHA Lost-Workday rates shown in Table 1.

Table 2.
Overall ACIG indemnity case frequency rates

Workers' compensation* Policy Year	Rate
2002/03 Baseline	1.84
2003/04 Rate	1.59
2004/05 Rate	1.41
2005/06 Rate	1.10
Overall Rate Reduction	40.2%

*Rates reflect new reporting criteria

Table 3 outlines the ACIG general liability case rates for 33 contractors--the number of members ACIG writes commercial general liability coverage for. The formula is the number of general liability claims exceeding $5,000 multiplied by 200,000 man-hours divided by man-hours worked.

Table 3.
Overall ACIG general liability case rates

General Liability Policy Year	Rate
2002/03 Baseline	0.57
2003/04 Rate	0.49
2004/05 Rate	0.27
2005/06 Rate	0.14
Overall Rate Reduction	75.4%

Table 4 outlines the ACIG auto liability case rates for 14 contractors--the number of members ACIG writes auto liability coverage for. The formula is the number of auto claims exceeding $5,000 per 100 vehicles.

Table 4.
Overall ACIG auto liability case frequency rates

Auto Liability Policy Year	Rate
2002/03 Baseline	1.07
2003/04 Rate	1.01
2004/05 Rate	0.90
2005/06 Rate	0.82
Overall Rate Reduction	23.4%

Table 5 outlines the total cost of expected losses to incur for all of the ACIG contractors for workers' compensation, general and auto liability by policy year, and the total of actual costs incurred. The overall decrease is the total cost in dollar savings.

Table 5.
Expected vs. indicated losses

Policy Period	Expected Losses	Indicated Losses	Decrease
2003/04	$49,330,005	$37,084,993	$12,245,012
2004/05	$46,953,881	$37,911,382	$ 9,042,499
2005/06	$63,453,735	$55,149,179	$ 8,304,556
Total Decreased From Expected Losses			$29,592,067

9. KEY RESULTS FROM PLS

The key results from Project Lifesaver are the following:

- Annual strategic planning meetings with each member.
- Structured contractor action plan that is focal point of meeting.
- Best practices established and measured in the areas of claims, risk management, and safety.
- Annual best practices meetings.
- Loss analysis from projects.
    - Reduction in loss rates in all lines of coverage.
    - Two year decrease in expected losses of $21,287,511.
    - Decrease in expected losses of $29,592,067 across three policy years.

After the third round of PLS meetings was conducted, a post-mortem survey was distributed to the membership. The objective of the survey was to have the respective safety and risk managers, and the CEOs, COOs, and VPs "rank" what they thought were their company's top priorities of safety initiatives from among the benchmarking safety survey categories. Table 6 shows the overall or combined ranking averages, and the rankings of each category of initiative for the 43 safety and risk managers, and 32 operations (CEO, COO, and VPs) personnel. From Table 6, it is interesting to note that both groups rated "daily safety planning" and "new employee orientation" as the top two priorities of safety initiatives from the benchmarking safety survey.

Table 6.
Ranking summary of top priorities of safety initiatives

Category of Initiative	Overall	Safety	Operations
Daily Safety Planning	1	1	1
New Employee Orientation	2	2	2
Site Specific Safety Plan	3	4	3
Hiring and Firing Smart	4	3	5
Zero Injury Performance	5	5	4
Every Task Planning	6	6	6
Incident Investigations	7	7	9
Contractor and Subcontractor Safety Management	8	8	10
Behavior Based Safety	9	9	8
Safety Recognition	10	10	7
New Employee Identification	11	11	11
Perception Surveys	12	12	12

10. CONCLUSIONS

The frequency reductions across all lines of business have had a very favorable impact to ACIG's contractor members. The frequency rates continue to decline even though man-hours and payroll continue to rise. The severity of accidents is on the rise though. Medical inflation is one of the key drivers for this, as well as access to occupational care. Another key driver behind the severity is the average age of the construction trade worker. BLS statistics indicate that the average age of the trade worker is between 49 and 53 years of age. With this increase in age, and the outlook of a continued rise in age, medically treating the trade workers and bringing them back to maximum medical improvement is taking longer. Another ACIG objective ("unwritten") during Project Lifesaver was to go the entire policy year without incurring a direct payroll fatality. During the first policy year, this was accomplished while incurring over 48,000,000 man-hours. Ranked as the two top priorities of safety initiatives by operations and safety personnel after the implementation of PLS through the Contractor's Action Plan were Daily Safety Planning and New Employee Orientation.

As with any new program initiative, one of the key elements is to keep the strategic goals fresh. Going forward, ACIG is planning to add new surveys to benchmark with the members. The surveys include a Risk Management survey, claims survey, and a quality construction component.

11. PROJECT LIFESAVER PHASE II GOALS - NEXT 4 YEARS (2007 TO 2010)

- Prevent jobsite deaths.
- Achieve a 40% reduction in PLS loss rates for the next four (4) years.
- Develop and validate Best Practices.

12. PROJECT LIFESAVER PHASE II KEY ACTIVITIES - NEXT 4 YEARS (2007 TO 2010)

In order to assist the members in achieving this new set of goals we propose to do the following:

- Develop an enhanced Incident Investigation/Root Cause training program to assist members in analyzing incidents and developing lessons learned.
- Conduct Safety Culture Evaluations and identify key characteristics of successful companies.
- Conduct regional workshops on "Establishing a Safety Culture."
- Assist members in facilitating a Subcontractor Summit for "Creating a Zero Injury Culture."
- Continue the renewed emphasis on Fleet Safety for all members.
- Continue to evaluate Best Practices and Risk Mitigation techniques as relates to quality and construction defect claims.

- Continue the annual Best Practices meetings with an emphasis on Executive and operations participation.
- Continue annual Project Lifesaver meetings with an emphasis on the Contractor Action Plan.

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14. APPENDIX

General Contractor Project Lifesaver Meeting Contractor Action Plan (CAP)
The following Contractor Action Plan (CAP) is an example of one of ACIG's General Contractor's strategic initiatives for safety improvement. The plan is completed by each ACIG contractor member and submitted for ACIG staff review and input prior to the CEO management team meeting.

1. PLS Progress

Please list safety milestones accomplished over the last year and include current string of days since last LTA.

Newly acquired industrial division is up and running injury-free.

As of 10/20/06, it has been 42 days since our last Lost Time Accident.

2. Best Practices - Safety, Claims & RMS

Please list the ACIG Best Practices that have been implemented, dropped or modified over the last year.

Semi-monthly telephonic claim reviews.

Quarterly OSHA Recordable review meetings.

Weekly safety meetings and daily Job Hazard Analysis (JHA's).

We have installed GPS monitoring equipment in all of our vehicles throughout the organization.

Initiated on-line hiring process with on line background checks for all trade employees.

3. Key Initiatives From Last Year's Meeting

Shown below are the areas you identified as key areas of focus during last year's meeting. Please indicate which activities have been completed, and on a scale of 1-5, rate their overall effectiveness.

	Completed?		**Rate of Effectiveness**				
	Yes	**No**	**1**	**2**	**3**	**4**	**5**
Subcontractor management	X			X			
Pre-qualification	X						X
Site-specific safety plans		X					
Improved control of contracts	X					X	
DOT checks	X			X			
Ongoing project safety planning meetings	X						X
Review crisis management procedures		X					
Hiring practices	X						X

4. Lessons Learned

Shown below are some of your more recent losses. Please provide us with a list of lessons learned for each claim.

7/19/05, GC024480, claimant: Power line to transformer replaced. When power was turned on, surge occurred causing electrical damage to near-by homes.

If there are any questions as to how the project is to proceed, the job should be stopped until questions are answered. Any scope changes should be documented in writing and all necessary signatures should be obtained. Maintain all physical evidence.

5. 2006/2007 Strategic Focus Areas

Please list the strategic areas that will be the focus of your PLS initiatives for the coming year.

Update our safety program by reviewing the safety benchmarking activities and determine if any key areas that we are not doing consideration should be given if we should.

Peer review the crisis management program and determine project-specific applicability.

Aging workforce of our signatory trade unions.

6. PLS Goals

Please list the goals or milestones you have set for the coming year.

Reduce OSHA recordables by 50 percent. Implement and roll out any applicable programs and processes based on our key strategic focus areas above.

7. 2006/2007 Challenges

Please list the challenges you anticipate in implementing or achieving your 2006 PLS goals.

"Hurry up" mentality of owners.

Raising the awareness of all new employees.

Anticipating shortages of our qualified trade personnel.

Significant amount of upcoming backlog of work in bad weather months.

8. ACIG Support

Please list the areas where you feel ACIG could assist you during the coming year.

Continued regular frequency support of the ACIG safety consultants.

Coordination of member communication on topics of mutual interest.

a. How did we do in servicing your organization?

Exceeded goals.

b. Are there additional services we can provide?

We can discuss this during our PLS management meeting.

PROBLEM AREAS IN PERSONAL FALL PROTECTION

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ABSTRACT

Falls from elevation have historically constituted the largest portion of construction worker fatalities, and this proportion has increased in recent years. Fall protection can be provided by many means including the minimization of work at heights, the use of guardrails or nets, and the use of personal fall arrest systems. This paper is focused on those fatalities resulting from incidents where there was some type of failure in the use of the personal fall arrest system, the last line of defense against fall hazards. A review of 184 fall fatalities will demonstrate several of the common shortcomings in the use of personal fall arrest systems. From these identified shortcomings, several recommendations are offered on how personal fall arrest systems can be made more effective.

Key words: Falls, Roofs, Personal Fall Arrest Systems (PFAS), Roof Anchors

1. INTRODUCTION

Construction workers are employed in one of the most dangerous industries. In the United States, approximately 1300 construction workers die as a result of a construction accident each year. Of these, over a third of the deaths are attributed to falls from elevation. There are a number of ways by which workers can be protected from falls. For example, work can be arranged so that more tasks are performed at ground elevation. Work on ladders can be minimized and work performed on scaffolding should be performed on fully installed scaffolds. Thereafter, if fall hazards are still presented, guardrails or nets might be employed. If none of these approaches are deemed adequate, personal fall arrest systems (PFAS) must be employed as the last line of defense against fall hazards.

In an earlier study, the Occupational Safety and Health Administration (OSHA) fatality data were examined for the inclusive years of 1985 and 1989. The results showed that 33% of the fatalities were due to falls. In the mid 1990s, OSHA made significant changes in its regulations to reduce the number of fatalities due to falls, including the reduction in the height at which fall protection must be provided and the elimination of the use of safety belts (safety harnesses were mandated). More recent data on construction worker fatalities has determined that there has been an increase in the proportion (up to about 38%) of fatalities due to falls.

Since there has been a notable increase in fall fatalities, it was apparent that this subject warranted additional study. While there are many aspects of fall protection that can be examined, this study was focused on those fall accidents that were associated with incidents in which personal fall arrest systems were or should have been employed. The objective of the study was to determine the primary areas of weakness in the use of personal fall arrest systems and to devise recommendations by which these fatalities might be reduced significantly.

2. LITERATURE REVIEW

Falls have the focus of several studies in the area of construction safety. The first notable study in which falls were identified as a major area of concern in the construction industry was conducted on the fatality data collected by OSHA in the inclusive year of 1985 through 1989. That study showed that construction worker deaths were attributed primarily to falls (33%), struck by accidents (22%), caught in/between accidents (18%), electrocutions (17%), and other causes (10%).

Based on national construction industry statistics, in 1994 and 1995 about 30% of the fatal injuries to construction workers were due to falls. Falls from roofs accounted for 20% of these falls, mostly sustained by roofers and framing carpenters. Based on national residential construction fall statistics, fall-related fatalities accounted for 33% of all fatalities in residential construction (Singh 2000).

Huang and Hinze (2003) analyzed construction worker fall accidents based on data collected by OSHA from January 1990 through October 2001. The results showed that falls accounted for 36% of the construction-fall accidents, and that the proportion of fall related accidents increased from 1990 through 2000. Inadequate/inappropriate use of fall protection (harnesses) was a cause of more than 30% of the falls. The data were examined separately for the period from 1997 through 2000 to evaluate the influence or effect of the new fall standards implemented after 1997. The analysis of that data showed that more than 50% of the falls occurred on such projects as commercial buildings and single-family or duplex dwellings. Almost 30% of the falls were from roofs and more than 70% of the falls occurred at heights less than 30 feet. At the time of the fall accidents, 21 percent of the injured workers were performing roofing activities, 8% were erecting structural steel and 7% were working on exterior carpentry.

Another study about falls in the construction industry was conducted at the University of Florida by using OSHA fatality inspection data for the years 2002 and 2003. The analysis of the data shows that 36% of the construction worker deaths were due to falls, 37% of the fall injuries occurred on roofs, while 47% of the fall injuries were related to scaffolds. The results also revealed that 29% of the injured workers were roofers, 13.4% were carpenters, and 13% were ironworkers. Figure 1 shows the relationship between the frequency of fatalities and the heights of the falls. Almost half of the falls occurred at the elevations of 20 to 29 ft (24.4%) and 10.5 to 19 ft (22.9%).

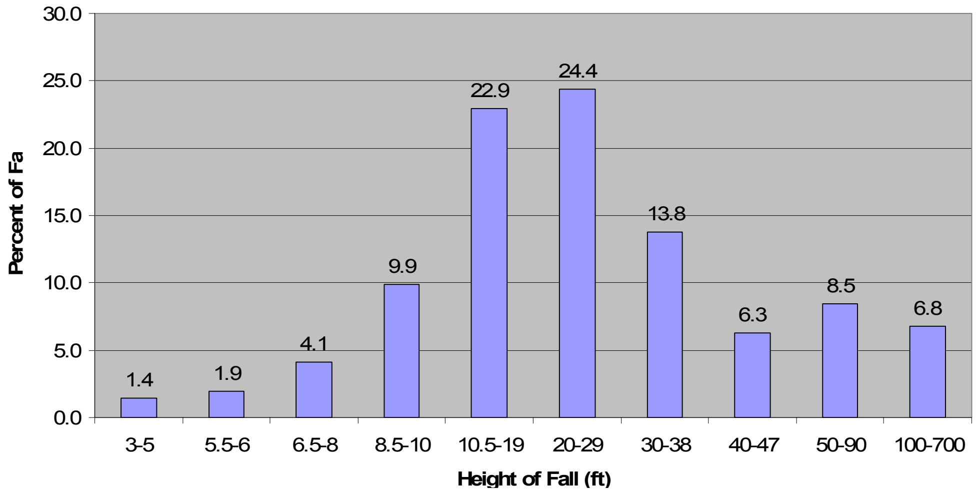

Figure 1. Distribution of fall fatalities by height of fall

Failure to provide adequate fall protection ranked #1 among the most frequently cited OSHA construction regulations and had a total of six rankings in the top 50 citations (OSHA 1993). Standards related to scaffolding were ranked seven times while standards related to ladders/stairways were ranked four times in the top 50 citations. Thus, 17 (34%) of the top 50 frequently-cited OSHA Construction Standards were associated with fall protection.

Bobick (2004) examined Bureau of Labor (BLS) data from 1992-2000 to analyze falls through roofs and floor openings and surfaces. He found that more than 50% of all fall-caused deaths occurred on projects built for private firms. Fall-related deaths accounted for about 32% of all deaths in the private sector of the construction industry. The number of fatal injuries caused by falls on private construction projects increased to 40% from 1992 to 2000. Most fall-related deaths occurred when workers were performing roofing, siding and sheet metal activities, as well as erecting structural steel. The average number of fall-related deaths for roofers was 20.9 deaths per 100,000 roofers.

Fredericks et al. (2005) conducted a survey to investigate safety practices employed by Michigan roofing contractors. Based on BLS data, Fredericks et al. found that fall accidents accounted for 26% of all injuries sustained in the roofing industry, but that falls accounted for 75% of all fatal cases in the roofing industry. Results of the study showed that the most prevalent sources of injuries were motion/positioning (31%), slips/trips (22%) and tools/machinery (22%), while slipping was the primary event leading to falls (59%). Roofing workers spent 61% of the workday on roofs. Regarding the height, 44% of the respondents said their workers operated at heights from 10 to 12 feet, while 22% of the companies worked at heights from 21 to 30 ft. The survey results also showed that

52% of the respondents said that 11 to 30 feet distance was the most common distance traveled for a manual carry.

Singh (2000) conducted interviews with construction company managers and roofing workers in the Hawaiian Islands to identify the most appropriate fall protection systems. Interview results showed that construction managers (CMs) and workers agreed that PFAS are the most common fall protection method used and that 75% of the workers used PFAS. Workers stated that they used PFAS mostly during roof sheathing. Workers also thought that PFAS is the best fall protection system to be used during truss installation. In addition, 42% of the workers thought that PFASs are the preferred method of fall protection for roof slopes from 4:12 to 8:12 pitch, while both workers and CMs agreed that PFASs are the primary fall protection system for roof slopes above 8:12 pitch (Singh 2000). Duncan and Bennett (1991) stated that active systems of fall protection, such as PFASs, provide better protection than passive systems.

Huang and Hinze (2003) found that 13.5% of worker falls involving roofing were due to insufficient or lack of personal protective equipment (PPE), while 11.5% were due to the removal (to make them inoperative) of safety devices. About 33% of the fall accidents were caused by human misjudgment of a hazardous situation. A typical scenario would be when workers do not tie-off their full body harnesses when working at elevations or they unhook a body harness to move to a different location. Researchers agree that fall prevention is a more effective method than fall protection (Holt 2001, Singh 2000, Huang and Hinze 2003). PFASs, such as full body harnesses, should be used for fall prevention. OSHA regulations state that only properly tied-off body harnesses are qualified as PFASs for fall protection (OSHA 1998 in Huang and Hinze, 2003).

3. RESEARCH APPROACH

Falls have obviously continued to constitute a disproportionate percentage of all construction worker deaths. While others have examined some aspects of construction worker deaths attributed to falls, this study had as its focus those fall fatalities that involved or should have involved personal fall arrest systems. Personal fall arrest systems consist of safety harnesses, lanyards and an anchorage device. The lanyard is a device that essentially connects the worker's safety harness to an anchorage device. When the term "personal fall arrest system" is used, it is assumed that all three components are being addressed.

This study was conducted by examining OSHA data that was generated through the investigation of construction fatality cases. These data included 10, 598 fatalities that were investigated between 1990 and the first half of 2004. These investigation reports contain various types of coded information related to the fatality (account number, date of occurrence, time of occurrence, gender of victim, age of victim, cause of the accident, and a narrative description of the accident itself). In this study, the information of primary interest was contained in the narrative description.

The narrative descriptions were examined with the focus being on those aspects of the accident that pertained to the victim's personal fall arrest system. While the other coded information was considered in this study, it was determined that this additional information was of limited value for this effort. Additionally, some of this information was also available in the narrative descriptions as well. With a specific focus on the use of personal fall arrest systems, many fall fatalities were not considered. Examples of those fall cases not examined further in this study were those in which workers fell from scaffolding that was installed improperly, from ladders, through floor openings, and through skylights. Cases involving workers who fell because guardrails were removed were also not included in this investigation. Instances of workers falling from roofs and unprotected edges were also not considered in this study if the narrative description did not specifically mention the use of personal fall arrest systems, especially the use of a safety harness.

A total of 184 construction worker fatalities were identified in which some aspect of personal fall arrest systems were mentioned in the narrative description. These incidents were examined to determine the root causes as far as the use of personal fall arrest systems were concerned.

4. RESULTS

Each of the fatality cases were examined to determine the nature of the cause of the fatality with particular focus on the role that was played by the personal fall arrest system. Cases were not considered applicable if the use of the personal fall arrest system did not play a crucial role in the accident itself. For example, if a worker was wearing a harness at the time of making contact with electric wiring, the harness itself was not considered to have played a significant role in the incident.

Through the examination of the different fatality cases, it was determined that the underlying causes could be categorized into common groups of related factors. These different causal factors will be described. To help understand the nature of the incidents, some of the narrative descriptions will be provided. Some of these descriptions had extraneous information removed, but the essence of the factors related to the incidents has remained intact. Information that was not included might include descriptions of the nature of the bodily damage incurred by the fatality victims.

No Harness worn

Several of the fatality fall cases involved workers who were not wearing safety harnesses at the time of the fall incident. There was insufficient information provided in most cases to determine if the workers had the personal fall arrest systems provided and they simply did not use it for the task being performed or if such personal protective equipment was not provided to the workers. The following cases are typical of the cases where no personal fall arrest systems were being utilized by the fall victims.

- Employee #1, an iron worker, was standing 23 feet above the ground on a six-inch wide steel truss receiving bundles of metal roof decking material. He was not protected from falling by nets, a safety harness, or any other means. When employee #1 took a step backward, he apparently miss-stepped, and fell 23 feet. He landed on his head and shoulders and was killed.

- Employee #1 and employee #2 were working on the roof of the building approximately 27 feet high. Employee #1 was placing a stringer at the edge of the building when suddenly he lost his balance and fell to the ground. He was not wearing a body harness and was killed by the fall.

Lanyard unhooked

A number of the fall incidents took place where personal fall arrest systems were provided to the workers. These were typically instances in which workers were wearing safety harnesses and they had previously been tied off to an anchorage connector. In some cases there were no clear explanations why the worker unhooked the lanyard. It might be surmised in some cases that the workers unhooked the lanyards to move to different work locations, but this could not be verified in most instances because of the lack of witnesses. The second case below may be construed to be one in which the worker was moving to a different location, but this is not clear as the worker was using a retractable lanyard that offered mobility while being tied off.

- An ironworker was setting bridging on bar joists and fell approximately 27 feet from an I-beam. The victim was initially observed by co-workers as wearing a safety harness and being tied-off with a lanyard to a static line. For some unknown reason, he unhooked the lanyard. The victim landed face/chest first to a small mound of clay/sand material. He died two weeks later from his injuries.

- Ironworker installing roof decking on a flat roof disconnected his self-retracting lanyard from his harness and was walking on the decking. He stepped onto a piece of decking that did not properly overlap a bar joist. The piece of decking slipped off the bar joist and the employee fell 34 feet to his death.

Harness improperly worn

When personal fall arrest systems are employed it is imperative that they are used properly. Furthermore, these systems should not be altered in any way. Some of the fatality cases included instances in which workers were equipped with the personal fall arrest systems, but for some reason they were not worn properly. As shown in the following incident description, the worker failed to secure the leg straps resulting in the worker falling free from the harness during the fall. In the second case, the harness was modified so that there were no leg straps on the harness. These practices, and others similar them, proved to be unfortunate and fatal errors.

- An employee was 265 feet high working on a communications tower installing co-ax cable when he fell from the tower. He was wearing a body harness with a shock absorbing lanyard and a positioning strap at the time of the accident. His harness leg straps were not buckled and his lanyard did not show any signs of being exposed to fall impact forces.

- The ironworker fell approximately 80 feet and died after having gone to the top of the southeast corner column of a building. Witnesses stated that he had been working with the raising gang crew and had climbed the (12 ft.) ladder which did not go all the way to the top of the 15 ft high column. He then climbed up on top of the column to unbolt a large lifting lug from the top of the column. The crane swung free with the lug attached without incident. After that, there was no direct witness account as to whether he fell from the column or from the ladder. The ladder was observed to be defective (too flexible due to wear), was too short for the task, and could not sit square against the column due to the shape of the column. A fall protection harness which was being worn by him was missing the leg straps.

Removed Harness

The proper use of personal fall arrest systems should adequately protect workers from fall injuries. Such systems are to be used at all times when workers are at risk of sustaining falls. There were instances when workers were at elevation and, for no known reason, removed their safety harnesses. Other fall victims apparently removed their harnesses when relocating to other work areas. The following are typical of such cases.

- Employee #1 was part of a six-member crew that was installing new felt and shingles on an existing apartment building roof. The crew was installing felt on the roof while employee #1 was marking the felt with chalk. When employee #1's coworker stopped to refill the chalk container, employee #1 removed his safety harness. He fell from the gable end of the roof and was killed.

- An employee removed his safety harness and stepped out of an aerial lift onto a building. He subsequently fell 25 feet to his death.

Lanyard Broke

Personal fall arrest systems must be kept in good condition to ensure the safety of workers who rely on them. If personal fall arrest systems deteriorate over time, they must be replaced. Incidents were noted where the lanyards failed, generally for no apparent reason. Possibly the quality of the lanyards had deteriorated with age and through extensive use.

- Employee #1 was killed when he fell while installing steel roof trusses at a height of about 20 feet. He was wearing a safety harness with the lanyard properly attached to a point having the required load carrying strength. The lanyard, a rip-stitch shock-absorbing type, broke before the rip-stitch shock absorber functioned. The victim struck steel floor joists that had been installed at the floor level.

- Two steel workers were laying a sheet of decking when apparently one employee slipped and fell. Apparently his lanyard broke (possibly cut by the sharp edge of the decking) and the victim fell 38 feet to his death onto the concrete floor below.

Not 100% tie off

To ensure the safety of their employees, some companies implement policies in which workers at elevation are to be tied off at all times. This is only possible with the use of twin-leg lanyards. With twin-leg lanyards, workers can be tied off 100% of the time, even when relocating positions. This is done by having both legs of the lanyard attached. One leg is unhooked and the worker then moves in the direction of the next position. When the worker extends the lanyard that is still hooked, the worker attaches the loose leg of the lanyard and unhooks the other leg. In this way, the worker is never in an at-risk condition. With single-leg lanyards, workers are always at risk whenever the lanyard is unhooked. Anything less than 100% tie-off places workers at risk. As demonstrated in the following cases, workers are at risk whenever a single-leg lanyard is unhooked or when both legs of a twin-leg lanyard are unhooked.

- An employee was working 30ft above the ground when he unhooked his safety harness while changing positions. He lost his balance and fell to the ground. His injuries were fatal.

- A steel worker was connecting a steel beam at the highest point of the new building being built. He was in the center of the building when he fell twenty eight feet to the ground. The worker was wearing a full body harness with twin-leg lanyards. The worker unsnapped his lanyard from the attachment point, and reached out to disconnect a steel choker used to set the beam in place when the fall occurred.

Malfunction of personal fall arrest system components

Personal fall arrest systems, when functioning properly, should provide adequate protection to workers when working at elevation. A few instances have been noted where workers have fallen while utilizing personal fall arrest systems, but where a component of the system failed. One commonly-known problem is that lanyard hooks, that are designed to withstand 5,000 pounds of static force, should not be subjected to side-loading. The hooks are not designed to withstand a side-loading force. Unfortunately, unusual circumstances can arise in which such side-loading might occur. This requires diligence on the part of workers to ensure that such conditions do not occur.

Retractable lanyards provide a means by which workers can walk freely while remaining secured to an anchorage point. Depending on the type of retractable device, workers can move from ten to twenty feet (approximately three to six meters) from the anchorage point. This is a valuable feature as the worker is not in a position of tripping over the lanyard as it constantly retracts when slack is introduced into it. It is only when the worker falls or introduces a sudden acceleration force on the lanyard that the retractable device locks up and does not allow the lanyard length to be extended. The second case below describes an instance where one such device failed.

- Employees were installing sheet metal decking on the 3rd level of a steel structure. Employee #1 was placing short sections (16') of decking over 3 joists. As he progressed with this task, he kicked the last sheet placed to make it fall into place and interlock with the previously laid sheet. The sheet slipped away from the 3rd joist and the employee started falling through to the lower level. At the time of this event, the victim was wearing a full body harness and was tied-off to a retractable cable block about 15'-18' away. As he fell, somehow the cable hook came undone/slipped out of the "d" ring attached to the body harness. The block had been recently purchased and put into service just a couple of days before the event. The victim fell approximately 36 feet to his death.

- An employee fell 60 feet while decking a metal roof. The employee was wearing a full body harness and a self-retracting lanyard, however, the lanyard did not activate until he had fallen 29 feet. At that time the self retracting lanyard cable broke and the employee fell another 31 feet.

Tied off but killed

In most instances, when personal fall arrest systems are properly maintained and utilized, adequate fall protection will be ensured. It is imperative that the work conditions also be fully evaluated. The personal fall arrest system should restrict a worker's fall to no more than six feet (approximately 1.8 meters). This does mean that the personal fall arrest system does not prevent falls from occurring, but they are designed to restrict the distance that workers fall. Rather than falling to the ground or to a lower level, a worker with a properly-employed personal fall arrest system will only fall a short distance, generally without sustaining any injuries. The following example is one that demonstrates the need to carefully evaluate the work conditions before setting up a work task with a personal fall arrest system.

- The deceased was involved in connecting a steel beam approximately 15 feet above the ground. He was on the beam, and was wearing appropriate personal fall protection equipment. After completing his connections, he stood, and then fell from the beam. His harness and lanyard limited his fall to approximately three feet, and prevented him from falling to the ground. Unfortunately, the lanyard caused him to swing into the support column, and to strike his head.

Structure Collapsed

Instances where entire structures fail are rare, but such events offer little means of avoiding injury to those working on the structure. Structures must be properly secured prior to placing workers in vulnerable situations. To ensure the structural stability of structures, some redundancy in the support system appears necessary. The following incident gives the details of an unfortunate event in which workers were complying with the proper use of personal fall arrest systems, but the entire structure failed.

- Three employees were in the process of installing purlins or scattering them on the frame of the engineered building under construction. All of the workers agreed they heard a loud "pop" and the frame lines of the structure started to collapse. The three workers were wearing personal fall protection (harnesses) but the anchor posts and cable collapsed with the structure. The individuals fell at least 30 feet to the concrete slab or the gravel railroad bed located inside the structure. Two workers were hospitalized and one worker died as a result of injuries sustained. One of the surviving employees suffered severe permanent injuries, and the other sustained moderately severe injuries.

Role of Roof Anchors

Of all fall fatalities, perhaps the location of greatest concern relates to work performed on roofs. The roofs of particular interest are those that are sloped. Most sloped roofs occur in residential construction. Perhaps the significance of roofs is not that surprising when it is realized that approximately two million new homes are constructed each year in the United States during strong economic periods. In addition, workers are exposed to falls from existing houses when they perform repairs and when they apply new roofing materials.

With the high number of construction worker deaths that occur due to falls from sloped roofs, one might assume that there are no effective means by which construction workers can be protected on sloped roofs. This is often the general consensus; however, there are several methods by which workers on roofs can be afforded protection from falls. Perhaps the most effective method is to have workers on sloped roofs tied off to roof anchors, devises that are affixed to the roof structure. Roof anchors should be capable of supporting 5,000 pounds (nearly 2300 kilograms) of static force, according to the Occupational Safety and Health Administration regulations.

Despite the fact that roof anchors are commercially available, the use of roof anchors is not extensive in the U.S. construction industry. In addition, in the few instances when roof anchors are employed, they are generally removed or covered with roofing materials at the conclusion of the construction effort. This renders the anchors unavailable for use by roof maintenance and repair workers or any other workers who may have occasion to be on these roofs.

If conditions do not change in the way that roofing work is done, the construction industry is destined to continue to have significant numbers of worker deaths due to falls from roofs. Perhaps the primary question that remains unanswered is why the employers of roofing workers do not fully comply with the OSHA regulations to prevent worker injuries and deaths.

An examination of roofing practices observed in Europe provides some revealing information about providing for worker fall protection. These consist of permanent devices that are attached to many European buildings that have sloped roofs. These devises appear as hooks that are generally located slightly below the pitch of the roof. On roofs with clay tile or slate tiles, the hooks are used to support a ladder that has one of its top rungs supported by the hook (see Figure 2). The ladder takes the weight of a worker on a clay tile or a slate roof and distributes it over a broader area of the roof. This prevents the worker's weight from actually breaking any of the rigid or brittle roofing tiles or shingles. On long roofs, additional hooks will be located further down the slope from the upper hooks. Such hooks have been noted on roofs with slopes considerably over 45 degrees and with roof slopes as little as 4:12 pitch.

In Germany, these hooks were noted on roofs of buildings that were under construction and they have been noted on roofs of buildings that were considerably older than a hundred years. Thus, the practice of incorporating these hooks in the roofs has been around for scores of years. The above description mentioned the use of the roof hooks on clay tile and slate tile roofs; however, similar hooks were noted on roofs with asphalt shingles. Thus, the purpose of the hooks is not purely for worker weight distribution on rigid tile roofs (see Figure 2).

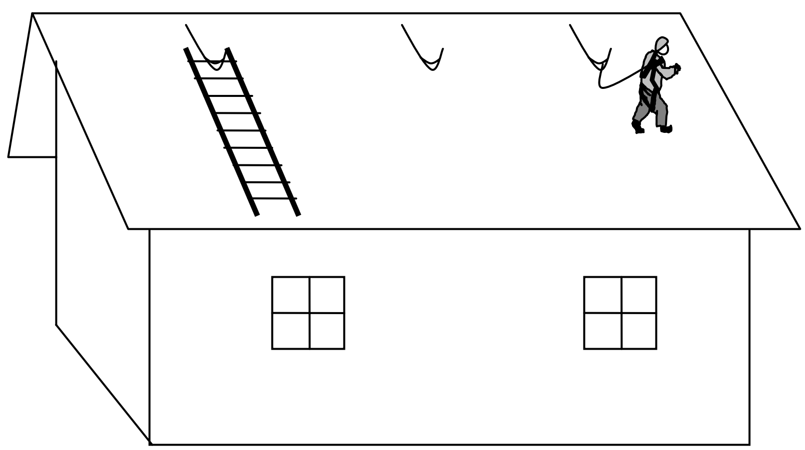

Figure 2. Example of permanent hooks on roofs for fall protection

It is worth mentioning that the hooks are used for other purposes than to support ladders. One system consists of ropes being attached to a series of rollers that are supported from the hooks. These rollers can be adjusted so that the system can be moved up and down along the roof. A plank would then be used to span between the two frames or rollers. This would then provide a working surface for workers who could reach virtually any part of the roof with the use of the system.

5. CONCLUSIONS

In the construction industry in the United States, falls account for over 36 percent of the construction worker fatalities. Falls can take place from any point of elevation whether from ladders, scaffolding, unprotected edges, floor openings, roofs, or some other elevated location. This research has examined the role of personal fall arrest systems in providing for the safety of workers at elevation. Specifically, the study examined instances in which a flaw was noted in the employment of personal fall arrest systems. From this information, it is apparent that many fatalities could be avoided if workers would adhere to proper practices in the use and maintenance of the protective fall equipment. Most fall fatalities involving personal fall arrest systems occurred because workers were not provided with the equipment, the workers failed to wear the equipment, the workers removed the safety devices, the workers or others altered the equipment, or the system did not provide 100% fall protection.

From this information, it can be concluded that when other means of fall protection are not provided that the proper employment of personal fall arrest systems by workers at elevation would eliminate most fall deaths. It is also evident that in some instances, the workers do not use personal fall arrest systems because suitable anchorage points were not provided. Whenever personal fall arrest systems are employed, failure to fully assess the overall jobsite conditions can also result in mishaps.

6. RECOMMENDATIONS

The review of the various fall fatalities provides clear evidence of the general nature of circumstances in which worker fall deaths occur. From this information it quickly becomes apparent that employers must provide their employees with personal fall arrest systems, devise clear policies on the proper employment of the personal fall arrest systems, fully train all of their employees in the safe use of personal fall arrest systems, and enforce compliance with the fall protection policies.

Because of the importance of having adequate anchorage connectors, employers should carefully evaluate jobsite conditions before workers are placed at risk at elevation. This includes planning the locations of anchorage connectors. When practical, this should be done during the design phase of projects.

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ANALYSIS OF CONSTRUCTION FATALITIES WITH A CAUSE CODE OF OTHER

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ABSTRACT

Considerable efforts are expended to find ways to curb the high death toll and the high injury rate in the construction industry. The Occupational Safety and Health Administration (OSHA) is mandated to monitor the causes of fatalities as one way of identifying the areas that pose the greatest risk to construction workers. Whenever fatalities are investigated by OSHA, a determination is made about the cause of the fatality. There are five broad categories of causes of fatalities, including falls from elevation, electrocutions, struck by accidents, caught in/between accidents and other accidents. While most causes have been extensively examined, those fatalities attributed to "other" causes have received minimal attention. This is despite the fact that nearly ten percent of the construction worker fatalities (in excess of one hundred deaths per year) are categorized as other accidents. This paper describes the results of a study of 795 incidents (primarily construction worker fatalities) that were attributed to "other" causes. Results show that other fatalities are attributed to various specific events, many of which appear to be unrelated. Depending on the specific cause, some fatalities occur at certain times of the year and they are often associated with specific types of work.

Keywords: Asphyxiation, Causes of Accidents, Cause Codes, Heat, Lightning, Natural Causes

1. INTRODUCTION

As part of their efforts to fulfill its mission of ensuring the safety and health of America's workers, the Occupational Safety and Health Administration (OSHA) conducts inspections of workplaces. Inspection priorities are, in order of priority: imminent dangers-accidents about to happen; fatalities or accidents where three or more workers are sent to the hospital; employee complaints; referrals from other government agencies; targeted inspections (focused on employers that report high injury and illness rates, and special emphasis on hazardous work); and follow-up inspections.

OSHA inspection reports of construction accidents include a short narrative of the accident and also include the categorization of accidents into one of five standard categories: falls (from elevation), electrical shock, struck-by, caught in/between, and other. OSHA collects the inspection results and then catalogs them electronically in the Integrated Management Information System (IMIS).

Part of accident prevention includes understanding the nature and causes of accidents. While many types of construction accidents have been analyzed, published research provides little information on those accidents classified as "other". The primary research objective of this study was to examine construction accidents categorized as "other", looking for commonalities and contrasts among those factors associated with the accidents. This information could be used to assist in accident prevention efforts in the future.

2. LITERATURE REVIEW

Previous research about construction fatalities utilized data from several sources, including OSHA accident investigations, the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI) and the National Institute for Occupational Safety and Health (NIOSH) National Traumatic Occupational Fatalities (NTOF) surveillance system. Some studies have focused on specific kinds of events, while studies focused on fatalities within a specific segment the industry, such as a given demographic segment, specific equipment use, or specific circumstances. Some studies focused on risk analysis and others examined the systems used for categorizing fatal events.

Derr et al. (2001) examined OSHA data in the IMIS system from 1990 to 1999 to analyze construction fatalities due to falls. The purpose of the study was to analyze risk factors in fatal falls and to analyze trends in fall rates. Huang and Hinze (2003) analyzed construction fall accidents that occurred from January 1990 through October 2001 using data from OSHA investigations. They reported on the types of projects associated with most falls, the most common fall heights, and the extent of use of personal protective fall arrest systems.

McCann et al. (2003) examined CFOI data from 1992 to 1998 for electrical deaths and injuries among construction workers. They analyzed information on 7,489 construction industry fatalities and reported on the causes of these fatalities, the trades of the victims, and the type of work performed at the time of the accident. Hinze and Bren (1996) reported on incidents involving power line contacts using OSHA IMIS data for 1985-1995. The authors reported that riggers or spotters had the highest frequency of fatalities involving equipment contacts with power lines. The authors recommended improved training for spotters as well as other occupations with high risk of power line contacts.

Hinze et al. (2005) used data from the OSHA IMIS database from 1997 to 2000 to report on construction related struck-by accidents. The authors reported that the work commonly associated with these events included work involving wood assemblies, block walls, soil/rock and steel/rebar/pipe. That study concluded that many incidents resulted from failure to comply with existing OSHA regulations for signaling, materials handling, crane use, and trenching.

Chen et al. (1999) analyzed data from four previous studies of unionized construction workers, including ironworkers, construction laborers, sheet metal workers and operating engineers. From the death certificates, the authors established the cause of death and up to three contributing factors. The authors utilized a system with 33 categories of injuries based on the NTOF Surveillance System.

Calls for changes in the coding system used for incident cause classifications were found in a number of articles. Hinze et al. (1996) suggested a more descriptive system with 19 categories. Chen et al. (1999) suggested the use of 33 categories of causes of injuries. Bondy et al. (2005) reviewed several injury coding schemes and reported that they had derived a matrix of over 100 categories to classify contributing factors.

Ore and Stout (1997) used NTOF data from 1980 – 1992 to examine fatal occupational injuries among construction laborers. The authors reported that the primary causes of fatalities included falls; motor vehicles; machinery; electrocutions; struck by falling objects; suffocations; struck by/against objects; natural and environmental factors; homicides; and explosions.

A search of peer-reviewed journals yielded no articles specific to the analysis of the causes of construction accidents classified by OSHA as “other”. Information concerning these fatalities may be found in articles specific to a category event, but these articles are not specific to construction. Examples of this include articles on lightning deaths, burn fatalities, and hydrogen sulfide exposure.

Adekoya and Nolte (2005) used CFOI data and the National Centers for Health Statistics (NCHS) to analyze lightning deaths from 1995 – 2000. The authors identified 374 fatalities from lightning, equivalent to an annual fatality rate of 2.3 deaths per 100,000 persons. They reported 129 work related fatalities from lightning from 1995 – 2002, including 44 fatalities in the agricultural industry and 39 fatalities in the construction industry. The fatality rate per 100,000 workers was higher for construction workers at 5.9, than for agricultural workers at 4.5. Work related lightning fatalities were highest in Florida, Texas, Georgia and Tennessee.

Quinney et al. (2002) examined work related burn fatalities using CFOI data. They examined 1,189 worker fatalities related to thermal burns from 1992 – 1999. The annual fatality rate due to thermal burns was 0.11 per 100,000 workers. The occupations with the highest fatality rates per 100,000 workers were mining (0.77), transportation and public utilities (0.38), agriculture, forestry, and fishing (0.24), and construction (0.22).

Fuller and Suruda (2000) examined work related deaths from 1984 to 1994 due to hydrogen sulfide exposure using OSHA’s IMIS database. The authors reported 57 incidents of hydrogen sulfide exposure resulting in 80 fatalities. The authors reported 22 fatalities in the petroleum industry, but did not list the frequency of fatalities for other industries. Of the 80 fatalities, 69 occurred within a confined space. Nineteen workers died attempting to rescue coworkers.

3. RESEARCH METHODOLOGY

The objective of this research was to develop an understanding of the nature of those construction fatalities categorized as “other”. Since this category of fatalities is not descriptive of the circumstances surrounding these types of accidents, this research was undertaken to devise additional categories that more clearly describe the nature of the conditions resulting in these construction worker deaths. By understanding the nature of fatalities and by identifying possible trends in their occurrence, preventative measures might be more effectively developed.

Data from fatality investigations were obtained directly from OSHA. The data contained information that included more recent investigations than those included in the OSHA website. These data were provided in an electronic document as a spreadsheet that included investigation information on 9600 construction related incidents that were investigated by OSHA between 1990 and 2004.

Analysis was performed with Microsoft Excel 2002 with Service Pack 3 to perform sorting, counting, statistical calculations and to generate tables and charts. Each investigation was examined to determine the cause of the incident. After the event categorization was completed, the causes categorized as “other” were isolated for further analysis. This resulted in 795 incidents with fatalities that were attributed to “other” causes and this was the database that was examined in greater detail.

Further review of the data revealed 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”. The incidents categorized under these extraneous categories were reviewed and the incidents which would otherwise be categorized as “other” were examined. The “other” incidents were purged of duplicate entries when more than one fatality resulted from one accident.

The next step in the analysis was to examine the descriptive abstracts of the “other” accidents to determine the type of death, the time of death, conditions or circumstances at the time of the accident and the primary cause or agent of death. The results were then inspected to identify conditions or agents which were more prevalent than others for a given type of incident. This step was designed to provide an additional level of detail for these “other” incidents. The categories utilized were those identified in the literature and additional categories were developed when incidents were found that did not “fit” well into the existing categories. Investigation of the descriptions of construction accidents classified as “other” yielded eight major categories including: natural causes, drowning, asphyxiation, burns, explosion-fire, hyperthermia, chemical exposure, and lightning.

Some incidents were difficult to classify due to a multitude of causes of death. For example, a person in a manhole may have been exposed to high levels of chemicals common in sewer gas such as hydrogen sulfide or carbon dioxide, and at the same time be in an environment with low levels of oxygen. Deaths from low levels of oxygen and high levels of carbon dioxide could be classified under asphyxiation, while deaths from high levels of carbon dioxide and hydrogen sulfide could be classified under chemical exposure.

This approach in the analysis was followed for all incidents classified as "other". Most of the information for determining the cause of the accident was gleaned directly from the descriptive abstracts. Since the study was of an exploratory nature and since the numbers of incidents included in each of the different categories tended to be small, rigorous statistical analysis was not conducted.

4. RESULTS

The data were examined by time of occurrence. The results show that the "other" fatalities have their highest frequency of occurrence during the month of July (see Figure 1). This may simply be a reflection of the level of employment in the construction industry which has higher employment levels during the summer months. When examined in terms of the distribution by day of the week, the results show that the highest frequency of occurrence of "other" fatalities was on Wednesday (see Figure 2). The data were examined further to determine the specific causes of the fatalities.

Table 1. Causes of "Other" Fatalities

Cause	Frequency	Percent of "Other" Fatalities
Natural Causes	243	30.57%
Asphyxiation	110	13.84%
Drowning	98	12.33%
Burns	97	12.20%
Explosion – Fire	75	9.43%
Hyperthermia	58	7.30%
Chemical Exposure	39	4.91%
Lightning	27	3.40%
Not Work Related	6	0.75%
Murder	4	0.50%
Drug Related	3	0.38%
Animal Bites	2	0.25%
Helicopter Crash	1	0.13%
Injury Complications	1	0.13%
Mesothelioma	1	0.13%
Suicide	1	0.13%
Unknown	29	3.65%
Total	**795**	**100.00%**

Natural Causes

Those fatalities resulting from natural causes were examined. The distribution of these 243 fatalities by month of the year was similar to the distribution of the total population of "other" fatalities, except for a higher number during December. There is no apparent rationalization for this phenomenon.

The cause of death most frequently cited was some type of heart problem, including heart attack, coronary disease, atherosclerotic cardiovascular disease, coronary atherosclerosis, coronary artery disease, congestive hart failure, cardiac arrhythmia, and heart aneurysm. These types of heart problems accounted for 210 of the fatalities due to natural causes. Although in small numbers, natural causes also included deaths due to cerebral aneurysm, asthma, legionella pneumophila, pulmonary edema, aneurism, subarachnoid hemorrhage, acute renal failure, emphysema, lung cancer, pneumonia, sepsis, stroke, and others.

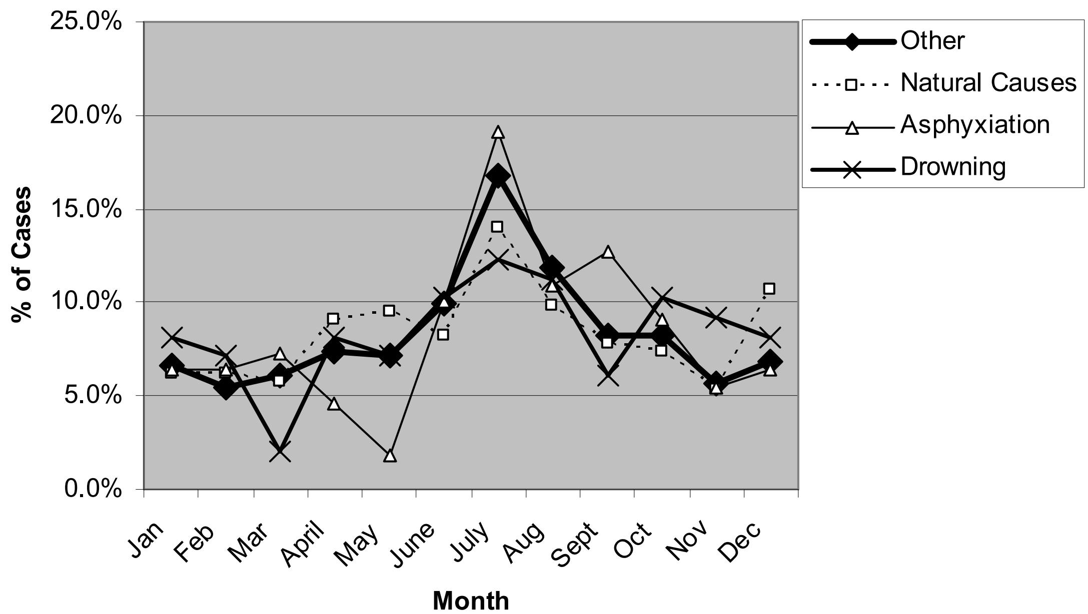

Figure 1. Distribution of Other Fatalities by Month

Asphyxiation

Asphyxiation was the primary cause of death in 110 incidents. When plotted by month of occurrence, the peak period for asphyxiation deaths was from June through October. Of all of these incidents, 90% occurred in confined spaces. From the descriptions, it was noted that 40 events occurred either in manholes or in utility vaults. Two incidents occurred in basements, one incident occurred inside an underground pipe and one incident occurred inside a sewer conduit.

The activities of the victims often resulted in the asphyxiations. In three cases, the workers were using welding equipment or a cutting torch. One incident involved a ruptured gas line. In six cases, it was specifically noted that the workers were wearing air-supplied respirators. In five of those cases, the air supply line contained nitrogen rather than breathable air (other workers were not aware that the hoses were for supplying air to the workers). In one case, a respirator was worn to protect the worker from dangerous fumes, but the worker was overcome by carbon monoxide produced by a generator in the work space.

Of the 110 asphyxiation fatalities, 76 were attributed to one or more chemical agents, including carbon monoxide (22.4%), insufficient oxygen (21.0%), nitrogen (14.5%), methane (11.6%), hydrogen sulfide (7.8%), and other gases (argon, gasoline, methylene chloride, etc.).

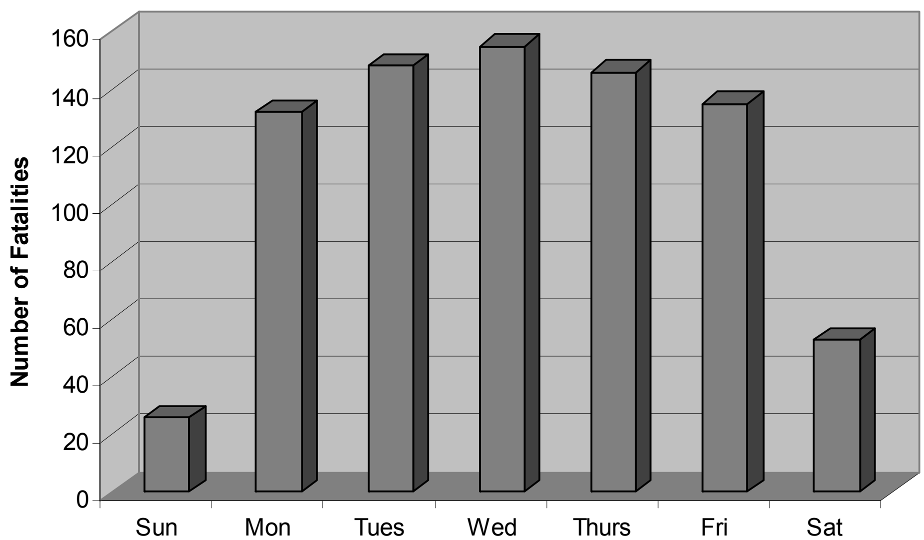

Figure 2. Distribution of "Other" Fatalities by Day of Week

Drowning

There were 98 incidents with drowning deaths in the database. Over a third of these deaths occurred in the months of June, July and August. The remaining incidents were fairly evenly distributed among the other months. One of the drowning victims was even wearing a flotation device at the time of the drowning incident. Most incidents specifically mentioned that flotation devices were not worn.

The most frequent drowning incidents occurred as a result of workers slipping or falling into a body of water (28.57%) or by being involved in an equipment/vehicle-related incident (26.53%). The equipment/vehicle-related incidents included equipment sliding or rolling into a body of water, workers driving equipment or vehicles into a body of water, and backing equipment or vehicles into a body of water. These incidents were generally those in which the operator or driver was trapped in the operating cabin that became submerged. Some drowning incidents (9.18%) consisted of workers being trapped in flooded pipes, tunnels and excavations. These drownings were due to broken or burst municipal water supply lines, excess runoff from heavy rains, and water that was released from a storm drain after having been intentionally blocked by an inflatable plug. Less frequent incidents included workers who entered a pool or body of water and drowned (8.16%), workers who were in boats or barges that overturned (6.12%), underwater diving accidents (6.12%), and trying to retrieve a boat that went adrift (3.06%).

Burns

There were 97 incidents with deaths that were attributed to burns. Burns were categorized differently than incidents resulting from deaths occurring in fires or explosions. These included workers who were involved in fires and received severe burns but did not die in the fire but they died sometime later as a result of the burns received. Also excluded from this category were chemical burns and scalding from hot water or steam. Particularly high frequencies of burns occurred in March, July and October while low numbers of burns were noted in February, April, and September.

The locations where burns occurred were provided for 63 of the fatalities. These locations included outside of buildings (31.75%), inside factories or plants (15.87%), inside commercial buildings (14.27%), inside houses (11.11%), and in basements (4.76%).

The source of the ignition was also examined. The most frequent ignition source was an electrical arc (43.57%) which was often associated with an electrical distribution panel or switchgear and a few were associated with high voltage power lines. The next most frequent ignition sources were pilot lights (7.69%) and welding arcs (7.69%). Electrical switches were the ignition source in 5.13% of the burn incidents. Other ignition sources in one or two burn incidents each included burning trees, heaters, tar kettles, cigarettes, electric fans, furnaces, metal slag, propane torches, shop vacuums, vehicles, water heaters, and others.

The primary agent that burned the victims was examined. This information was available for 87 fatality cases. In these cases, a total of 34 different combustible materials were noted. The most frequent agent that sustained the fire was gasoline (5.75%) and paint/primer (5.75%). Hydraulic fluid, lacquer thinner, and natural gas were each noted in 4.60% of the incidents. The victim's clothes were the agent in 3.45% of the cases while crude oil, diesel, fuel oil, kerosene, oil, propane, and solvents each being noted in 2.29% of the cases. Those agents mentioned in 1.15% of the cases included, among others, acetone, asphalt, butane, duct liner adhesive, ethylene glycol, hardwood floor sealer, lacquer, methane, methyl ethyl ketone peroxide, naphtha, roofing cement, transformer oil, and varsol.

Explosions and Fires

A total of 75 incidents included deaths in explosions and fires. In terms of time of occurrence, a high frequency of explosions/fires was noted in July and August and a low frequency was noted in December.

The locations of the fires and explosions were examined. The locations of the fires/explosions were provided for 44 of the fatality cases. The most frequent location was in large tanks (29.54%), containers that would hold from 10,000 to 55,000 gallons of water or crude oil. The next most frequent location was in factories or plants (13.66%). Another 13.66% of the incidents occurred “outside” without any additional details being provided. Excavations were noted in 4.54% of the cases. Seventeen locations were mentioned in a single incident, including an attic, basement, ditch, manhole, oil well, refinery, roof, van, warehouse and others.

The source of ignition was determined in 49 of the incidents. The most frequently noted source of ignition involved welding equipment or a torch (57.14%) followed by an electrical switch (6.12%). Each of the following was noted in 4.06% of the cases: band saw, circular saw, grinder, hammer and match. Noted in one incident each were the ignition sources of chemical reaction, cigarette, cut-off saw, drill, electric arc, engine, pilot light, and shop vacuum.

There were 33 different explosive or combustible agents identified in 60 of the explosion/fire incidents. The substances that were most frequently noted in these cases were natural gas (16.67%), gasoline (8.33%), propane (8.33%), acetylene (6.67%), crude oil (6.67%), paint/primer (5.0%), and explosives as dynamite (3.33%). Those substances each occurring in one incident each included aluminum, ammonia, ammonium perchlorate, benzoyl peroxide, butadiene, diesel, gilsonite, liquid nails, methane, motor oil olefins, oxygen, sodium azide, tar paper, terephthalic acid, and others.

Heat

Exposure to heat was the cause of 58 deaths which included heat stroke, heat stress, heat exhaustion, and hyperthermia. Forty-seven (81%) of these deaths occurred in the summer months of June, July, and August. There were no heat-related deaths in the inclusive months of October to March.

The tasks being performed by the victims at the time they were overcome by heat were examined. This information was provided in 48 incidents. Site work where the workers were exposed to direct sunlight was associated with 26.55% of the cases. Other heat-related cases involved concrete work (16.33%), general labor (16.33%), roofing (14.26%), pipelaying (8.16%), and carpentry work (4.06%). Other tasks involved in one death each included bridge work, electrical work, highway construction, insulation installation, masonry work, welding, and asphalt work.

Chemical Exposure

Exposure to chemicals resulted in 40 fatal incidents. The number of incidents was considered too small to draw any conclusions about the time of occurrence by month of the year.

The tasks/trades associated with the chemical exposure deaths were examined. This information was provided for 34 the chemical exposure incidents. The tasks/trades included pipe installation/repair (35.25%), boiler repair (8.82%), bathtub refinishing (8.82%), sewer repair (8.82%), and general labor (5.86%). Other tasks/trades were each involved in one incident, including asphalt application, cleaning electrical components, demolition, electrical work, floor tile removal, HVAC repair, pump motor replacement, spray-finishing, stripping walls, welding, and transportation (traffic accident).

The location of occurrence of the chemical exposure fatalities was examined. This information was provided for 30 cases. The most frequent location for chemical exposure fatalities was in a factory or plant (43.33%). This was followed by fatalities in manholes (13.33%), apartments (6.67%) and commercial buildings (6.67%). Other locations, noted in one incident each, included a bathroom, bridge construction, chemistry lab, dairy, gas station, hospital, lift station, sewer, and van. Two of the incidents that occurred in manholes and one that occurred in a factory or plant were further classified as occurring in confined spaces.

The chemical agents were examined in these death cases. This information was provided in each of the cases. A total of 23 different chemical were noted. The most frequently occurring chemicals were hydrogen sulfide (15%), steam (15%), hot water (12.5%), methylene chloride (7.5%), and carbon monoxide (5%). Those chemicals and substances that were each involved in one incident included acetone cyanohydrin, ammonia, black liquor, cadmium, chromium Freon-113, Freon-11, gasoline, hot ash, hot asphalt, hot liquid, hydrofluoric acid, methane, mastic remover, nickel, sour gas, stripper, and thallium. The concentrations of these substances were not noted in the database.

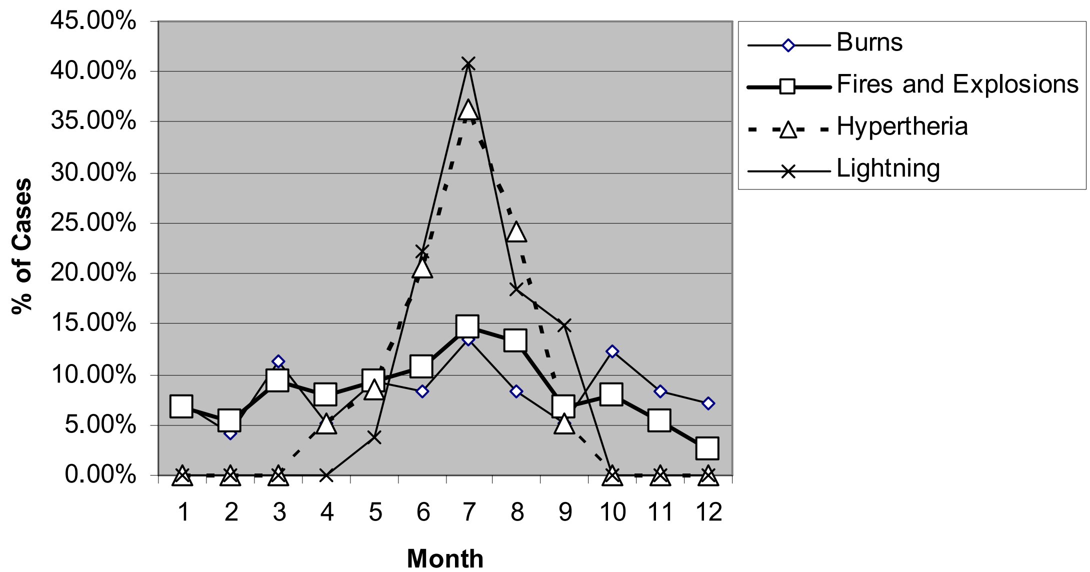

Figure 2 Distribution of Heat-related and Lightning Fatalities by Month

Lightning

There were 27 lightning deaths in the database. The month with the most deaths (40.74%) due to lighting was July. All of the lightning deaths occurred in the inclusive months of May (with one death) to September (with four deaths).

The location of the lightning victims at the time of the lightning strike was examined. This information was provided for 23 incidents. The most common location was on roofs (47.83%), followed by workers on the ground and away from protective structures (30.45%). Other locations that were each noted in one lightning incident included: on the third story of a building while installing plumbing, inside a house, on a catwalk, on a front-end loader and on an asphalt roller.

Low Frequency Causes

The remaining known causes of fatalities (19 deaths) occurred with such low frequency that no meaningful analysis could be performed with the data. Six of these were determined to be not work related. The remaining 13 cases included murder (4 cases), drug overdose (3 cases), animal bites (2 cases), with the remaining cases related to a helicopter crash, injury complications, mesothelioma, and suicide. Further consideration of these causes might suggest that the incidence of murder, drug overdose and suicide are also not work related.

Unknown Causes

Unknown causes accounted for 29 fatalities. From the accident descriptions, it appears that the true causes were not actually mysterious incidents in which the cause was not able to be determined, but rather that the investigation did not follow through to determine the cause of death. The following description of a fatality with an unknown cause of death is typical of these cases:

> Employee #1, a roofer, collapsed while picking up his tools and preparing to go home at the end of the workday. Employee #2 heard Employee #1 falling from the roof. Employee #2 called 911. The specific cause of the death has not been determined at this point.

From an examination of the cases with unknown causes, it appeared as if 17 of the deaths were the result of asphyxiation, heat exposure, or natural causes, but these would be conjecture based on the context of the incident.

5. CONCLUSIONS

Based on this analysis, it is evident that the fatality causes labeled as "other" would be more meaningful if they were classified more specifically. In the entire database that was examined, 8.26% of the fatalities were coded at being attributed to "other" causes. By using the eight specific cause codes of natural causes, asphyxiation, drowning, burns, explosion/fire, heat exposure, chemical exposure, and lightning, the category of "other" is reduced to represent 0.5% of the fatality cases. These eight cause codes are more meaningful and give a reasonable representation of the causes of the deaths of the construction workers.

The use of the term "other" to describe the cause of a fatality provides no information by which an employer can develop an effective safety program. Neither does it provide agencies, such as OSHA, with any characterization of fatality causes that might be effectively addressed by revisions to the regulations.

The various causes of fatalities classified as "other" appear to occur more frequently during the summer months, especially in July. For cases related to heat exposure, lightning, and drowning, this may simply be related to the elevated temperatures and weather conditions that are associated with the summer season. For other cases, it may be a reflection of the higher employment that is typical of construction during the summer months.

6. RECOMMENDATIONS

It is recommended that the cause codes used by OSHA be revised. The current cause codes are so broad in their definitions that little information is conveyed about the actual causes of accidents or how to prevent further occurrences. The individuals who are in a position of influencing the OSHA data collection process should encourage the compliance officers to provide more specific information about the fatalities that they investigate. The compliance officers can be assisted with the development of forms that solicit specific information about the circumstances surrounding fatality cases. This would result in more meaningful information about accident causation that could be readily searched and analyzed.

When the causes of various fatalities are examined, it is evident that there are patterns of causation with these other fatalities. Further study is warranted for each of the major cause areas that were identified. Further research might then be used to support the initiation of specific safety programs or the promulgation of specific regulations.

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CAUSES OF ACCIDENTS ON CONSTRUCTION SITES: THE CASE OF A LARGE CONSTRUCTION CONTRACTOR IN GREAT BRITAIN

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ABSTRACT

In the construction industry in Great Britain, it is estimated that workplace accidents and work-related ill-health cost society £3 billion – this is equivalent to 4% of the construction industry revenue of about £75 billion. Thus, the need to study, understand and effectively manage health and safety (H&S) on construction sites cannot be overemphasised. This paper presents an analysis of accident data recorded by a large construction contractor in Great Britain. The data cover a period of 36 months from April 2004 to March 2007. Pareto analysis was used to determine the relative importance of the causes of accidents on the basis of number of workdays lost. Differences between the four sectors (highways, infrastructure, rail and utilities) in which the company operates were investigated. The case study suggests that the main causes of accidents on construction sites relate to individual attitudes towards H&S. Ability and willingness to implement safe approaches to working and an awareness of their own and others' H&S can contribute to safe performances. It is suggested that the company could increase awareness of H&S issues among the workforce. This should be done on a regular basis through effective training, briefing and debriefing.

Keywords: Accidents, Large Construction Contractor, Great Britain

1. INTRODUCTION

For individuals directly involved, work place accidents and work related ill-health can lead to any of the following: death, permanent disability, treatment and time off work. For organisations directly involved and society in general, work place accidents and work related ill-health can lead to significant cost. In Great Britain, it was estimated that the cost to society as a whole of work place accidents and work related ill-health in the construction industry was £3 billion (HSE, 2004). This was equivalent to 4% of the construction industry's revenue of about £75 billion. Improving H&S safety performance on construction sites in the Great Britain could lead to significant human and financial gains – it would benefit all parts of society.

In Great Britain, there is a system for reporting events that happen in the work place that have a significant impact on the health and well being of the individuals concerned. This system is governed by the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR 95) which came into force on 1 April 1996. RIDDOR 95 requires any employer, self-employed person or anyone in control of work premises to report any death; injury that requires the injured person to be away from work or unable to do the full range of their normal activities at work; or reportable disease or dangerous occurrence that has not led to any negative consequence but could have (HSE, 2007b). Furthermore, RIDDOR 95 requires employers, employed people or anyone in charge of a work place to keep a record of any reportable event or disease for three years after the date it occurred. The record must include the following: date and method of reporting; date, time and place of event; personal details of those involved; and a brief description of the nature of the event or disease (HSE, 2007b).

This paper presents a case study of a major contracting organisation in Great Britain which runs a number of simultaneous construction sites (work places) all over the country, and is therefore subject to RIDDOR 95. In the interest of anonymity, the organisation will, hereafter, be referred to as Contractor A.

Contractor A is a large construction contractor with over 3400 employees and annual revenue in excess of £400 million. Contractor A's main clients are public sector organisations and regulated private sector organisations. Contractor A delivers services through two primary business segments: maintenance services; and project and engineering services. The maintenance services segment focuses on maintenance of highways and utilities networks through long term partnership and framework contracts (framework contract is a phrase used in the United Kingdom to refer to a contract that establishes terms and conditions under which subsequent contracts will be placed). The engineering and project services segment focuses on enhancement of highways/roads and rail infrastructure as well as waste management, flood protection, ground remediation, foundations, geotechnical engineering and building projects. Contractor A's activities can therefore be seen to fall under four distinct market sectors: highways, rail, utilities and general infrastructure (Begaw, 2007). Contractor A is promoted as a dynamic organisation that is keen to develop and maintain long-term relationships with its customers and supply chain. As of March 2007, Contractor A's forward order book exceeded £1 billion. It also envisaged £400 million worth of contract extensions. It is therefore clear that Contractor A is a significant player in the construction industry in Great Britain.

Like any other organisation in the construction industry, Contractor A can benefit from initiatives to improve H&S on its construction sites. Although Contractor A's H&S performance is quite good – with accident frequency rate of 0.23, placing it in the upper quartile in the construction industry (Begaw, 2007), it has opportunities to improve. Such opportunities can be clarified by analysing the records prepared and kept by the Contractor A under RIDDOR 95. It was for this reason that a study was undertaken to systematically investigate the available data with a view of making suggestions as to how Contractor A could improve H&S on its construction sites, thereby, make savings for itself and society.

2. RESEARCH PROBLEM

In Great Britain, RIDDOR 95 facilitates the authorities to: identify where and how risks arise; investigate serious events; and provide advice on how to reduce injury, ill health and accidental loss (HSE, 2007b). However, this tends to happen in the context of the entire nation. In order to generate organisation specific solutions, one needs to look at company specific data.

There is need to minimise injuries, diseases and dangerous occurrences on construction sites. When the causes of injuries, diseases and dangerous occurrences are known and understood, one may be able to design procedures and systems which can promote H&S on construction sites.

The aim of the study reported in this paper was therefore twofold: to identify the causes of accidents on company A's construction sites; and to suggest how accidents on Company A's construction sites can be minimised. In order to achieve this aim, the following objectives were pursued:

- Acquire information about incidences of injury, disease or dangerous occurrences;
- Analyse the information acquired in order to identify the primary and secondary causes of the incidences;
- Analyse data derived from the acquired information in order to quantify the relative importance of the primary and secondary causes; and
- Suggest strategies that can lead to reduction in incidences of injury, disease or dangerous occurrences.

3. METHODS AND RESULTS

Incidences of injury, disease or dangerous occurrences

In order to acquire information about incidents of injury, disease or dangerous occurrences, a senior manager in Contractor A responsible for H&S was contacted and requested to provide the information. As there was no interest in personal details of people involved in the incidences, it was easy to demonstrate that no breach of confidentiality or the Data Protection Act could arise. With assurances about confidentiality and data protection, the manager provided the information from records kept by Company A under RIDDOR 95 for the thirty six month period from 1 April 2004 to 31 March 2007.

From the information provided, it was found that 119 reportable accidents (including one fatality) and no diseases or dangerous occurrences had occurred during the period under study. For each of the accidents, the following data were obtained: sector of work, number of days of work lost and brief description of what happened.

Primary and secondary causes of accidents

The description of what happened in each accident was explored using a content analysis approach (Krippendorff, 2004) in order to identify the causes of the accident. By studying the words used to describe what happened in the accident, their meaning and context, the following primary and secondary causes of accidents were identified: casualty error, work method, poor quality kit, poor health, site set up, site conditions, plant operator error, plant failure and packing error.

Casualty error. This category includes all the actions, behaviours, omissions or misjudgements of the person who was injured in the accident. Examples in this category include: accepted poor kit, alpha sleep, carelessness, poor planning, human error, ignorance of wear limits, low self-respect, poor grip, poor observation and unsafe manual handling. Casualty error led to accidents summarised in Tables 1 and 2 below.

Work method. This category includes the procedures and/or techniques employed to execute the activities. Examples in this category include: mini-crane not properly fitted; poor practice – failure to use lifter; poor practice - manual handling; unsafe loading practice; unsecured shoring; and used tow-bar as a step. Work method led to accidents summarised in Table 3 below.

Poor quality kit. This category includes all situations in which defective and/or poorly maintained tools and/or equipment contributed to the accident. Examples in this category include: degraded cable; grinding disc in poor condition; fault with pump starter; grinder not maintained; and poor maintenance. Poor quality kit led to accidents summarised in Table 4 below.

Poor health. This category includes existing health conditions that contributed to the accident. In this category, there was only one case of arthritis that led to a back injury.

Site set up. In this category, all issues relating to how the site was set out and organised are included. There were two cases in which traffic cones were not placed in the right places and injuries occurred as a consequence.

Site conditions. This category includes the physical attributes of the site such as slope, dust and mud as well as the weather conditions such as wind and rain. The category also includes features of the site such as unprotected/unsecured temporary structures. Site conditions led to the accidents described thus:

- Fell through scaffolding ladder access gap and broke collar bone;
- Roping sprayer on back of truck - pulled rope, slipped and twisted knee;
- Walking over bank, slipped and pulled knee ligaments; and
- While lifting a manhole cover, foreign object got in eye.

Plant operator error. This category includes actions, behaviours, omissions or misjudgements of the plant operator. Examples in this category include low safety consciousness, poor judgment and unguarded machinery. Plant operator error led to the accidents described thus:

- 4-inch cut from sanding disc to leg;
- Hit by dumper bruising legs;
- Operative was run over by 3.5 ton dumper, sustained serious injuries;
- Roller rolled back off low loader and broke ankle;
- Run over by roller;
- Runway paving machine hit vehicle and vehicle injured foot;
- Slipped off tow-bar and broke bone while hitching up trailer; and
- Struck from behind by waste moving machine, resulting in severe bruising.

Plant failure. This category includes any type of malfunctioning of any piece of equipment/tool or any part of it. Examples in this category include structural failure and component jam. Plant failure led to the accidents described thus:

- Got thermoplastic from lorry - splashed onto, and injured, arm;
- High pressure hose burst, abdomen punctured; and
- Mobile tower section fell while loading resulting in broken rib.

Packing error. This category includes mistakes made in packing and loading materials and/components before they are brought to the site. Examples in this category include load not stacked properly and components not secured well. Packing error led to accidents described thus:

- Bag of cold tar fell and injured leg; and
- Injured while unlocking steel casings with crane from lorry.

Table 1. Accidents due to casualty error

Bruised hand on boring rods	Climbed down Hiab steps and twisted ankle	Crushed finger between valve & trench	Crushed thumb under ductile iron (DI) pipe
Cut tendon in hand lifting bollard	Cutting lighting column, saw jumped and cut leg	Deep cut to shin due to fall	Disc cutter hit leg
Dropped jackhammer on foot	Dropped road plate onto foot	Dropped wacker plate and pulled back	Exiting mini-digger cab incorrectly
Fell into manhole	Fell on uneven stairs	Forklift pushed sleepers, crushed hand and foot	Getting out of side door van, slipped on step
Hand caught under teleporter forks	Hit 415V cable	Hit by Hiab arm while loading column	Hit cable and suffered burns while using jack hammer
Hit hand while loading concrete	Hit hand while loading fence posts	Hit hand while loading kerbs	Hitting in road pin with sledgehammer, missed and hit index finger

Hurt back lifting blocks from bottom of dumper	Hurt back lifting concrete base sections	Hurt back lifting rubber hose	Injured back lifting riffling sample box
Jackhammer slipped onto foot	Jumped off piling rig and landed on brick	Kicked tarmac into dumper and fell off	Lost tip of finger lowering roll bar
Lost tip of finger whilst drilling	Member of public found dead in excavation	Missed footing and fell 1.5m hitting tracks	Opened guarding on auger and caught finger
Pallet fell forward and hit wrist	Paving slab fell onto foot	Pulled arm placing casings	Pulled back while moving toilet
Pulled wacker plate over foot and broke bones	Released quick hitch and impaled arm	Reversed roller and trapped thumb resulting in fracture	Slipped and fell 15m, while removing scaffolding
Slipped descending ladder, broke foot bone	Slipped off steps of grab lorry, jarred back of the wagon	Slipped on edge of trench / fell on sluice valve	Slipped on previously tipped stone

Table 2. Accidents due to casualty error (continued)

Slipped on road sign, fell and dislocated shoulder	Slipped on rough ground	Slipped on step of lorry, fell causing bruising to shoulder	Slipped on wet ground while getting out of van
Slipped on wet leaves	Slipped pushing wheelbarrow up slope	Slipped while levelling tarmac	Slipped, shin struck a trench sheet
Started vehicle and ran over own leg	Stepped off digger onto uneven ground and broke ankle	Stepped off lorry and turned ankle	Stepped off trailer and broker right ankle
Stepped on shovel and twisted ankle	Stepping out of van and broke a small bone in foot.	Stood awkwardly and twisted ankle	Strained back while using breaker
Strained stomach while lifting hydraulic pack	Struck by pipe-work rolling into excavation	Struck elbow whilst climbing out of excavation	Struck in face by blown off fusion saddle
Subcontractor slipped from the step on dumper	Swabbing wire whipped onto finger	Touched electric cattle fence while using listening stick	Tried to lift trailer alone and injured arm
Tripped on lanyard injuring back	Twisted ankle in Hiab	Twisted back during manual handling	While carrying equipment, slipped and

			winded self on timber support

Table 3. Accidents due to poor quality kit

Angle grinder disc broke, grinder jumped and cut knee
Cut hand when lifting
Electrical flash from loose lead on grinder caused burn to wrist
Hit 240V cable in poor repair and was burned
Whilst starting a pressure pump, starting handle kicked back and fractured thumb

Table 4. Accidents due to work method

Back strain whilst lifting trough lids	Boulder rolled into excavation and trapped in pit
Dropped compressor gun catching wedding ring and cut finger to the bone	Dropped manhole cover on foot, broke two bones
Dust in eye	Fell over wall whilst tree clearing, hurt shin/foot
Horizontal shoring slipped and hit head	Jarred back levering hydrant cover
Moving plastic 'T' pieces, felt twinge in back	Pulled back lifting filing trays
Pulled back while levering up manhole lid	Pulled muscle in back while moving a concrete chamber section
Pulled muscles in back while lifting	Slipped in excavation and broke foot while placing barriers
Stepping out of van, slipped off tow-bar jarring lower back	Stone flicked into eye
Took short cut, slipped down bank and twisted ankle	Unloading sheet piles, fell off the back of the wagon

Relative importance of the primary and secondary causes of accidents

From the acquired information and subsequent content analysis, a data set including the following variables was derived:

- Sector (measured on a nominal scale: 1 = utilities; 2 = infrastructure; 3 = highways and 4 = rail);
- Primary cause (measured on a nominal scale: 1 = casualty error; 2 = work method; 3 = poor quality kit; 4 = poor health; 5 = site set up; 6 = site conditions; 7 = plant operator error; 8 = plant failure; and 9 = packing (external) error);
- Secondary cause (measured on a nominal scale: 1 = casualty error; 2 = work method; 3 = poor quality kit; 4 = poor health; 5 = site set up; 6 = site conditions; 7

= plant operator error; 8 = plant failure; and 9 = packing error);

- Number of work days lost (measured on a ratio scale: 0 to ∞); and
- Inter-accident time (number of days after previous accident the accident occurred - measured on a ratio scale: 0 to ∞).

In order to identify the relative importance of the primary and secondary causes of accidents, Pareto analysis (Colman and Pulford, 2006) was undertaken for each of the variables with importance measured in terms of 'number of work days lost'. The results from this analysis are illustrated in Figures 1 and 2 below.

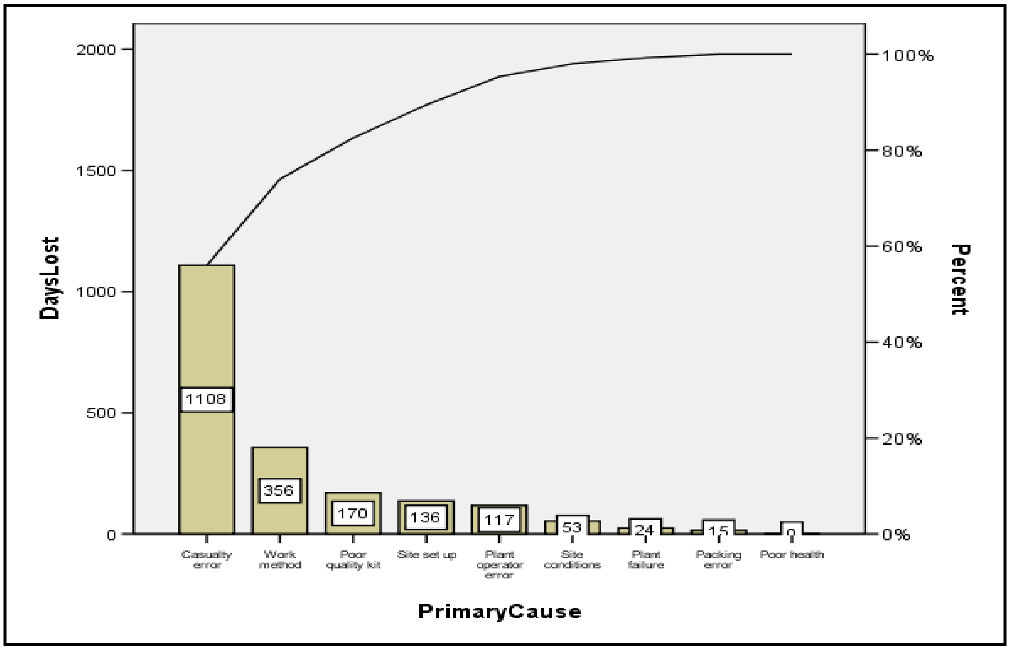

Figure 1. Relative importance of primary cause

Hayden-Elgin (1997) suggests that people tend to be comfortable with things that come in threes – this is a useful idea that can be employed to summarise the relative importance of primary and secondary causes of accidents in this case study. From Figure 1, it can be seen that the top three primary causes of accidents are casualty error, work method and poor quality kit – they account for over 80% of all the work days lost over the study period. From Figure 2, it can be seen that the top three secondary causes of accidents in the case study were work methods, casualty error and site conditions – they account for over 90% of the total work days lost over the study period. It can therefore be said that strategies to reduce accidents on Company A's construction sites that focus on site operatives, how they execute their work, what they use to execute their work and conditions in which they execute their work have potential to drastically improve H&S on the construction sites.

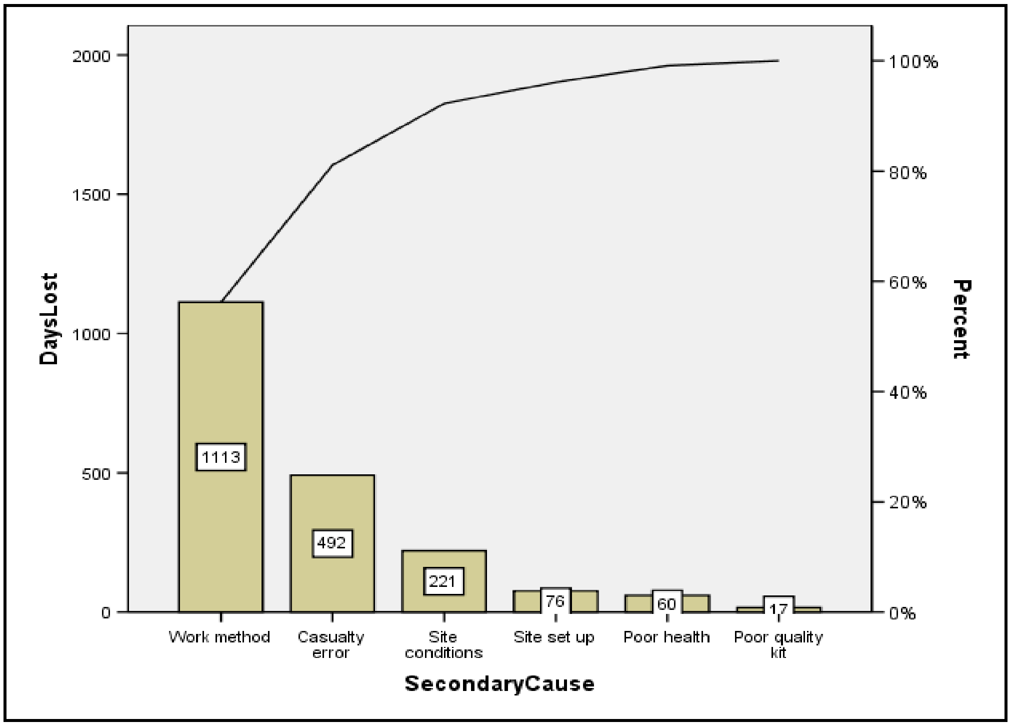

Figure 2. Relative importance of secondary cause

Strategies to reduce accidents

In order to propose strategies for Contractor A to reduce accidents on its construction sites, a detailed analysis of the data was required - this was done by: testing for normality of the inter-accident time and number of work days lost; and testing for differences between the sectors of Contractor A's work. Following the data analysis, mental imagery was employed to develop ideas.

Testing for normality. This was important because the results would lead to the appropriate tests for differences between the sectors. On carrying out the standard normality test, it was established that the inter-accident time and number of work days lost data were non-parametric. Therefore, tests to determine whether there were differences between sectors would have to be non-parametric tests (Coleman and Pulford, 2006).

Testing for differences. This was important because the results would help in establishing whether generic or sector-specific strategies were required. A series of Kruskal Wallis tests (Coleman and Pulford, 2006) were run. The results showed that there were no differences between the sectors as far as inter-accident time and number of work days lost were concerned. This suggests that it would be appropriate to design generic, rather than sector-specific, strategies to reduce accidents on Contractor A's construction sites.

Employing mental imagery. This was important because the causes of accidents were, in the main, related to human behaviour and the behaviour can be understood through quasi-perceptual experiences generated by mental imagery techniques (Thomas, 2007). Details of the issues considered and ideas proposed are presented in section 4 below.

4. PROPOSAL FOR REDUCING ACCIDENTS

Context

The proposal outlined below is based on the following researcher observations about the case study:

- The number of work days lost over the three year period is 1,979. This is equivalent to about 2.5fte positions – even for a large company, this is undesirable.
- The average inter-accident time is 9.28 days (about 3 accidents a month) – accidents are frequent and this is undesirable especially when the impact on individuals, their families and reputation of the construction industry is taken into account.
- The main causes of accidents relate to workforce attitudes towards H&S.
- The workforce's ability and willingness to implement safe approaches to working and awareness of their own and others' H&S can contribute to safer construction sites.

Proposal

It is suggested that Contractor A could increase awareness of H&S issues among the workforce by implementing the framework illustrated in Figure 3 below. The framework builds on the idea that people tend to like things that come in threes (Hayden-Elgin, 1997). The framework consists of three components: training, briefing and debriefing. Each of the components is itself decomposed into three activities. Each activity addresses three criteria. This framework is expected to be effective and preferred.

Training should be aimed at developing individuals who know what to do, how to do it without exposing themselves and others to risk and can help others to acquire similar levels of competence. At macro (organisation/project) level individuals' training needs should be initiated on joining the organisation and/or starting a new project and it should continue throughout the employment/project at a pace commensurate to organisational and individuals' needs. At micro (project phase/activity) level, individuals should be trained as project activities/phases advance and new skills/competences are required.

Briefing should be aimed at reminding individuals of what to do and what it takes to do it safely. It should be carried out on a daily basis at the beginning of the project activity for a few days. Thereafter, it could be carried out less frequently, but regularly, until the activity is completed.

Debriefing should be aimed at highlighting lessons to be learnt and reinforcing knowledge already acquired to facilitate the development of H&S awareness as an integral aspect of people's work practice. Like briefing, debriefing should be frequent at the beginning of project activities and less frequent, but regular, thereafter.

Training

- Initial training - to gain technical skills, health and safety awareness and professional values;
- Advanced training - to master technical skills, deepen health and safety knowledge and develop leadership skills;
- Periodic training - to value human life, understand human behaviour and communicate effectively.

Briefing

- Unpack tools/equipment - to ensure they are right, sufficient and safe;
- Prepare for work - rehearse processes, answer any questions and check understanding; and
- Discuss risks - identify risks, explain warning signs for the risks and highlight how the risk exposure can be minimised.

Debriefing

- Pack up tools/equipment - check, clean and recharge them;
- Reflect on what happened - identify risk events that occurred, explain why the risk events occurred and identify the impact of the events; and
- Reflect on what did not happen - identify risk events that were avoided, why the risks events were avoided and what needs to be done next time.

Figure 3. Framework for increasing H&S awareness

5. CONCLUSIONS

From the work undertaken in the case study, the authors can draw the following conclusions:

- It is important that H&S is taken seriously at all levels in the construction industry as it affects all of us either directly or indirectly;
- The causes of accidents on Contractor A's sites are: casualty error, poor quality kit, work method, poor health, site set up, site conditions, plant operator error, plant failure and packing error;
- The top three primary causes of accidents on Contractor A's sites are casualty error, work method and poor quality kit while the top three secondary causes are work methods, casualty error and site conditions;
- Action that focuses on effective training, briefing and debriefing of workforce can increase awareness of H&S issues among the workforce and lead to reduction in accidents on construction sites; and
- This case study provides useful lessons for Contractor A and other contractors in Great Britain and possibly other countries.

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ACCIDENTS, HIGH RISK TASKS AND ERROR PROOFING OPPORTUNITIES IN RESIDENTIAL FRAMING

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ABSTRACT

This study analyzes the high-risk tasks in residential framing and identifies areas for error-proofing the production process that can reduce the probability of accident occurrence. The research consisted of a cognitive approach to safety and focused on the task demands that contribute to errors and accidents. To understand the errors involved in framing accidents, 177 recordable injuries were examined that were sustained in a large framing company in 2005. The analysis first examined the frequency and severity of the different accident events. Falls during truss installation, falls during roof plywood installation, and saw cuts were the three most severe accident events and together accounted for 58% of the total workers' compensation costs. Nail gun injuries and falls from same level were also identified as significant incidents. Incident analysis and interviews with safety and production personnel were then used to identify the 'high risk' tasks (that is, activities and tasks with high frequency and/or high severity of accidents), and to understand the task features and errors that contribute to accidents during these tasks. Based on the findings, the study identified directions for error-proofing of the high risk tasks that can reduce the errors and accidents.

Keywords: Residential accidents, Framing, High risk tasks, Errors, Error proofing.

1. INTRODUCTION

Construction injuries remain a significant problem. In Arizona, the recent growth in construction activity has exacerbated the safety problem, as this growth was accompanied by a disproportionate increase in injuries in many trades. Table 1 summarizes employment and injury data for selected specialty trades in Arizona. According to the Industrial Commission of Arizona and the Bureau of Labor Statistics, the number of injury/illnesses for specialty trade contractors involved in Foundation, Structure, and Exterior Buildings jumped from 3,300 in 2004 to 5,700 incidents in 2005, representing a 73 percent increase. For framing contractors, the average employment in 2005 increased by 34%, while the number of injuries increased by 120%. Framing contractors have the highest incident rate among specialty trade contractors with a rate of 22 (equivalent to 22 injuries per 100 full time workers per year).

This study focused on residential framing operations. The goal of this study was to identify error-proofing interventions that can reduce the frequency and severity of accidents in residential framing. The focus of the study was on preventing the 'errors' or conditions that lead to loss of control and accidents, rather than improving the protective measures (such as personal protective equipment) that minimize the consequences of accidents. For example, the goal of the study was to prevent falls, rather than to develop fall protection system.

Error proofing techniques do not control the root causes of mistakes, such as human and environmental factors (fatigue, distractions, noise, lighting, etc.), but independent of the cause, they block or provide a warning about undesired outcomes at a point in the process where the consequences can be minimized. Error proofing has been used in the Toyota production system as the primary strategy for prevention of defects.

This study explored error-proofing as a possible direction for construction accident prevention. Identifying effective error proofing interventions requires a deeper understanding of the errors that lead to loss of control and the 'mechanisms' of accidents. Furthermore, the same accident event may be triggered by different causes. For example, a fall from a roof may be triggered either by overextending at the edge of the roof, or slipping on plywood. These involve different error mechanisms and reasons, and may be addressed with different interventions.

Table 1. Incident rates for selected building trades in AZ.

	2004		2005		% Change[3,4]		2005
INDUSTRY	Employment[1,2]	Total Cases[1]	Employment[1,2]	Total Cases[1]	Employment	Total Cases	Incident rate
Foundation, Structure, Exter Bldg Trade Contractors[5]	40.8	3.3	48.2	5.7	18%	73%	12.6
Framing Contractors	**11.7**	**1.5**	**15.7**	**3.3**	**34%**	**120%**	**22**
Masonry Contractors	9.4	0.3	10.8	0.7	15%	133%	6.8
Poured Foundation & Struct. Contactors	8.5	0.6	9.2	0.6	8%	0%	7.6
Structural Steel & Precast Conc. Contractors	2.6	0.2	2.9	0.3	12%	50%	10.7
Roofing Contractors	5.7	0.4	6.5	0.6	14%	50%	10.3

2. METHODOLOGY

To develop a deeper understanding of the accidents in residential framing, and the related errors the researchers analyzed 177 recordable accidents that occurred in a large residential framing company in 2005. This paper reports the initial findings of the study—it analyzes the frequency and severity of different accident events, it examines the tasks during which the accidents happened, and it investigates the errors and conditions that led to the most severe accidents.

Incident Data and Analysis

In 2005, the participating company recorded 177 recordable incidents. First-aid accidents with zero workers' comp costs were excluded from the analysis. In 2005 the company employed an average of 86 framing crews, worked 1.5 million labor hours, and framed over 2,800 houses. The incident records provided the following information:

- Date of incident
- Injured worker's position: foreman, carpenter, apprentice or laborer (incomplete records)
- Length of employment: months with the company
- Description of the incident (usually brief with little information).
- Workers' comp cost (actual or estimated). Indirect costs, such as production loss, etc. were not accounted for.

The analysis of the data included the following steps:

- Classified and analyzed the incidents based on the type of event.
- Classified and analyzed the incidents according to the activity and task that the worker was performing at the time of the incident.
- For the higher severity incident types, we investigated the errors that led to the incident event. Analyzed etiology with experienced personnel.

Incident Events.

Based on the injury descriptions, the researchers classified the incidents under the following 'Event' categories:

- **Falls** include falls to lower level, falls at same level, and falls from ladder.
- **Contact with tool/equipment/material** includes sawcuts, cuts on gussets, stepping on nails with static nail (e.g., stepped on nail), splinters
- **Struck by tool/equipment/material** includes injuries from nail guns, hammers, material falling from above, dropping materials during transport, dropping wall panels during lifting, debris in eye, etc.
- **Overexertion** includes injuries such as sprains and strains caused during walking, lifting, moving, etc.

Incidents and Main Activities.

Classified and analyzed the incidents according to the activity and task that the worker was performing at the time of the incident. After discussions with company personnel, we developed the following list of main activities and tasks included in each:

- **Site:** load/unload material and equipment, cleanup site, remove nails.
- **Walls:** (first or second floor) include layout, material handling of wall material, framing, lifting in place, installing blocking, installing shear walls, installing top plate.
- **Trusses:** (floor and roof trusses) include setting the truss, installing blocking and bracing, and sheeting, installing fascia, cutting tails, etc.)

- **Roof:** sheeting includes setting plywood on the roof

Each task includes transporting material, measuring, cutting, and nailing.

Incidents and Errors

For the incident events with the highest severity, the researchers examined the task errors that contributed to the particular events. This was done first through examination of the causes from the incident records. However, in most cases, the information provided in the incident description was too limited and did not identify the error involved. For the higher cost incidents, the researchers gathered additional information from the safety director and the quality control (QC) manager who had been involved in the incident investigation. The safety director and QC manager also identified the most common incident-related errors based on their experience. This part of the analysis identified errors related to particular work activities, and provided the basis for discussion regarding possible interventions for error prevention.

3. ANALYSIS OF INCIDENT EVENTS

Table 2 summarizes the frequency and severity of the various incident events. The frequency is indicated by the number of occurrences and % of cases, while the severity is expressed in terms of workers' compensation cost.

Table 2. Frequency and severity of incidents by event

EVENT	# of cases	$ cost	Frequency (% cases)	Severity (% cost)
Fall from trusses	10	293,432	6%	31%
Sawcuts	11	128,793	6%	14%
Falls from roof	5	123,812	3%	13%
Falls at same level (trip)	16	84,866	9%	9%
Nail gun	30	72,266	17%	8%
Overexertion	20	65,324	11%	7%
Hammer	5	53,145	3%	6%
Splinter	7	32,789	4%	4%
Fall from ladder	6	23,211	3%	2%
Dropped material	5	16,664	3%	2%
Cut on gussets	9	16,309	5%	2%
Nail (stepped on/contact)	15	5,266	8%	1%
Struck by wall panel	9	5,039	5%	1%
Struck by falling material	6	4,678	3%	1%
Debris in eye	8	1,535	5%	0%
Other	15	5,626	8%	1%
ALL ACCIDENTS	**177**	**932,755**	**100%**	**100%**

Figure 1 illustrates the relative frequency and severity of the different incident events, and indicates the five incident events with the highest severity. These are: (1) Falls during truss installation, (2) Saw cuts, (3) Falls during roof sheeting, (4) Falls from same level, and (5) Nail gun injuries. The top three incident events account for 58% of the workers' comp costs in 2005.

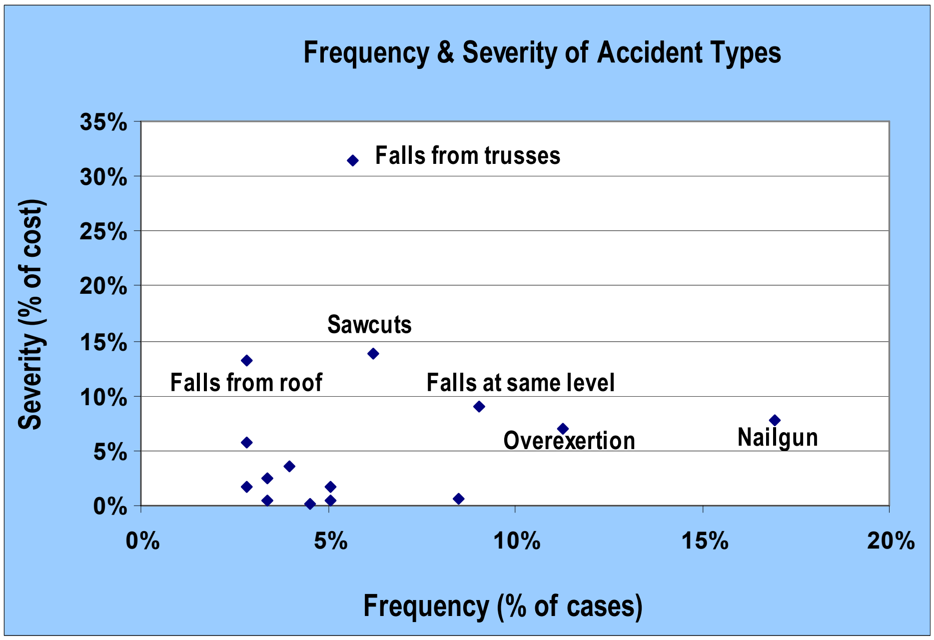

Figure 1. Frequency and severity of incident events.

Falls are 20% of the total incidents and account for 56% of the total workers' compensation costs. Falls during truss installation are only 6% of the total, but account for 31% of the total costs. Falls during roof sheeting are also severe, although less frequent. The 16 'falls at same level' include 10 falls on the ground, 4 falls on truss, and 2 falls on the roof.

Contact with Tool/Equipment/Material accounts for about 26% of all incidents. Of these, saw cuts have the highest total cost. The causes of saw cuts are examined in a later section. While splinters are an everyday occurrence, only seven cases were recordable incidents. In general, splinter incidents were of low severity, with the exception of one high cost case due to infection. Cuts on sharp edges (primarily gussets) accounted for 9 incidents and involved relatively low severity. Stepping on or inadvertently bumping into protruding nails was the cause of 15 recordable incidents, with low severity.

Struck by Tool/Equipment/Material accounts for 38% of the incidents and 17% of the workers' compensation costs. Nail gun injuries are the most common injuries (30 incidents), although not the most severe. For example, 26 of the 30 nailgun injuries cost less than $1,000, and only two incidents were more than $10,000. This category includes incidents such as hit by hammer (5 incidents, 2 of high cost), struck by material falling from higher level (6), material that the worker(s) dropped while handling (5), or wall panels dropped while lifting walls in place (9 incidents).

Overexertion (11 incidents) accounts for 15% of the incidents and 7% of the costs. They include sprains (mostly ankles and knees) and muscle strains (mostly back), primarily from material handling.

Figure 2 shows the distribution of incidents by cost category. As evidenced in the figure, 127 incidents had a cost less than $1,000 each (97 of them cost less than $500). In 2005, there were only two incidents over $50,000 (one fall from trusses, and one fall from roof).

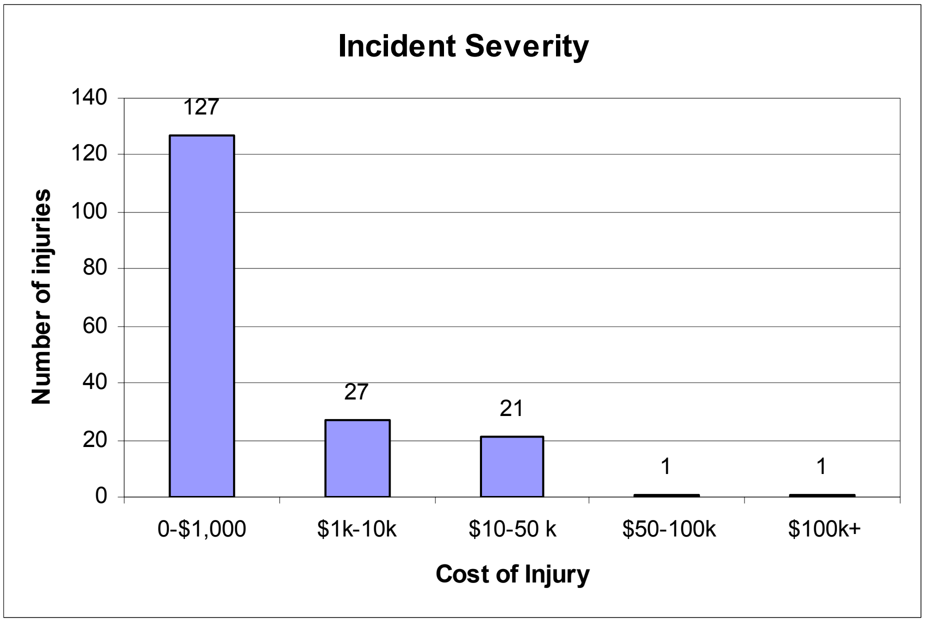

Figure 2. Distribution of incidents by severity (cost).

The first 5% of injuries (8 incidents) accounts for 49% of the costs. The second 5% accounts for 26% of the costs. Thus, the top 10% of the incidents (18 incidents) accounts for about $696,000, that is 75% of the total workers' compensation costs. The top 10% of the incidents (18 incidents) includes: 5 falls installing trusses, 2 falls during roof plywood installation, 3 saw cuts, 2 falls at same level, 2 'struck by hammer' injuries, one nail gun injury, one splinter, one overexertion and one fall from ladder.
The above analysis identifies the incidents with the highest cost, but in most cases not the specific activities related to the incidents. The following section examines the activities when incidents occur.

4. ANALYSIS OF INCIDENT BY ACTIVITY

The second step of the analysis examined the work activities during which incidents take place. Each incident was classified under the main activity and related task. For 39 incidents, the records did not identify the activity but only a subtask, for example, "nailing plywood" without specifying if it was for wall shear or roof sheathing. As listed previously, incidents were classified under five main activities:

- Site: load/unload material and equipment, cleanup site, remove nails.
- Walls (first or second floor) include framing, blocks, lifting, shear, top plate.
- Floor trusses (in case of a house more than 1 floors) include truss set up and sheeting
- Roof truss includes erecting the truss and framing the roof (install blocks, bracing, fascia, cut tails, etc.)
- Roof sheeting involves installing roof plywood.

Tables 3a and 3b summarize the number and severity of the incident events by main activity. Similar incident events occur during different activities. For example falls to lower level occur during truss and roof activities. However, the 'mechanism' of the incidents and the errors that lead to the loss of control are not necessarily the same—for example, some falls are a result of a worker stepping on an unsupported truss component, while others may result from slipping on the roof plywood. Furthermore, even very similar incidents (e.g., nail gun injuries) may have very different causes. In order to identify potential intervention that can prevent the incidents from occurring (rather than minimizing the consequences through protective equipment), the researchers examined the mechanisms and errors that contributed to the incidents.

Table 3.a Number of incidents by incident event and main activity.

MAIN ACTIVITY	Falls to lower level	Falls to same level	Falls from ladder	Saw cuts	Nail gun	Overexertion	Hammer	Splinter	Struck by material	Cut on gussets, etc	Nails	Struck by wall panel	Other	# of incidents
Site	-	4	-	-	-	2	2	-	6	-	2	-	-	16
Walls	-	2	2	2	16	14	2	3	2	2	3	8	2	58
Floor trusses	2	-	-	-	-	-	-	-	-	3	2	-	-	7
Frame Roof Trusses	8	4	1	2	4	5	1	2	2	5	1	-	-	35
Plywood roof	5	2	-	1	1	1	-	-	3	-	1	-	-	14
Activity not specified	-	3	3	6	8	5	-	2	1	1	6		8	43
Other		1			1					2				4
TOTAL	15	16	6	11	30	27	5	7	14	13	15	8	10	

Table 3.b. Cost of incidents by incident event and main activity (in $1,000)

	Type of Incident													
MAIN ACTIVITY	Falls to lowe level	Falls to sam level	Falls from ladder	Saw cuts	Nail gun	Overexertio	Hammer	Splinter	Struck by Material	Cut by gussets, etc	Nails	Struck by W panel	Other	Total $
Site	-	62.6	-	-	-	<1	1.4	-	16.7	-	<1	-	-	82
Walls	-	7.2	19.5	19.3	12	36	52	25	1.2	<1	<1	4.7	<1	177.7
Floor trusses	<1	-	-	-	-	-	-	-	-	1.3	1.4	-	-	3.4
Frame Roof Trusses	292.6	3.6	<1	22.4	1.7	2.6	<1	6.9	2	14.8	<1	-	-	346.2
Plywood roof	123.8	1.5	-	38.1	<1	<1	-	-	1.7	-	<1	-	-	166.2
Activity not specified	-	9.5	3.5	49	57	28	-	<1	2.1	1	2.4		1.7	154.7
Other		<1			1					1.2				2.7
TOTAL $	417.2	84.9	23.2	129	72	68	53	33	22.6	18.4	5.3	4.7	2	933

5. ERRORS AND ERROR PROOFING DIRECTIONS

The third part of the analysis investigated the most common errors and conditions that increase the likelihood of occurrence of incidents during the different framing tasks. The investigation was based on the incident records, and interviews with the safety director and QC manager. The errors related to the most severe injuries are discussed below.

Falls from trusses

The incident analysis indicated 14 falls from trusses: 10 falls to the ground, and 4 falls to the same level. The task with the highest fall risk was truss installation and the most common errors related to such falls are the following:

Truss erection/positioning the truss. This task requires dynamic coordination of a heavy component (pulling-pushing and directing the truss). Excessive pulling by any member of the crew may pull the truss off the support, and cause the workers to be off balance. Furthermore, the truss design influences the difficulty of the task—for example, ‘bullnose’ trusses require more careful handling and coordination.

Overextending is an error that can lead to a fall during truss erection, or other tasks. Installing fascia is a task that requires coordination (two crew members), and handling a heavy beam over the edge of the roof.

Cutting tails (protruding parts of the truss) is another activity with increased risk of falling, as it involves work at the edge of the trusses and the use of a power tool. A common error is stepping on an unsecured component. This task also poses increased risk of a saw cut injury due to the awkward position of the worker when performing the task.

Unsecured components. Stepping on unsecured truss components (along with failure to realize that the truss component is not secured) are a common cause of falls. In one fall, the hanger supporting a truss came off, while in another incident, the brace on the ridge (where the lead worker was sitting) came off.

Naturally, the likelihood of these mistakes increases with rushing and inexperience. Typically, these tasks are performed by the more experienced crew members.
Error proofing interventions should focus on:

- reduce the difficulties of positioning the trusses,
- prevent stepping on unsecured components, and
- prevent workers from overextending when working near the edge of the roof.

Falls from roof (during sheeting)

The incident descriptions indicated that ‘tripping’ was involved in all cases, but did not provide any more information. According to the experts, overextension, slipping on the roof and stepping or tripping on unsecured plywood are three common errors associated with falls from roofs.

Wind can also lead to loss of control while carrying plywood. Installing the first row of plywood near the edge of the roof is quite risky—some foremen allow only their most experienced carpenters to work on this task. Material handling also involves significant risks, due to reduced visibility and increased slipping hazards.

Cutting the plywood on the roof generates saw dust that creates slippery conditions. Wearing shoes that minimize the likelihood of slipping is important, and that is why framers typically wear snickers rather than work boots.

Rushing while handling large pieces of plywood on a sloped roof increases the likelihood of errors.

Potential error proofing interventions can target the following:

- prevent loose plywood (or stepping on loose plywood) on the roof.
- reduce cutting on the roof to avoid creating more slippery conditions
- provide warnings regarding slippery conditions

Saw cuts

Tasks that involve cutting in awkward positions have greater potential for error. Such tasks include cutting notches on studs, cutting truss tails, ripping boards and cutting plywood. In these activities, it is more difficult to maintain control of the tool, and more likely that the saw may bind and kick back. Using a dull blade increases the possibility of the saw kicking back. Another error is placing hands too close to the saw, where a small slip or loss of control can bring the body part in contact with the blade. Six of the 11 saw cut injuries resulted from the saw kicking back (the other 5 cases did not provide sufficient information for analysis). The power of the saw makes it difficult to control when it kicks back.

Potential intervention to prevent saw cuts may include:

- minimize the amount of cuttig at awkward positions and locations
- reduce the power of the saw to increase the ability to maintain control when it kicks back.
- use sensors and automatic shutoffs when a dull blade is used.
- use sensors and automatic shutoffs when the saw kicks back.

Nail gun injuries

Nail gun injuries are typically of low cost, but relatively frequent. From the list of incidents and the interviews, the researchers identified the following different errors.

- Nail bounces on hard material (knot, another nail, metal strap)
- Accidental discharge due to tool operation: e.g., shooting a second nail on the re-load
- Accidental discharge caused by the worker, e.g., walking with the finger on the trigger
- Nailing errors: nail is fired in the wrong direction, in combination with hand position. Sometimes nails break through the wood and puncture the worker who might be positioning the wood with the free hand.

Ten of the 30 nail gun injuries occurred within the first 3 months of employment, and 22 of the 30 injuries happened within 1 year of employment.

Error-proofing intervention should focus on the following:

- prevent accidental discharge.

- prevent accidental triggering of the nail gun.
- avoid nailing on hard surfaces

Falls at same level

This category includes10 falls at ground level, 2 falls on a roof, and 4 on a truss. The most common error in falls at ground level is tripping. In 5 of the 10 cases, a load was being carried when the worker tripped. Tripping is also the main cause for sprains. Of the 11 injuries involving sprains (mostly ankle and knee), 9 cases were caused by tripping.

The falls at ground level indicate a failure in the interaction between worker and work area and they are influenced by two major factors: (1) the condition of the work area, and (2) the worker's awareness, which is often reduced due to the task (handling material) or rushing. The worker's experience appears to make a difference: 6 of the 16 falls at the same level occurred within the first 3 months of employment, and 11 of the 16 incidents were sustained by workers with less than 1 year of employment. Prevention of falls at the same level requires reducing the tripping hazards or increasing each worker's ability to detect the hazards, e.g., make the material handling task less difficult).

6. SUMMARY AND CONCLUSIONS

The goal of this research was to identify specific errors that lead to incidents in residential framing. The examination of the 177 incidents found that the incidents with the highest severity are falls from trusses, falls from roof, saw cuts, nail gun incidents and falls at same level. The analysis of each type of accident identified the tasks where such events occur and the most common errors that produce them, as well as some task characteristics and conditions that increased the likelihood of errors. The identification of the errors points out directions for interventions to prevent these accidents. Finally, the study proposes an improved system of collecting information about accidents, one that tracks the production tasks and errors that lead to the accidents. The next phase of this research will include the following:

- Analysis of more framing accidents, as this study has only considered the injuries experienced by the employees of one company in one year.
- Collection of input from production personnel (foremen) to understand in more depth the errors and the task conditions affecting the likelihood of errors, and to understand strategies that crews use to reduce the risks on particularly high-risk tasks.
- Identification and evaluation of potential interventions to prevent accidents. Error-proofing interventions can aim at the following issues:
  - reduce the complexity of the product, or work process or
  - block or detect the errors at a point in the process where they are easier to be blocked or detected

Finally, another long-term goal of this research path is the development of a typology of errors that will assist with systematic identification of interventions that can prevent the occurrence of errors.

7. ACKNOWLEDGEMENTS

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THE COST OF CONSTRUCTION ACCIDENTS: AN EXPLORATORY STUDY

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ABSTRACT

This paper presents the results of a study to establish the actual accumulated costs of construction related health and safety accidents given that occupational accidents and their associated costs are a serious concern, fundamentally for management and the construction industry at large. Further, accidents have huge cost implications that potentially affect not only overall project performance but the sustainability of the enterprise. The study builds on the premise that all accidents are preventable, accompanied by positive performance impacts and outcomes. The findings of a pilot study are presented in this paper. They suggest that the costs of accidents are under calculated and in reality only represent the figurative "tip of the iceberg."

Keywords: Cost, Direct Costs, Indirect Costs, Construction, Accident, Health and Safety

1. INTRODUCTION

Construction worker injuries and illnesses have cost implications attached which, arguably, can have a major impact on a construction organisation. It is not possible to insure against all the costs arising from accidents. However, it is possible to prevent accidents from occurring. Consequently, the costs of accidents can be avoided, time and money saved and harm to people prevented.

Research has frequently focused on the costs of occupational accidents and ill-health, without much attention to the economic benefits coupled with health and safety. This paper reports on a study of the direct and indirect costs associated with construction accidents within the context of a major stakeholder in the South African construction industry. The authors contend that all accidents are preventable. Further, the prevention of accidents results in positive performance impacts and outcomes that ultimately result in economic benefits overall.

Accidents by their very nature are undesirable events given the resultant unpleasant and damaging consequences to the affected organisation. Accidents at work and the accompanying occupational injuries are a considerable economic burden to employers, employees and to society as a whole [1]. “During the last financial year alone, the Labour Department in South Africa has paid out R319 million (about $50 million U.S.) on claims for work-related injuries and illnesses, and this payout is just for compensation of employees and medical costs [2]. The construction sector has the worst record relative to occupational accidents and overall health and safety performance. More workers are killed in the construction industry than in any other major industrial sector. The South African Department of Labour reports that the injury rate in construction is higher than the rate for private industry as a whole.

Construction accidents account for 4% of the global Gross Domestic Product (GDP). South Africa obviously contributes to this tragic scenario. Occupational accidents and diseases in South Africa account for approximately 3.5% of its GDP, which translates to about R30 billion (about $4.2 billion U.S.). There are other aspects, apart from the financial and economic impacts which cannot be measured in any accurate and tangible terms, namely the strain of the loss of a family member, particularly if the worker was the only family breadwinner [3].

Typically, construction organizations do not accurately and comprehensively track or calculate the actual costs associated with occupational accidents. When the costs are tracked, they usually do not include the costs related to schedule delays, added administrative time, lower morale, increased absenteeism, and poor customer relations. These indirect costs are not, *prima facie,* so obvious.

2. DIRECT AND INDIRECT COSTS

The costs of accidents can be categorised into direct and indirect costs [4]. Various direct and indirect costs are associated with any accident and the extent of these varies with the severity of the consequences of an accident. Severity can range from minor accidents involving little or no absence from work to fatalities.

Direct Costs

Direct costs tend to be those associated with the treatment of the injury arising from the accident and any unique compensation offered to workers as a consequence of being injured. These easily-identified expenses are known as the ‘direct costs’ associated with accidents.

The direct costs are by and large covered by workmens’ compensation insurance. Further, historical records can be reviewed to determine the expenditure attributed to each particular injury. Most of these costs are covered by workers' compensation insurance, such as medical expenses, lost wages, sick leave administration, temporary disability payments and hospitalization. However, others must be covered by the business itself. What may initially be classified as an inconsequential or minor accident, can prove to be immensely costly in terms of indirect costs.

Indirect Costs

Less evident expenses associated with accidents are known as "indirect" or "hidden" costs and can typically be several times greater than the value of the direct costs. According to Levitt & Samelson (1993) indirect costs include:

- reduced productivity for both the injured worker(s) upon returning to work and the crew or workforce;
- clean-up costs;
- replacement costs;
- stand-by costs;
- cost of overtime;
- administrative costs;
- replacement worker orientation;
- costs resulting from delays;
- supervision costs;
- costs related to rescheduling;
- transportation; and
- wages paid while the injured is idle.

The indirect or hidden costs usually exceed the direct costs. Indirect cost data is considerably more difficult to access than direct costs because the information is not often captured or quantified as it accrues. When estimates of indirect costs are made, it is common for the records to be either inaccurate or incomplete or both. Research conducted by the University of Washington (Hinze, 1992) determined the indirect costs (excluding claims and material damage costs) to be more than 1.67 times the direct costs of accidents [6]. Other studies suggest that the ratio between direct costs and indirect costs varies widely, from a high of 1:20 to a low of 1:1 [7]. Research conducted in South Africa determined the indirect costs to be 14.2 times the direct costs (Smallwood, 2000).

These costs are usually several times greater than the insured or direct costs. An iceberg graphically reflects the relationship between direct and indirect costs. The costs recoverable through insurance are visible but hidden beneath the surface are the uninsured or indirect costs. Like an iceberg, most of the costs are not immediately visible. Estimated ratios of direct to indirect costs from previous studies range from less than 1:1 to 1:36. A conservative estimate for the ratio is 1:2, although several authorities use a 1:4 ratio in calculating total costs of injuries related to accidents [8].

Examples of indirect costs that are usually not covered by insurance include:

- Overtime costs
- Time lost by injured employee
- Idle workers lost time
- Remedial work/correction
- Injured employee's productivity loss costs
- Supervision and management lost time
- Incident investigation costs

- Production loss and process delays
- Transportation costs
- Training of replacement employee(s)
- Additional medical costs
- Damage to equipment, plant, tools, or other property
- Idle plant and equipment
- Legal expenses
- Reduced morale
- Overhead cost borne by injured employee/family
- Negative image
- Funeral Costs; and
- Other (including pain & suffering)

These indirect costs, which are often overlooked, have been found to be quite detrimental to the overall performance of the business. It is important to note that there is no definitive or ultimate list of cost factors that can be employed to completely determine all indirect costs relative to accidents.

Impact of severity on cost

The costs associated with construction-related accidents can vary radically depending on the severity of the consequences of the accident and other influencing conditions. Severity can range from minor accidents involving little or no absence from work to fatalities. The more severe the accident the longer the time typically required to recover and return to normal occupational duties. Consequently, the associated costs are much higher. The more intensive the medical treatment required the higher will be the costs associated with the accident.

3. RESEARCH

In an attempt to determine the cost of construction accidents, a comprehensive review of construction related accidents was conducted within a major construction organization with a five-year construction volume in excess of R150 billion ($25 billion U.S.).

The number of accidents reported during the period of 2 April 2006 to 31 December 2008 was 710 (see Table 1). For the purposes of this exploratory study, 15 construction related accidents were randomly selected of which only five accidents were analyzed for this paper. Limitations may however exist due to the relatively small sample that was measured.

Analysis of the records highlighted the dominant prevalence of three categories of accidents, namely

1. accidents involving persons cut or caught in/between;
2. being struck by or against; and
3. falls.

Consequences ranged from fatalities to severe lost time and major medical treatment.

The South African Compensation Commissioner predetermines the approximate costs for the following types of accidents, namely [8].

Fatality	R1.500,000
Lost Time Accident	R30,000
Medical Treatment	R3,500
First Aid Treatment	R1,000

In Table 2 these estimated claim costs are used where actual costs were not available at the time the accident report was concluded. It is evident that investigation costs, irrespective of the nature of the accident, are a major cost item. Given this finding, it is imperative that the funds are spent judiciously by ensuring that an accurate and comprehensive record of costs is kept and maintained.

Of particular interest to this study is the ratio of indirect costs to direct costs despite the incompleteness of the cost records when compared with the lists of items produced from the literature.

Table 1: Total number of construction-related for 2006/2007

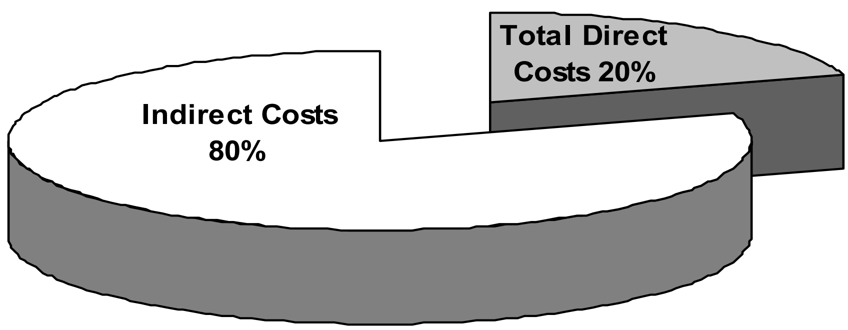
Nature of Incident	Number per type of Injury Classification					TOTAL No. of Incident Type	% of Incident Type	Cumulative sum of the %
	Fatalities	LTI's	Occupational diseases	Medicals	First Aids			
Cut or Caught in / between / on	0	32	0	113	50	**195**	27.46	27.46
Struck by / against	0	27	0	64	48	**139**	19.58	47.04
Fall (same level)	0	22	0	51	13	**86**	12.11	59.15
Vehicle Accident - Motor	11	15	0	50	2	**78**	10.99	70.14
Over Stress (over exertion, ergonomics...)	0	5	0	31	4	**40**	5.63	75.77
Fall (different level)	1	13	0	11	9	**34**	4.79	80.56
Foreign Body	0	1	0	19	14	**34**	4.79	85.35
Rigging / Lifting Equipment	0	7	0	13	3	**23**	3.24	88.59
Falling Object	1	3	0	7	10	**21**	2.96	91.54
Occupational Hygiene Agencies	0	0	5	5	2	**12**	1.69	93.24
Contact - Electrical	0	4	0	4	1	**9**	1.27	94.501
Explosion / Fire / Burn	0	2	0	1	6	**9**	1.27	95.77
Animal / Insect Bite	0	1	0	6	1	**8**	1.13	96.90
Plant / Equipment / Structural Failure	2	3	0	2		**7**	0.99	97.89
Mobile / Moving Equipment (cranes, forklifts, …)	0	0	0	2	2	**4**	0.56	98.45
Contact - Environmental	1	0	0	0	2	**3**	0.42	98.87
Vehicle Accident - Construction	0	1	0	1	1	**3**	0.42	99.30
Obstacle / Hazard / Housekeeping	0	0	0	1	1	**2**	0.28	99.58
Unlawful Acts (fraud, theft, vandalism, assault, ...)	1	1	0	0	0	**2**	0.28	99.86
Handling (lifting, pulling, pushing)	0	0	0	1	0	**1**	0.14	100.00
total no of injury classifications	**17**	**137**	**5**	**382**	**169**	**710**	100.00	

Table 2: Direct and Indirect costs of sample accidents

Cost Category	Accident Report Number: i-2007-7-1208 — Accident Cause: Struck Against(Rib Cage)	%	i-2007-7-1214 — Struck By (Fracture)	%	i-2007-7-1230 — Fall (Fatality)	%	i-2007-8-1257 — Caught In (Dislocated shoulder)	%	i-2007-9-1601 — Struck by (Fracture)	%	Total Costs	%
Direct												
Medical (ambulance, doctor, medication, hospital)	800	66.7%	1700	48.6%			3450	41.8%	1850	27.8%	7800	1.50%
Wages for injured person/s	400	33.3%	1800	51.4%	500000	100.0%	4800	58.2%	4800	72.2%	511800	98.50%
Direct Costs (Rands)	1200		3500		500000		8250		6650		519600	100.00%
Indirect												
Overtime costs	600	1.7%	1800	4.7%	6000	0.3%	4800	6.6%	4800	10.7%	18000	0.9%
Time lost by injured employee	1250	3.6%	1600	4.1%	60000	3.2%	2700	3.7%	1100	2.5%	66650	3.2%
Idle workers lost time	900	2.6%	450	1.2%	3000	0.2%	1200	1.6%	650	1.5%	6200	0.3%
Remedial work/Correction	400	1.1%	400	1.0%	32000	1.7%	2000	2.7%	400	0.9%	35200	1.7%
Injured employee's productivity loss costs	2300	6.5%	1350	3.5%	12500	0.7%	2600	3.6%	2200	4.9%	20950	1.0%
Supervision & Management lost time	2600	7.4%	4800	12.4%	34600	1.8%	4800	6.6%	6800	15.2%	53600	2.6%
Incident investigation costs	12500	35.5%	14700	38.1%	198500	10.6%	19300	26.5%	15600	34.9%	260600	12.6%
Production loss and process delays	2600	7.4%	3000	7.8%	148000	7.9%	18000	24.7%	2400	5.4%	174000	8.4%
Transportation costs	280	0.8%	600	1.6%	6700	0.4%	540	0.7%	400	0.9%	8520	0.4%
Training of replacement employee	450	1.3%	600	1.6%	2750	0.1%	670	0.9%	550	1.2%	5020	0.2%
Additional medical costs	200	0.6%	0	0.0%	250	0.0%	450	0.6%	150	0.3%	1050	0.1%
Damage to equipment, plant, tools, or other property.	700	2.0%	400	1.0%	600	0.0%	1200	1.6%	550	1.2%	3450	0.2%
Idle plant and equipment	250	0.7%	750	1.9%	27000	1.4%	4500	6.2%	300	0.7%	32800	1.6%
Legal expenses	0	0.0%	0	0.0%	44000	2.3%	0	0.0%	0	0.0%	44000	2.1%
Reduced morale	1250	3.6%	1400	3.6%	18000	1.0%	1500	2.1%	1300	2.9%	23450	1.1%
Overhead cost borne by injured employee/family	2700	7.7%	2650	6.9%	17000	0.9%	2400	3.3%	2100	4.7%	26850	1.3%
Negative image	0	0.0%	0	0.0%	63000	3.4%	0	0.0%	0	0.0%	63000	3.0%
Funeral Costs	0	0.0%	0	0.0%	27000	1.4%	0	0.0%	0	0.0%	27000	1.3%
Other (including pain & suffering)	6200	17.6%	4100	10.6%	1178000	62.7%	6200	8.5%	5400	12.1%	1199900	58.0%
Total Indirect Costs (Rands)	**35180**	100.0%	**38600**	100.0%	**1878900**	100.0%	**72860**	100.0%	**44700**	100.0%	**2070240**	100.0%
Total cost	**36380**		**42100**		**2378900**		**81110**		**51350**		**2589840**	
Ratio of Direct: Indirect costs	**1:29**		**1:11**		**1:4**		**1:9**		**1:7**		**1:4**	

The study explicitly established that those indirect costs relating to other costs which include pain and suffering (58%), incident investigations (12.6%) and production loss and process delays (8.4%) are the foremost construction accident expenses with the utmost financial impact.

Diagram 1: Chart illustrating the disparity between the direct and indirect costs



A distinctive finding from this study demonstrates the substantial disparity between the direct and indirect costs relative to construction accidents.

5. CONCLUSION

The findings of this exploratory study suggest that a comprehensive analysis of the cost of accidents is necessary for any organization to completely understand the broad implications of accidents. Such an analysis will enhance the prospects of an improved allocation of resources to proactive strategic health and safety interventions that will prevent accidents from occurring. However, to achieve this objective all costs need to be captured and recorded. Clearly there is an obvious need to develop a new approach to conducting accident investigations and the recording of essential data.

This preliminary study has confirmed that indirect costs exceed direct costs of accidents. Further, several costs were not recorded suggesting that the overall costs are even greater given their incompleteness and lack of accuracy. The authors argue that these costs in reality represent only a portion of the costs that are beneath the figurative "tip of the iceberg".

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CONSTRUCTION ACCIDENT CAUSATION: AN EXPLORATORY ANALYSIS

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ABSTRACT

The construction sector has poor health and safety performance in most countries. Accidents occur in almost all construction related activities. These accidents are multi-causal in nature with combinations of factors needing to coincide to give rise to an incident. This study is premised on the principle that all accidents are preventable and reviews several of the existing causation theories. A sample of accidents drawn from the records of a multi-national/parastatal organisation was examined to determine their recorded causes. These were compared against the theories reviewed. The findings suggest that the true cause of the accidents are incorrectly recorded, requiring a possible revision of the instrument used for investigation and recordkeeping.

Keywords: Causation, Construction, Accident, Theories, Prevention, Investigations

1. INTRODUCTION

Many recent accidents involving loss of life and limb have occurred on construction sites around South Africa. These have created negative impressions of the industry and sector (Haupt and Smallwood, 2005). Construction represents ‘a challenging regime in which to manage health and safety’ (HSE, 2001) and includes enormous diversity in terms of the size and range of its activities. Construction activities occur in a hazardous environment with direct exposure to many hazards.

Compared to relatively stable manufacturing or retail environments, construction projects involve constant change. Consequently, legislators battle to legislate for the enormous variations in the nature of construction projects. It is expected that unitary health and safety regulations apply generically across the entire industry, from domestic extensions to major infrastructure projects. The widespread use of sub-contractors and self-employed workers creates a situation where multiple approaches to health and safety exist on the same site, resulting in a ‘complex communication chain’ (HSE, 2001). One of the greatest problems faced by those responsible for the overall management of a project is the need to integrate a wide variety of contractor 'styles' within the overall project.

The findings of a recent study in South Africa during which 252 industry stakeholders were surveyed indicated a need for the following:

- Endeavors to enhance the health and safety culture of the industry; and
- The realization that all accidents can be prevented (Smallwood and Haupt, 2004).

There are a number of theories relative to the causation of accidents on construction sites. Despite these theories and others, accidents have continued unabated. Typically, these theories have focused on the construction worker as being the primary cause of accidents – a basic tenet of the behavioural safety approach espoused by Geller, Krause and others.

Emphasis on individual failures 'results in a reliance on short term solutions rather than any attempt to uncover more fundamental management or organisational problems' (Whittington et al, 1992). The remedy targets a specific event or operative, such that no effort is made to uncover the underlying cause of the accident. HSE research (2001) observes that 'changes at the direct level alone will not deliver the degree of change being sought, nor would the improvement be sustained'.

Accidents are preventable and should be regarded as failures of management. None of the theories comprehensively address these issues. However, in line with the modern accident theory, the aim of organisations should be to shift the emphasis from errors on the part of the individual to the management and organisational errors that cause poor health and safety performance.

2. THEORIES OF CAUSATION

There are a number of accident causation theories, which Hinze (1997) refers to, that relate to construction sites which are typically regarded as dangerous and hazardous. These include, *inter alia*:

a) Accident Proneness Theory

There are 2 views, namely an old and new view.

Old view: Injuries happen to people who have a genetic predisposition to being injured. This suggests that certain individuals have inherent characteristics that predispose them to a greater probability of being involved in accidents.

New view: Accident proneness is being increasingly viewed as being associated with the propensity of individuals to take risks or to take chances. This view is more positive for health and safety, given that behaviour can be altered.

This theory focuses on personal factors related to accident causation and is based on the assumption that when many persons are placed in similar working conditions some would be more likely than others to sustain an injury suggesting that accidents are not randomly distributed.

b) Goals-Freedom-Alertness Theory

This theory suggests that accidents are the result of unsafe behavior resulting from an unrewarding psychological climate that does not contribute to mental alertness. Accidents are therefore attributed to low-quality work behaviour occurring in an unrewarding psychological environment.

c) Adjustment Stress Theory

Any complications or negative stresses imposed on an individual either by the internal environment (e.g. fatigue; lack of sleep; or psychological stresses such as worry, personal problems) or by the external environment (e.g. noise; temperature; excessive physical strain) will increase accident occurrence. If the worker cannot adjust to the stress, the chance of injury is increased.

d) Chain of events (Domino theory)

This theory is not truly a theory of accident causation, but is often referred to as one. It is based on accidents being characterized as occurrences that result from a series of events which are all linked in that each event is followed by yet another event. It is really a conceptual portrayal of how accidents occur. The chain of events states that there is not a single cause of an accident but rather many causes.

In general, every accident is preceded by a series of events or activities. If any one event or activity had been done differently, the accident would not have occurred ("break the chain to avoid the accident"). Different people may be associated with the different links in the chain. There are many links in the chain and only one link needs to be broken to prevent an accident.

e) Distractions Theory

The Distractions Theory suggests that health and safety is situational, namely that workers perform tasks in an environment that is known to be hazardous. This theory states that accidents are caused when workers are distracted when they are performing their work tasks. There are two types of distractions:

i) Jobsite Hazards - Workers will try to avoid being injured. They will naturally focus on the hazard. Pressure to get the task done may cause the worker to be distracted and to ignore the hazard, resulting in an injury – Figure 1.

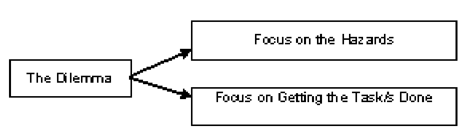


Figure 1: Distractions Theory – Jobsite Hazards

ii) Mental worries - Workers will try to focus on the work to be done, but may be distracted by worries caused by personal or job-related concerns. Failure to be able to focus on the work increases the likelihood of being injured.

More modern accident theories have shifted the emphasis from errors on the part of the individual to the management and organisational errors that cause poor health and safety performance. There are 2 of these theories (HSA, 2002), namely:

f) <u>Reason's Framework for Accident Causation</u>

Professor James Reason at the University of Manchester developed a theory of accident causation that spans the entire accident sequence from organisational to individual levels. The theory follows modern trends in seeking causal factors that are removed in both time and space from the onset of the incident. Previously, accident investigations tended to highlight the role of the frontline operator as the most obvious and immediate instigator of the accident. Accidents in the construction industry are particularly prone to such interpretations – incidents regularly occur to individuals acting alone. Reason's theory incorporates an organisational level analysis that takes into account the input of management and decision-makers.

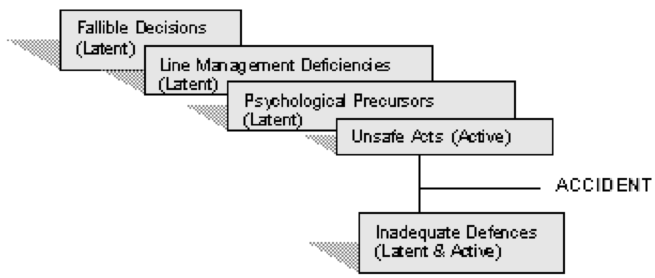


Figure 2: James Reason (1990) – Accident Causation Model

The model divides active and latent failures. Active failures are "those errors and violations that have an immediate adverse effect. These are generally associated with the activities of 'front-line' operators" (Reason 1990) which correspond to the activities of construction personnel on-site such as driving into contact with overhead power lines or failure to wear PPE. Many health and safety interventions aim at the level of the general operative e.g. programmes to encourage the wearing of hard hats or instituting health check campaigns. However, there are an infinite number of unsafe acts that can precipitate accidents on a construction site – "the vast majority of them are unforeseeable and occasionally quite bizarre" (Reason, 1990). Attempts to reduce the number of unsafe acts can only have limited value. It would be more beneficial to aim at the level of latent failures.

Latent failures correspond to errors at the Head Office and Site Management levels. They are "decisions or actions, the damaging consequences of which may lie dormant for a long time, only becoming evident when they combine with local triggering factors.

Their defining feature is that they were present in the system well before the onset of a recognisable accident sequence" (Reason 1990). Research by the HSE (1992) found that many of the preconditions of unsafe behaviour originate in poor management decisions or an organisational culture in which health and safety goals may be considered subordinate to production goals. This research also noted that "violations are known to occur more frequently in situations where responsibilities are ambiguous or ill-defined, training poor and time pressures high – not atypical conditions for the construction industry."

g) Constraint-Response Theory

Suraji, Duff and Peckitt (2001) of University of Manchester Institute of Science and Technology (UMIST) and the Health and Safety Executive in the UK, developed a causal model specific to construction accidents. They cite Reason's model as a theoretical description but note the lack of specific detail necessary to guide practical investigation and intervention – "the effective mitigation of causal factors requires better knowledge of which factors are most influential, who may reasonably be expected to control those factors and how such control may most effectively be achieved" (Suraji, Duff and Peckitt, 2001).

Similar to Reason's model, the Constraint-Response Model extends the scope of the accident causation process to include management and organisational aspects. The model classifies two types of factors – distal and proximal, equivalent to latent and active failures in Reason's configuration – see Figure 3.

Distal factors are at management level and include
- Project conception restraints;
- Project design constraints; and
- Project management constraints

Proximal factors operate at site management and injured person levels and include
- Inappropriate construction planning;
- Inappropriate construction control;
- Inappropriate site condition;
- Inappropriate construction operation; and
- Inappropriate operative action

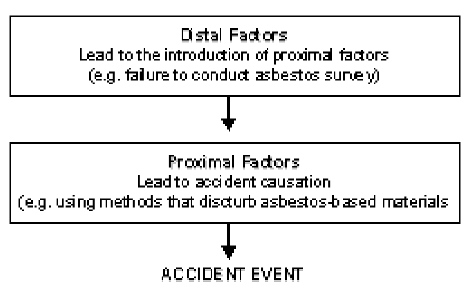


Figure 3: Suraji, et al. (2001) – Accident Causation Model

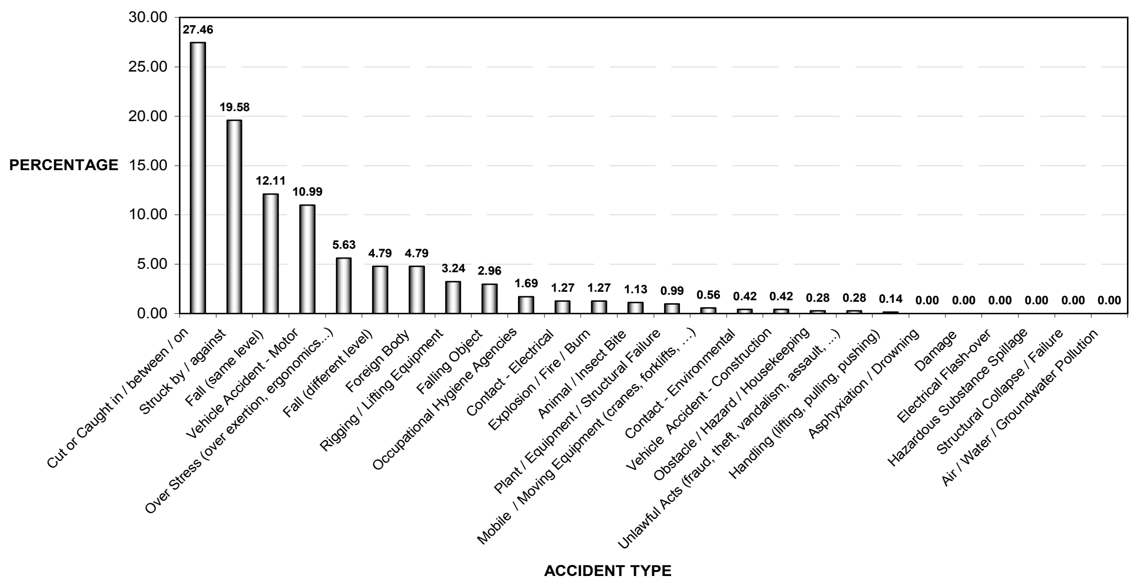
The premise of the theory is that each participant experiences **constraints** on their activity such as a client facing difficulties in obtaining funding. The **responses** to these constraints in turn create a set of constraints for subsequent participants. For example, a client may reduce the project budget such that the designer is constrained by inadequate design budget. The designer may respond by reducing the design resources for the contract. The project management team may in turn be constrained by the late delivery of the design detail, and so on throughout the project chain. The sequence of constraints and responses ultimately create situations where the proximal factors are manifest such as 'unsuitable existing topography' (inappropriate site conditions) or inadequate supervision of operative work (inappropriate construction control).

Both theories offer a framework in which to locate the contributory factors that may be identified in this exploratory study. They represent a systemic approach to identifying the underlying causes of accidents, taking into account decisions and actions upstream of the accident event. The models also facilitate the description of accidents with multiple causes at various levels. While Reason (1990) presents a generic model, Suraji et al (2001) have tailored the model to include actors and conditions relevant to the construction sector.

3. RESEARCH DESIGN

A comprehensive review of construction related accidents was done using the accident database of one of the divisions within a large energy utility in Southern Africa, where major capital expansion is being undertaken, of approximately 150 billion ZAR (about $25 billion) over the next 5 years.

The period of review was 1 April 2006 to 21 December 2007, where 1321 accidents (first aid, medical and lost time incidents) were reported and recorded. Graph 1 illustrates the distribution of the various types of accidents that have occurred during this period. A random sample was then drawn using systematic random sampling, where an accident was randomly chosen and then every 15th accident was selected in order to obtain 10 accidents for selection and analysis for this exploratory study.



Graph 1: Different Types of Construction Related Accidents from 1 April 2006 – 31 December 2007

4. FINDINGS AND DISCUSSION

The final 10 selected accidents for this study were analysed in terms of the actual causes identified and recorded during their investigation, namely immediate, contributory and root causes and then the analysis was compared to the seven theories of causation, previously described. The theories were annotated as shown in Table 1 for easy reference and comparison.

Table 1: Annotation of Theories of Causation

Theory	Focus In Terms of Accident Causation	Annotation
Accident Proneness Theory	On the worker	**A**
Goals-Freedom-Alertness Theory	On the worker	**B**
Adjustment Stress Theory	On the worker	**C**
Chain of events (Domino theory)	On the worker	**D**
Distractions Theory	On the worker	**E**

Reason's Framework for Accident Causation	**Active Failures** - associated with the activities of the 'front-line' operators	$\mathbf{F^A}$
	Latent Failures - associated with Head Office and Site Management levels	$\mathbf{F^L}$
Constraint-Response Theory	**Distal factors** are at management level and include Project conception restraints; Project design and Project management constraints;	$\mathbf{G^D}$
	Proximal factors operate at site management and injured person levels	$\mathbf{G^P}$

The comparison of causes is indicated in Tables 2 and 3.

Table 2: Comparison of the Causes of 10 Randomly Selected Construction Accidents to the Various Causation Theories

Accident No.	Accident Description	Construction Accident Data – Actual Causes Identified from Investigation Reports		
		Direct Cause/s	**Contributory Cause/s**	**Root Cause/s**
1	Construction of Transmission tower. Injured worker was using a size 30 spanner to tighten bolts on the monopole (T186/187) for the attachment of ladder units, when the spanner he was working with snapped and he fell forward onto the structure and his ribs struck one of the extended bolts of the ladder unit causing bruising of the ribs and pain.	1] Incorrect/inadequate tool **(D; F^A;G^P)**	1] Lighting **(D; F^A;G^P)** 2] Visibility **(D; F^A;G^P)** 3] Footing **(D; F^A;G^P)** 4] Ventilation **(D; F^A;G^P)** 5] Temperature **(D; F^A;G^P)** 6] Noise level **(D; F^A;G^P)** 7] Clearances **(D; F^A;G^P)**	1] Failure of a hand tool **(D; F^A;G^P)**
2	The injured worker was busy breaking down a concrete plinth with a jack-hammer. In the concrete there were three steel reinforcing rods standing upright. The jack-hammer slipped from the area where the injured worker	1] Jackhammer slipped **(D; F^A; G^P)** 2] Reinforcing was in the way when the jackhammer slipped	None identified	1] Inadequate risk analysis conducted **(D; F^A;G^P)** 2] Inadequate method statement **(D;**

Accident No	Accident Description	Construction Accident Data – Actual Causes Identified from Investigation Reports		
		Direct Cause/s	Contributory Cause/s	Root Cause/s
	was breaking, causing his left hand ring finger to be caught between the jack hammer and the steel reinforcing.	and lodged his hand between the jackhammer and the reinforcing causing the fracture **(D; F^A; G^P)**		**F^A;G^P)** 3] No proof of training for use of jackhammer **(D; F^L;G^P)**
3	The injured worker and workers A and B were in the process of inserting a drill rod (4.2m long) into one of the booms of a 2 boom Seco Drill Rig. While the injured worker and worker A were feeding the drill rod through the guides and as the end of the rod approached the Drifter (Chuck), worker B engaged the Drifter, as this would have locked onto the rod and the rod would commence rotation. Worker B shouted, "stop" assuming that the injured worker and worker B will stop pushing the rod and stand clear, which worker A did do, however the injured stopped pushing the rod, but still held on to the rod. As the rod started rotating, the injured's glove became snagged on the rod and he shouted, but before worker B could disengage the Drifter, the injured worker's arm had been twisted to such an extent that his shoulder was dislocated.	1] Arm lodged in moving machinery **(D; F^A;G^P)**	1] Deviation by individuals **(A; D; F^L; G^P)** 2] Improper position or posture for the task **(D; F^L;G^P)** 3] Failure to warn/make safe **(D; F^L;G^P)**	1] Inadequate identification of critical safe behaviours **(D; F^L;G^P)** 2] Misunderstood instructions **(B; D; F^L;G^P)** 3] Poor judgement **(B; D; F^L;G^P)** 4] Inadequate identification of job hazards **(D; F^A; G^P)** 5] Standard terminology not used **(D; F^A; G^P)** 6] Inadequate horizontal communication between peers **(D; F^A; G^P)**
4	While pulling down on the damper blade, the Fitter pushed against the scaffold toe-board with his one foot to support himself, causing the kick-plate to dislodge and fall down, landing on the injured' left foot, causing a fracture.	1] A falling scaffold toe board **(D; F^A; G^P)**	None identified	1] Hazards not identified correctly by scaffold builders and Contractors personnel as far as the scaffold is concerned **(D; F^A;G^P)** 2] Contractor personnel did not

Accident No.	Accident Description	Construction Accident Data – Actual Causes Identified from Investigation Reports		
		Direct Cause/s	**Contributory Cause/s**	**Root Cause/s**
				utilise the correct equipment that was freely available **(D; F^A;G^P)** 3] Supervision is inadequate / incapable due to substandard discipline amongst the crew **(D; F^L;G^P)**
5	The injured worker was part of a team working on the Boiler steam drum refurbishment. On the specific morning this team was instructed to perform housekeeping tasks to clean the area where they were working. In the process of moving some of the baffle plates, to stack it next to a work bench, the injured worker stepped on top of previously stacked material. (Uneven plates with protruding steel brackets.) As he stepped away from the stack of plates his foot got caught on one of the protruding brackets and he fell on the floor (grating). He twisted his ankle causing him to collapse and hit his hip on one of the protruding flanges. He sustained a fractured hip.	1] Improper stacking. The injured did not adhere to proper stacking process and procedures **(A; D; F^A;G^P)** 2] Improper positioning: Taking up unsafe position, the injured worker was fully aware of the protruding bracket from the baffle as he participated in the stacking process **(A; D; F^A;G^P)**	1] Hazardous arrangement or lay out - Poor stacking and housekeeping in working area **(D; F^A;G^P)** 2] Personal factors: There was a lack of concentration on the part of the injured. He did not comply with safety awareness	1] No proper risk assessment conducted before they could remove the steel material **(D; F^A;G^P)** 2] Inadequate supervision: The supervisor failed to respond to the Client's request to stack steel material and barricade area two weeks prior to the incident **(D; F^L;G^P)**

Accident No	Accident Description	Construction Accident Data – Actual Causes Identified from Investigation Reports		
		Direct Cause/s	**Contributory Cause/s**	**Root Cause/s**
			by taking part in bad stacking practice **(A; B; D; F^A;G^P)**	
6	The injured worker who was conducting inspections, was standing on a scaffold platform at 46m level. The scaffold platform gave way, resulting in the worker falling through 4 platforms (where there was openings), approximately 12m, where he finally landed on the platform at 35m level.	1] Injured was not wearing safety harness **(A; D; F^A;G^P)** 2] No risk assessment **(D; F^A;G^P)** 3] Supervisor not there to supervise job **(D; F^L;G^P)**	1] No risk assessment (**D; F^A;G^P)** 2] No training on fall protection **(D; F^L;G^P)** 3] Insufficient lighting **(D; F^A;G^P)** 4] Modified scaffolding to install Spring supports on the main steams **(D; F^A;G^P)**	1] No supervisor on site to do site workplace risk assessment **(D; F^L;G^P)** 2] Unsafe scaffolding**(D; F^L;G^P)**; 3] Injured worker did not stop going up the scaffolding even though he could see that the scaffolding was unsafe **(D; F^A;G^P)**

Accident No.	Accident Description	Construction Accident Data – Actual Causes Identified from Investigation Reports		
		Direct Cause/s	Contributory Cause/s	Root Cause/s
7	The injured worker was inter-connecting a bank of eighteen 12 volt batteries under the direct supervision of his supervisor. Later in the day, 2 contractor employees from another company entered the battery room and asked the supervisor what they were doing. The injured worker, turned to greet the contractor employees and in doing so, touched an open terminal of another battery with the bare end of the interconnecting cable, thus creating a temporary short circuit across 6 batteries. The flash resulted in 1st degree burns of 2 fingers and 2nd degree burns of 3 fingers of his left hand.	1] Loss of concentration due to distraction **(A; B; D; E; F^A;G^P)** 2] Lack of adequate training in handling distractions **(D; F^A;G^P)** 3] Lack of sufficient experience **(D; F^A;G^P)**	None identified	1] Failure to secure work area **(D; F^A; G^P)**
8	While busy with the marking of the roof bolts at the exploratory tunnel for a pump storage scheme project, the Bolter Technician and a Team Leader were stuck by a rock (800mmx500mmx100mm) that came loose from the hanging wall, hitting the Bolter Technician on the head, and the Team Leader on his left shoulder.	None identified	1] The practice of examining misfires and sockets before the drilling of support holes **(D; F^A;G^P)** 2] Inadequate work standards **(D; F^L;G^P)** 3] Inadequate leadership and	1] Inadequate work standards – The current procedure requires the operator to make the hanging and the face safe, before marking of the roof bolts, forcing him to work under unsupported roof **(D; F^L;G^P)** 2] Inadequate Leadership and Supervision – The current system could not demonstrate that leadership is actively participating in the hazard identification and risk assessment process (Planned Task

Accident No.	Accident Description	Construction Accident Data – Actual Causes Identified from Investigation Reports		
		Direct Cause/s	**Contributory Cause/s**	**Root Cause/s**
			supervision **(D; F^L;G^P)**	Observation, the process of cleaning the face and barring process with the use of a TLB need to be assessed) **(D; F^L;G^P)**
9	Installation of a Latchway unit at a transmission tower: Worker A climbed up the tower and was followed by the injured worker. Worker A had to loosen the step bolt so that the bracket that holds the Latchway cable could be installed between the step bolt's nut and the member. Due to the way that the step bolts were tightened, by the previous team, worker A could only loosen the nut of the step by using a hammer. After the step bolts were loosened, worker A took one of the brackets out of his bag, for installation. As he removed the bracket, the hammer had caught onto the bracket in the bag. The hammer then fell and bounced off a lower step bolt and struck the injured worker in his left eye.	1] Taking unsafe position; **(A; D; F^A;G^P)** 2] Using unsafe equipment (Equipment was not attached to harness) **(D; F^A;G^P)**	None identified	1] Deviation from requirements **(D; F^A;G^P)** 2] Taking unsafe position **(A; D; F^A;G^P)** 3] Using unsafe equipment (equipment not attached to harness) **(D; F^A;G^P)**
10	The crew was busy rigging a clean gas chamber inside the precipitator into its final position. The chamber has a mass of 14.5 ton and was rigged by two 10 ton chain	1] Mechanical failure of chain block **(D; F^L;G^P)** 2] Inadequate Planning - The	1] Inadequate Planning	1] Inadequate Program Standards - The elements of the contractor

Accident No.	Accident Description	Construction Accident Data – Actual Causes Identified from Investigation Reports		
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	blocks which were hand operated by the crew. The crew consists of two teams of six people each who in turn operated the two chain blocks. The crew were standing on top of the clean gas chamber with their safety harnesses tied onto two 2, 5 ton electric hoists and crawls which are independent of the main structure. When the chamber was ±300mm from its final position, one of the chain blocks failed. The chain block that failed was in use for the first time after it was returned from a service provider where it had undergone servicing and a load test. The chamber fell and came to a standstill at an angle of ± 45°. The crew members were hanging from their safety harnesses and were lowered onto the chamber with the electric hoist. The most severe injury (compound fracture of the arm), was sustained by the person operating the chain block at the time of the failure. The rest of the injuries were sustained as the sudden (violent) movement of the falling chamber caused the people to pendulum swing from their harness lanyards, bringing them into contact with surrounding structures such as hand railing and scaffolding.	possibility of a chain block failing under these rigging conditions was very remote. Yet, the fact that people were required to work on top of a structure being lifted, the "What If' test could have been applied and back-up safety measures could have been in place**(D; F^L;G^P)** 3] Inadequate Design and Inadequate Maintenance - Although this was the 3rd clean gas chamber to be installed at this project, this whole operation was new to the contractor and they had no "lessons from the past" to guide them as to possible pitfalls **(D; F^L; G^D)**	**(D; F^L;G^P)** 2] Inadequate Job Analysis **(D; F^L;G^P)** 3] Inadequate Job Observation **(D; F^L;G^P)**	S.H.E plan such as risk assessments, method statements, and training etc is of an acceptable standard. The programme however does not cover items such as managing change and new tasks / jobs **(D; F^L; G^D)**

Table 3: Total number of Causation Theories per Type of Cause

	Causation Theories									
	A	B	C	D	E	F^A	F^L	G^D	G^P	**Total No. of Causes**
Direct Cause Number	5	1	0	17	1	14	4	1	17	**18**
Contributory Cause Number	2	1	0	22	1	16	6	0	22	**22**
Root Cause Number	1	2	0	25	0	16	9	1	24	**25**
Overall Total No. per Theory	8	4	0	64	2	46	19	2	63	**65**

It can be noted from Table 3, above, that out of a total of 65 causes, the following theories ranked, from highest to lowest: D, G^P, F^A, F^L, A, B, E, G^D, C. However, with specific focus on root causes, as it these causes that corrective active action are based on so as to avoid repeat accidents, the following theories ranked from highest to lowest: D, G^P, F^A, F^L, B, A, G^D, C, E.

An interesting observation can be seen with reference to Table 1, where theories A, B, C, D, E, F^A, and G^P are focused on the worker in terms of causation of accidents, with exception of theory G^P, whose focus ranges from worker to site management. Theories F^L and G^D focus on causal factors upstream of the project lifecycle model and failures at head office/site management. The findings in Tables 2 and 3 suggest that the accident investigators have categorised the causes of most of the accidents in terms of the worker being the agent. Further, there is no recorded evidence of management or organisational contribution. Rather, the “trigger event” is analysed.

Given that the intent of any accident investigation should be to prevent its recurrence, all root causes need to be investigated. Clearly the present system of accident investigation and recordkeeping focuses on the downstream event or the last domino in the chain. Arguably, this approach by only addressing the final trigger event will not prevent repeat accidents from occurring.

The authors argue, based on the evidence, that behavioural health and safety interventions, as part of a safety, health and environmental management system, would not necessarily prevent accidents. Rather they might reduce accidents but not prevent them. Considering that the ultimate goal for any construction stakeholder is to strive for zero accidents, any approach which does not prevent accidents is seriously flawed.

5. CONCLUSION

The findings suggest that the true causes of accidents are incorrectly recorded. Consequently it is likely that remedial interventions could be misdirected and as a result fail to prevent their reoccurrence. Therefore, a new approach to investigation is required. Possible restructuring of the investigation team and revision of the instrument used for investigation and recordkeeping are consideration for a new approach.

In line with modern theories of accident causation, which emphasise the importance of factors upstream of the accident event, it is proposed that future legislation and campaigns should focus on events and decisions made at the management level. The causes of failures suggest that remedial action at the early phases of a project lifecycle model could pre-empt errors further along the project lifecycle.

Time and thought invested at the start of a project lifecycle model, according to the HSE (2006), will pay dividends not only in health and safety, but also in:

a) reductions in the overall cost of ownership;
b) reduced delays;
c) more reliable costings and completion dates;
d) improved communication and co-operation between key parties; and
e) improved quality of the finished product.

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SAFETY ISSUES

9

CONSTRUCTION HEALTH AND SAFETY PERFORMANCE IN DEVELOPING AND DEVELOPED COUNTRIES: A PARALLEL STUDY IN SOUTH AFRICA AND SINGAPORE

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ABSTRACT

According to relevant literature, the difference in accident rates between developed and developing countries is remarkable. This disparity of construction health and safety performance between developing and developed countries prompted the research team to examine the underlying causes for such a disparity. This study was initiated by the Southern African Built Environment Research Center to examine (1) the construction health and safety practices adopted by construction practitioners in both developing and developed countries, and (2) the sources of the disparity of construction health and safety performance between developing and developed countries. To achieve these aims, parallel surveys were conducted in South Africa (SA) and Singapore. Singapore was chosen because of its improved health and safety performance and the recent review of its health and safety regulatory framework. The results show that there are significant differences both in people's perceptions of construction site health and safety and in the frequency of various types of accidents between the two nations. The findings of this study have practical impacts on enhancing health and safety performances for developing countries. It is timely to ascertain the disparity of construction health and safety performance between SA and Singapore given that the construction regulations of SA are currently under review so as to achieve improved health and safety performances.

Keywords: Construction health and safety; Safety climate; Safety performance

1. INTRODUCTION

Although the field of occupational health and safety has always been a focus of academic research, only a few researchers have investigated or compared the occupational health and safety performance or approaches between developing and developed countries (King and Hudson 1985; Suazo and Jaselskis 1993; Koehn et al. 1995; Hamalainen et al. 2006). As shown in Table 1, the disparity in occupational accident rates between different regions is remarkable (Hamalainen et al. 2006). Regions in Table 1 were divided by using the World Bank divisions (The World Bank Group 2001). Both the fatality rates and the accident rates in Other Asia and Islands (21.5 and 16434 per 100 000 workers respectively) and Sub-Saharan Africa (21 and 16012 per 100 000 workers respectively), which consist mainly of developing countries, are much higher than that of Established Market Economies (4.2 and 3240 per 100 000 workers), which consists of developed countries.

Table 1 Occupational accidents by regions

Region	Fatality rate (per 100 000 workers)	Accident rate (per 100 000 workers)
EME [1]	4.2	3240
FSE [2]	12.9	9864
OIA [3]	21.5	16434
SSA [4]	21.0	16012
LAC [5]	17.2	13192
MEC [6]	18.6	14218
Singapore	9.8	7452
South Africa	19.2	14626

[1] Established Market Economics; [2] Former Socialistic Economies; [3] Other Asia and Islands (excluding China and India); [4] Sub-Saharan Africa (Including South Africa); [5] Latin America and the Caribbean; [6] Middle Eastern Crescent.

Source: Hamalainen et al. (2006)

Construction projects and activities by their nature are characterized by high risk of exposure to hazards. According to King and Hudson (1985), there are three times as many fatalities on construction sites in developing countries than in industrialized ones. They attributed this disparity partly to the weak regulatory systems in developing countries. This viewpoint was further supported by the research of Suazo and Jaselskis (1993) through their in-depth comparison of construction health and safety codes in the United States and Honduras. Koehn et al. (1995) compared the approach towards construction health and safety in a developed country, namely the United States, and a typical developing country, namely India. Lack of health and safety training, management commitment, and various health and safety procedures and insufficient health and safety rules and regulations were identified as the main causes leading to the poorer health and safety performance in developing countries such as India (Koehn 1995).

Generally, there is a lack of comprehensive analysis of the underlying causes of the difference in construction health and safety performance between developing and developed countries. This study was initiated by the Southern African Built Environment Research Center with the purpose of examining the sources of such a disparity. The objectives of this research are to investigate (1) the construction health and safety practices adopted by construction practitioners in both developing and developed countries, and (2) the sources of the disparity of construction health and safety performance between developing and developed countries. To achieve these aims, parallel surveys were conducted in South Africa and Singapore. Singapore was chosen because of its improved health and safety performance and the recent review of its health and safety regulatory framework. As indicated in Table 1, both the accident and the fatality rates in South Africa (19.2 and 14626 per 100 000 workers respectively) are significantly higher than those of Singapore (9.8 and 7452 per 100 000 workers respectively). It is timely to identify the sources of the disparity in construction health and safety performance between SA and Singapore given that the construction regulations of SA are currently under review so as to achieve improved health and safety performance across the construction sector.

2. MEASUREMENT OF CONSTRUCTION HEALTH AND SAFETY PERFORMANCE

Health and safety performance can be used by owners to compare health and safety performance of different organizations to assess which organization has a better health and safety record. It also allows comparison of health and safety performance between projects and can also be used by organizations internally to maintain line accountability for health and safety and to pin point problem areas. Health and safety performance can be broadly classified into two groups which are lagging indicators like accident rates and leading indicators like measurement of health and safety climate (Flin et al. 2000).

The research of Teo and Fang (2006) clearly demonstrates that the players in the construction industry are aware that historic and statistical data do not accurately reflect health and safety performance. The results of their research have shown the importance of leading indicators over lagging indicators to measure a construction organisations expected health and safety performance. The advantage of using health and safety climate is that actions can be taken to alter the course of health and safety performance if an indicator predicts poor performance, for example, changes can be implemented to increase the probability of good health and safety performance (Hinze, 1997; Fang et al, 2001).

Accident frequency rate, however, is still considered as an important indicator of health and safety performance. As stated by the U.S. Department of Labor (1955), frequency is a more valuable indicator of health and safety performance than severity, since blind chance usually plays a greater part in determining the seriousness of an injury than it does in determining how frequently accidental injuries occur. Therefore, accident frequency rate is the most commonly used indicator for health and safety performance despite it only reflecting one aspect of health and safety performance.

To determine the disparity of construction health and safety performance between developing and developed countries and explore the underlying reasons of such a disparity, both leading indicators such as health and safety climate and lagging indicators such as accident frequency rate are employed in this research. The in-depth comparison of all dimensions of construction health and safety climate and the frequency rate of different types of accidents between South Africa and Singapore enables us to understand what causes the disparity of construction health and safety performance between developing and developed countries.

3. DIMENSION OF HEALTH AND SAFETY CLIMATE

Health and safety climate is deemed as an explanatory measure indicating the perception of the workforce and its attitudes towards health and safety within the organizational environment at certain or given point in time. Various previous studies (Flin et al, 2000; Mohamed, 2002; Toole, 2002; Mearns et al, 2003) have defined measuring of health and safety climate as taking the 'health and safety temperature' of an organization. Dimensions are the major features or levels of a health and safety climate (Glendon and Stanton 2000). Dimensions of a health and safety climate differ from industry to industry (Fang et al. 2006). In the construction industry, many researchers have attempted to find the common dimensions of health and safety climate (see Table 2). Although there are various factors to measure a health and safety climate, the dimensions in several of the latest research studies demonstrate strong similarities (Glendon and Litherland 2001; Mohamed 2002; Fang et al. 2006; Teo and Fang 2006). Mohamed's factor structure could be deemed as representative since the dimensions were derived from an extensive literature review rather than through the factor analysis method. Teo and Fang (2006) compared the health and safety climate framework in Singapore and Hong Kong and found that there is very little difference between the two countries. The two additional significant factors of Singapore health and safety climate framework are communication and feedback and IT Intelligence.

Table 2 Review of health and safety climate in construction industry

Author(s)	Dimension
Dedobbeleer and Beland (1991)	Management commitment; Risk/involvement.
Niskanen (1994)	Work pressure; Supervision; Work value; Responsibility.
Glendon and Litherland (2001)	Communication and support; adequacy of procedures; work pressure; personal protective equipment; relationships; Health and safety rules.
Mohamed (2002)	Commitment; Communication; Health and safety rules and procedures; Supportive environment; Supervisory environment; Workers' involvement; Personal appreciation of risk; Appraisal of work hazards; Work pressure;

	Competence.
Fang et al. (2006)	Health and safety attitude and management commitment; Health and safety consultation and training; Supervisor's and workmate's roles; Risk taking behavior; Health and safety resources; Appraisal of health and safety procedure and work risk; Improper health and safety procedure; Worker's involvement; Workmate's influence; Competence.
Teo and Fang (2006)	Communication & Feedback; Supervisory Environment & Supportive Environment; Health and Safety Rules & Procedures; Training Program & Competence Level; Health and Safety Investment; Workers' Involvement & Work Pressure; Personal Risk Appreciation & Appraisal of Work Hazards; IT Intelligence.

Based on the comprehensive literature review on construction health and safety climate in combination with the objectives of this research, an eight-factor health and safety climate structure is used as the indicator for health and safety performance to facilitate the comparison of the construction health and safety performance in South Africa and Singapore. Using this, the relatively poorer health and safety practices in developing countries such as South Africa could be identified. The eight dimensions of construction health and safety climate are management commitment, communication and feedback, supervisory environment, supportive environment, health and safety rules and procedures, training and competence, workers' involvement and personal risk appreciation, and work pressure. As a lagging indicator of health and safety performance, the frequency rate of different types of accidents is also discussed in this paper to further expound on the effects of the eight dimensions have on construction health and safety performance.

4. METHODOLOGY

A questionnaire survey is an effective method to gain data on attitudes toward issues and causal relationships. It is a widely used method to describe general perceptions about health and safety practices (Ojanen et al. 1998; Mohamed 2002; Fang et al. 2006). For this particular study, a questionnaire survey was selected as the method of data collection. Parallel surveys in South Africa and Singapore were conducted to examine the construction health and safety practices adopted by construction practitioners in both countries and the causes of work site accidents. The questionnaire was designed with three major parts. The first part asked for general information of the respondents. The second part comprised of 32 statements on the health and safety practices on construction sites. The final part of the questionnaire consisted of 8 statements about the causes of accidents on construction sites. Respondents were required to rank the factors on a 5-point scale where 1 = strongly disagree/ never/ not at all and 5 = strongly agree/ always/ very much for the statements found in the questionnaire.

The population consisted of all parties in the construction industry of Singapore and South Africa. Questionnaires in Singapore were sent out by post, with self-addressed and pre-stamped envelopes, to randomly selected parties (Table 3 and Table 4). In the Singapore survey, the response rate was 12.67% and more than 80% of the respondents were top management where their average working experience was 16 years. The minimum and maximum working experiences were 2 years and 36 years respectively, with 58% of the respondents having more than 15 years of experience. In the South Africa survey, questionnaires were handed out for completion to 325 delegates attending national health and safety training workshops over a 12 month period. The minimum and maximum working experiences of SA respondents were 0.8 years and 40 years respectively.

Table 3: Distribution of respondents in Singapore

Designated Respondents	Sampling Frame	Sent Out	Returned
Authority (Land and Transport Authority, Ministry of Manpower and Building and Construction Authority	N.A.	3	1
Architect	Singapore Board of Architects	54	5
Engineer	Professional Engineers Board	60	2
Main Contractor	BCA Contractors Registry	100	22
Sub-contractor	BCA Contractors Registry	63	3
Health and safety Auditor	MOM	20	5
Total		300	38

Table 4: Distribution of 325 respondents in South Africa

Designated Respondents	Sampling Frame	Completed
Top management	Workshop delegates	26.4%
Site supervisor	Workshop delegates	49.8%
Workers	Workshop delegates	23.8%
Total		100.0%

Statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS) software package. Comparison of the mean value of the perceptions of health and safety practices on construction sites in the two countries was carried out to check whether there were differences in the perceptions of health and safety practices in both countries. The mean value of the frequency of different types of accidents from the questionnaire was calculated to obtain the rank of different types of accidents on construction sites so that the common types of accidents could be compared between South Africa and Singapore.

5. FINDINGS

Construction health and safety climate of Singapore and South Africa

Thirty-two statements about health and safety climate were categorized under eight dimensions of construction health and safety climate (Table 5). The mean scores of responses to each statement were calculated and compared between the two countries. As can be seen in Table 5, among the eight dimensions of health and safety climate, obvious differences existed in three of them, namely (1) management commitment, (2) supervisory environment, and (3) training and competence level.

Management commitment

Table 5 clearly showed the disparity in management commitment between Singapore and South Africa. The results showed that management commitment in South Africa was not as strong as that in Singapore. Five out of seven statements about management commitment raised in the questionnaire survey had higher mean scores in Singapore than in South Africa (see Table 5). Arguably, this difference might be one of the major reasons for the poorer construction health and safety performance in South Africa considering that several previous studies have demonstrated the critical role management has in improving health and safety performance (Abudayyeh et al. 2006; Zohar 1980; Jaselskis et al 1996). The head office management in South Africa was less intolerant of poor construction health and safety (mean score of 3.641) and did not address health and safety issues (with the mean score of 3.667) as much as in Singapore (mean scores of 3.946 and 4.000 respectively). The lack of management's commitment to site health and safety in South Africa was confirmed by less support for incentive or punitive programs (mean scores of 3.329 and 3.087 respectively) than in Singapore (mean scores of 3.703 and 3.865 respectively). The research conducted by Koehn et al. (1995) parallels this research finding, suggesting that there tends to be a lack of management commitment to health and safety programs and various procedures in developing countries.

Supervisory environment

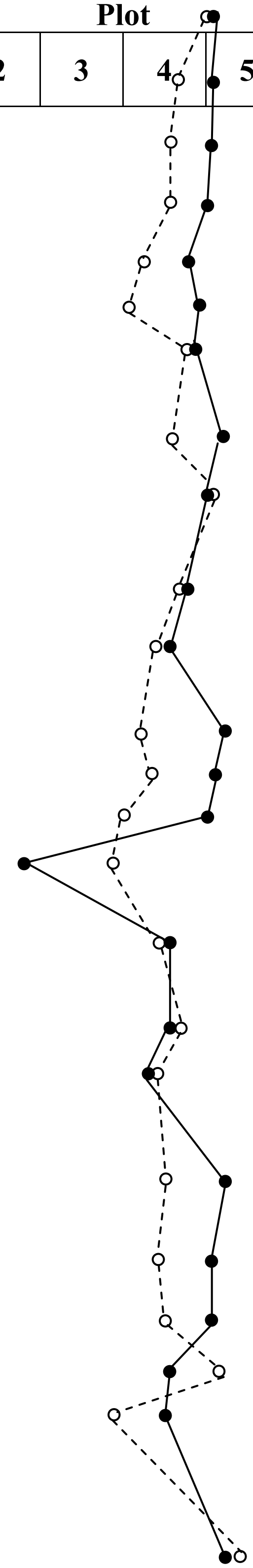
Differences were found in the supervisory environments of South Africa and Singapore. As shown in Table 5, the four statements covering the dimension of supervisory environment had different mean scores in each country. There was a relative lack of proper supervision in South Africa (mean scores of 2.750 and 2.003 in South Africa and Singapore respectively), in terms of trained H&S staff (3.376 in South Africa and 4.162 in Singapore) or representatives (3.686 in South Africa and 4.027 in Singapore) and regular H&S inspections on site (3.152 in South Africa and 4.000 in Singapore). A successful health and safety management system program is based upon the premise that health and safety is both a management responsibility and a line function (Mohamed 2002). While top management help develop the health and safety program, its actual success depends upon the ability of supervisory personnel to ensure the implementation of the program during daily operations (Agrilla 1999). Therefore, the lack of proper supervision in South Africa could be another major contributor to the disparity in construction health and safety performance in South Africa and Singapore.

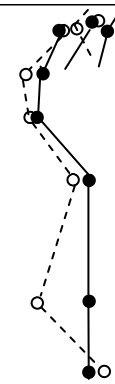
Training and competence level

The third category of construction health and safety performance difference between Singapore and South Africa was evident in the disparity of training and competence levels on construction sites in each of the countries. More health and safety training and education was needed in South Africa (mean score of 4.134) than in Singapore (mean score of 3.730) since workers in South Africa did not receive as much education and training about site health and safety, such as regular training programs (3.202 in South Africa and 3,711 in Singapore), orientation/instruction for new workers (3.748 in South Africa and 4.162 in Singapore) and training in the proper care and use of PPE (3.732 in South Africa and 4.026 in Singapore). The finding of relatively poor training and competence level in developing countries is similar to the findings of Koehn's research (Koehn et al. 1995), which indicated that on many construction sites in India, a typical developing country, no training programs for the staff and workers existed; therefore, no orientation for new staff or workers was conducted. Workers were required to learn from their own experiences. Training is a major factor influencing health and safety levels (Jaselskis et al. 1996). Competence level is a measure of workers' confidence that they had the skill to perform a particular job safely (Mohamed 2002). To ensure safe work performance and sound health and safety management, training is essential for both workers and management to achieve the required competence levels (Teo and Fang 2006). Enhancing health and safety training on construction sites in developing countries could be one of the most powerful ways to effectively reduce the disparity in construction health and safety performance between developing countries and developed ones.

Table 5 Comparison of H&S practices in Singapore (SG) and South Africa (SA)

Factor/Health and safety practice	SG	SA	Plot			
MANAGEMENT COMMITMENT	**Mean**	**Mean**	**2**	**3**	**4**	**5**
The H&S of workers is important to the head office management	4.054*	4.016*				
The head office management ensure compliance with H&S legislation and regulations	4.081*	3.793*				
The head office management always address H&S issues	4.000*	3.667*				
The head office management are intolerant of poor construction H&S	3.946*	3.641*				
Workers are rewarded for good H&S	3.703*	3.329*				
The firm penalizes workers for poor H&S	3.865*	3.087				
The head office management insists on the elimination of hazards	3.838*	3.703*				
COMMUNICATION AND FEEDBACK						
We have regular H&S meetings	4.158*	3.609*				
Workers are encouraged to report unsafe and unhealthy behavior and working conditions	3.946*	4.082*				
Results of H&S inspections are always discussed at H&S meetings	3.730*	3.647*				
All workers are kept informed of the provisions of the H&S plan	3.568*	3.409*				
SUPERVISORY ENVIRONMENT						
The firm employs trained H&S staff on projects	4.162*	3.376*				
We have trained H&S representatives on site	4.027*	3.686*				
H&S inspections are done regularly and at least daily	4.000*	3.152				
There is a general lack of proper supervision	2.003	2.750				
SUPPORTIVE ENVIRONMENT						
Workers are responsible for the H&S of their fellow workers	3.865*	3.795*				
HEALTH AND SAFETY RULES AND PROCEDURES						
We have a written H&S policy in place	3.892*	3.992*				
Each project has a project-specific H&S plan	3.59	3.61				



•	5*	2*	
○ **TRAINING AND COMPETENCE LEVEL**			
All workers undergo orientation/induction before they are allowed to start work on site	4.162*	3.748*	
Construction accidents are caused by unsafe worker acts or behavior	4.054*	3.673*	
Workers are trained in the proper care and use of PPE	4.026*	3.732*	
More H&S education and training is needed	3.730*	4.134*	
Workers are regularly trained in H&S	3.711*	3.202	
WORKERS' INVOLVEMENT AND PERSONAL RISK APPRECIATION Workers have the right to refuse to work in unsafe conditions	4.184*	4.275*	
Workers are responsible for their own H&S	3.865*	3.549*	
Most workers on site view health and safety as important	3.632*	3.656*	
Workers are involved with H&S inspections	3.297	3.298	
Workers are consulted when the H&S plan is compiled	3.162	2.914	
Workers participated in the formulation of the H&S policy	3.054	3.027	
Workers regularly report unsafe and unhealthy behavior and working conditions	3.612*	3.485*	
WORK PRESSURE			
The firm is only concerned with getting job done as quickly as possible	3.676*	2.924	
Workers often work shifts or overtime	3.622*	3.810*	
Singapore ***South Africa***			

* Statistically significant at 5% level

Comparison of frequency rate of different causes of accidents on construction sites

According to the annual H&S report of the Ministry of Manpower of Singapore (2006), the most common causes of accidents resulting in injuries or fatalities on construction sites include step on, struck against or by objects, falls of persons, struck by falling objects and caught in or between objects (Table 6). These categories of accidents result in 78% of total number of injuries and 96% of the total number of fatalities in 2006. In South Africa, however, there were differences relative to the dominant causes of accidents resulting in injuries in terms of frequency rate when compared with that of Singapore. Lifting of heavy or awkward or irregular materials ranked highest among the eight common causes of construction site accidents in South Africa. Another cause of accidents not found as a common cause of accidents in Singapore was related to ergonomics, or working in awkward postures and positions, losing balance, slipping and tripping. This ranks as the third most common cause of accidents on sites in South Africa. In addition, caught in or between objects ranked fourth in Singapore. This cause is less frequent than contact with hot substances/objects, exposure to/contact with electricity, and exposure to/contact with harmful substances.

Table 6: Rank of types of accidents on construction sites in Singapore in 2006

Rank	Type	Injuries*	Fatalities
1	Step on, strike against or by objects	661	1
2	Fall of persons	596	15
3	Struck by falling objects	362	5
4	Caught in or between objects	275	2
5	Exposed /contact with harmful substances	16	0
6	Contact with hot substances /objects	14	0
7	Exposed /contact with electricity	5	0
8	Fire/ explosions	4	0
	Others	482	1
	Total	2415	24

** Figures include both fatal and non-fatal injuries*

Source: www.mom.gov.sg

Table 7: Rank of types of accidents on construction sites in South Africa

Rank	Types of Accidents in Construction Industry	N	Mean
1	Lifting of heavy or awkward or irregular materials	253	3.020
2	Struck by objects	253	3.004
3	Working in awkward postures and positions, losing balance, slipping and tripping	252	2.960
4	Falls of persons	253	2.909
5	Contact with hot substances /objects	251	2.873
6	Exposed /contact with electricity	249	2.695
7	Exposed/contact with harmful substances	251	2.574
8	Being caught in or between objects	249	2.430

6. DISCUSSION

The differences found between South Africa's and Singapore's most common causes of accidents resulting in injuries and fatalities of workers on construction reflects the difference of health and safety practices in the construction industry of the two nations and can be explained by another finding of this research. That is, the differences of health and safety climate mainly exist in the three dimensions of management commitment, supervisory environment, and training and competence level.

The unavailability of a wide variety of machinery and equipment for materials handling on construction site could be one of the major factors causing the high rate of injuries resulting from lifting of heavy or awkward or irregular materials in South Africa. In most developing countries, which tend to have more labor-intensive construction industries, the use of modern technology may be resisted by employers for the sake of lower labor costs. Additionally, public sector clients may dictate the more intensive use of labor due to government policy and high rates of unemployment. Further, little consideration has been given to repackage materials with workers in mind through standardization and weight reductions. To reduce this causal factor, a clear commitment from management to construction health and safety should be demonstrated by increasing the health and safety budget to address improvements for equipment, technology and materials. The higher incidence of injuries resulting from working in awkward postures and positions, losing balance, slipping and tripping in South Africa is mainly due to inappropriate worker techniques, poor work organization, a lack of respect for the wellbeing of workers, inadequate labor protection, and general lack of site supervision. The accidents due to contact with hot substances/objects, exposure to /contact with electricity, and exposure to/contact with harmful substances in South Africa is partly attributable to the general 'do not care' attitude of workers and management,, the absence or improper use of PPE, and the general lack of site supervision.

In most developing countries, there is a strong tendency for construction workers to be highly mobile. They tend to frequently transfer from one site to another and even transfer from one trade to another. The majority of the workers may not even understand the job and do not possess the necessary skills to perform the job. According to Koehn (1995), lack of understanding of the job is one of the major causes of construction accidents in developing countries. Levitt and Samelson (1993) report that even small amounts of time (less than one hour) spent on health and safety orientation for new workers before they begin working can significantly reduce injuries to new workers. Therefore, health and safety training and orientation become important management driven initiatives to inculcate workers with the necessary techniques and awareness of health and safety issues.

In addition, the proper use of PPE after mitigating hazard exposure has been an effective way to prevent workers from being injured or to alleviate the injuries to some extent in developed countries. For the majority of contractors in developing countries, however, maximizing profit is the prime concern and the health and safety budget is limited. Workers on such projects are more likely to be directly exposed to all kinds of hazards.

To alter this situation, top management should demonstrate their commitment by increasing the health and safety budget of projects.

Finally, as Mahalingam and Levitt (2007) found, while education or training could be a long-term strategy to grow health and safety culture in developing countries, safety policy enforcement was an effective way to achieve short-term improvement of health and safety performance. Because of the lack of an appropriate health and safety culture in the construction industry of developing countries, workers are less sensitive to health and safety issues. Therefore, it is necessary to enhance site health and safety supervision accompanied by regular health and safety inspections. The findings of this paper suggest that management commitment, supervisory environment, and training and competence level are three relatively weak aspects of construction health and safety practices in developing countries such as South Africa than those of developed countries such as Singapore.

Hence, the difference in incidence of the common causes of accidents on construction sites in South Africa and Singapore further supports the previous finding that the main sources of disparity between the two nations lie in management commitment, supervisory environment, and training and competence level.

7. CONCLUSIONS

In this paper, the disparity of construction health and safety performance between developing and developed countries was ascertained and the main sources of this disparity were investigated through a comparative study in a developing country, South Africa, and a developed country, Singapore. Management commitment, supervisory environment, and training and competence level were identified as the major sources of the disparity of construction health and safety performance in developing and developed countries. This finding is further confirmed by the difference in the incidence of different causes of accidents resulting in injuries and fatalities on construction sites in South Africa and Singapore. The findings of this particular research do not mean that other factors are not important for improving construction health and safety performance in developing countries, but rather, that a developing country such as South Africa does not perform as well in these three areas of construction health and safety. The findings of this research have practical implications for improving construction health and safety performance in developing countries. Learning from developed countries with better construction health and safety performance relative to the practices and experiences of management commitment to site health and safety, enhancement of the supervisory environment, health and safety training or orientation, and raising the competence levels of workers could be useful to enhance construction health and safety performance in developing countries.

One potential limitation of this research is the self-reported data collection method.The conclusion would be more persuasive if more objective evidence such as site health and safety inspection records, health and safety management system audit records, or comprehensive health and safety statistics in developing countries could be included in future studies.

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HEALTH SAFETY AND ENVIRONMENTAL MANAGEMENT SYSTEMS IN CHINA NATIONAL PETROLEUM CORPORATION

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ABSTRACT

This paper aims to introduce the health, safety and environmental management systems (HSEMS) being implemented in China National Petroleum Corporation (CNPC). These systems of CNPC are based on the industrial standard for petroleum and natural gas industries. In 2004, the standard was revised. The requirements from the government and other stakeholders were integrated into the new standard so as to make it more applicable. A case study was conducted on a western Libya gas onshore pipeline project to specifically examine the application of the CNPC HSEMS. The results reveal that the HSEMS of CNPC meets the demands of clients, and complies with the local regulations. Good HSE performance has been achieved during the execution of the project.

Keywords: CNPC, HSEMS, Pipeline Project

1. INTRODUCTION

China National Petroleum Corporation (CNPC) is a world-leading integrated energy corporation with businesses covering oil and gas upstream and downstream operations, oilfield services, engineering and construction, petroleum material and equipment manufacturing and supply. CNPC supplies a full range of petroleum materials and equipment and has an excellent global reputation as a contractor and services supplier in seismic exploration, well drilling, well logging, and pipeline and engineering construction. In seeking a greater international role, CNPC strives for expanding overseas business. CNPC owns oil and gas assets and interests in 27 countries, and provides oilfield services, engineering and construction in 49 countries worldwide. Businesses play a key role in society. CNPC is obliged to fulfill the social responsibility to promote the harmonious development of society. "Caring for energy, Caring for you" is CNPC’s unwavering commitment. Every employee from CNPC is fully aware of the company's responsibilities to society, which permeates every aspect of everything that has been done.

The company attaches the greatest importance to employees' health and safety in conformity with the "people and health first" and "combination of prevention and treatment with prevention as the priority" guidelines. CNPC strengthened monitoring of employees' occupational health and safety as well as occupational-disease inductive factors in operations with regard to the environment, high flow rate, intense work and many occupational diseases in the oil production industry. CNPC conducted a comprehensive survey of occupational-disease inductive factors in various operational premises covering oil and gas production, oil processing, well drilling, well logging, downhole operations, pipeline engineering and material & equipment manufacturing. CNPC specially checked hazardous factors, as well as protective facilities and equipment in operational sites, and took active measures according to these conditions. CNPC pays considerable attention to the health of field workers who work in more dangerous and risky environments. Investigations of working sites are conducted beforehand and priority will be given to the health of the staff in emergency rescue planning and residence selection. Meanwhile, the company dispatches health supervision teams, who strive to eliminate hazardous factors and ensure the health of field workers by giving them related information and training, and identifying potential occupational hazards.

Environmental protection is also an important part of CNPC's commitment to society. In strict conformity with environmental laws and regulations, CNPC actively promotes clean operations and does everything it can to build an environmentally friendly company that operates in harmony with the environment. CNPC has adopted the ISO14001 Environmental Management System to continuously improve environmental management performance. By 2006, CNPC's 135 subsidiary companies had achieved ISO14001 certification or obtained Environmental Labeling status. Environmental factor identification and selection programs have been carried out across the whole group, and the Technical Guidelines for the Identification and Selection of Environmental Factors have been issued and environmental management plans and emergency plans have been compiled to control and monitor hidden hazards and handle emergencies. In addition, CNPC has established an environmental protection fulfillment accountability system, including environmental protection indices (e.g. pollution control and rate of standard discharge) into the comprehensive performance assessment for enterprise management and operation.

An annual environmental protection index system was established to ensure the effective monitoring of total pollutant discharge, and responsible people were identified at each level to control standard pollutant discharges and handle emergencies. In terms of ensuring clean operations, CNPC launched a "green operation" demonstration activity and a clean production technology innovation program. In addition, a series of new technologies and new equipment were developed, including clean operation in well drilling, ecological protection during pipeline construction, recycling of refinery sewage and the reduction of greenhouse gas emissions.

CNPC has adopted a strict environmental impact assessment for all construction projects and carried out the "Three-tier HSE Management" system to ensure that environmental protection facilities and major engineering projects are designed, constructed and completed simultaneously. In 2006, CNPC achieved the 100% implementation of the environmental impact assessment and environmental protection checking and approval system. CNPC continued to carry out the three-level prevention and control program for enterprises operating near rivers, lakes or other public water environments. In 2006, with the continuous growth in oil and gas production, crude runs and the production of major chemicals, discharges of COD (chemical oxygen demand) and major oil-type pollutants were respectively reduced by 4.6% and 5.4% compared to 2005.

2. HEALTH SAFETY AND ENVIRONMENT MANAGEMENT SYSTEM IN CNPC

The influence of management must be apparent in the HSE policies it sets, the degree to which those policies are observed, and the concern with which it treats any violation. Managers must leave no doubts in the minds of employees that they are concerned about accident prevention. This concern to prevent injury and damage must be sustained continually, rather than intermittently or only temporarily being presented with an accident report. In the following part, the management on HSE in CNPC is presented in detail, including HSE policy and objectives, and HSE management system.

HSE policy and objectives

It is the objective of CNPC to provide and maintain a safe and healthy work environment at all times. The goal of CNPC is to prevent occupational accidents, injuries and illnesses. The CNPC management team places accident prevention and the protection of the health and safety of every employee prior to any other consideration of job operation or administration. The Health, Safety and Environment Policy of CNPC is to comply with the applicable laws, codes, standards and regulations in respect for occupational health, safety and environment protection issued by the government. All the staff personnel must strictly comply with the CNPC procedures, regulations, guidelines and rules for health, safety and environment. The HSE policy of CNPC is generally summarized in Table 1.

Table 1. HSE policy of CNPC

Policy	Detailed Description
HSE Policy	• Being suitable for the activity, product and service of CNPC, and for the risk of health, safety and environment; • Including the commitment for continual improvement, cleaner production and prevention of accidents; • Including the commitment for abiding by the laws; • Forming the documents and implementation; • Informing every employee for understanding respectively; • Periodical audits.

CNPC strengthens the safety consciousness of the employees through many training sessions so as to keep firmly in their minds that creating a safe and comfortable condition and living environment is each employee's responsibility and duty. All the management and administration departments of CNPC will try their best to implement the HSE Policy into each activity to minimize any HSE risk and mitigate any pollution in order to protect the environment and eliminate the environment impact. It is the responsibility and duty of all the management and administration departments of CNPC to maintain and promote the HSE Policy and keep all the contractors clearly aware of that. Any deviation from the above laws, regulations, rules and CNPC regulations will be considered as violation of the Policy. CNPC is pursuing rigorous and frequent audits to ensure that each partner in the shared responsibilities attains the contractor's goal to prevent injuries and diseases, and to limit losses by exemplary leadership in the prevention of accidents, injuries and illnesses. The HSE objectives of CNPC are generally summarized in Table 2.

Table 2. HSE objectives of CNPC

Objective	**Detailed Description**
Health	• The aim of the health plan is to protect personnel from any health hazards that may be associated with the work • Provide and ensure effective medical and first aid facilities (doctor, medical clinic, medicines and registers) • Carry out occupational physical checks to ensure that all personnel are medically fit to work and fitness certificates are available in their files. • Conduct thorough surveillance for poisonous and deleterious working areas. • Develop and encourage preventive medical care attitudes among employees. • Periodic health inspections on messing, catering and accommodation facilities to ensure and maintain good standards of health and hygiene at all times. • Adequate number of first aid boxes shall be available and well maintained in all field locations, including residential and industrial areas. • Records of sickness and absenteeism of personnel will be maintained by the medical personnel on a regular basis. They shall be analyzed for any possible trend towards occupational illness.

Objective	Detailed Description
Safety	• The prime target shall be for an accident-free environment. The main areas of intervention are the following: • Ensure the HSE plan is a line management responsibility by commitment and implementation. • Addressing critical safety activities and identifying hazards prior to starting the work by induction training, regular safety meetings, refresher training and toolbox talks. • Ensure that all personnel have and use approved work procedures, and that they are fully trained with full understanding of their jobs and equipment. • Establish regular inspections and audit programs for monitoring the implementation of HSE plans and procedures.
Environment	• The prime target is to take all responsible precautions to avoid pollution or contamination of the working locations or water. The main objectives are the following: • Maintain environmental pollution to minimum levels. • Dispose of solid waste and wastewater according to the " waste management plan". • Reinstatement of work areas after completion of construction related activities, as per the Construction Environmental Management Plan.

HSE management system

The HSE management system is a part of the total management system. It helps risk management with health, safety and environment related issues on matters of business for the organization. The system includes the organization structure, HSE plan, HSE responsibility, HSE procedure, process and resources needed for the establishment and implementation of health, safety and environment policy. Generally, this HSE system is summarized in Table 3.

Table 3. HSE management system of CNPC

HSE System	Detailed Description
Leadership and Commitment	• The president of CNPC provides powerful leadership and explicit commitment for the establishment, implementation and continuous improvement of the health, safety and environment management system.

	• The detailed obligations of the CNPC president on HSE include: a) Informing the organization of the importance to implement the laws; b) Establishing health, safety and environmental policy; c) Insuring the establishment and realization of health, safety and environmental targets; d) Managing the audit; e) Insuring the availability of the necessary resources.
Structure of Organization, Resources and Document	• In the HSE management of CNPC, the issues related to structure of organization, resources and documents consist of a) The structure and responsibility of organization; b) The representative of the president; c) Resources; d) Training, consciousness and ability; e) Consultation and communication; f) Documents; g) Document control.
HSE Plan	• The HSE plan of CNPC covers: a) The identification of health , safety and environmental hazards, risk assessment and risk control; b) The laws; c) Targets; d) health , safety and environmental management plans.
HSE Procedure and Process	• In the CNPC HSE management system, the procedures and processes are related to the issues of system implementation, HSE inspection, and HSE improvement. • The system implementation covers: a) The integrity of facilities; b) Contractor and/or supplier; c) Customer and product; d) Community and public relations; e) The control of operations; f) The management of modifications; and g) Emergency response. • The HSE inspections and improvements include: a) The monitoring for performance; b) Non-conformance, modification and prevention; c) Accident, report and investigation; d) The management of records; and e) audits.

3. CASE STUDY ON WESTERN LIBYA GAS PROJECT ONSHORE PIPELINES

General introduction of western Libya gas project

CNPC won the bidding for WESTERN LIBYA GAS PROJECT ONSHORE PIPELINES and become the EPC contractor of the project in 2002. The owner, AGIP GAS BV sought the provision in Libya of a fully-operational oil and gas onshore pipeline between the Wafa Desert Plant and the Wafa Coastal Plant. This pipeline objective was to convey gas and oil products in the capacities and at the pressures specified in the technical documents. This was to be achieved in a professional manner in accordance with good engineering practice and in an efficient and expert manner, with all due diligence and expedition, and in full conformity in all respects with the contract.

The onshore pipelines system is intended to transport the gas and oil treated at the Wafa Plant from the Central Plant in Wafa to the Mellitah Plant on the Libyan coast. Hydraulic calculations and economic optimizations have suggested the adoption of a ND 32” for the gas pipeline and of a ND 16” for the oil pipeline. The Wafa treatment plant will produce a sales gas; in order to cope with the sales requirements. Gas was to be delivered at Mellitah at 35 bara as a minimum with a maximum temperature of 35 °C. The unstable liquid will be treated at Mellitah with the production of a stable oil and LPG; the unique target during the transport is to avoid the vaporisation of the liquid mixture. For safety reasons, isolating valves have been planned with a maximum spacing of about 32 km according to the ANSI B31.8 code. Furthermore, two intermediate pig trap stations are located along the pipeline route. The isolating valves will be allocated in proper line valve stations (LVS). Each LVS will be used for both pipelines (oil ND 16" and gas ND 32"). At some location, a cathodic protection station may also be provided. Table 4 reveals the environmental parameters and data along the pipeline route from Wafa Central Plant to Mellitah (taken from Ghadamesh meteo-climatic series recorded in the period 1989-1998). These parameters and data should be corrected, when necessary, to take into account the different elevations between Ghadames and the pipeline site.

Table 4. Environmental parameters

Item	Parameter
TEMPERATURE	Minimum winter temperature (December):-2.5 °C; Maximum summer temperature (July): 48.2 °C.
HUMIDITY	Mean relative humidity 37 %; Maximum relative humidity 83 %; Minimum relative humidity 9 %.
BAROMETRIC PRESSURE	Maximum monthly mean at Wafa level 963.4 hPa; Minimum monthly mean at Wafa level 936.7 hPa.
WIND FREQUENCY DISTRIBUTION	From EAST 75%; From NORTH 11%; From WEST 7%; From SOUTH 7%.
WIND SPEED	Max wind speed 95.5 km/h; Wind speed for winter design 25.2 km/h; Wind speed for summer design 9.0 km/h.
RAINFALL	Maximum rainfall recorded in 1 day: 20 mm; Maximum rainfall recorded in 1 month: 76 mm; Maximum rainfall recorded in 1 year: 100 mm

Dust and sandstorms occur often from November to May, and are usually caused by west and south-west winds. Cloudiness is very rare. Fog occurs sometimes during winter mornings. The vegetation is very scanty, consisting of grass and shrubs. The wildlife is scant as well: only reptiles and insects are frequent. The EPC contractor should consider the peculiar environment reported above to plan all the work phases and to ensure safe work conditions. The construction of both pipelines depends on the EPC contractor equipment and the number of sections to be awarded. Because of the extensive length of the gas and oil pipelines, it is envisaged that installation will be organised in three main sections: Wafa Central Plant to Intermediate Pig Trap No.1; Intermediate Pig Trap No.1 to Intermediate Pig Trap No.2; Intermediate Pig Trap No.2 to Mellitah Plant. There are different conditions along the pipeline route, including: flat sections, sloped sections, wadi cross sections, road crossings, watercourse crossings, loose stone surface soil, mobile dunes of sand, small rural areas and very small populated areas. For each section the following working phases has been foreseen: camping facilities and yards preparation; staking and signalling of the pipeline route; stockpiling yards preparation; handling and storage of materials; doubling joint strings construction; accessing road construction; right of way opening; trenching excavation; stringing 32” pipe; bending 32” pipe; stringing 16” pipe; bending 16” pipe; aligning and welding 16” pipe; non destructive testing 16” pipe; coating repair 16” pipe; lowering 16” pipe; aligning and welding 32” pipe; non destructive testing 32” pipe; coating repair 32” pipe; lowering 32” pipe; backfilling; hydrostatic testing, dewatering and drying; final cleaning-up and restoration of right of way.

HSE requirement of the western Libya gas project

The EPC contractor and all its employees, agents and subcontractors shall comply with all applicable Libya Government safety and environmental regulations and all owner safety, health and environmental Guidelines/Procedures and other related rules and regulations at all times. Specifically, The EPC contractor shall comply with the provisions of the owner, and the owner shall make all other such related requirements, specifications and standards known to EPC contractor. The EPC contractor may request from the owner representative copies of those owner standards, rules and regulations which are applicable to this contract. The EPC contractor shall also take or cause to be taken any additional measures under the direction of the owner’s representative to prevent the injury or death of any person, or any damage or loss of property during the EPC contractor’s performance of the work. The EPC contractor shall maintain the company HSE documentation at the work site. The owner may monitor and inspect any work site for compliance with the above referenced safety, health and environmental requirements.

Any deviation by the EPC contractor from the owner's (or other applicable) safety, health and environmental requirements (or rules and regulations) must be approved, in advance in writing by the owner’s representative. Should the EPC contractor fail to comply with any of the requirements of this document, the owner shall notify the EPC contractor in writing of this situation. Upon receiving such notification, the EPC contractor shall immediately take all necessary corrective actions. Any corrective action shall, unless provided otherwise in this contract, be taken at the EPC contractor's expense. If the EPC contractor fails to take prompt corrective action, the owner’s representative may direct the EPC contractor to suspend all or part of the work until satisfactory corrective action has been taken. Costs incurred by the EPC contractor as a result of such work suspension shall be solely the EPC contractor's responsibility, and any resultant EPC contractor

performance delays shall not be deemed excusable hereunder. The EPC contractor may request assistance from the owner with respect to the implementation of its safety, health and environmental requirements. The owner's representative (or the owner representative's designated party or parties) shall assist the EPC contractor by explaining good safety and sound environmental practices, pointing out unsafe conditions, and by applying experience and judgment, to assist the EPC contractor in improving safety and to safeguard the environment. Such assistance by the owner shall in no way relieve the EPC contractor of its responsibilities set forth in this document.
HSE practice of CNPC in western Libya gas project

Project HSE documentation. The scope of the HSE documentation is to define the safe working procedures and practices that shall be followed by all personnel involved in the Western Libya Gas Project-Onshore pipelines. The project HSE Plan may require updating along with the project construction progress. The program has followed the principles of the laws and regulations on the health, safety, and environment made up by the Libya government. The key elements of the project health, safety and environmental management system shall include documentation listed in Table 5.

Table 5. HSE documentation of western Libya gas project

Name	Elements
Basic Documents	1) Project HSE plan; 2) HSE Contractor policy; 3) Hazards identification & risk assessment; 4) Construction environmental management plan.
Supporting Plans	1) Waste management plan; 2) Water management plan; 3) Transport and traffic management plan; 4) Journey management plan; 5)Pre-commissioning, commissioning and operating safety Manual.
Environment Protection	1) Environmental impact assessment (EIA); 2) Environment monitoring and auditing
Monitoring Program	HSE audit report

HSE hazard assessment. The HSE procedure has been prepared in accordance with contractual requirements and it addresses specific hazard identification and analysis. It is considered that the project specific hazard identification and analysis provides for all the foreseeable hazards, addressing: the hazard assessment, threats associated with the hazard, controls and mitigations and recovery measures. It is anticipated that once construction activities commence, project management will experience unforeseen and unexpected occurrences, which will require further specific hazard identification and analysis prior to continuing with operations. Therefore this document has to be considered as a "living document" and as such will be continuously monitored and updated when required by circumstances. The HSE coordinator is responsible for such activities.

On the principle of reducing personal injury, environment pollution and property loss, the contractor will be expected to carry out risk assessment for construction activities and pipeline operations and maintenance. According to actual conditions encountered during construction execution, identify and analyze foreseeable hazards and impacts in field operations and key work procedures. Consideration shall be given to the following: flammable and explosive substances, poisonous and harmful gases or chemicals, radioactive substances, confined operation spaces, lifting operations, electrical work, and hot work.. Experience can be helpful for identifying the hazards of construction activities, while the LEC method can be used to assess the relative threat posed by the hazards.

$$\mathbf{D=L\times E\times C} \qquad (1)$$

Where□
L——likelihood of the accident
E——exposure frequency of the human body in the hazardous environment
C——loss and consequence of the accident
D——the degree of the danger
Assessment method of above factors is given in Table 6 to Table 9:

Table 6. L-Likelihood of the accident

Mark	Likelihood of the HSE accident
10	Extremely possible
6	Quite possible
3	Possible but not often
1	Moderately Impossible, out of expect
0.5	Quite impossible
0.2	Extremely impossible
0.1	Unexpected Occurrence

Table 7. E-Exposure frequency of the human body in the hazardous environment

Mark	Exposure frequency
10	Continuous exposure
6	Exposure in daily work
3	Once a week, or occasional exposure
2	Once a month
1	Several times every year
0.5	Uncommon exposure

Table 8. C-Consequences of HSE accident

Mark	Consequence
100	Big calamity, multiple death
40	Calamity, several death
15	Very severe, single death
7	Severe, badly injured
3	Cause temporary disability
1	No harm expected

Table 8. D-Degree of danger of HSE accident

Mark	Hazard degree	Risk grade
>320	Extremely dangerous, work can't be continued	5
160—320	Very danger, need immediate rectifying	4
70—160	Obvious danger, need rectifying	3
20—70	Danger, need attention	2
<20	A little danger, acceptable	1

Emergency response plan. The emergency response plan is about the effective and timely emergency response measures taken by the contractor to control or mitigate the spreading and expansion of any emergency accident during the period of the construction, pre-commissioning, and commissioning phases. It applies to the emergency response of accidents in the campsite, construction site, transportation and the pipeline pre-commissioning, etc. All the staff personnel shall know their responsibilities and actions to be taken to keep any emergency case under control and restore conditions to the normal state.

Prior to starting construction work, the contractor shall organize an emergency response team (ERT) including HSE supervisor, site manager, medical personnel and other relevant personnel. The HSE supervisor shall determine the measures to be taken according to the actual conditions. The site manager shall arrange the required equipment and personnel and direct the emergency response activities on site. The emergency response direction center will be located in the main campsite near Mellitah, where the person is assigned to be on duty all the time, so that a distress message can be received when the emergency occurs. The member of ERT shall have been trained on HSE knowledge, experienced in construction, know what to do when an emergency occurs and address the consequent hazard. The training of the personnel aims to make the personnel aware of what shall be done when the accident occurs and the duty of each person (e.g. during "tool box" talks foreseen by the Project HSE plan).

The contractor will train its personnel at least twice a year. By doing so, the personnel will be skilled in taking timely and effective measures to respond to the accident and reduce personnel damage and property loss. The content of training and drilling shall cover: using of fire prevention equipment and fire extinguishers; emergency response methods in case there is a poisonous gas leakage; safe withdrawal; rescue of sick persons. Sufficient contingency equipment and devices shall be equipped, so that quick actions can be made and effective measures can be taken when the accident occurs. There shall be sufficient and effective fire fighting equipment such as fire extinguishers. There shall be an ambulance and first-aid kits when the sick or injured person needs treatment.
When there is oil leakage, the upstream and downstream block valves shall be turned off and the rescue shall be organized. There shall be breathing apparatus in case there is leakage of natural gas or other poisonous gases. Proper communication facilities will be equipped in the emergency team, such as radiotelephone and walkie-talkie to ensure smooth contact with the outside when an accident occurs. Prior to construction activities beginning, the contractor shall establish a set of emergency response signals, being updated constantly, which will be introduced to the staff and subcontractors, and shown on the bulletin board in the campsite and on the construction site. The information shall include but not be limited to: safe withdrawal route and gathering place; location of fire extinguishers; location of the clinic; location of the ambulance; and the phone number and fax number of the local hospital and firehouse.

Different emergency response measures shall be taken for different situations involving accidents. When it is dangerous, the followings shall be considered: stopping all activities at once except rescue activities; evacuating the scene and having all personnel gather as a designated safe place; and checking whether there are any injured persons; and saving property and equipment after it is verified that the personnel has been evacuated to a safe place. According to the HSE Plan the following shall be treated: radioactive materials; explosives; fire and explosions (different from oil/gas leakage); hydrocarbon spillage and fire; chemicals; traffic; and health emergency at the work site.

Investigation and report. After the response to the accident and after the injured worker(s) has been taken to be treated by a medical professional, the investigation and analysis shall be carried out, The investigation will cover the cause and course of the accident, casualties, property damage and measures to prevent recurrence of the accident. The investigation report shall confirm whether the measures taken are correct and if the emergency response plan needs to be updated. At first, the report will be oral or a prompt report of the accident (see attachment 1) shall be produced and delivered to the contractor HSE department, safety manager and someone in top management. When the investigation is completed, a monthly HSE report will be submitted to the contractor's project manager and the company's HSE manager. The investigation and analysis report shall contain the measures to prevent recurrence of the accident, be distributed to every foreman and site HSE supervisor. A copy shall be kept in the archives for the investigation report.

4. CONCLUSIONS

Health, safety and environmental management systems (HSEMS) play an important role in the operation of China National Petroleum Corporation (CNPC). The crux of the problem on HSE should be controlled on every part of every project. The HSE performance is continuously improving with the execution of HSEMS. Meanwhile, a set of procedures should be made to support HSEMS. Some means by which a manager of CNPC can be responsible for an effective program in any operation are to:

- Establish in writing and disseminate specific and firm safety policies for the organization, and then ensure they are carried out;
- Provide a coordinated effort, integrating the safety efforts of all organizations concerned;
- Direct the participation of all subordinate organization heads in the safety effort, with specific responsibilities assigned to each. Ensure that each manager passes on suitable guidance to personnel under his or her jurisdiction.

5. ACKNOWLEDGEMENT

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OCCUPATIONAL HEALTH AND SAFETY IN AUSTRALIA: THE CONSTRUCTION INDUSTRY'S RESPONSE TO THE NATIONAL STRATEGY 2002-2012

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ABSTRACT

In 2002, the *National OHS Strategy 2002-2012* was agreed upon by all Australian governments, the Australian Chamber of Commerce and Industry and the Australian Council of Trade Unions. The Strategy established ambitious targets for the reduction of occupational injury and workplace fatalities in Australian industry, including a reduction in the incidence of fatalities of at least 20 per cent by 30 June 2012 (with a reduction of 10 per cent being achieved by 30 June 2007) and a reduction in the incidence of workplace injury by at least 40 per cent by 30 June 2012 (with a reduction of 20 per cent being achieved by 30 June 2007). The Strategy establishes five priority areas to achieve these targets: (I) to reduce the impact of risks at work; (II) to improve the capacity of business operators and workers to manage OHS effectively; (III) to prevent occupational disease more effectively; (IV) to eliminate hazards at the design stage; and (V) to strengthen the capacity of government to influence OHS outcomes. Workers' compensation statistics show that the fatality rate in the Australian construction industry is 9.2 per 100,000 workers, compared to 3.1 for all industries and since 1997/98 an average of 49 construction workers are killed each year – nearly one per week. The paper presents the Australian construction industry's OHS performance in relation to the National Strategy objectives and describes the industry-led development of a Guide to Best Practice for Safer Construction. The manner in which the Guide addresses the five priority areas contained in the National Strategy is described and the potential impact of the Safer Construction project is considered.

Keywords: Safer Construction Guide, National Strategy, Safety Performance, Australia.

1. INTRODUCTION

This paper describes an industry-initiated and led research and development project, in which current best practices used in the management of OHS in the Australian construction industry were identified and documented in a '*Guide to Best Practice for Safer Construction*.' In particular, the safety performance of the Australian construction industry is analysed in relation to the *National OHS Strategy 2002-2012*. The development of the Guide and its basic structure are described and the relationship between the Guide and the National OHS Strategy is discussed.

2. THE NATIONAL OHS STRATEGY 2002-2012

In 2002, the National OHS Strategy established clear and ambitious targets for the reduction of work-related deaths, injuries and illnesses in Australia. The Strategy was agreed to by all Australian governments, the Australian Chamber of Commerce and Industry (ACCI) and the Australian Council of Trade Unions (ACTU) to sustain a significant, continual reduction in the incidence of work-related fatalities with a reduction of at least 20 per cent by 30 June 2012 (with a reduction of 10 per cent being achieved by 30 June 2007), and to reduce the incidence of workplace injury by at least 40 per cent by 30 June 2012 (with a reduction of 20 per cent being achieved by 30 June 2007).

The five priorities identified by the National Strategy to achieve OHS improvements and to nurture longer-term cultural change in Australian industry are:

1. To reduce the impact of risks at work,
2. To improve the capacity of business operators and workers to manage OHS effectively,
3. To prevent occupational disease more effectively,
4. To eliminate hazards at the design stage, and
5. To strengthen the capacity of government to influence OHS outcomes.

The National Strategy focuses on particular OHS risks and industry sectors. Targeted risks are falls from height, musculoskeletal disorders and hitting or being hit by objects. Building and construction is identified as a priority industry due to its high occupational injury and illness incidence rate (of occupational injury and illness) and the high number of compensation claims arising in construction, compared with other industries.

OHS performance of the Australian construction industry

Relative to other industries, the occupational health and safety (OHS) performance of the Australian construction industry is poor. Workers' compensation statistics show that the fatality rate in the Australian construction industry is 9.2 per 100,000 workers, compared to 3.1 for all industries and since 1997/98 an average of 49 construction workers is killed each year – nearly one per week (Fraser, 2007).

Figure 1 shows the absolute number of non-fatal compensation claims for work-related injuries and illness between 1997/98 and 2005/06 for the Australian mining and construction industries. Taking year 2001-02 as the base year from which the National Strategy was introduced, the number of claims has increased from 13,055 in 2001/02 to 14,330 in 2005/06, representing an increase of 9.8%. In comparison, the mining industry figures fell from 2,595 to 2,260, a decrease of 12.9% in the same period.

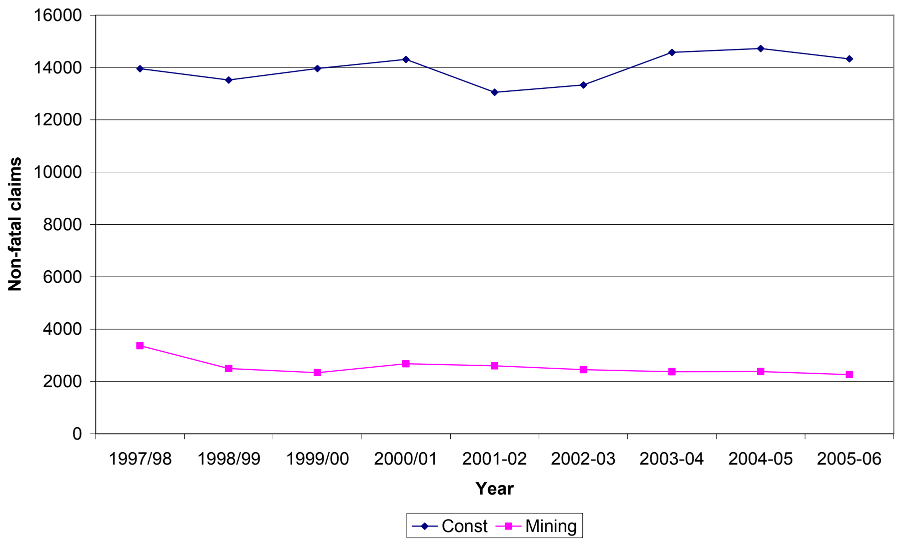

Figure 1: Number of non-fatal claims for occupational injuries and diseases in the construction and mining industries, 1997/98-2005/06 (Source: Australian Safety and Compensation Council, 2007)

Figure 2 shows the data for reported work-related fatalities in the same period. Again, taking 2001-02 as the base year, recorded fatalities in the construction industry fell from 47 in 2001-02 to 33 in 2005-06, a decrease of 29.8%. In comparison, mining fatalities fell from ten in 2001-02 to 5 in 2004-05, but rose again to 12 in 2005-06, indicating an overall increase.

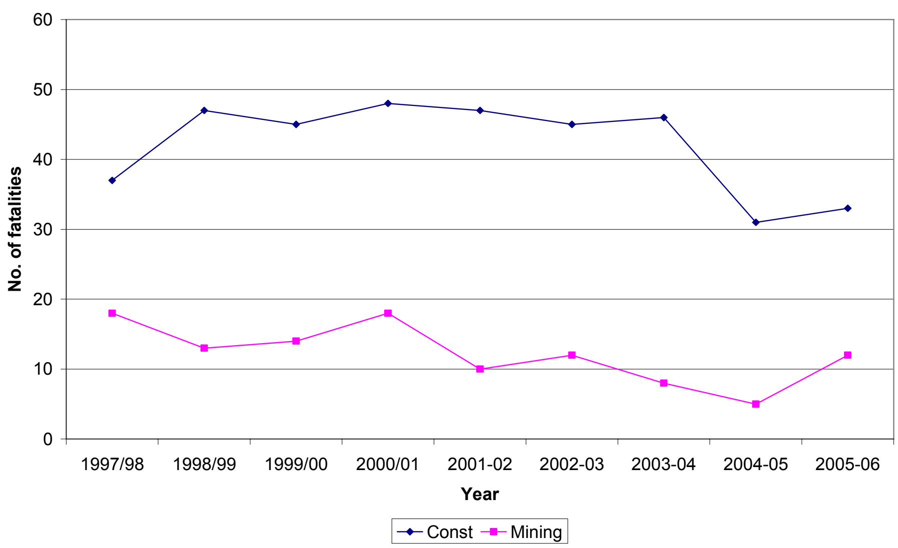

Figure 2: Number recorded fatalities in the construction and mining industries, 1997/98-2005/06 (Source: Australian Safety and Compensation Council, 2007)

However, the numbers of compensation claims and recorded fatalities tend to be misleading as they do not account for the volume of work. Figure 3 shows the incidence rate of all claims (claims per 1,000 employees) in both the mining and construction industries for the period. The incidence rate in the construction industry fell from 30.3 in

2001-02 to 26.0 in 2005-06, a decrease of 14.2%. The mining industry incidence rate fell from 34.2 to 18.6 (45.6%) in the period. Figure 3 also shows that in 1997/98 the Australian mining industry had a higher incidence rate than the construction industry and that it has improved substantially. In 2002-03 the mining industry incidence rate fell below that of the construction industry and has continued to decline at a greater rate than that of the construction industry.

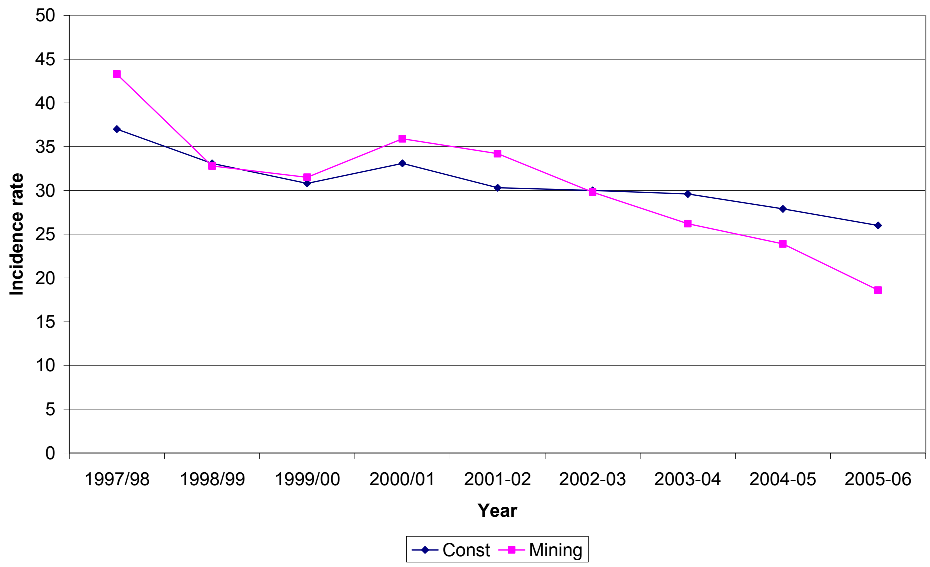

Figure 3: Incidence rate of occupational injuries and diseases (per thousand employees in the construction and mining industries, 1997/98-2005/06 (Source: Australian Safety and Compensation Council, 2007)

Figure 4 shows the frequency rate (claims per million man hours worked) for the mining and construction industries. Since 2001-02 the construction industry frequency rate has fallen from 15.7 to 13.5 (14.0%). In comparison, the mining industry's frequency rate fell in the same period by 29.6%. Figure 4 shows that between 1997/98 and 1999/00 frequency rate fell in both the mining and the construction industries. In 2001/02 (the base year), the frequency rates in these industries was roughly the same. However, since 2001-02, the frequency rate for the mining industry has declined at a faster rate than that of the construction industry.

These compensation-based statistics are also considerably lower than those published by the Australian Bureau of Statistics (ABS). Using data collected in the Multi-Purpose Household Survey (MPHS) conducted in 2005 – 2006, the construction industry had an incidence rate of 86 per 1,000 employed people, almost twice that indicated in the ASCC compensation statistics (ABS, 2006). This difference is largely due to the fact that the ASCC relies solely on workers' compensation claims data and excludes self-employed persons, when the ABS dataset includes non-fatal injuries or illnesses sustained by all categories of workers, irrespective of whether these have been claimed under workers' compensation. The ABS figures are not collected every year and therefore cannot be used to gauge the industry's progress against the objectives of the National Strategy, but they do suggest that compensation-based statistics do not reflect the magnitude of the OHS problem.

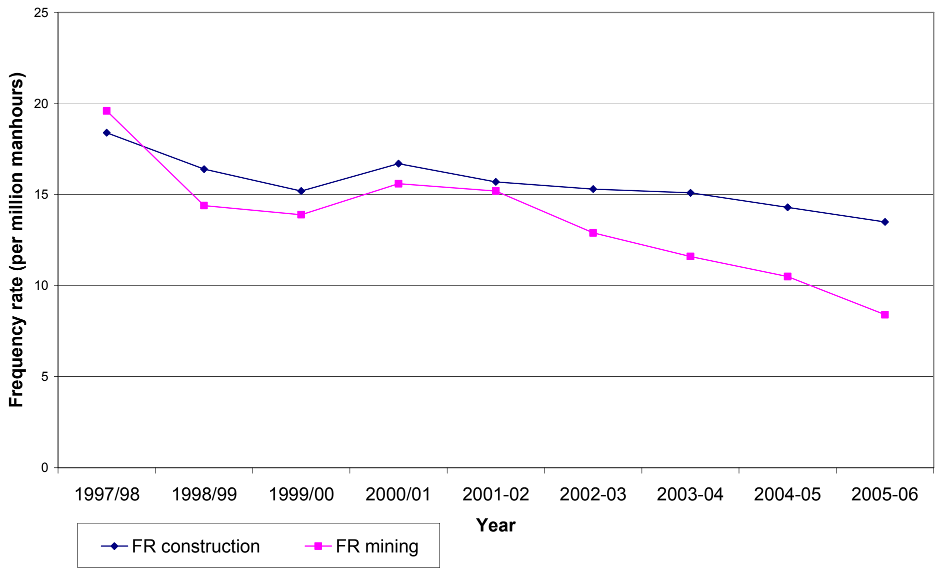

Figure 4: Incidence rate of occupational injuries and diseases (per thousand employees in the construction and mining industries, 1997/98-2005/06 (Source: Australian Safety and Compensation Council, 2007)

The ASCC statistics, though conservative, show that the Australian construction industry has not performed as well as it could have in improving safety performance since the National Strategy was instigated. The number of fatalities in the industry declined by 29.8% between 2001-02 and 2005-06, a greater reduction than the Strategy's target of 10% by 30 June 2007. However, the total number of non-fatal claims for occupational injury and illness in the construction industry has increased rather than decreased in the period since 2001-02. This might be partly due to an increase in the volume of work and hence risk exposure. But, even using the more meaningful safety measures of incidence and frequency rates, the construction industry appears to fall short of meeting targets established by the National Strategy. Incidence and frequency rates have both fallen in the mining and construction industries since 2001-02. In construction both incidence and frequency rates have reduced by 14%, which falls short of the target reduction of 20% by 30th June 2007. In comparison, the mining industry's incidence and frequency rates fell by 45% and 29% respectively. Thus, even after factoring the increased volume of work arising as a result of a 'boom' in the construction and resources sectors, the construction industry's safety performance relative to the mining industry's has been disappointing.

3. THE 'SAFER CONSTRUCTION' PROJECT

The relatively poor safety performance of the Australian construction industry was concerning to industry participants, prompting senior representatives of each of the key stakeholders groups in the construction industry, i.e. clients, designers and constructors, to embark upon a collaborative project to improve the safety performance of the construction industry. The project, titled 'Safer Construction' was commissioned by Engineers Australia and funded by the Cooperative Research Centre for Construction Innovation. A high level industry task force was established to oversee the development of a '*Guide to Best Practice for Safer Construction*', hereafter referred to as 'the Guide.' The task force was made up of senior representatives of major industry stakeholder groups, industry peak bodies and professional institutions. Represented were: Engineers Australia; the Property Council of Australia; the Australian Procurement and Construction Council; the Association of Consulting Architects Australia; the Association of Consulting Engineers Australia; the Royal Australian Institute of Architects; the Australian Constructors Association; and the Master Builders Association. Also invited to participate in the task force was a representative of the Office of the Federal Safety Commissioner. Thus, the task force was representative of construction clients, the design professions and constructors, as well as government and policy makers.

The project sought to identify safety 'best practices' currently in use in the Australian construction industry. These best practices were to relate to the project lifecycle, from planning, through design and construction to commissioning. The best practices were to represent tasks for construction clients, designers and constructors, with an emphasis on cooperation, communication and reaching consensus about what is a reasonable allocation of responsibility for safety in a given project situation. The result was to be a voluntary Guide, documenting safety best practice.

Research and development

A research team was established to research and develop the Guide. The research team comprised of researchers from RMIT University, Queensland University of Technology and Curtin University.

Interviews were conducted to identify what safety practices were currently implemented in the Australian construction industry. Data were collected for 42 construction projects. Consistent with the focus on best practice, the sample was skewed towards the better performing projects. The highest Lost Time Injury Frequency (LTIFR) rate for these projects was 25.5 and the lowest was 0. The mean LTIFR for the surveyed projects was 5.3. This compares to an industry average of 22.6 for general construction and 19.7 for construction trade services. Data were collected from a variety of different types of project. The project cost ranged from $2.7 million to $2.5 billion, with a mean value of $205 million dollars. Nineteen of the projects were procured via a Design & Build strategy, five were traditional Design-Bid-Build projects and thirteen projects were procured using an alternative strategy.

The qualitative survey data was subject to thematic analysis, undertaken independently by two occupational health and safety specialists. The researchers coded the data from each project according to whether there was evidence of specific safety management practices in the project. The data revealed well established practices for the management of safety during the construction stage but far less activity during the planning and design stages of construction projects. For example, in only 50% of the projects was there evidence that project stakeholders other than the designer had input into design decision-making. In 64% of cases there was some attempt to eliminate safety risks during the design stage but in only 36% of the projects was this risk reduction considered to be innovative. In only 50% of the projects was project specific safety information communicated to prospective constructors and in only 40% of the projects was safety included in project specifications at the tender/award stage. Although not universal, 'best practice' in the pre-construction stages of projects was apparent, for example a process known as Construction Hazard Assessment Implication Review (CHAIR) was used in some projects to analyse design safety risks during the construction stage (New South Wales WorkCover Authority, 2001). In the construction stage there was evidence of more widespread safety management activity, largely undertaken by the constructor. For example, in 90% of projects detailed work methods developed prior to commencing major construction activity, meaningful arrangements were made for worker consultation in safety risk management and training needs were carefully analysed and appropriate training was provided. However, in only 57% of projects was there evidence that on-site design changes were subject to a rigorous risk assessment to determine and manage their safety implications.

The data collected were used to identify examples of best practice, as well as areas in which substantial 'gaps' existed for incorporation into the Guide. In particular, client-led safety management in the planning and procurement of construction work was not well established and the degree to which design safety processes were implemented depended largely upon the design and construction organizations involved in the project. These data were used to distil practical examples of safety best practice which are used throughout the Guide. Gaps were then filled by a comprehensive review of Australian and international literature addressing the issue of construction safety management.

4. THE GUIDE TO BEST PRACTICE FOR SAFER CONSTRUCTION

The Guide is made up of two parts: *Best Practice Principles* and *Best Practice Tasks*. The former document establishes broad principles for the management of OHS within the construction industry. There is some overlap between these principles and the National Strategy Priority Areas. The 'Safer Construction' principles are:

- Principle 1: Demonstrate Safety Leadership,
- Principle 2: Promote Design for Safety,
- Principle 3: Communicate Safety Information,
- Principle 4: Manage Safety Risk,
- Principle 5: Continuously Improve Safety Performance, and
- Principle 6: Entrench Safety Practices.

At the heart of the guide is an 'Implementation Table', specifying safety practices to be undertaken at four life cycle stages of a construction project, i.e. Planning, Design, Construction and Commissioning. The practices are numbered and organised under the principles that they represent. Figure 5 shows a small section of this Table, indicating the layout of project stages, principles and practices.

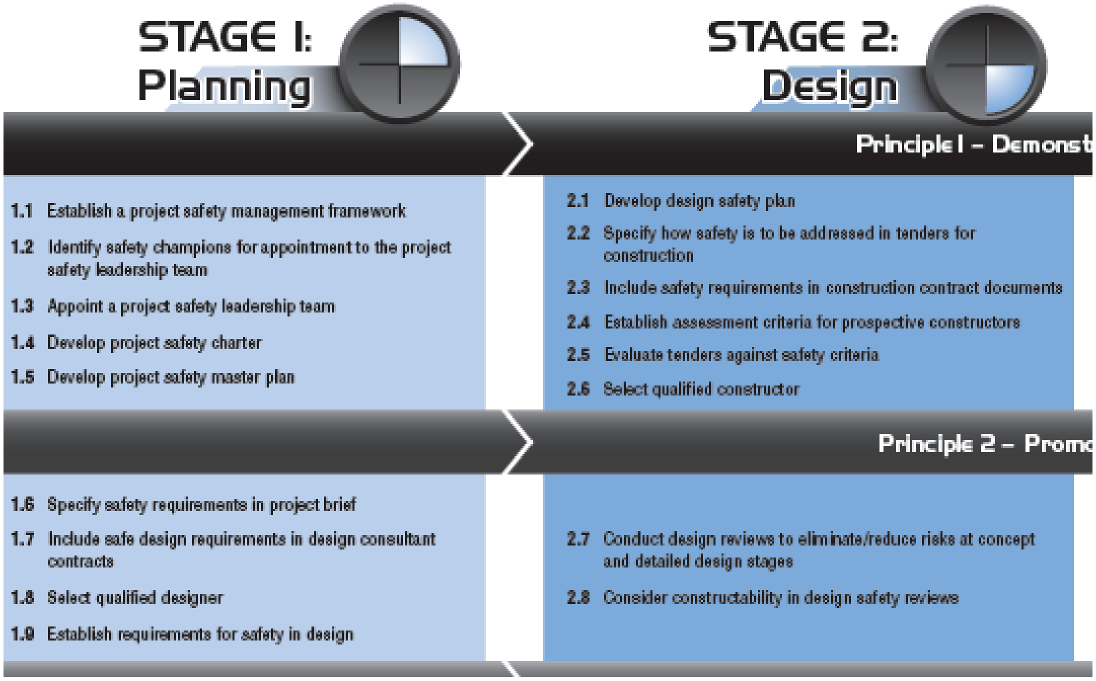

Figure 5: Layout of the Safer Construction Implementation Table.

Part two of the Guide (*Best Practice Tasks*) documents each of the best practices using a standard layout that is intended to provide the user a concise tool for implementation, monitoring and review .The layout includes:

- Best Practice – the identifying name of the best practice,
- Description – a short description of the best practice,
- Key Benefits –the key benefits to be achieved by implementing the best practice,
- Desirable Outcome – the behavioural and procedural changes effected by the implementation of the best practice,
- Performance Measure – any output measures that can be recorded for the best practice, and
- Leadership – which party would typically take responsibility for this best practice and who needs to be consulted/ involved.

Guidance in relation to the National Strategy Priority Areas

It is hoped that the Guide will accelerate the reduction in incidence and frequency rates of occupational injuries and illnesses in the Australian construction industry. It is a voluntary document designed to complement, state-based occupational health and safety legislation and the initiatives of compensation agencies and regulatory authorities. With considerable industry input into the formulation of the Guide, and its endorsement by many of the Australian construction industry's professional and stakeholder groups, the Safer Construction project constitutes an attempt by the entire construction industry to ‘get its house in order.’ As the ASCC statistics show, the industry need to improve its OHS performance if the targets established in the National Strategy are to be met. The Guide addresses the Five Priority Areas addressed in the National Strategy in several respects.

Priority area 1: Risk reduction.

The Guide identifies management requirements for effective safety risk reduction at all stages in the project process. From planning through design, construction to commissioning, the Guide advises that decisions should be made on the basis of a careful consideration of the safety implications of available options. Decisions made about project options, design of the permanent structure, design of the construction process, choice of plant, equipment, materials and construction methods and project organisational arrangements should be made following an assessment of safety risks, using an appropriate and recognized risk assessment method.

The Guide recognises that all risk reduction measures are not equal and, wherever possible, safety risks should be eliminated through design or engineering solutions to create a safe workplace. It is always better to make the workplace safer than rely upon behavioural controls because people are fallible and will always make mistakes.

Where workplace risks cannot be physically removed, the Guide clearly states that they should be reduced so far as is possible. An established ‘hierarchy of controls’ is specified by the Guide, which states that, when a risk cannot be eliminated, risk control measures should be considered in the following order:

- Substitute the hazard giving rise to the risk with a ‘less risky’ hazard,
- Isolate the hazard from people whose safety could be at risk,
- Minimise the risk by engineering,
- Apply administrative measures, e.g. the adoption of safe systems of work, and
- Use personal protective equipment.

The Guide also provides for the capture and communication of safety risk throughout the project lifecycle, via a project risk register. The Guide expressly requires that this risk register be made available to those who must manage or work with a risk. Consistent with the concept of equity in risk management, the Guide also advises that all project decision-making that could have an impact upon safety risk should involve input from those parties that could be affected by that risk.

Priority area 2: Increase OHS management capacity.

The National Strategy identifies the need to build the motivation and ability of employers to manage safety risks effectively and of workers to work safely. The National strategy also recognizes the need for: increased participation in safety consultation, the development of safety competencies and the provision of systematic OHS management guidance and training, targeted to meet the needs of stakeholders, including those in small to medium sized enterprises (SMEs). The Guide provides a clear, stage-by-stage set of tasks for the systematic management of safety based upon the construction project process. The provision of detailed information about each task, including its likely outcomes/benefits, will provide a greater understanding of the case for using the Guide, as well as its accompanying tools, thus addressing the need to motivate construction industry participants to adopt the safety management practices documented. Safer Construction Principle 6, Entrench safety practices' also focuses primarily on the development of safety management capability within the construction supply chain, with an emphasis on the development of longer term relationships, the provision of mentoring schemes for SME design firms and sub-contractors.

Priority area 3: Prevent occupational disease.

The prevention of occupational disease is not directly addressed by any of the Safer Construction principles. However, it is implicit in all of the Safer Construction tasks. The Guide states that the term 'safety' is intended to include occupational health and therefore the Safer Construction practices apply as much to the reduction of risk of work-related illness as they do to injury reduction.

Priority area 4: Hazard elimination through design.

The National Strategy defines the elimination of physical hazards at the design stage as an area of national priority. The strategy aims "to build awareness and observance of this approach and to give people the practical skills to recognise design issues and to ensure safe outcomes" (Commonwealth of Australia, 2002, p.9). The case for design OHS in construction is compelling. Recent analysis identifies design as a causal factor in fatalities and serious injuries in the construction industries of other developed economies (Suraji et al. 2001; Behm 2005; Gibb et al. 2004). Safer Construction Principle 2, 'Promote design for safety', responds directly to Priority Area 4. The outcomes for this priority area, as defined in the National Strategy, include the adoption of safer approaches across the lifecycle of the product or process, the raising of awareness of the importance of safe design among the design professions, clients and the community, more systematic and cooperative application of risk management principles by designers, clients and others and the integration of safe design considerations in procurement.

In taking a project lifecycle perspective and by recommending clients engage in the procurement of safe design, the Guide has the potential to produce these outcomes. The Guide suggests that construction clients ensure that they engage a designer who has a demonstrated understanding and awareness of safety risk management appropriate to the project requirements. Where a number of organisations or individuals contribute to the final design with their contributions being coordinated by a prime design manager, the Guide suggests that all organisations and individuals should participate in appropriate risk assessments and safety management decisions appropriate to their sphere of control. Further, the Guide establishes the need for comprehensive and systematic design safety reviews to be conducted at appropriate intervals during the design process. The Guide recommends that design risk management activities are cooperative, involving clients and, where possible, those who will be exposed to the safety risks, including constructors and maintenance representatives. This is consistent with the systematic and cooperative application of risk management principles envisaged in the National Strategy. The Guide also specifies that safety risks arising as a result of the design should be eliminated wherever possible. Where elimination is not possible, efforts to reduce safety risk through design modification should be made. The Guide suggests that a similar risk assessment and reduction process should be applied to any design changes made during the construction stage. Not mentioned in the National Standard but considered important in the promotion of safe design in construction industry is the issue of communicating safety information arising as a result of design risk management to other project stakeholders, particularly those whose safety could be affected by design decisions. The Guide advises designers to document residual risk, i.e. the identified risks remaining following the design safety risk management process and to clearly communicate this information to relevant stakeholders - including the client, the constructor, and the owner/occupier.

Priority area 5: Strengthen the capacity for government influence.

The National Strategy states that 'Governments are major employers, policy makers, regulators and purchasers of equipment and services. They have a leadership role in preventing work-related death, injury and disease in Australia (Commonwealth of Australia, 2002, p.9). Outcomes anticipated in the National Strategy for this priority area include the development of a whole of government approach to consider and account for the safety implications of government work, the improvement of governments' performance as employers, and the use of the supply chain for the improvement of safety by governments, project managers and contractors. In establishing a comprehensive set of safety management tasks for construction clients, the Guide has the potential to significantly strengthen the capacity for government influence concerning the safety performance of the construction industry. As clients of construction, Australian Government agencies can play a significant role in leading the industry's safety improvement efforts.

As the initiators of projects, clients are in the best position to drive the cultural change needed to bring about further safety improvements in the construction industry. At the most basic level, the client's selection of project delivery strategy determines the timing and nature of engagement of both the designer and constructor, which can have an impact upon the extent to which safety issues are integrated into project planning and communicated within the project delivery team. Clients make key decisions concerning the project budget, project objectives (including timelines) and other performance criteria, which can create the pressures and constraints known to have a significant impact upon safety in the construction stage (Suraji et al 2001). Research by the Health and Safety Executive (UK) identifies client requirements as being one of the most significant root causes of on-site accidents (HSE 2003). Bomel (2001) identified client company culture and contracting strategies as areas presenting considerable opportunities for safety improvement in the UK construction industry. In the USA, Huang and Hinze (2006a; 2006b) empirically evaluated the impact of a range of client-led safety initiatives on safety performance in the construction process. The US research revealed that the involvement of the client in pre-project planning, financially supporting the constructor's safety programme and participating in the day-to-day project safety activities were important requisites for excellent project safety performance. Winkler (2006) describes how client involvement in construction contractors' safety processes has created a set of shared values supportive of safety in the UK construction industry.

The Office of Government Commerce in the UK (OGC 2004) and the Scottish Executive have developed processes designed to help public sector construction clients to raise the health and safety standards of workers engaged in their construction projects. Adoption of the Safer Construction Guide by government agencies has the potential to further integrate safety management into the planning and procurement of public sector construction projects in Australia.

5. CONCLUSIONS

The Guide is intended to reflect 'best practice' in the management of safety on construction sites. It is a voluntary document and it was not intended that it replace or supersede any State/Territory or Commonwealth law relating to construction OHS. In particular, legislative requirements for constructors (as employers) establish minimum requirements for on-site OHS during the construction stage. However, the Guide recommends an increased role for construction clients (in the planning stage) and designers (in the design stage) in achieving OHS best practice during the construction stage. The Guide recognises that clients, in particular, can do a great deal to drive OHS best practice in construction projects. Clients (and/or their professional advisors) make decisions about what is to be constructed, the terms and conditions upon which each of the parties is to be engaged, as well as budget and schedule requirements for a project. The client's selection of project procurement method is particularly important because this dictates when and how other key project stakeholders will be engaged to advise on OHS in the project. For example, a designer could be expected to consider OHS during the design stage but would not reasonably be expected to advise upon the OHS risk implications of design issues during the construction stage, unless explicitly instructed to do so by the client. Defining, up-front, the roles and OHS responsibilities of each key stakeholder in a project is recommended within the framework of the Guide. In articulating best practice, the Guide provides an opportunity for property, design and construction professionals to enhance the professional services that they provide and improve OHS performance within the construction industry.

As a voluntary document, the question of the Guide's adoption and impact is likely to be raised. The voluntary nature of the Guide is in contrast to legislative strategies adopted, for example, in the United Kingdom. In the UK, the Construction (Design and Management) Regulations were enacted in the mid-1990s and have recently been reviewed and re-written. These Regulations created statutory OHS responsibilities for construction clients and designers as well as creating a new overall OHS coordination role called the 'planning supervisor' (now replaced with an OHS Coordinator). Prior to the recent review, this legislative response was widely reported to have had limited impact on the UK construction industry's OHS culture or performance. Criticisms were based on the fact that clients and designers failed to integrate OHS into their decision processes and the creation of a new administrative role with overall coordination responsibility for project OHS, did not 'fit' comfortably with existing roles and relationships in the construction industry. It is hoped that, as a collaborative industry-initiated and endorsed document, the Safer Construction Guide will be widely adopted by industry stakeholders, thereby effecting cultural change in the Australian construction industry with regard to OHS. The Guide was launched in September 2007 and it is therefore too early to ascertain its impact. However, the extent of the Guide's adoption should be evaluated in future research.

The Guide and its supporting documentation can be downloaded and more information about the Safer Construction project found at the following website: http://www.construction-innovation.info/.

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INSTITUTIONAL AND ECONOMIC CHALLENGES TO HEALTH AND SAFETY MANAGEMENT WITHIN SMEs IN DEVELOPING COUNTRIES: A CASE STUDY OF GHANA

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ABSTRACT

The health and safety performance of the construction sector is an important issue in Ghana's implementation of the Millennium Development Goals (MDGs). Much has to be achieved in this direction if Ghana is to attain the goal of a middle income country by 2015. This paper presents information on safety and health on construction sites obtained through interviews conducted with the aim of examining the institutional structure responsible for the implementation of safety and health standards on construction sites and the economic contexts within which construction SMEs manage health and safety. In Ghana, the institutions having a stake in safety and health at workplaces are comprised of government departments and agencies, consultants, employers' organisations and the trade union. Eight exploratory interviews were conducted as part of a larger study involving key informants within these organisations. The findings of the paper highlight the significance of an enabling institutional structure and commitment of government in facilitating health and safety management. Based on the findings of the study, key barriers to safety and health management within construction SMEs are identified and recommendations for overcoming those barriers are made.

Keywords: construction safety and health; developing countries; SMEs.

1. INTRODUCTION

The construction sector in developing countries plays a significant role in physical development and employment of the otherwise largely unemployed labour force. There are however major challenges to increasing the productivity of the sector in developing countries including low levels of macroeconomic performance, limited resources, reliance on institutional structures and procedures largely inherited from developed countries which once ruled them and poor infrastructural development (Coble and Haupt 1999; Gibb and Bust 2006; Ofori 1999). In the wake of these challenges, it is not surprising that construction in developing countries contributes a large quota to occupational accident statistics. In comparison with developed countries, construction sites in developing countries are ten times more dangerous than in developed countries (Hämäläinen et al. 2006). The construction industry of Ghana is the second most hazardous industry after manufacturing (Government of Ghana (GOG) 1987).

Small and medium-sized businesses dominate the construction industry in many developing countries. In Ghana, Addo-Abedi (1999) reported that virtually all domestic construction businesses operate as small scale contractors managed by owner/managers and their spouses and in some cases, their children. These SMEs are constrained by limited access to financial and information resources as well as regulations and procedures which make it difficult to effectively manage the safety and health aspects of their operations. The quality of working conditions within SMEs is therefore relatively unsatisfactory when compared with working conditions in large construction businesses within the country. Considering that a sizeable proportion of the labour force in construction is employed within construction SMEs, this raises the level of concern for safety, health and welfare within the SME sector in construction as many workers are exposed to hazards on site.

The government of Ghana in its development strategy (Government of Ghana (GOG) 2005) aims to move the country into a middle income country by the year 2015. This requires commitment by the government to improving productivity of all economic sectors of the country. For this to be achieved working conditions need to be improved, particularly for construction. Anaman and Osei-Amponsah (2007) have shown that Ghana's construction industry has potential as a driver of economic growth, although government's commitment to improving productivity of the sector is low. Improving the health and safety performance of the sector is one means of enhancing the productivity of the construction sector in Ghana.

Definition of SMEs

Domestic construction businesses in Ghana operate within the domestic construction market and are managed as family businesses, rarely employing up to 200 employees (Addo-Abedi 1999). They may be regarded as SMEs based on the similar characteristics they possess. This paper therefore defines SMEs as family run domestic contractors with the following thresholds relating to medium, small and micro construction businesses:

- an upper threshold of 199 employees and a lower threshold of 30 employees are adopted for medium-sized construction businesses;
- small businesses are ones which employ 10-29 persons; and
- micro businesses are construction businesses whose number of employees does not exceed 10.

2. BACKGROUND TO OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION IN DEVELOPING COUNTRIES

Occupational health and safety administration in many developing countries evolved from institutional and legal frameworks developed by colonial administration to manage the safety, health and welfare aspects of industrial settings at the time. In Ghana, a labour department, established in 1938, was responsible for implementing the Factories Ordinance passed in 1952 to provide a code of protection for factory workers (Visano and Bastine 2003). Presently, rates of industrialisation in developing countries require effective occupational health and safety administrative systems to control hazards and to provide decent working environments that meet international standards. Higher rates of occupational accidents, particularly in construction, means developing countries might be poor at managing the risks of hazards at workplaces. It is therefore against this background that this study was initiated.

Past studies on health and safety management in construction in developing countries provide ample evidence of lapses in the management of safety and health at construction sites. These studies have identified key problems associated with safety and health at construction sites and are summarised in Table 1. Their findings reveal weaknesses in occupational safety and health administration, economic conditions, climatic conditions and the characteristics of the construction industry of developing countries influence safety and health at construction sites. Also, the effective implementation of safety and health programs is absent in most construction businesses in developing countries. The construction industry of Ghana shares in many of these features of safety and health management in the construction industry of developing countries.

Table 1

Author(s) and Year	Summary of research	Key constraints to effective safety and health management
Suazo and Jaselskis (1993)	Compared the occupational safety and health administration system of a developing country (Honduras) and that of a developed country (US)	The study found that the occupational safety and health administration of the developing country Honduras was incomprehensive and limited in coverage
Koehn et al., (1995)	The study examined problems in health and safety management of construction projects in a developing	The study identified ignorance on the part of workers, bureaucracy and time pressures as factors militating against effective safety and health management in the construction sector.

	country; India	
Koehn and Reddy (1999)	The study explored safety problems and labour requirements in the construction industry of India	The findings of the study indicated certain characteristics of construction in developing countries contributed to poor safety and health performance of the industry: •availability of cheap labour means workers are compelled to take unacceptable risks because of fear of being dismissed; •workers cannot afford the cost of proper nutrition because of low wages leading to fatigue and slow rate of work; and •poor health and safety attitudes.
Haupt and Smallwood (1999)	Study examined health and safety practices on community projects in South African Construction industry	The findings of the study indicate that health and safety practices are rarely adopted on community projects: typically, no inductions are conducted; workers are not consulted on health and safety issues; PPE is seldom provided; and policies, rules and health and safety programs are not implemented.
Peckitt et al., (2002)	Compared health and safety risk management between a developed country (UK) and a developing countries (Caribbean countries)	The study found that: •positive influences on the safety culture of the British construction industry include; relatively high levels of regulation, resources and formal health and safety management systems; •Positive influences on the safety culture of the construction industry of the Caribbean include: strong personal locus of control for safety, high risk perception and slow pace of work. •

Smallwood (2002)	Study examined the link between religious believe systems and safety and health	The study's findings showed that religion puts emphasis on the need for conservation of life and the environment
Peckitt et al., (2004)	Examined the role of societal culture in influencing safety culture of the construction industries of UK and	The findings of the study demonstrate that societal cultural biases have an impact on safety culture. Societal orientations to power relationships, time, human relations, materialism and risk taking were found to be important factors influencing safety culture of

	the Caribbean	both countries
Mwombeki (2005)	Study investigated the implementation of health and safety on construction sites in Tanzania	The study found that a majority of Tanzanian contractors, small or large, appear to understand the importance of health and safety programs but did not implement such programs to improve the poor health and safety performance of the construction industry
Gibb and Bust (2006)	The study investigated the implications on safety and health of carrying out engineering and construction projects in developing countries	The study identified a number of factors having a negative impact on health and safety management in developing countries: poor infrastructure; problems in communication; unregulated practices; adherence to traditional methods of working; non availability of construction equipment; extreme weather conditions and corruption.

Health and Safety Management within Ghanaian Construction SMEs

The construction industry of Ghana, like many developing countries, is dominated by SMEs which operate within the domestic market (Addo-Abedi 1999). Constraints which construction SMEs face include:

- lack of access to financial resources (Eyiah and Cook 2003; UNCTAD 2001);
- delayed payments (European Commission 1994);
- lack of adequate resources to manage their own operations efficiently and effectively (European Commission 1994); and
- regulatory systems that hinder the establishment and growth of SMEs (Eyiah 2004).

In addition to the aforementioned constraints, construction SMEs in Ghana lack the necessary capacity to undertake large contracts because contracts are not packaged to suit small contractors. In the face of scarce resources and these constraints, many of them are unlikely to commit sufficient amounts of funds and the right types of resources in the management of health and safety. Responsibility for enforcing health and safety standards on construction sites lies with many government departments and agencies (refer to Table 2). Some owner/managers are genuinely confused about their responsibilities under the various health and safety legislation.

Employees of construction SMEs are exposed to hazards which cannot be ignored, as international funding bodies and some clients of the construction industry demand that SMEs demonstrate corporate social responsibility in respect of a decent working environment and the physical environment. These are issues which government needs to address to increase productivity of the construction sector in line with its Growth and

Poverty Reduction Strategy (Government of Ghana (GOG) 2005). This study therefore aims at assessing the institutional capacity for managing health and safety within construction SMEs which have a significant role to play, albeit with a strong institutional backing, in the country's transformation into a middle income country. The preceding background introduction underscored the rationale of a study designed to explore how the institutional and socio-economic environments impact health and safety management within SMEs. The aims of the study were to:

- examine the key contextual influences on health and safety management practices within SMEs, not only in Ghana but also in other developing countries; and
- make recommendations based on the analysis of the contextual environment of Ghanaian construction SMEs, for improving health management within construction SMEs, not only in Ghana but also in other developing countries.

The current paper reports on the findings of exploratory interviews of health and safety institutional stakeholders conducted in the first phase of the research.

Table 2 Implementation of safety and health legislation

Government department/agency	Health and safety law mandated to implement	Summary of applicability to construction sites
Factory Inspectorate Department	Factories, Offices and Shops Act 1970	Sections 57, 6-8, 10-12, 19, 20, 25-31, 33-40, 43-54 and 60-87 are applicable to building and civil engineering works
Labour Department	Labour Act 2003 Workmen's Compensation Law 1987	Part XV of the Labour Act concerns health and safety and applies to workplaces including construction businesses Workmen's Compensation Law 1987 is applicable to construction businesses
Environmental Protection Agency	Environmental Protection Agency Act (Act 490) Pesticides Control and Management Act (Act 528)	Both Acts are applicable to building and civil engineering works and therefore of relevance to construction businesses
Mines Department	Mining Regulations 1970	Building and civil engineering works carried out under the ambit of mining companies are affected by the regulations
Town and Country Department	Planning and Building Regulations	Applicable to all physical developments.
National Road Safety Commission	National Safety Commission Act (Act 567)	Applicable to road construction works

National Occupational Health Unit	Ghana Health Service and Teaching Hospitals Act (Act 526)	Applicable to all occupations including construction

3. METHOD

Semi-structured interviews were conducted with key informants within institutions with related responsibilities for safety and health on construction sites. Key informants were persons within the participating institutions who had attained the status of director or deputy director or were head of a division. A total of 11 interviews were conducted (Table 3). The interview questions sought information on the following:

- characteristics of respondents' organisations;
- involvement of respondents' organisations in implementing safety and health standards within construction SMEs;
- relevant safety and health laws they seek or are mandated to implement;
- key barriers to effective implementation of health and safety standards within construction SMEs; and
- instance(s) of exemplary implementation of safety and health standards within SMEs.

Data from document sources were also analysed. The respondents came from three safety and health enforcing departments and agencies, two government departments responsible for regulating the activities of the construction industry of Ghana, two employers' associations, one trades union representative and one private consulting organisation in the built environment.

Table 3 Persons interviewed

Organisation/institution	Number of persons interviewed	Schedules of persons interviewed
Labour Department	1	Deputy Chief Labour
Factory Inspectorate	2	Chief Factory Inspector Deputy Chief Factory Inspector
Environmental Protection Agency	1	Acting Regional Director
Ghana Highway	1	Principal Engineer
Public Works Department	1	Principal Q/S
Private consultants	1	Managing Director
Ghana Employers'	1	Training Officer

Contractors' Association	2	National Executive Secretary President of Association of Road Contractors
Construction and Building Materials Workers Union	1	National Chairman
Total	11	

4. RESULTS OF THE STUDY

This section summarises the main results of the interviews. The empirical data are presented as narratives and quotations.

Influences of Government Institutions on Health and Safety Management within SMEs

The influence of government institutions with responsibility for implementing health and safety standards is minimal. The Factory Inspectorate Department which is responsible for enforcing health and safety legislation in most of the countries economic sectors including construction rarely carry out inspections of construction sites. Although it is a requirement for contractors to register their sites with the department, it is mainly large international construction businesses operating in the country that comply with the requirement. The response of one interviewee of the department indicates construction SMEs' compliance with the Factories, Offices and Shops Act is less than desirable:

> "I must say that the most serious abuse of the Factories, Offices and Shops Act occur in the informal sector which includes small domestic contractors in the country. Many of the owner/managers of small construction businesses are ignorant of their responsibilities under the health and safety law affecting the construction sector. The Department has embarked on educational campaigns to help raise the level of health and safety awareness within the construction sector" (view expressed by personnel of Factory Inspectorate Department during interviews).

Views of other departments with responsibility for implementing safety and health standards within construction SMEs portray the sector as one which pays little regard for the safety and health of its employees. Hazards associated with construction activities are often overlooked, resulting in serious accidents. One respondent of the Labour Department said:

> "Small-scale contractors want to make the maximum profits and would not provide the necessary personal protective equipment for their workers. They do not evaluate the risk involved in carrying out construction work and as such do not take steps to minimise or eliminate hazards. Some of their workers are employed without

completing their apprenticeship training; while some may not be trained. They may not be sensitised for their safety. Most of their workers are from the informal sector where they may not go under any regulation or union. They would not want to spend their time, money and other resources to train their workers up to a certain standard of safety and health". (Personnel of Labour Department).

Consultants' involvement in safety and health management within SMEs often follows the dictates of clients and funding bodies. Consultants' involvement in health and safety issues is far better on projects funded by international donor agencies and clients who aspire to implement health and safety standards that meet ILO guidelines on construction health and safety. One interviewee commented upon the attitudes of consultants as follows:

> "The moral commitment to ensure safe and healthy sites is very low amongst consultants in this country. We do not set a good example and that is the problem. If for instance, I go to a construction site today and I put on the necessary helmet, boots and the necessary personal protective equipment then I will be doing a lot of service to improving construction site health and safety. Professionals are not committed to improving health and safety at construction sites; we talk of ensuring safer construction sites but we are not serious" (Personnel of Architectural and Engineering Services Limited).

The involvement of employers' associations in health and safety management within construction SMEs is limited to instances of strained industrial relations between employers and their employees where the issue(s) of contention relates to safety and health conditions at the workplace. Many construction SMEs are not registered with the Ghana Employers' Association and this limits the extent to which the association can protect their interest. The position of the Association regarding safety and health within construction SMEs is summarised by one interviewee as follows:

> "The health and safety standard of SMEs has not been very encouraging and that is why employers must have the benefit of coming to join us so that we may take the advantage to educate them about safety laws and health and safety standards to be maintained at the workplace. The only way we can reach SMEs is for them to come to the health and safety forums that we organise" (Personnel of training division of Ghana Employers' Association).

Many Employees of construction SMEs are temporal and do not belong to the Construction and Building Materials Workers Union (CBMWU) making it difficult to bring pressure to bear on owner/managers to improve safety and health at construction sites. This can be inferred from the low number of collective bargaining certificates concluded by the Labour Department. In 2003, 8 collective bargaining certificates were issued to CBMWU and 2004, 9 were issued (Department of Labour-Ghana 2004).

The interviewees indicated that government departments faced a number of constraints in implementing health and safety standards within construction SMEs. Lack of resources was seen as a major obstacle to the departments in performing their functions in an efficient manner. One interviewee put it this way:

> "Like many government departments, the labour department suffers from high labour turnover and perennial budget cuts. Approved estimates of items relating to staff T & T, utilities, office consumables, office accommodation, and other expenditure are partially released, making the expected outputs of the department difficult to achieve" (Personnel of Labour Department).

Coordinating the activities of the many departments responsible for implementing health and safety standards was also seen by some of the interviewees as a major obstacle to improving the health and safety performance of the informal sector including construction SMEs. Analysis of the content of various health and safety legislations revealed many areas of jurisdiction where government departments and agencies overlap.

Safety and Health Legislation Aapplicable to Construction

The three government departments interviewed indicated the health and safety legislation they are responsible for implementing was applicable to construction and therefore relevant to construction SMEs. Ghana's main health and safety law is the Factories, Offices and Shops Act. The safety and health concerns of building works and civil engineering construction are covered under the act. Laws such as the Labour Act, the Environmental Protection Agency Act, and the Workmen's Compensation Law have specific provisions for safety and health which are applicable to construction. Other laws that also have provisions related to the health and safety on construction sites, include the Mines Regulations and the Road Safety Commission Act. Much safety and health legislation in Ghana has not been regularly revised to bring it up to date with prevailing socio-economic conditions in the country. For instance, fines for abusing health and safety legislations are very low.

5. DISCUSSION OF RESULTS

The administration of health and safety requires an efficient and adequately resourced institutional structure to implement health and safety standards nationally. However, this is not the case in Ghana where there are many departments and agencies with overlapping responsibilities for enforcing occupational safety and health standards. The number of departments and agencies responsible for health and safety results in time consuming bureaucratic processes and spurs corruption in the construction industry (Kenny 2007). The institutional structure for implementing health and safety standards on construction sites managed by SMEs in this sense, does not facilitate ease of compliance with health and safety laws because of the many procedures required under the slightly different health and safety regulations which different departments and agencies seek to implement. Indeed, many owner/managers are simply ignorant and confused as to which organisations to report accidents to and their responsibilities relating to safety, health and welfare laws. Tetteh (2003) has pointed to areas of jurisdiction as the 'bone of contention' between departments responsible for occupational health safety and dissatisfaction amongst employers in Ghana.

Coordinating the activities of the ministries, departments and agencies responsible for occupational health and safety is far from achievable as there is no law mandating any of the institutions with the responsibility to coordinate the activities of the rest. There is no national policy on occupational safety and health and this adds to the problem of occupational safety and health management within the construction SME sector in the country. All the institutions lack adequate resources to effectively carry out their functions with the most severely constrained being the Factory Inspectorate Department with neither funding mechanisms nor adequate logistical support.

Inspection of construction sites is rarely carried out and flagrant abusers of occupational safety and health law are not penalised. The absence of pressure which can be brought to bear on owner/managers of construction SMEs means some less scrupulous owner/managers can take advantage of the lack of punitive deterrent measures to place economic gain above other business objectives including health and safety. It is therefore not uncommon to find some owner/managers who would manage their businesses without bothering the least about health and safety issues. This unfortunate situation does not encourage owner/managers to manage the health and safety aspects of construction sites. On the other hand, where there is strict implementation of inspections and fines that are high enough to deter potential abusers of health and safety law, owner/managers will be compelled to manage the health and safety aspects of their operations more effectively. Research provides evidence to support this view that fines and other punitive measures for breaking health and safety laws compels employers to proactively manage health and safety because of fear of being penalised or exposed (Wright 1998).

In light of this discussion, it is apparent that reducing the number of departments and agencies responsible for construction sites to one institution would help enforce health and safety legislation. Laws defining funding mechanisms of such a single department would also need to be implemented and enforced. This will help to overcome the current practice whereby departments and agencies depend solely on government subsidies which are often woefully inadequate. Specific construction health and safety laws are necessary to ensure that responsibility for construction site safety is equitably shared among project participants. Government, being the major client, needs to demonstrate commitment to health and safety. This is unfortunately not what appears to happen on public projects. A scheme similar to the Hong Kong 'Pay For Safety Scheme' (PFSS) (Hong Kong Government 1996) is recommended whereby a specified percentage of the contract sum for every public project is set aside to meet the cost of implementing specific elements of safety and health programs.

6. CONCLUSIONS

This paper has considered the role of the institutional structure and economic context for safety and health management within construction SMEs in a developing country such as Ghana. The key constraints to effective implementation of safety and health standards were identified. Based on the constraints identified, recommendations were made for improving the safety and health performance of construction SMEs in Ghana and developing countries.

The findings of the study reveal shortcomings not only in government arrangements for implementing health and safety on construction sites, but also the involvement of stakeholders in the implementation of safety and health standards on construction sites managed by SMEs. Remedying the shortcomings of the institutions responsible for safety and health in construction is key to the success of any construction project. This study has implications for policy making regarding the deficiencies in the present system of implementing safety and health standards on Ghanaian construction sites, and suggests solutions that if adopted, could bring about improved safety and health performance of construction SMEs.

The national culture of Ghana has influence on workers' attitudes and behavior at workplaces. Awareness of cultural influences and owners' perceptions on safety and health are necessary for a complete understanding of health and safety management within SMEs. The study recommends further research on the impact culture has on health and safety management within SMEs and on the implications this could have on the design of health and safety interventions.

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AN EVALUATION OF HEALTH AND SAFETY MANAGEMENT IN SMALL CONSTRUCTION ENTERPRISES IN THE UNITED KINGDOM

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ABSTRACT

The United Kingdom (UK) construction industry has one of the best safety records within the European Union, with fatalities and serious injuries being about one third of the European average. However, despite a number of recent initiatives, accidents still regularly occur on UK construction sites. A disproportionate number of fatalities occur in small construction enterprises employing fifteen operatives or less. In 2007, a survey of small construction enterprises in Southern England was carried out to identify factors which contribute to this relatively poor safety record. The survey was based on prior research which had identified three interrelated factors that influence health and safety (H&S) management: the individual's competence and attitude; the job tasks and environment; and the organisational culture and leadership. It was found that project managers on small construction sites had limited knowledge of H&S requirements which often resulted in a poor or potentially dangerous work environment and a poor safety attitude within the workforce. It was concluded that increased awareness and training of project managers in small construction enterprises should be a priority for all who seek to improve H&S on construction sites.

Keywords: England, Health, Safety, Small Construction Enterprises

1. INTRODUCTION

The UK construction industry is characterised by a small number of large construction enterprises. Many of these enterprises are effectively management contractors, sub-contracting the actual work to smaller sub-contractors. There are also a large number of small enterprises offering specialist or trade services or alternately acting as main contractors on small projects. Figure 1 below demonstrates the size and employment profile within the UK (DBERR, 2007).

There has been continued concern over the number of accidents in the construction industry. In response to these concerns, a Construction Health and Safety summit, which was held in 2001, set ambitious targets for reduction in fatalities and injuries (HSE, 2002). Although the targets are not yet being achieved, there as been a continued reduction in accidents statistics as shown in Figure 2 below (HSE, 2007a). Within the

European Union (EU), the UK has one of the lowest rates of construction injuries. In 2003 the EU/UK rates per 100,000 workers were 10.6/3.6 for fatalities and 6502/1980 for injuries resulting in over three days off work, making UK construction about three times safer than the EU average (HSE, 2004a).

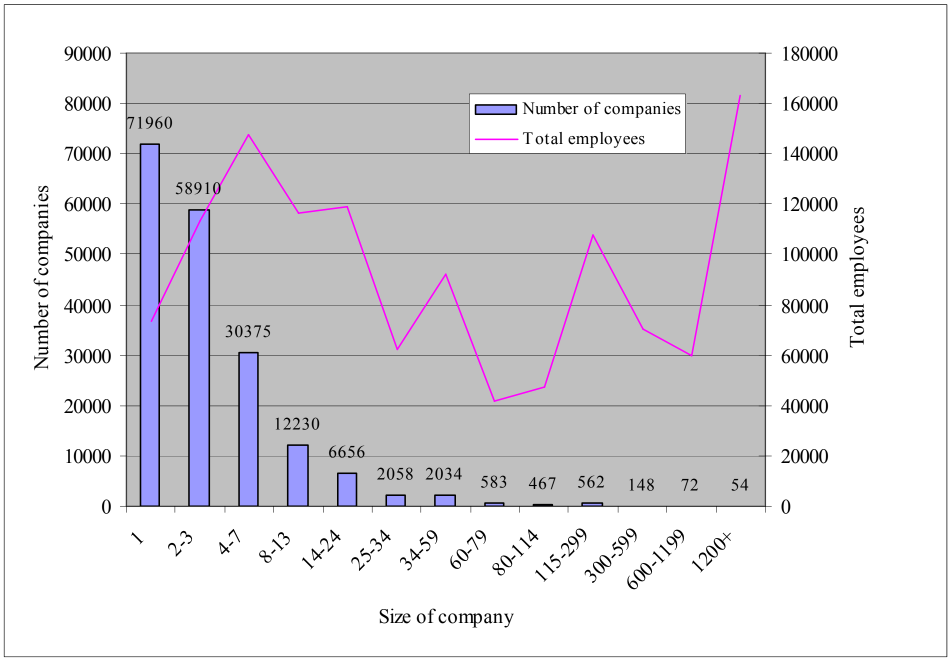

Figure 1. Profile of company size and number employed within the UK construction industry (DBERR, 2007)

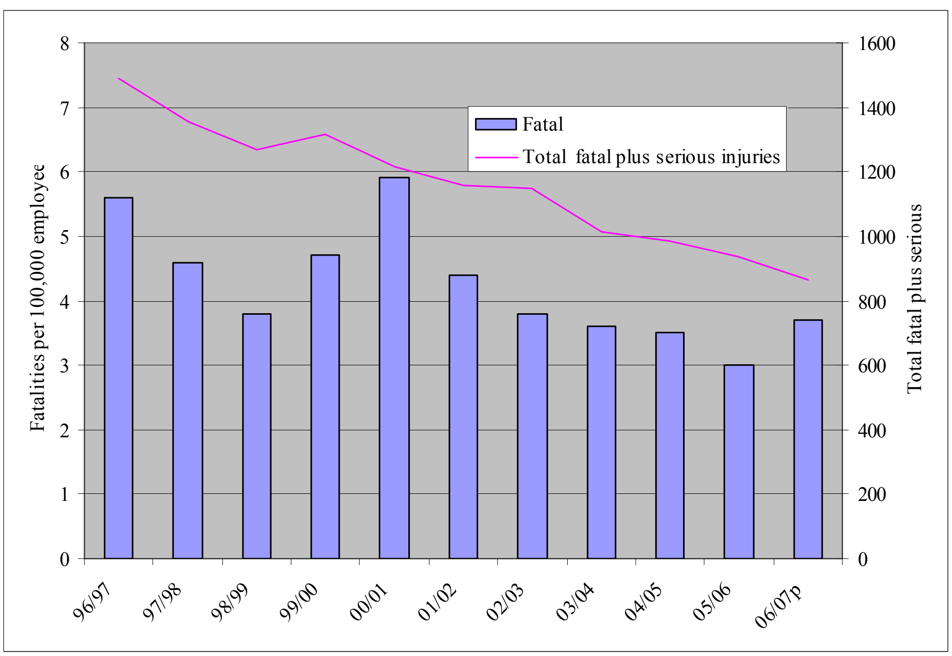

Figure 2. UK construction accident statistics (HSE, 2007a)

Under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR 95), all enterprises have to report incidents which result in fatalities, major injuries and injuries which result in more than three days off work. However, HSE (2002) have expressed concern about the completeness of injury reporting from self employed persons. Although the trend in these figures is encouraging, there is clearly no room for complacency. Construction remains one of the most dangerous of the UK business sectors, with the rate of fatal injuries in construction averaging 4.8 times the all industry average (HSE, 2007b).

HSC (2007) estimated that enterprises with less than 15 employees face a disproportionately higher risk of injury and ill health than those who work for larger employers, as demonstrated in Table 1 below.

Table 1. Accident ratios for small construction enterprises

Proportion of enterprises employing	Construction work by value	Workforce	Fatalities	Injuries	Ill health
> 15	17%	26%	67%	57%	61%
< 15	83%	74%	33%	43%	39%

For all industries, HSE (2007a) has suggested that motivating small and medium enterprises (SMEs) to improve their standards is undoubtedly the single greatest challenge facing HSE in relation to construction and, indeed, others who seek improvements in industry practices.

2. RESEARCH PROBLEM

The problems with small construction enterprises are not restricted to the UK. Wojcik (2003) reported that in Kentucky, as nationally in the US, small construction enterprises (≤10 employees) far outnumber larger contractors. These enterprises are too small, too dispersed and too numerous for effective regulatory oversight from state or federal agencies charged with protecting workers from illness and injury. In addition, small construction enterprises rarely have formal employee safety programs.

Lin and Mills (2001) measured occupational health and safety (OHS) in 44 construction enterprises by questionnaire and concluded that company size had a significant influence on a company's OHS performance and that overall performance decreases with reducing company size. Through an interview survey on a similar number of sites, Monk (1994) arrived at very similar conclusions. All statistical and literature analysis therefore leads to the conclusion that H&S management in small construction enterprises is poor compared to larger enterprises and that there is much scope for improvement.

None of the research mentioned above separated small contractors who operated as sub contractors to larger enterprises from those who operated as main contractors on their own small projects. The objective of the research reported in this paper was to investigate attitude to H&S implementation between large and small main contracting enterprises.

3. METHODS AND RESULTS

Following guidance from Oppenheim (1992) a questionnaire was designed to capture awareness of, attitudes towards, and practice of H&S. Likert scales were designed as the measurement scale. Questions were kept as simple as possible to encourage responses from managers who may be lacking a high level of formal education.

Between June and August 2007, a total of 30 sites were visited along the central south coast of England, including 24 small sites and 6 large sites. These sites were chosen to meet the criterion: the contractors must be main contractors. The site managers who have overall responsibility for H&S were approached. After explaining the purpose of the study and giving assurances for anonymity, the site managers were requested to complete the questionnaire. The questionnaires were completed in the presence of the researcher who would answer any clarification questions that respondents might have.

Analysis of direct reports

1. The first question required respondents to describe their knowledge to describe their knowledge of the four most common H&S laws. All site managers from the large construction enterprises described their knowledge of each law as very good. The site managers from the small construction enterprises responded as follows: 12%, very good; 42%, good; 29%, medium; 17 %, poor; and 0%, none. As can be seen, almost half (46%) of the site managers from the small construction enterprises had limited knowledge of the most common laws and would therefore be unable to enforce their requirements.

2. Site managers were then asked how much H&S training they had received. All site managers from the large construction enterprises responded that they had received a large amount of training. The site managers from the small construction enterprises responded as follows: 12%, large amount; 21%, a lot; 58%, some; 8%, a little; and 0% none. This suggests that only one third of the site managers from the small construction enterprises had received adequate training, which may account for their lack of knowledge on the safety laws.

3. Site managers were asked about the willingness to undertake further H&S training. All site managers from the large construction enterprises indicated that they would definitely consider undertaking the training. The site managers from the small construction enterprises responded as follows: 0%, definitely; 50%, likely; 42%, possibly; 8%, unlikely; and 0%, never. Although no site manager

from the small construction enterprises would definitely undertake training, the results suggest that most might consider it. However, the results may have been influenced by the respondent's lack of knowledge exposed in the earlier questions.

4. Site managers were asked if they normally completed jobs on time. All respondents from the large construction enterprises indicated that they always completed their work on time. The site managers from the small construction enterprises responded as follows: 12%, always; 71%, often; 17%, sometimes; and 0%, never. Completion of project on time tends to be a priority on large sites and, provided the site is properly managed, this should not present safety problems. Work on small sites tends to be less likely to be completed on time - this increases pressure, especially towards the end of the project, on the workforce to finish work quickly, which may then increase the risk of accidents.

5. Following on from the above, site managers were asked if they agreed with the statement that 'the workforce were always given adequate time to complete the work'. All site managers from the large construction enterprises strongly agreed with the statement. The site managers from the small construction enterprises responded as follows: 21% strongly agreed; 58%, agreed; 13% were neutral; 8% disagreed; and 0% disagreed. Just over one fifth of site managers from the small construction enterprises could not confirm that the workforce were always given sufficient time to complete their work. This collates with the previous question and shows that workers on small sites are sometimes under time pressure.

6. Site managers were asked to indicate how aware the workforce was about H&S regulations. Site managers from the large construction enterprises were unanimous in claiming a high degree of awareness - they pointed out the common use of site induction, use of method statements and safety inspections. The site managers from the small construction enterprises responded as follows: 33%, very aware; 38%, quite aware; 29%, neutral; 0%, a little aware; and 0%, unaware. Although site managers from the small construction enterprises claimed workforce awareness of H&S regulations, it can be seen from finding 1 above, that this is not always the case. If the site manager lacks awareness it is also likely that the workforce will also be lacking.

7. All site managers, from large and small sites claimed to identify significant risks on their projects.

8. Site managers were asked about the frequency with which safety systems and procedures were developed for each project. All site managers from the large construction enterprises stated that safety systems and procedures were always developed for each project. The responses from site managers from the small construction enterprises were as follows: 20%, always; 34% often; 25% sometimes; 21%, rarely; and 0%, never. Almost half of the site managers from the small construction enterprises do not generally develop site specific safety

plans. These procedures are essential in establishing safe methods of working. Failure to develop and communicate safety procedures may well increase the risk of an accident occurring. This result accords with finding 6, showing that lack of site specific safety systems and procedures is reflected in the poor safety awareness of the workforce. Furthermore, with reference to finding 7, it is fair to assume that site managers from the large construction enterprises will use a systematic system to identify risks, take appropriate actions and communicate them to the workforce. Site managers from the small construction enterprises, acting as sub contractors, will rely on and follow the main contractor risk assessments. Site managers from the small construction enterprises, where the company is the main contractor, are more likely to rely on their own experience due to lack of knowledge and training.

9. The next question continued the theme of site organisation by asking if the equipment/tools used were suitable for the task being undertaken. This question could be seen as questioning the planning ability of site managers and hence a degree of bias was to be expected. Site managers from the large construction enterprises were unanimous in confirming the suitability of equipment. The responses from site managers from the small construction enterprises were as follows: 42%, definitely; 58% probably; 0% neutral; 0%, unlikely; and 0%, never. Although it reflects badly on their management skills, over half of site managers from the small construction enterprises admitted that the workforce sometimes used inappropriate equipment for their task, which would increase the risk of an accident. This continues the theme from finding 8 that there is often a lack of proper planning on small construction sites.

10. Continuing the equipment theme, site managers were asked if they actively took steps to reduce workforce manual handling. Again, site managers from the large construction enterprises were unanimous in confirming the provision of suitable equipment. The responses from site managers from the small construction enterprises were as follows: 59%, always; 33% often; 8% sometimes; 0%, rarely; and 0%, never. Over 40% of site managers from the small construction enterprises admitted to not always taking appropriate steps to reduce the possibility of injuries from manual handling. This may be due to lack of knowledge about legal responsibilities, poor site panning or the financial cost of hiring suitable lifting equipment.

11. Site managers were asked if they involved the workforce in drawing up site method statements and safety rules. This was found to be common practice on all large sites. For small sites, the response was similar to previous questions: 54%, always; 25%, often, 21%, sometimes; 0%, rarely; and 0%, never. Almost half of the small construction enterprises do not always involve the workforce in planning how the work should be done. In the small site sample, most of the site managers were also part of the workforce. It would be expected to be common practice for the site manager to discuss methods with colleagues, so this result is particularly disappointing. In common with finding 8, one cannot avoid the

suspicion that some small site managers may not even know what a method statement is and therefore cannot confirm that they are developed them with or without involvement of the workforce.

12. Site managers were asked as to how often they monitored the workforce to ensure procedures were adhered to. All site managers from the large construction enterprises confirmed that they always monitor the workforce. The responses from site managers from the small construction enterprises were as follows: 29%, always; 58% often; 13% sometimes; 0%, rarely; and 0%, never. As most of the site managers from the small construction enterprises were part of the workforce, the result that only 29% always monitor the safe behaviour of the workforce is surprising. This, perhaps, shows ignorance of basic management responsibilities.

13. Site mangers were asked to identify who is responsible for H&S on their site. The question was purposely left open, with no suggestions given, so a range of responses were received. 30% of the site managers from the large construction enterprises suggested that the site manager/site agent/foreman (30%) – 17% suggested the H&S officer while 53% suggested that everyone was responsible. 8% of site managers from the small construction enterprises suggested that the main contractor was responsible and 92% suggested that the site manager/site agent/foreman was responsible. Over half of large contractors expected everyone on site to be responsible for H&S, each individual having responsibility for themselves and others. Only 30% of large contractors identified the site manager and 17% identified the H&S Officer individually, confirming whole group responsibility. 8% of small contractors were working as sub contractors to large contractors and they were unanimous in placing responsibility with the main contractor. The remaining small contractors all identified the site manager or equivalent. Small contractors are unlikely to have designated H&S Officers. No small contractor suggested that everyone on site has safety responsibilities, confirming their belief that safety enforcement is purely a management role.

14. The final question required site managers to indicate what other responsibilities the person responsible for H&S had. Among large contractors, the person responsible for H&S also had the following roles (34%, general/project management; 11%, site management; 21%, no other responsibilities; and 34%, not applicable). Among the small contractors the corresponding values were: 25%, 61%, 8% and 6% respectively. The responses from site managers from the large construction enterprises indicate that safety is seen as a senior management role and also a general workforce responsibility. The responses from site managers from the small construction enterprises confirm their belief that the site manager is solely responsible.

Researcher assessment of site safety

At each site visited, the researcher performed an inspection of the site and completed an assessment form. The assessment form included standard safety criteria: maintaining safe and suitable access and egress, providing sufficient working space, ablution facilities, safety signs, and protection/separation for the general public. The purpose of this assessment was to gain information on the safety aspects of the site so that questionnaire responses could be compared to reality. Site safety was checked by noting if the workforce were wearing hard hats, fluorescent jackets and steel capped footwear. Also, if work was occurring two or more metres high from the ground then the assessment form required that there be suitable and sufficient toe boards, guard rails, barriers, working platforms, adequate ladders, handrails, scaffolding support, lighting and ventilation.

All the six large enterprises fulfilled all of the site safety criteria. However, the small enterprises revealed some very different results:

- 20% of the sites visited did not provide suitable access and egress with rubble and materials blocking the entrance.
- 20% of the sites posed a danger to the public because of debris lying around the site and the site not being properly cordoned off.
- Almost a third (32%) of sites visited did not provide suitable working space. The risk of injury is greatly increased when the working space is confined by tools and rubble around the workers feet, making it much easier to slip or fall in these conditions.
- An alarming 37% of all the small sites visited did not have any safety signs visible around the site which is very worrying as these signs inform people of the dangers on the site and the protective clothing that must be used etc.
- Only 55% of the small sites had ablution facilities, the ones that did not have facilities may have been able to use the resident's home toilet instead. With regard to staff wearing the correct safety gear, it was found that one in four of employees did not wear the complete personal safety equipment, whether it was hard hats, fluorescent jackets or steel capped footwear.
- For work that was happening 2 or more metres above ground it was noted that 10% of toe-boards were not secured properly, 15% of the guard rails were not sufficiently bolted and 12% of the barriers were not fastened adequately. Furthermore, the adequacy of ladder fastenings was poor with 38% of the ladders seen not fastened to the scaffolding. As falling from heights is one of the biggest killers, one would have thought more effort would have been put into ensuring everything was done to prevent any further accidents happening, but this is clearly not the case. Furthermore 8% of the handrails were not sufficiently fastened, which could be extremely dangerous as a worker could rest again the rail thinking it would be safe. Scaffolding support is clearly an integral part of the safety of the workforce as they will be climbing and working on it, thus it was concerning to see that 17% of the small construction sites visited did not have adequate scaffolding support.

The assessment showed that safety management of small sites could often be greatly improved.

4. CONCLUSIONS

From the work done in this study, the authors can draw the following conclusions.

- The UK construction industry is a major employer and contributor to the country's wealth. It is characterised by a small number of large enterprises and a much larger number of small enterprises.
- The H&S performance of the UK construction industry is one of the best in Europe with a clear trend of constant improvement. However, it is still one of the most dangerous UK industries. Small construction enterprises have a disproportionately high accident ratio when compared to larger construction enterprises.
- Large enterprises tend to have dedicated personnel to ensure safe working practices on site and these supported effectively by the site management team. Managers of small construction enterprises have much less knowledge of safety law and regulation but many of these managers do not see the need to improve their understanding. There is a clear difference in management attitude towards safety between large and small enterprises.
- Sites run by small construction enterprises are often characterised by a poor working environment, untidiness (which increase the risk of slips or trips), lack of personal protective equipment, insufficient time to do the work, inappropriate equipment, unsafe manual handling and insecure working from height.
- Construction sites run by small construction enterprises often lack appropriate job resources and have inadequate safety resources. The lack of method statements and specific risk analysis on these sites means that the dangers of certain tasks or work areas cannot be properly communicated to the workforce. Leadership on site safety matters is also lacking due to poor knowledge levels by site management.
- It is can be said that much work still needs to be done to improve safety standards of small construction enterprises and that the safety awareness of the site manager should be the target for this improvement.

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SAFETY IN THE ONTARIO CONSTRUCTION INDUSTRY

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ABSTRACT

Four researchers in construction safety collaborated in a study to investigate factors that might affect safety on Ontario non-residential construction sites. A few of the findings from this study are discussed here. A questionnaire was developed to collect 3 types of data from over 900 construction workers, including personal characteristics, attitudes toward safety, and the number of safety incidents experienced by the workers in the previous three months. Information was obtained on three types of incidents: physical injuries (from headaches to broken bones); psychological injuries (stress); and, accidents.

The nature of employment in the construction industry is characterized by short job tenure and high project mobility. Project mobility (the movement of workers between projects) is a fact of the construction industry. With each project, workers face new challenges for the type of work to be performed and the hazards particular to that site. Key findings from this study show that increased job tenure positively impacts worker safety and workers with the shortest job tenure were further negatively impacted if they had high project mobility.

Keywords: Safety, Tenure, Mobility

1. INTRODUCTION

The construction industry in Ontario, Canada is a world leader in both safety standards and safety results (CSAO 2004). This is largely attributed to the support offered by government boards and employer associations who actively involve themselves in improving safety. As shown in Figure 1, a downward trend in construction fatalities is evident from 1966-2005. However, in 2003 there were 30 deaths reported in the Ontario construction sector, up 58% from 2002 (CSAO, 2004). Because it is commonly accepted that deaths represent the tip of the iceberg in terms of workplace safety, this concern about the sudden rise in fatalities was justifiable.

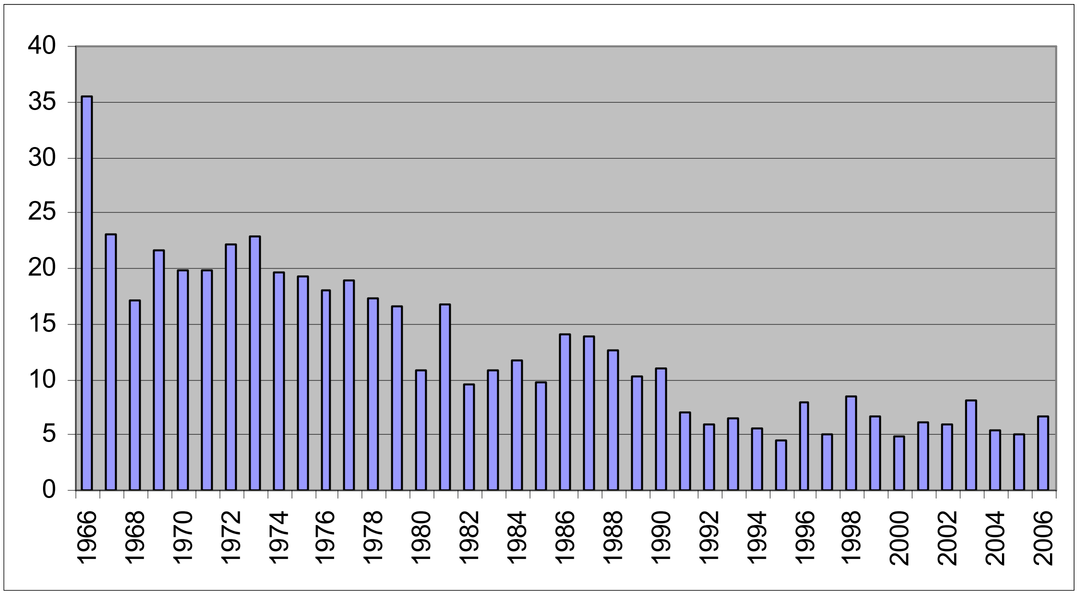

Figure 1: Fatalities per 100,000 workers (adapted from CSAO 2006)

Bird (1974) proposed that for each major injury (including both fatalities and critical injuries) there may be as many as 600 near-misses (Figure 2).

Figure 2: Bird's incidents triangle

For example, while 20 deaths may not seem like a large number to some - relative to the total number of workers (over 396,000; CSAO 2005) - that same year, the Workplace Safety Insurance Board (WSIB) of Ontario (2005) reported that there were almost 5,600 lost-time injuries in the Ontario construction industry. This represents a significant cost to workers, organizations, and society.

The aim of the research described in this paper was to determine the impacts of age, tenure and project mobility on safety in the Ontario non-residential construction sector.

2. RESEARCH METHODOLOGY

Between 2004 and 2006, 938 construction workers from 84 non-residential construction sites across Ontario completed self-administered questionnaires. Each survey contained 105 questions and took approximately 15 minutes to complete. Surveys were distributed to the participants during specified times (e.g. breaks or safety meetings) for immediate completion of the survey. Participants then placed the survey in locked collection boxes, which the researchers took with them at the end of the session. A research ethics review of the procedures used was undertaken to ensure no harmful impacts were experienced by the workers as a result of providing this information. In total, 911 valid questionnaires were collected with a sampling error of +/-2.7% at 90% confidence, or +/- 4.3% at 99% confidence.

Each survey consisted of three sections: demographics, attitudes, and health and safety outcomes (injury and accident reporting). In addition to injuries and accidents, the demographic portion of the survey collected information on age, trade, years in construction, tenure with employer, number of employers and projects in the previous 3 years, hours worked per week in high and low season, job position, safety committee participation, and union membership.

Table 1 shows the items that measured physical injuries, psychological injuries, and accidents. Workers were asked to report the number of times they experienced each occurrence in the past 3 months (based on norms in the psychological literature, it is assumed that workers can accurately recall events in the past 3 months).

Table 1: Health and Safety Outcomes

Physical injuries	Psychological injuries	Accidents
headache/dizziness	lost sleep due to work-related worries	exposure to chemicals
persistent fatigue	unable to concentrate on work tasks	overexertion while handling/lifting/carrying
respiratory injuries	unable to enjoy day-to-day activities	trap by something collapsing/caving/overturning
strains/sprains	felt constantly under strain	slip/trip/fall on same level
cut/puncture	losing confidence in self	struck against something stationary
temporary loss of hearing	felt incapable of making decisions	struck by moving vehicle
eye injury		struck by falling/flying objects
electrical shock		contact with moving machinery
dislocated/fractured bone		fall from height
skin rash/burn		
hernia		

3. CHARACTERISTICS OF THE SAMPLE

Table 2 presents a summary of the demographic data, including the mean, median, and definition of the data quartiles. Age was reasonably distributed across the skilled trades.

Job tenure in construction is characteristically short. Although some workers had been with their current employer for decades (10 per cent had been with their current employer 10-19 years, 3.4 per cent 20-29 years, and 1.2 per cent more than 30 years), these few workers skewed the sample mean to 5.34 years although the median was just 2.5 years. Participants had a median of 2 employers in the previous 3 years.

Table 2: Description of the workers in the sample

Demographic	Mean / %	Med-ian	Q1	Q2	Q3	Q4
Age (years)	38.3	38	18-29	30-38	39-45	46-69
Years in construction (experience)	15.1	14	0-5	6-14	15-22	23+
Years with current employer (job tenure)	5.34	2.5	0-0.99	1-2.5	2.6-7	>7
No. construction employers in the last 3 years	2.91	2	1	2	3	4+
Number of projects worked in last 3 years (project mobility)	10.8	5	1-3	4-5	6-10	11+
Job position: Supervisor	26.9%					
Job position: Journeyman	56.3%					
Job position: Apprentice	16.9%					

Table 3 shows the health and safety outcomes experienced in the previous 3 months by the surveyed workers. Only 87 respondents out of 911 reported no injuries or accidents, resulting in approximately 90% of the respondents experiencing at least one outcome.

Table 4 provides correlation coefficients between the demographic variables. Age and experience are highly correlated at r =0.78. These two factors are moderately correlated to job tenure. Project mobility is unrelated to the other factors, providing further support that mobility is relatively constant throughout the industry and not particular to newcomers.

Table 3: Descriptive Statistics for Health and Safety Outcomes

Outcome Variable	Mean	Median	Yes (%)	No (%)
Number of physical injuries	5.83	4	81.3%	18.7%
Number of psychological injuries	3.57	1	54.8%	45.2%
Number of accidents	3.38	2	65.9%	34.1%

Table 4: Correlation coefficients between demographic variables

	Age	Experience	Job Tenure	Project Mobility
Age	1.00			
Experience	0.78	1.00		
Job Tenure	0.39	0.42	1.00	
Project Mobility	-0.03	-0.03	0.09	1.00

4. DISCUSSION

The nature of employment in the construction industry is characterized by short job tenure and high project mobility. Project mobility (the movement of workers between projects) is a necessary characteristic of the construction industry. With each project, workers face new challenges for the type of work to be performed and the hazards particular to that site. Of course, within that site, they also experience changed conditions on a daily basis as the construction of the project proceeds.

As shown in Table 5, the number of projects worked does not significantly change with age. So, this is not just a young worker's condition.

Table 5: Project mobility by age quartiles

Age Quartiles	**Project Mobility (No. projects in 3 years)**
18-29	9.73
30-38	11.96
39-45	8.52
46-69	8.22

Short job tenure and high project mobility have evolved to accommodate the cyclic nature of this industry. But, what are the impacts of these practices on safety?

Although it is well established that younger workers experience more injuries than older workers, combining youth with high project mobility significantly increases psychological injuries, as shown in Table 6. This may be due to the stress of having to learn trade skills while continuously changing project-specific expectations and practices. Note that physical injuries and accidents also increase with project mobility, although to a lesser extent.

Table 6: Impact of project mobility on workers aged 18-29 years

Number of Projects (last 3 years)	Physical Injuries (3 months)	Psychological Injuries (3 months)	Accidents (3 months)
1 to 3	7.5	3.7	4.4
4 to 5	8.1	3.9	3.8
6 to 10	8.1	4.6	5.0
11 or more	8.3	5.7	4.8

While job tenure and age are correlated (r =0.39), an interesting trend is shown when the data are examined from the perspective of job tenure, as shown in Table 7. The first three quartiles have similar means for age and experience, indicating that job tenure less than seven years is common throughout the industry, and not particular to youth or newcomers to the industry. Interestingly, the number of injuries and accidents decrease as job tenure increases. It takes seven years with one employer to see a significant drop in physical injuries and only two-and-a-half years for a drop in accidents. Psychological injuries appear mostly unaffected by job tenure.

Table 7: Mean values grouped by tenure quartiles

Tenure Quartiles (years)	Age (years)	Experience (years)	Number of Projects (last 3 years)	Physical injuries (last 3 months)	Psycho-logical injuries (last 3 months)	Accidents (last 3 months)
Less than 1	36.2	14.0	7.3	6.1	3.8	3.8
1 to 2.5	33.7	11.1	8.8	6.6	3.8	4.1
2.6 to 7	36.7	13.2	10.6	6.3	3.5	3.2
7.1 to 44	43.8	22.3	12.1	4.2	3.3	2.5

Responses from workers who had been with their current employer for a short time indicated they experienced the highest number of injuries and accidents. However, this was made worse if the worker also had very high project mobility, as shown in Figure 3.

It appears that the lack of stability in both employer and site is very detrimental to worker safety. All categories of injuries and accidents increase significantly with increased mobility. Employers may wish to pay special attention to new workers who have extensive project mobility. While that experience may appear useful in expanding their insight to the work involved, it appears to prevent them from learning, practicing, and becoming comfortable with safety best practices. Special programs may be set up to assist new employees with integration into the safety culture of the organization. In addition, mentorship of these new employees by experienced and safety conscious trades people may help reduce the likelihood of an injury or accident.

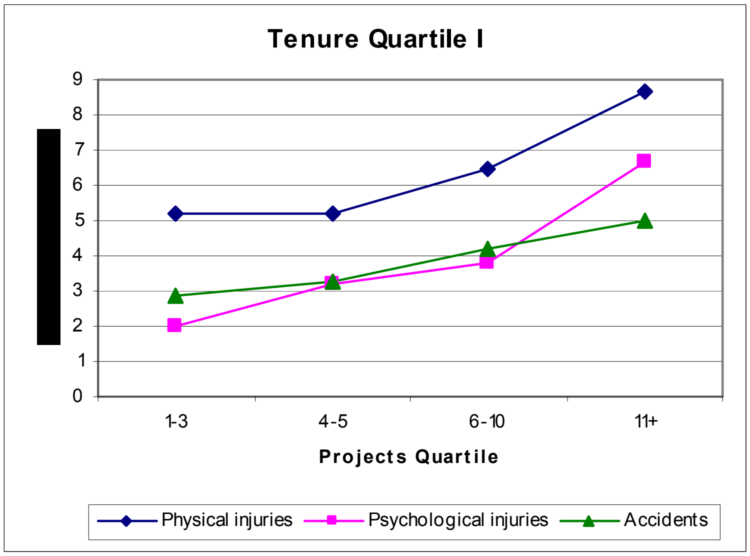

Figure 3: Impact of project mobility on short tenure workers

The establishment of safety groups is becoming more common. It is hoped that these structures will also provide some support to the mobility and tenure problem. Members of a safety group can establish a common safety culture amongst themselves that may mimic longer job tenure if the workers stay employed within the safety group. This premise is being investigated at this time.

5. CONCLUSIONS

The nature of employment in the construction industry is characterized by short job tenure and high project mobility. Key findings from this study show that increased job tenure positively impacts worker safety and workers with the shortest job tenure were further negatively impacted if they had high project mobility.

In most jurisdictions, each time workers change employers and projects, they must adjust to a new safety culture. It would be very difficult to change the nature of employment in the construction industry; however, it may be possible to create an environment that mimics longer job tenure through the establishment of industry wide safety and prevention programs. Consistent safety cultures across firms may provide the same benefits as long term employment with one firm.

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SOUTH AFRICAN CONSTRUCTION SITES - ARE HIGH-RISK CONSTRUCTION ACTIVITIES RECEIVING THE PRIORITY THEY DESERVE?

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ABSTRACT

In the South African construction industry health and safety related risks remain unacceptably high. Arguably, this situation is largely due to ineffective hazard identification and risk management. Construction companies seem to be able to manage those hazardous site operations where the assessed risk is low, rather than diverting the necessary resources to those hazardous operations where the potential for serious injury or damage is high. The result of this mismanagement of risk is that South African construction sites remain places where serious injuries and fatalities continue to occur unabated. This paper reports on a study that sought to quantify which areas of safety and health risk management are being neglected by construction companies in the Western Cape Province. The research tool used was an audit checklist that was developed in 2004 based on the Construction Regulations (2003). The audit format aimed to objectively judge the performance of Principal Contractors relative to compliance with the requirements of the Construction Regulations. Construction related injury statistics were analysed to ascertain whether there was any relationship between the types of injuries that were prevalent and the manner in which risk categories were managed.

The findings indicate that construction companies do not allocate the necessary resources to those health and safety management areas that have the potential of causing the most serious injuries.

Keywords: Construction, Safety, Hazard, Risk, Injury

1. INTRODUCTION

The effective management of construction hazards in the form of hazardous activities and situations can be best achieved if the associated risks are properly assessed and then prioritized. Construction companies need to systematically identify those hazardous operations and activities that have the potential of causing the most serious injuries so that the necessary preventative measures can be taken to eliminate the risk of such injuries occurring. These ‘high risk’ operations or activities need to be prioritized so that the necessary resources such as, time, money, safety equipment, and supervision are made available. It is believed that an objective hazard identification and risk assessment (HIRA) strategy forms the basis for effective safety and health risk management. This HIRA strategy must be initiated at the outset of the construction project and constantly reviewed as the project progresses through its various stages (Hinze, 1997).

This risk assessment process serves to clarify, *inter alia,*

- what could go wrong in terms of what injuries or damage could result;
- what are the chances of these injuries and damages occurring; and
- what the severity of the consequences are likely to be.

Once the responses to these questions are known, the necessary safety and health strategies and resources can be deployed to the hazardous operation in question so as to eliminate the risks all together or if this is not possible, to minimize the risk to below an industry acceptable level.

The research reported in this paper suggests that construction companies place insufficient emphasis on the management of site operations that have the potential of causing the most serious injuries.

2. LITERATURE

Construction remains one of the most dangerous sectors of industry (Hinze, 1997; Coble et al., 2000; Haupt, 2001) with injury rates remaining unacceptably high. The debate of what is acceptable and when an injury rate is regarded as unacceptable is a debate in itself but it is reasonable to say that the high rate of serious injuries definitely needs some serious attention. The National Safety Council (NSC) in the United States of America, found that in 1991, construction injuries accounted for 11% of all work related injures, and more than 30% of all fatalities (Vargas et. al., 1996). This alarming trend is replicated in most other parts of the world.

It is believed that too much attention is placed by construction site management on lower risk activities and operations instead of concentrating attention on the activities that have the potential of causing the most serious injuries (Hinze, 1997). Many studies suggest that hazardous activities such as:

- working at heights (including scaffolding);
- trades working directly above each other;
- working with temporary site electrical installations;
- working in close proximity to construction vehicles, mobile plant and tower cranes;
- erecting and dismantling formwork; and

- working in trenches and excavations lead to the most serious injuries on construction sites (Larsson and Field, 2002; Hinze, 1997; China Statistical Yearbook of Construction, 2001).

In fact most fatalities occur as a result of these very 'high risk' activities. It is also apparent that although there is a global decrease in construction injuries, serious injuries and fatalities remain consistently high (Khalid, 1996).

For the purpose of this paper, a serious injury in South Africa is defined in terms of the Occupational Health and Safety Act 85 of 1993 as a 'reportable injury' (Section 24 of the OHS Act), which includes:

- death;
- unconsciousness;
- loss of a limb;
- likely to die;
- permanent physical defect; and
- unable for at least 14 days, to work or continue with the activity for which worker was employed.

This paper investigates the relationship between serious injuries and the poor management of 'high risk' site activities and operations. It is evident from statistics depicting the health and safety performance of the construction sector that serious injury rates remain high and that this is a global phenomenon. Clearly, construction companies throughout the world seem to be making the same mistake of concentrating their efforts on the areas on site where the probability of injury is less and where the nature of the resulting injury is less severe.

According to Goodloe (1996), smaller construction companies are considered to have more ineffective health and safety management systems in comparison to their larger counterparts. This argument is useful and will be referred to later in the paper.

Reasons why construction companies misplace their emphasis on activities that cause the most serious injuries include:

- Not clearly identifying the causes of previous injuries on which they can base their management decisions – e.g. spending money on high risk activities that cause expensive injuries (Hinze and Gambatese, 1996);
- Top management not driving the adopted health and safety management system and not giving the site management the necessary authority to make health and safety related decisions; and
- Hazard identification and risk assessment strategies that are not properly implemented when the site work starts or have not been reviewed before new site activities begin, i.e. identifying the high-risk activities and prioritizing them.

3. RESEARCH

The objectives of this research are to:

- Identify those areas of the Construction Regulations promulgated in July, 2003 in South Africa that are not being successfully complied with and that require improved risk management strategies; and
- Examine the relationship between badly managed hazards / hazardous operations and resultant serious injuries.

The results of the research will confirm that construction companies need to assess safety and health risks in a more effective manner so that they understand what site practices have the potential of leading to the most serious injuries and major damage. The consequence of this approach will arguably lead to a reduction in serious injuries, resulting in safer, more productive and ultimately more profitable construction sites.

4. METHODOLOGY

In order to achieve the objectives of this study, a research tool was required. In 2004, a prototype construction site auditing system was developed based almost entirely on the Construction Regulations promulgated in July 2003. The premise for the audit system was that it needed to be as objective as possible and had to show Principal Contractors where they were failing to comply with the Construction Regulations so that the necessary emphasis and resources could be directed to those areas of non-compliance. The audit system was fundamentally a mechanism to gauge whether a Principal Contractor's health and safety management system was functioning as required and if not where it was falling short.

An effective and objective audit tool would ensure that the results achieved would be similar regardless of whether the audit was conducted by different auditors. A comprehensive, detailed knowledge of the Construction Regulations and practical understanding of construction health and safety are prerequisites.

The approach followed is simply that the Principal Contractor under audit begins with 100% compliance and loses points based on failure to prove conformance with the relevant regulations being scrutinized. The audit tool also includes reference to legal requirements included in other regulations promulgated under the Occupational Health and Safety Act 85 of 1993 that are not included in the Construction Regulations (2003). The results give an unparalleled overall picture of how well a particular Principal Contractor's construction site was complying with South African construction health and safety legislation. The results of construction site audits conducted between 2004 and 2007 are reported in this paper. The auditors had extensive knowledge of construction legislation and more than 12 years' practical construction health and safety experience.

Construction related injuries in the Western Cape were analysed using the injury claims data from Federated Employer's Mutual Assurance (FEMA) fund. The injuries were assessed for seriousness and cause so that a relationship, if any, could be determined between these two characteristics and then compared with the results of the construction audits. This was used to determine if the poor management of 'high risk' construction activities leads to the serious injuries continuing to occur on sites.

5. FINDINGS

The results of the EACI (E and A Continuous Improvement) audit system were extracted and analyzed. The audits were conducted over a period of three years, namely from 2005 to 2007. Fifty-one audits were conducted on 22 sites with 9 separate construction companies being involved. Most of the sites were audited more than once with 8 sites being audited more than three times during their contract period.

The audit tool

The EACI audit system as previously explained was based primarily on the requirements of the Construction Regulations (2003) and serves to measure the compliance of the Principal Contractor with the regulations. The following aspects are audited, namely:

- Written appointments
- Pressure vessels
- Risk assessments
- <u>Scaffolding</u>
- <u>Fall protection (incl roof work)</u>
- Public and site
- Structures
- Personal protective equipment
- <u>Formwork / support work</u>
- First aid
- <u>Excavations</u>
- Demolition
- Illumination
- Suspended platforms
- Housekeeping
- Materials hoists
- <u>Electrical installations/machinery</u>
- Batch plants
- Raising persons
- Explosive powered tools
  Supervision of construction work
- Fire hazards and precautions
- Hazardous chemical substances
- <u>Lifting machines</u>
- Duties of Client
- Construction vehicles and mobile plant
- Duties of Principal Contractors
- Incident management
- Supervision of construction work

The six underlined groupings were identified as hazardous construction activities/operations/areas which had the potential of causing the most serious injuries. The research was strictly limited to these six groupings as they were prevalent on most construction sites and were processes that typically ran for most of the construction period (with the exception of excavation work which is most prevalent at the commencement of a project).

It must also be noted that even though most of the sites were audited more than once, their results did not necessarily improve each time. In fact no trend could be identified indicating either a clear increase or decrease in compliance of any of the groupings. This finding seems to indicate that the Principal Contractors did not adopt an approach of compliance with the groupings in question. It can therefore be deduced that the Contractor did not see these groupings as being of a particularly high-risk nature and did not see them as a priority to direct the necessary resources to the areas/activities/operations.

Table 1 presents the results from the 51 audits carried out. The results (percentages) of the six 'high risk' groupings are shown with the final column indicating the total percentage attained taking all thirty audit groupings into account. It is apparent from the findings that the results of the six 'high-risk' groupings when averaged out are all below the average total score obtained for all the audits together. This is a clear indication that the groupings are not seen to be priority areas on the construction sites audited.

Table 1. EACI audit results

Date	Site	Company	Fall prot	Form / support	Lifting Mach	Scaffold	Elec	Excav	Audit total
01.12.05	Site 1	Audit 1	54	46	86	40	85	-	81
09.02.06		Audit 2	68	46	85	63	90	-	82
26.09.06		Audit 3	69	33	50	38	80	-	79
-	Site 2	Audit 1	40	33	77	60	75	88	77
22.11.05		Audit 2	40	46	82	100	50	-	81
11.04.06		Audit 3	65	46	96	88	45	-	82
13.03.07	Site 3	Audit 1	96	33	86	100	90	63	74
16.05.07		Audit 2	94	83	73	72	85	59	86
04.07.07		Audit 3	89	83	44	91	90	-	87
07.08.0		Audit 4	81	83	91	73	70	-	88

7									
10.03.05	Site 4	Audit 1	81	50	81	100	44	71	80
02.06.05		Audit 2	77	37	61	100	87	87	87
28.07.05		Audit 3	81	38	82	90	38		87
22.09.05		Audit 4	83	75	82	53	30	90	75
02.08.06	Site 5	Audit 1	94	58	61	100	90	58	88
13.10.06		Audit 2	89	75	91	44	90	100	89
06.12.06		Audit 3	89	58	91	61	90	47	87
22.02.07	Site 6	Audit 1	81	70	84	77	100	-	92
16.08.07		Audit 2	92	71	91	81	70	-	89
05.04.05	Site 7	Audit 1	91	96	93	90	100	95	97
01.06.05		Audit 2	89	100	93	100	100	100	98
10.08.05		Audit 3	92	71	88	100	95	-	95
05.10.05		Audit 4	80	71	82	85	80	-	89
15.02.06		Audit 5	71	50	70	100	80	-	87
19.04.06		Audit 6	75	79	86	90	70	-	90
14.06.06		Audit 7	89	75	91	62	70	-	-
28.10.05	Site 8	Audit 1	50	71	91	81	80	-	83
14.02.06		Audit 2	61	45	86	81	70	-	81
21.04.06		Audit 3	73	46	86	65	70	-	76
21.09.05	Site 9	Audit 1	75	33	83	70	30	44	80
23.11.05		Audit 2	62	58	84	84	90	100	76
17.08.07	Site 10	Audit 1	86	58	100	81	95	72	88

Apr '07	Site 11	Audit 1	79	33	77	33	40	33	79
Jun '07		Audit 2	86	17	94	93	50	50	86
28.08.07		Audit 3	89	-	82	77	10	100	84
06.03.07	Site 12	Audit 1	75	33	88	75	87	-	80
08.08.05	Site 13	Audit 1	38	25	82	90	80	-	76
07.02.06		Audit 2	92	83	92	90	90	-	87
08.06.05	Site 14	Audit 1	73	100	92	72	75	-	84
04.05.06	Site 15	Audit 1	75	71	100	50	95	-	87
07.03.05	Site 16	Audit 1	50	75	89	56	90	-	78
07.07.05		Audit 2	90	33	84	77	87	-	81
03.05.06	Site 17	Audit 1	64	67	63	91	95	60	75
02.02.06	Site 18	Audit 1	90	100	86	100	100	100	89
07.07.05	Site 19	Audit 1	85	42	56	75	86	-	78
02.02.06		Audit 2	63	33	83	100	95	-	79
08.02.07	Site 20	Audit 1	83	83	71	94	90	94	88
12.03.07	Site 21	Audit 1	77	-	98	-	90	-	83
06.12.06	Site 22	Audit 1	84	75	27	93	87	-	86
-		Audit 2	68	-	83	50	75	-	86
			76%	59%	80%	78%	77%	76%	82%

- Excavation work was not always taking place on the sites audited and was therefore not always scored.

The injury statistics

The injury statistics data studied indicates that there is a relationship between the six 'high-risk' groupings identified in the EACI audit results and the causes of serious injuries. This is demonstrated in the tables below. The Chinese and Turkish examples (both developing economies) compare well with the FEM (Federated Employer's Mutual Assurance fund) statistics for injuries in the Western Cape (South Africa).

Table 2. Injuries in the Chinese construction industry (1999)

Accident category	Fatality	Severe Injury
Falling from height	524 (48)	133 (44)
Electrocution	124 (11)	4 (1)
Hit by falling materials	116 (11)	45 (15)
Collapse of earthwork	148 (13)	36 (12)
Use of heavy machine	71 (6)	38 (13)
Lifting of weights	45 (4)	18 (6)
Toxic and suffocation	29 (3)	2 (1)
Use of motor	8 (1)	3 (1)
Fire and explosions	20 (2)	3 (1)
Others	12 (1)	17 (6)
Total	1097 (100)	299 (100)

The figure in parentheses indicates the percentage of the total.
Source: China Statistical Yearbook of Construction (2001), pp. 105.

Table 3. Chinese fatal injuries due to fall from height (1999)

Type	Fatality	Severe injury
Hole and edge	182 (35)	24 (18)
Scaffolding	133 (25)	51 (39)
Crane	78 (16)	13 (10)
Tower crane	35 (7)	9 (7)
Formwork	34 (6)	9 (7)
Construction machine	10 (2)	10 (7)
Earthmoving	7 (1)	3 (2)
Building demolition	7 (1)	-
Others	38 (7)	14 (10)
Total	524 (100)	133 (100)

The figure in parentheses indicates the percentage of the total.
Source: China Statistical Yearbook of Construction (2001), pp. 105.

Table 4. Statistics of injuries according to how they occur (Turkish construction industry)

Type of injury	Fatalities	% of total
People falling	538	36.6
Material falling	139	9.5
Caving of excavations	98	6.7
Part of structure collapsing	86	5.9
Shocking by electricity	212	14.4
Injuries by construction machines	162	11.0

Source: Adapted from a paper by Mungen, 1997. Employment related accidents in the Turkish construction sector and applications of occupational safety. Health and Safety in Construction, 1997, Eds. Haupt and Rwelamila.

Mungen (1997), further categorizes falling from heights injuries in Turkey into the following (see table 5).

Table 5. Falling from heights – main causes of injuries (Turkey)

Cause	%
Falling from floors and platforms	28.1
Falling from scaffolding	23.1
Falling into holes e.g. elevator shafts	9.8
Falling from roof	9.3
Other	29.7

Source: Adapted from a paper by Mungen, 1997. Employment related accidents in the Turkish construction sector and applications of occupational safety. Health and Safety in Construction, 1997, Eds. Haupt and Rwelamila.

Federated Employer's Mutual Assurance Company (FEM), a registered workman's compensation supplier to the construction industry, keeps very reliable injury statistics. Table 6 sets out fatal injury claims by description for the Cape Town reporting region, while table 7 sets out fatal injury claims for the entire South African reporting region. It must be born in mind that not all construction companies are registered with FEM. Many companies are registered with the Government Commissioner for which recent statistical data is not readily available.

Table 6. FEM claim statistics (fatalities) – Cape Town region

Description	No. fatals (Jan–Jul ’06)	No. fatals (Jan-Jul ’07)
Fall onto different levels	8	2
Struck by	2	2
Caught in, on, between	2	1
Fall on same level	0	0
Other	1	0

Source: FEM statistical records 2006 and 2007

Table 7. FEM claim statistics (fatalities) – South Africa (total)

Description	No. fatals (Jan–Jul ’06)	No. fatals (Jan-Jul ’07)
Fall onto different levels	13	7
Struck by	11	5
Caught in, on, between	3	3
Fall on same level	0	1
Other	3	3

Source: FEM statistical records 2006 and 2007

The findings of Hinze (1996), suggest that falls from elevated positions are the most common cause of construction worker fatalities with the leading causes being:

- Off roof
- In scaffolding collapse
- Off scaffolding

A final interesting finding is that smaller construction companies are considered to have more ineffective health and safety management systems in comparison to their larger counterparts (Goodloe, 1996). Most serious injuries in fact occur on sites controlled by medium and small contractors. This information is interesting as the construction companies audited as part of this research were in the most part within the top five as far as annual turnover goes and smaller principal contractors could show even more evidence of failure to comply with ‘high-risk’ health and safety management requirements.

6. DISCUSSION AND CONCLUSION

In summary, this study suggests that certain hazardous activities/operations/areas on construction sites are not being optimally managed by the construction companies concerned even though there is clear evidence that these hazardous activities are causing the most serious injuries including the most fatalities in the industry.

Although the reasons for this apparent lack of focus on serious injury causing activities are not discussed in detail, the answers must certainly lie with an acceptance by company management and decision makers that there is a clear relationship between certain 'high-risk' activities and serious injuries.

It's probably safe to say that companies need to spend their resources more effectively and concentrate more of their efforts (time, money, supervision) on these 'high-risk' activities/areas. Their site management officials (site managers, foremen, team leaders, engineers, engineering technicians and health and safety officers) need to be trained on hazard identification and risk management techniques and strategies. Site foremen must on a mandatory basis be trained on scaffold and excavation/trench safety. Team leaders/gang bosses should be included in the site health and safety system by making them responsible for hazard identification and risk management of their team and their immediate sections on site. Site personnel, including foremen and others must be disciplined for non-conformance to company and site health and safety procedures. Lastly, subcontractors must be proficient in the health and safety management of the risks associated with their particular trade/operation i.e. roofing contractors; structural steel contractors; earthworks and civil contractors; and other contractors who have to work in elevated positions to conduct their trade.

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RISK

10

QUANTIFICATION AND COMMUNICATION OF CONSTRUCTION SAFETY RISK

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ABSTRACT

Construction risk is typically defined in terms of likelihood and severity and is quantified by multiplying the probability of an event by the potential impact of that event on project budget or schedule. The quantification and communication of construction safety risk, however, involves the application of safety terminology and management techniques to the field of risk management. This paper presents a method for quantifying construction safety risk and risk mitigation ability using scales that define risk in terms of safety and health. First, several scales that can be used to quantify the probability and severity components of safety risk are presented and accompanied by a discussion of their benefits and limitations. Second, a method for quantifying construction safety risk mitigation, using the proposed scales, is introduced. Finally, the reactions of several construction safety risk experts to the use of one proposed scale are presented. It is believed that these methods are useful as they provide the construction industry with a standard method for quantifying and communicating safety risk, and the ability of various activities to mitigate a portion of such risk, using consistent and practical terminology.

Keywords: Safety, Construction, Organizational Issues, Risk Management

1. INTRODUCTION

According to the Bureau of Labor Statistics (2006), the construction industry, the largest single-service industry in the United States, consistently employs approximately 5 percent of the American workforce. Data assembled by the National Safety Council (2003) indicates that the construction industry accounts for approximately 12 percent of the United States' occupational fatalities and has the third highest fatality rate of all US industries. In fact, in 2003 nearly 10 of every 100,000 workers employed on a construction site were fatally injured (NSC, 2003).

Other studies have shown similar evidence that construction safety is an important issue that deserves attention. For example, Kartam (1997) found that one in every six US construction workers will suffer a serious injury each year. Researchers in the United

Kingdon (UK) have found that construction workers in the UK are five times more likely to be killed and two times more likely to suffer a serious injury than the all-industry average (Carter and Smith 2006). Specifically, the fatality rate in 1998 in the UK was 5.6 fatalities per 100,000 workers and, during the same year, the average fatality rate in construction for the European Union as a whole was over 13 fatalities per 100,000 workers (Carter and Smith 2006).

In recent years, safety performance has become a more recognized issue in the construction industry because studies have shown that hazardous work environments can have a significant impact on schedule and budget performance. Hinze et al. (2006) observed that construction safety has gained attention because of the increasing workers' compensation insurance premiums that have resulted from a great increase in medical costs and convalescent care. In 2004, the construction industry experienced 460,000 disabling injuries and the cost of these disabling injuries was estimated to be $15.64 billion (NSC 2006). Hazardous conditions have also been found to have indirect effects because they slow operations and undermine productivity (Yi and Langford 2006).

Because of the high direct and indirect costs associated with accidents and hazardous conditions, construction safety risk research is needed to improve the overall performance of construction projects. This paper presents a proposed method of quantifying safety risk that incorporates the full spectrum of risks. Use of the strategically-designed scales presented in this paper is expected to improve the consistency of risk quantification and communication. The reactions of several construction safety and risk management experts to the proposed scales are also included. Before proceeding, however, the current methodologies for risk quantification are presented and the limitations of these methods are highlighted.

2. RISK QUANTIFICATION

Most safety risk literature focuses on risk analysis and the relative risk levels among trades or industries. For example, Barandan and Usmen (2006) discuss the comparative injury and fatality risks for trades involved in the construction of buildings using data published by the Bureau of Labor Statistics (BLS 2007). Likewise, Lee and Halpin (2003) created a predictive tool for estimating accident risk in construction using fuzzy inputs from the user.

One of the most common methods of quantifying safety risk, employed by Jannadi and Almishari (2003) and Baradan and Usmen (2006), is illustrated in Equation 1. According to this equation, risk is composed of three primary components: probability, severity, and exposure. In risk quantification, probability refers to the chance of a potential event (e.g., number of events per day), severity represents the potential outcome of an event (e.g., dollars per event), and exposure describes the duration of potential contact with a potentially hazardous situation (e.g., days). The role of exposure is to convert a unit risk (e.g., dollars per day) to a cumulative risk (e.g., dollars). Both of the studies cited above evaluate techniques for identifying and quantifying safety risks in construction. However, neither study indicates how the spectrum of probability and severity levels should be defined or communicated to the workforce.

Activity Risk Score = (Probability) x (Severity) x (Exposure) (Eq. 1)

The following sections will highlight current methods used to quantify probability and severity, potential limitations of current practice, and a proposed scale that exploits the benefits and minimizes errors and omissions in the risk quantification process.

Probability (Risk in general and Safety risk)

Quantifying the probability of event occurrence is a seemingly easy task. When analyzing safety risk the most commonly-used units of probability are: incident rates and subjective measures. Brauer (1994) classifies probability as frequent, probable, occasional, remote, and improbable. Baradan and Usmen (2006) take a more advanced approach by calculating incident rates using data published by the Bureau of Labor Statistics (BLS). For non-fatal injuries, BLS data is reported in terms of incident rate (i.e., number of injuries or illnesses per 100 full-time workers) while the probability of fatality is reported as the number of deaths per 100,000 full-time workers. While this approach to calculating probability of construction safety incidents is more advanced, one should note that the BLS data is only recorded and published for very high severity incidents (i.e., lost work-time incidents and fatalities). A risk analysis that incorporates only high-severity, low-probability data ignores a significant portion of risk, namely high-probability, low-severity events. According to risk management theory, comprehensive and formal risk analysis should include all types of risk.

The probability scale shown in Table 1 is proposed by the authors. This scale incorporates all levels of probability from zero to incidents that may occur once every six minutes per worker. The scale incorporates the use of incident rates by using incidents per worker-hour. Each probability level (from 1 to 10) is separated by a power of ten. This large range of probabilities allows one to include all types of incidents when calculating cumulative risk.

For reference, data published by the BLS in 2005 indicates that the US construction industry accounted for 1,186 fatalities and 414,900 lost work-time incidents (not including fatalities). Also, in 2005, the construction industry employed approximately 7,336,000 workers, each averaging 38.6 hours of work per week. This results in a total of 14.7 billion worker-hours. Using this information we can easily calculate that the average number of worker-hours per fatality was approximately 12.5 million worker-hours per fatality and 35,490 worker-hours per lost work-time injury. As one can see, the proposed probability scale includes these values and allows for the inclusion of incidents of higher probability.

Table 1: Proposed Probability Scale

Incident rate	Probability Score
Impossible	0
Negligible	1
10-100 million worker-hours	2
1 to 10 million worker-hours	3
100,000 to 1 million worker-hours	4
10,000 to 100,000 worker-hours	5
1,000 to 10,000 worker-hours	6
100 to 1,000 worker-hours	7
10 to 100 worker-hours	8
1 to 10 worker-hours	9
<0.1 to 1 worker-hour	10

A major benefit of this scale is the ease of use relative to other methods of quantifying probability. Determining exact probability values for high-probability risks such as minor musculoskeletal injuries related to ergonomics would require detailed recordkeeping on behalf of the employer. Though it may be possible to calculate close approximations of these values within individual firms, defining the industry-wide probability values for various incidents would be very difficult. Using their years of experience, construction experts should be capable of determining the approximate range for both their firms and the industry as a whole.

Severity (Risk in general and Safety risk)

While probability lends itself well to quantification through the use of incident rates, quantifying severity is more abstract. It is not surprising that most safety studies concentrate on two severity levels: lost work-time incidents and fatalities. As previously indicated, data is rarely collected for low-severity injuries such as minor musculoskeletal injuries or persistent pain despite the fact that many studies indicate that these injury types are also high risk (Hess et al. 2004). In other words, the product of probability and severity for low-severity injuries is comparable to high severity injuries. Therefore, it is important to define a continuous measure of severity that includes both low-severity injuries and high fatality injuries.

Several publications such as Hinze (1997) and Hill (2004) describe the range in severity of several incident types. Likewise, the Canadian Organization of Oil Drilling Contractors (2004), and the Occupational Safety and Health Administration (2007) have produced online resources that define a spectrum of possible incident severities. Using these publications as guidance, definitions of a few incident severity types have been included below.

Fatality: A work related injury or illness that results in death.

***Lost work-time*:** An injury or illness that prevents an employee from returning to work the following workday.

***Restricted work case*:** An injury or illness that prevents an employee from performing work in normal capacity, but does not result in days lost from work.

***Medical Treatment Only*:** Any work related injury or illness requiring medical care or treatment beyond first aid. In this category the worker must be able to return to their regular work and function in normal capacity.

***First Aid*:** Any treatment of minor scratches, cuts, burns, splinters and so forth. In this category the worker should be able to return to work following the first aid treatment.

With the exception of first-aid injuries, the above incident types would be considered "OSHA recordable." That is, the injuries must be recorded in the employer's occupational injury log. However, as many construction professionals and researchers are well aware, there are a significant number of incidents that result in minor injuries such as persistent pain, temporary pain, discomfort, and close-calls. In fact, Heinrich (1931, as cited in Hinze 1997) claims that for every major injury there are 29 minor injuries and 300 no-injury accidents. It is the opinion of the authors that ignoring the contribution of these high-probability, low-severity events is a major flaw in most construction safety literature and risk analyses.

Studies that focus on construction ergonomics have reported that a significant portion of construction related claims involve low-severity incidents. For example Hess et al. (2004) found that strains and sprains accounted for 31.5 percent of workers' compensation claims by union construction laborers in the state of Washington between 1990 and 1994. While most of these incidents are not "OSHA recordable" and would not be reflected in BLS annual statistics, they represent a large portion of the yearly workers' compensation costs. Because high-severity injuries such as fatalities and disabling injuries involve a relatively high number of workers' compensation claims, this data suggests that ergonomic issues, such as strains and sprains, occur relatively frequently. If one were to assume that the total number of workers' compensation claims is representative of the cumulative safety risk on a construction site, minor injuries such as strains and sprains would account for a significant portion of risk. Most risk analyses ignore such risks.

Based on the descriptions provided in the references cited above, a continuous scale (shown in Table 2) has been produced that captures both high severity injury types such as lost work-time injuries, disabling injuries, and fatalities, and low-severity injuries such as temporary discomfort, temporary pain, and persistent pain. The risk scores and descriptions have been modeled after the descriptions in Hinze (1997), Hill (2004), the Canadian Organization of Oil Drilling Contractors (2004), and the Occupational Safety and Health Administration (2007). The authors believe that the spectrum of possible injury types is included in this scale.

One may note that the scale is continuous from 0 to 10 but that the severity score for a fatality breaks the continuity and is represented by a score of 256. Previous research (Soloman and Abraham 1980; NIOSH 1999; Baradan and Usmen 2006) indicates that the severity of a fatality should be valued at twice that of non-fatal injuries. In other words, these publications suggest an inflation factor of 2 for fatalities when conducting a risk analysis. The authors of this paper suspect, however, that an inflation factor of 2 may be an underestimate, especially if risk is defined in terms of monetary costs. Take, for example, the cost estimates made by the National Safety Council (2007). In 2007 the NSC estimated that the cost per death was $1,190,000 and the cost per disabling injury was $38,000. These figures represent the sum of the estimated wage loss, medical expenses, administrative expenses, and employer costs but exclude property damage. If one were to use this data to calculate an inflation factor, the value in 2007 would be approximately 31 ($1,190,000 / $38,000 = 31.3). Figure 1 illustrates the ratio of estimated fatality cost to the estimated cost of a disabling injury using the NSC data published from 1998 to 2007. The NSC *Injury Facts 2007* defines "disabling injury" to include those in which the injured person is unable to effectively perform their regular duties or activities for a full day beyond the day of the injury. This includes the lost work-time and medical case severities shown in Table 2. Therefore, the inflation factor of 32 should be multiplied by 8 to get a risk score of 256 for fatalities.

Table 2: Proposed Severity Scale

Severity	Description	Score
Near miss	Incident that does not result in harm to a worker	0+
Negligible	Incident that resulted in extremely minor (mostly unnoticeable) injury	1
Temporary discomfort	Incident that resulted in temporary discomfort (one workday or less) but does not prevent the worker from functioning normally	2
Persistent discomfort	Incident that resulted in persistent discomfort (more than 1 workday) but does not prevent the worker from functioning normally	3
Temporary pain	Incident that resulted in temporary pain (one workday or less) but does not prevent the worker from functioning normally	4
Persistent Pain	Incident that resulted in persistent pain (more than 1 workday) but does not prevent the worker from functioning normally	5
Minor first aid	Incident that required minor first aid treatment. The worker may not finish the workday after the incident but returned to work within 1 day.	6
Major first aid	Incident that required major medical treatment (worker returned to regular work within 1 day)	7
Lost work-time	Incident that resulted in lost work time (worker could not return to regular work within 1 day)	8

Medical Case	Incident that resulted in significant medical treatment and resulted in lost work time (worker could not return to regular work within 1 day)	9
Permanent Disablement	Incident that results in an injury that causes permanent disablement	10
Fatality	Incident that results in the death of a worker	256

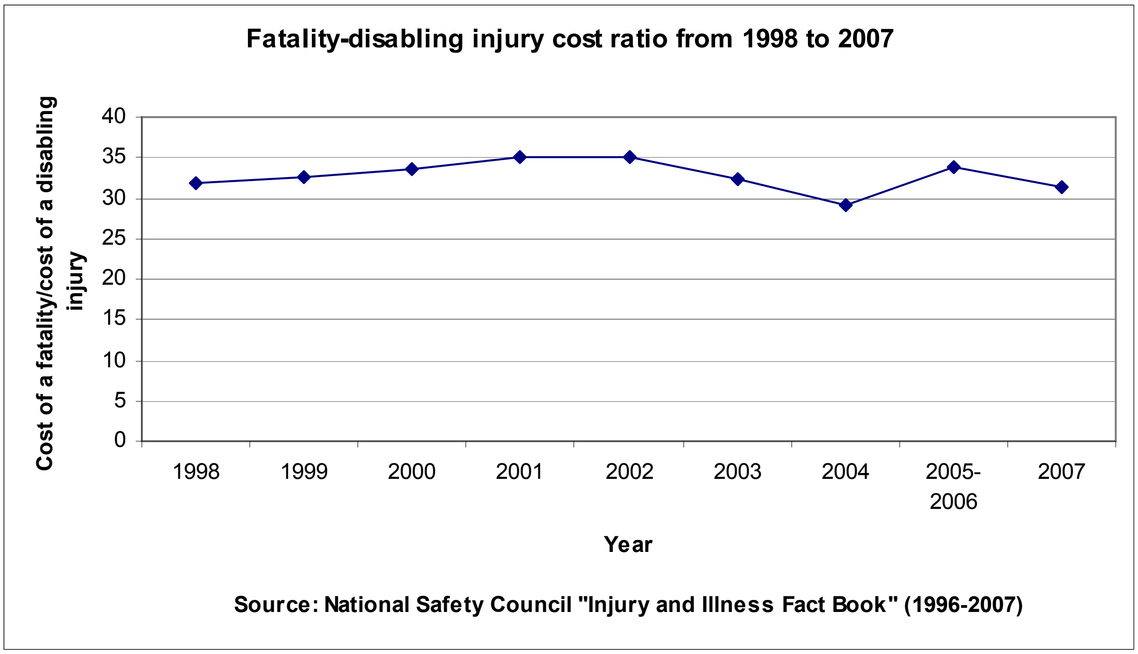

Figure 1: Fatality-disabling injury cost ratio from 1998 to 2007

3. RISK COMMUNICATION

The probability and severity scales presented in this paper can be used to quantify relative risk levels by multiplying the probability score by the corresponding severity score. While most average risks are expected to exist in the 10 to 100 range, the scales allow for possible risk values from 0 to 2,560. It is expected that these ranges can be used to communicate risk to workers and managers in several different ways. Communicating risk in numerical form might not be effective for communicating high risk activities to workers. Therefore, the resulting risk analysis can easily be divided into categories such as very low, low, medium, high, and very high. When describing the relative risk of activities or processes to workers, subjective descriptions could be represented by percentiles, subjective interpretation, or visual code as illustrated in Table 3. In this example, risk values for many or all activities or processes can be compared to each other.

Table 3: Subjective risk interpretation

Percentile	0-20	20-40	40-60	60-80	80-100
Subjective Interpretation	Very Low	Low	Medium	High	Very High
Visual Code	Green	Yellow		Red	

It would not be appropriate to create an industry-wide chart for subjective interpretation of safety risk because of the many confounding factors that affect risk values for individual firms. One firm, for example, may feel that a risk score of 25 is unacceptable while another may find a score of 25 to be low for their organization. This difference in risk perception may be the result of various factors such as type of work performed, skill of the workforce, or the maturity of the safety and health program. It is suggested that firms use the proposed scales to calculate cumulative risks for various activities, organize the activities by percentile and report the risk values accordingly. The authors suggest that subjective terms be used to communicate relative risk to workers using the terminology in Table 3 or by using visual codes such as red, yellow, and green.

The scales can also be used to communicate more advanced knowledge to management in terms of worker-hours per incident severity type. Currently, most safety hazards are communicated in terms of their hazardous exposure. Activities such as job hazard analyses, inspections, and safety meetings are used to convey potential hazards to workers. In this communication it is rare that information regarding the probability of an injury or the possible range of severities is communicated. Therefore, workers are not typically aware of their risk, but rather the condition. The use of the risk scales, and subsequent interpretation, may be useful for alerting workers of high-risk activities thereby increasing awareness.

4. BENEFITS AND LIMITATIONS OF THE PROPOSED SCALES

The scales presented in this paper are based upon a thorough literature review, industry data, and risk management theory. While the authors believe that the use of the scales would be beneficial to the industry, it is important to validate these claims. In an effort to assess their benefit to the industry, several construction safety and risk management experts were asked to review the scales and describe their benefits and limitations.

As part of an ongoing Delphi study, a panel of 29 construction safety experts was created and asked a series of questions pertaining to the viability of the proposed probability and severity scales. Potential experts were identified and selected from the ASCE Site Safety Committee and the ASSE Construction Safety Specialty Committee, and from contacts provided in peer-reviewed publications. Of the 29 expert panelists, 10 respondents commented on various aspects of the scales and their applicability to construction projects.

In order to be qualified as an expert in the field of construction safety or risk management, the panelists were required to meet at least four of the eight requirements listed in Table 4. Criteria for expert qualification was obtained from guidelines presented in Delphi studies such as Veltri (2006), Rogers and Lopez (2002), and Rajendran (2007). Table 4 indicates the percentage of qualified expert panelists that met each requirement. The authors believe that input from experts was desirable for this study because individuals that meet the requirements in Table 4 are likely to have a holistic understanding of the construction industry and would, therefore, provide the most valuable critique.

Table 4: Expert Qualification

Requirement	Percentage of expert panelists meeting this requirement
1. Primary or secondary author of a peer-reviewed journal article on the topic of construction safety or health	60%
2. Invited to present at a conference with a focus on construction safety or health	80%
3. Member or chair of a construction safety and health-related committee	90%
4. At least 5 years of professional experience in the construction industry	100%
5. Faculty member at an accredited institution of higher learning with a teaching or research focus in the areas of construction safety or risk management	40%
6. Author or editor of a book or book chapter on the topic of safety or risk management	40%
7. Advanced degree from an institution of higher learning (minimum of a BS) in Civil Engineering, Construction Engineering and Management, Occupational Safety and Health, or similar field	100%
8. Designation as a Professional Engineer (PE), Certified Safety Professional (CSP), Associated Risk Manager (ARM) or a Licensed Architect (AIA)	80%

The expert panel was asked to review the scales, provide their general thoughts about the scales, and indicate if the scales would be useful for risk quantification and subsequent communication of risk to workers. The experts were also asked to identify any similar scales encountered during their careers.

Overall, the scales received a favorable review from the expert panel. All respondents indicated that the proposed scales make sense theoretically and are appropriate for measuring unit risk. In other words, the panelists believed that managers can use the scales to accurately quantify risk per worker-hour. Two of the ten respondents (20%)

indicated that they would like to use the scales to quantify risk in their businesses because they are understandable and highly representative of all types of risk. Each of the respondents believed that the scales can be used to define an entire spectrum of risks with a reasonable degree of accuracy. In fact, one respondent indicated that, "This is the only set of useful risk scales I have ever encountered."

A few experts indicated that the probability scales were the most difficult conceptually because, "Using scales like 1 in a million or 1 in 10,000 are difficult for people to grasp." Therefore, the authors suggest that individuals quantify probability in terms of more tangible time periods such as hours, days, weeks, months, and years. These values can then be converted to worker-hours when the scales are implemented.

When communicating risk to workers, all experts agreed that the numerical measures may pose a problem for workers. While the scales are likely to be useful to managers and executives, workers may find the numerical measures too abstract. The experts suggest the use of a simple scale that uses only subjective interpretations of the risk levels. An example of such an interpretation was provided earlier in this paper (see Table 3). Other methods of interpretation may include quantifying probability using the Likert scale (e.g., 1 = very low probability; 5 = extremely high probability). Severity could also be quantified in more tangible terms of expected number of days of work (for lost work time incidents) and degree of treatment required (for first aid and medical-case). According to the comments of the expert panel, the scales in their raw form as they are presented in Tables 1 and 2 in this paper would be inappropriate for risk communication with laborers. The scales would, however, be useful for communicating risk levels to executives and upper management, especially if risk was quantified or converted to monetary terms.

Given the limitations identified, the expert panel was asked to suggest revisions to the scales. While each of the experts indicated that the scales should be interpreted for the workers, they also agreed that the scales in their raw form are ideal for risk analysis and initial quantification of safety risk. Despite the suggested methods of interpreting the scales, no panelist suggested revisions to the proposed scales. When the expert panel was asked to identify similar scales encountered during their careers, all but one respondent indicated that the no similar scale or risk quantification method had been encountered. One individual indicated that they had created and used a scale that involved OSHA recordable rates and severity defined in terms of days away from work. One should note, however, that this scale does not differ significantly from those reviewed in the literature presented earlier in this paper.

5. CONCLUSIONS

The probability and severity scales proposed in this paper take into consideration risk management theory and existing literature to improve upon existing methods of risk quantification. It was found that all methods identified in the literature focus on high severity, low probability incidents. According to ergonomic studies and risk management theory it is inappropriate to ignore low severity, high probability risks. Data and guidance from the National Safety Council, the Bureau of Labor Statistics, and the Occupational Safety and Health Administration were used to create a realistic spectrum of probability and severity values. Finally, a panel of certified experts in construction safety and risk management was asked to comment on the viability of the scales. The proposed scales received a favorable review from the expert panel. Experts commented that the scales were unique, representative, and conceptually accurate. The experts did, however, suggest that the scales be converted to simpler, less abstract terms if the scales were to be used to communicate risk levels to workers. Based on this suggestion, the authors provided guidance for interpretation.

Overall the authors believe that the proposed probability and severity scales define probability and severity in such a way that a full spectrum of risks can be included in a risk analysis. Support from a panel of construction safety and risk management experts confirms this claim suggesting that the scales may be appropriate for widespread use in the construction industry.

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CONSTRUCTION WORK RISKS FOR CHILDREN AND THE PUBLIC: INVESTIGATION OF LABOUR AND CRIMINAL COURT FILES AND ANALYSIS OF ACCIDENTS

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ABSTRACT

Construction work zones create risks not only for the construction worker, but also for members of the public where the construction work is carried out on a site that is in close vicinity to the property boundary or to any public place. Construction sites located in city centers, especially for public works projects, pose a risk for the neighboring dwellers and the public, those referred to as third parties. The third party liabilities, indemnities or claims are important for the contractors who perform projects in the city centers. Death of children resulting from construction activities is another aspect of the hazardous conditions on construction sites. In this study, 952 expert witness reports were investigated to identify the characteristics of the third party injuries on or near the construction sites. The reports investigated were submitted to criminal and labour courts by the academicians at Technical University of Istanbul Civil Engineering Faculty. Fatal and non-fatal injuries were analyzed by cause of accident, type of construction work and occurrence time of day. According to the expert witness assessments, responsible parties, employees, employers or third parties, were presented and their role in the accidents were discussed. The leading causes that resulted in injuries to children were the focus of the investigation, along with the mitigation and abatement measures and safety techniques to be employed on construction sites located in downtown areas.

Keywords: Construction accidents, Third party injuries, Children deaths, Risks for public

1. INTRODUCTION

In Turkey and most industrialized and developing countries, the construction industry is one of the most significant in terms of contributing to the GDP, in terms of impacting the health and safety of the working population and improving our quality of life. Unfortunately for many construction workers, their families and entourage, working in the construction industry has resulted in dramatic pain and suffering because of an occupational fatality or serious injury. A variety of indices have been used to depict and examine the impact of injuries; however, the incidence rates reported around the world are sufficient to reveal the negative situation of the industry. There is a wide range of reported incidence rates, varying from country to country, however in comparison to the western countries, fatalities are particularly high in the Turkish construction industry.

The construction industry is a project-based industry where accident rates will vary from project to project. Each project is unique and each project type (for example, a road or a bridge) has its own characteristics, methods of work performance, materials employed and techniques for construction. On the other hand, the construction industry is characterized by contingent forms of work, heavily reliant on contracting and subcontracting and the use of labour hire firms. Contingent forms for work have been linked with undesirable occupational and health and safety outcomes. (Lingard and Rowlinson, 2005).

In addition to the facts mentioned above, the hazardous nature of construction work itself creates risks not only for the construction worker, but also for members of the public, especially where the construction work is carried out on a site that is near or adjacent to the property boundary or to any public place. Moreover, construction sites may be attractive for children passing nearby and regarded as a “play garden.” For example anytime where water is ponded, children will be attracted to it resulting in construction sites posing drowning hazards. The hazards for children or non-employees (third parties in judicial terms) may take different forms and they should be investigated in detail. Unfortunately, there has been little research in the construction industry that reveals the characteristics of third party injuries (including children), accident causes, hazardous conditions affecting the public and the responsible parties in the accidents. A limited number of safety manuals and books in the field of construction safety mention children and third party safety (Holt, 2006; HSE 2001, ILO 1995), legal issues, responsibilities and liabilities (Lingard and Rowlinson, 2005). The report on youth labor force by the US Department of Labor mentions employees under eighteen years old in the construction industry. In the codes of practices, manuals, directives and fact sheets of some public agencies such as OSHA of the USA, HSE of Great Britain, EASHW of the European Union et al. the protection of the non-employee and/or children is mentioned; however, detailed investigations and studies do not exist. Since the claims and indemnities exist in these kinds of accidents and the legal process requires determination of the liable party or parties, the lawyers, legal practitioners and other law professionals are very interested in the accidents where non-employees are exposed.

Knowledge of causation patterns provide a starting point for focusing particular preventive measures on the risks to the public that includes children. The aim of this study is to investigate the characteristics of accidents that effect third parties. This is to help focus attention of the safety professionals on the non-employee and children deaths that occur as a result of construction activities. Understanding accident causation patterns will provide a starting point for focusing particular attention on preventive measures for the risks to the public, including children. Investigation of the cases and descriptions of accidents which are presented in the scope of this study can be used to provide information about prevention techniques for safety professionals, contractors and subcontractors to perform safe construction not only for the employees but also for the public.

2. MATERIALS AND METHODS

In Turkey, the broadest archive on occupational accidents is the Social Insurance Institution (SII) General Directorate's archive. The main documents included in this archive come from the criminal and labour courts. All injury records in Turkey are collected by the General Directory to facilitate the process of compensation claims and other legal issues. In this archive, only the cases whose legal procedures are completed are stored. Unfortunately, the Institution interests are primarily in employee-employer relationships, labour compensation and indemnity. Non-employee or children deaths or non-fatal injuries are out of the interest and field of responsibility of the SII. Additionally, in Turkey there is no proper classification or documentation system for the causes of industrial accidents and it is especially in the construction industry where data collection is insufficient. In addition, the number of unregistered workers in the construction industry is at very high levels. Because of these negative factors, many of the injuries are not recorded and documented. The Social Insurance Institution General Directorate's official statistics only give the number of total injuries, fatalities or permanent incapacity cases by industry (Müngen and Gurcanli, 2005). Therefore, the derivation of data concerning non-employee or children fatalities on construction sites through the recording system of Turkey is very difficult.

On the other hand, judges in the criminal and labour courts demand expert witness testimony, especially from the universities for most of the occupational accident cases. To reach a clear verdict, along with the assessment of safety measures on site, it is important to consider materials, construction methods and distribution of safety responsibilities. The authors and their colleagues from the civil engineering faculty, frequently cooperate with lawyers (to decide on the responsibilities of prime and sub-contractors for example, regarding the contracts) and engineers from other disciplines such as mechanical engineers (for heavy equipment accidents, for example). Examining the case files in detail, provides the basis this analyses.

When an accident occurs, whether a claim is made or not, an investigation is executed by the public prosecutor. If the public prosecutor decides that one or more person is faulty, then the documents are sent to criminal court and a comprehensive official investigation results in a verdict about who is responsible for the accident. The final verdict is generally based on an expert witness report that distributes the responsibility as a fraction of eight (for example; site engineer, injured worker and supervisor responsible for the accident are 2/8, 3/8 and 3/8 respectively). Labour courts are responsible for the compensation issues. Here again, in many cases the final verdict is reached with the aid of an expert witness report that distributes the responsibility for an accident by percentage.

For the preparation of an expert witness report, an investigation on the premises is generally performed and the judge submits the judicial documents to the experts, including the following:

- Statements made by witnesses and the defendant(s)

- Preliminary official record and drawing of the location where the accident occurred
- Accident report written by the employer
- Statements made by the victim about the accident and his/her relatives
- Statements made by employees (site engineer, safety manager, chief engineer of the prime contractor and frequently the subcontractor) who are responsible for safety in the company
- Investigation record and photos
- Contracts between prime and subcontractors that indicate the responsibilities regarding safety measures
- Technical specifications of the work done and equipments being used
- Formerly written expert witness report(s)

Sorock et al. (1995) indicated that insurance claim accident narrative data can be used to identify and describe crashes in construction work zones. One advantage of this claim-based analysis is its comprehensiveness. That is, these crashes may be reported more often than reported to the police due to the fact that they are primarily for reimbursement purposes. These court data files give the opportunity to perform detailed accident analyses. The scope of this study included 952 expert witness reports which were submitted to criminal and labour courts and 966 fatal and non-fatal injuries reports that were examined thoroughly. These reports represented all regions of the country and included incidents that occurred between 1972 and 2006. It should be noted that in insurance claims judicial action and law suits may take a long time to resolve. In many cases, the authors and their colleagues wrote expert witness reports on incidents that had occurred 15 years ago. Unfortunately, these court files are the only source of information of construction accident data in Turkey.

The distribution of these construction accidents, according to the occupation and cause, are shown in Table 1 and Table 2. As shown in Table 1, 12.1 percent of all the accidents effected third parties, whereas 14.3 percent of the fatal cases effected third parties. It should be noted that figures for non-fatal cases may not depict the whole picture, since many low severity injuries are not recorded. These figures require a focus on the third party involved in the accidents. In the data, 120 of 966 victims were non-employees and 67 of these 120 victims were children. The accident analyses are not only performed for the third party cases, but the study was focused on the incidents involving children and in the next section these cases are analyzed in detail.

Table 1. Distribution of the investigated accidents by occupation

Occupation	Fatalities	%	Non-fatal injuries	%	Total	%
Unskilled laborers	311	47,8	167	52,8	478	49,5
Craftsman	190	29,2	97	30,7	287	29,7
Apprentice	3	0,5	6	1,9	9	0,9
Superintendent Personnel	11	1,7	2	0,6	13	1,3
Equipment Operators	12	1,8	7	2,2	19	2,0
Drivers	4	0,6	2	0,6	6	0,6
Other Operators and Co-drivers	6	0,9	1	0,3	7	0,7
Technical Personnel	4	0,6	5	1,6	9	0,9
Other Personnel	16	2,5	5	1,6	21	2,2
Third parties	93	14,3	24	7,6	117	12,1
Total	650		316		966	

Table 2. Distribution of the investigated accidents by accident cause

Cause of accident	Fatalities	%	Non-fatal injuries	%	Total	%
Fall from height	350	53,8	165	52,2	515	53,3
Injured by falling, bouncing object	83	12,8	46	14,6	129	13,4
Building/structure collapse	74	11,4	36	11,4	110	11,4
Contact with electricity	53	8,2	12	3,8	65	6,7
Cave-ins (while or after excavation)	33	5,1	7	2,2	40	4,1
Heavy equipment accidents	26	4,0	9	2,8	35	3,6
Other types (drowning, burning, scratches, cuts caused by sharp edged tools)	15	2,3	14	4,4	29	3,0
Fire or explosion	11	1,7	9	2,8	20	2,1
Caught between part of a machine	2	0,3	13	4,1	15	1,6
Traffic accident on site			4	1,3	4	0,4
Caught between/crushed under material	3	0,5	1	0,3	4	0,4
Total	650	100,0	316	100,0	966	100,0

3. RESULTS

3.1. The accident causes that third parties are exposed

In previously performed studies on construction accidents (Mungen and Gürcanlı 2005, Colak et al. 2004), the leading accident causes that resulted in fatalities were revealed in detail. The ranking of the most prominent causes were a bit different in these two prior studies, as in this study. However, falls ranked first in all studies, regardless of the data source.. Although these prior studies were focused on the accidents where employees were exposed, the high incidence of falls from height also exists for non-employees as shown in Table 3. Note that 52.2 percent of all non-employee and 50 percent of children fatalities are caused by falls from height. Moreover, children are the victim of 28 of 49 third party involved fatal falls from height. On the other hand, in the previous studies children deaths by drowning were categorized in the general "other" category. However, if the investigation is narrowed down to child deaths, it is obvious that drowning is a problem and ranks fourth. In seven of eight drowning cases, the victims were children. Table 3 also points out the high proportion of child fatalities in most third party involved incidents. In all types of accidents, the proportion of the children fatalities or non-fatal injuries is above fifty percent.

Table 3. Fatal and non-fatal non-employee injuries by causation

	Third parties				**Children**			
Cause of Accident	**Fatalities**	**%**	**Non-fatal injuries**	**%**	**Fatalities**	**%**	**Non fatal injuries**	**%**
Fall from height	49	53.3	3	12.5	28	50.0	3	27.3
Building/structure collapse	18	19.6	8	33.3	10	17.9	5	45.5
Injured by falling, bouncing object	13	14.1	8	33.3	7	12.5	1	9.1
Drowning	8	8.7			7	12.5		
Heavy equipment accidents	3	3.3			2	3.6		
Contact with electricity	4	4.3	1	4.2	2	3.6	1	9.1
Fire or explosion	1	1.1	1	4.2			1	9.1
Traffic accident on site			3	12.5				
Cave-ins								
Caught between part of a machine								
Caught between/crushed under material								
Total	96		24		56		11	

It might be argued that, the reason for the low number of non fatal accidents is due to lack of sufficient data. In many low severity injury accidents, the victims do not apply to the official bodies or sue the contractor, subcontractor or owner. Therefore it can be stated that the non-fatal third party injuries do not reflect the whole picture. This argument should orient safety professionals towards focusing on fatal injury records to characterize and analyze third party involved incidents. However, it is interesting that, the proportion of children involved accidents is again very high. In 11 of 24 cases children were injured and the first two leading causes are again falls from height and building/structure collapse.

3.2. Hazardous construction sites for the public

The 966 accidents were classified according to the type of construction site (Table 4), revealing that 300 of the fatal and 132 of the non fatal accidents occurred on residential and commercial building sites, followed by industrial, institutional and small residential building sites. On the other hand, as depicted in Table 5, the five most hazardous work areas for the public (85.1 of all deaths) were residential and commercial building sites (46.2%), industrial building sites (12.2 %), institutional building sites (12.2 %), small building sites (9.6 %) and channel works (4.9 %). This distribution reflects roughly the number of construction projects comprising all construction work in Turkey.

Table 4. Distribution of the investigated cases by type of construction work

Type of construction work	Fatal Cases	%	Non-fatal cases	%	Total	%
Residential and commercial buildings (houses, apartments, stores, offices etc.)	300	46,2	132	43,1	432	45,2
Industrial buildings	79	12,2	33	10,8	112	11,7
Institutional buildings (schools, hospitals)	79	12,2	32	10,5	111	11,6
Small residential and other buildings	62	9,6	35	11,4	97	10,2
Channel works (irrigation, water, sewage systems and other underground facilities)	32	4,9	9	2,9	41	4,3
Other	30	4,6	15	4,9	45	4,7
Wells	13	2,0	4	1,3	17	1,8
Mining plants	12	1,8	7	2,3	19	2,0
Roads and highways	9	1,4	10	3,3	19	2,0
Bridges, viaducts	8	1,2	10	3,3	18	1,9
Tunneling works	7	1,1	3	1,0	10	1,0
Unknown	7	1,1	13	4,2	20	2,1
Dams	6	0,9	9	2,9	15	1,6
Marine facilities (wharves, dredging)	3	0,5	3	1,0	6	0,6
Towers	2	0,3	0	0,0	2	0,2
Electric transmission lines	1	0,2	1	0,3	2	0,2
TOTAL	650		316		966	

Table 5. Fatal and non-fatal non-employee injuries by type of construction work

	Third parties				Children			
Type of construction work	**Fatal Cases**	**%**	**Non-fatal injuries**	**%**	**Fatal Cases**	**%**	**Non fatal injuries**	**%**
Residential and commercial buildings	39	42.4	12	50.0	18	32.1	5	45.5
Institutional buildings	15	16.3			11	19.6		
Small residential buildings	12	13.0	4	16.7	6	10.7	2	18.2
Wells	9	9.8	1	4.2	7	12.5	1	9.1
Other	6	6.5	2	8.3	4	7.1	1	9.1
Channel works (irrigation, water, sewage systems and other underground facilities)	7	7.6	3	12.5	5	8.9		
Roads and highways	2	2.2	1	4.2	1	1.8	1	9.1
Bridges, viaducts	2	2.2			1	1.8		
Unknown	2	2.2	1	4.2	1	1.8	1	9.1
Industrial buildings	1	1.1			1	1.8		
Electric transmission lines	1	1.1			1	1.8		
Tunneling works								
TOTAL	96		24		56		11	

The ranking of hazardous construction projects is similar for all accident cases and for non-employee incidents except the figures for industrial building sites where third party accidents are almost non-existant. Since the vast majority of the industrial building projects are far from the city centers, their location is isolated from the public and non-employees (including children) do not pass nearby or through these sites. Similar arguments can be given for the low number of third party accidents on tunneling works, marine facilities, dams, towers and mining plants.

If children fatalities are isolated, it may be easily seen that the construction sites that are generally located downtown or near dwellings are the most dangerous construction zones for children. The figures of fatal cases for residential and commercial, institutional, small residential building sites, wells and channel works rank sequentially and comprise the vast majority of children deaths (83.9%), with 32.1% of the child deaths occurring on residential and commercial building sites located near downtown areas.

3.3. The hours of day that investigated cases occurred

In Table 6 and Figure 1, distribution of the non-employee involved accidents by to the time of occurrence is presented. Unfortunately, in only 332 of 952 court files was the exact time indicated. It is important to find the time of occurrences for further studies. In a previous study, it is found that the timing of accident occurrence was most frequently between 11:00 and noon (Hinze et al, 1998). Another study investigated fatal accidents that occurred in Illinois highway work zones in the period 1996–2001 in order to determine the safety differences between night time and daytime highway construction. The lighting and weather conditions were included in the study as control parameters to see their effects on the frequency of fatal accidents occurring in work zones (Arditi et al, 2007). In this study it was found that the timing of accident occurrence was most frequently between 10:00 and noon, paralleling the findings mentioned above (Hinze et al, 1998). A significant number of accidents occurred between noon and 16:00.

Table 6. Distribution of the third party accidents by hour

	Total		**Third Parties**		**Children**	
Hour	**Fatal cases**	**Non-fatal cases**	**Fatal cases**	**Non-fatal cases**	**Fatal cases**	**Non-fatal cases**
00:00-02:00						
02:00-04:00	1					
04:00-06:00	1					
06:00-08:00	2					
08:00-10:00	26	23	3	1	1	1
10:00-12:00	*35*	*37*	*2*	*5*	*1*	*2*
12:00-14:00	32	18	2	4	2	3
14:00-16:00	39	22	3	1	1	1
16:00-18:00	*48*	*17*	*8*	*3*	*6*	*2*
18:00-20:00	15	10	2	2	1	
20:00-22:00	4	1	3		2	
22:00-24:00	1					
Total	204	128	23	16	14	9

For accidents involving children, the time interval of 16:00-18:00 was of particular interest. This coincides with the time when children are dismissed from schools. In all eight incidents in this time interval, the victims were children who passed a construction site near to their schools and they also entered the site to play!

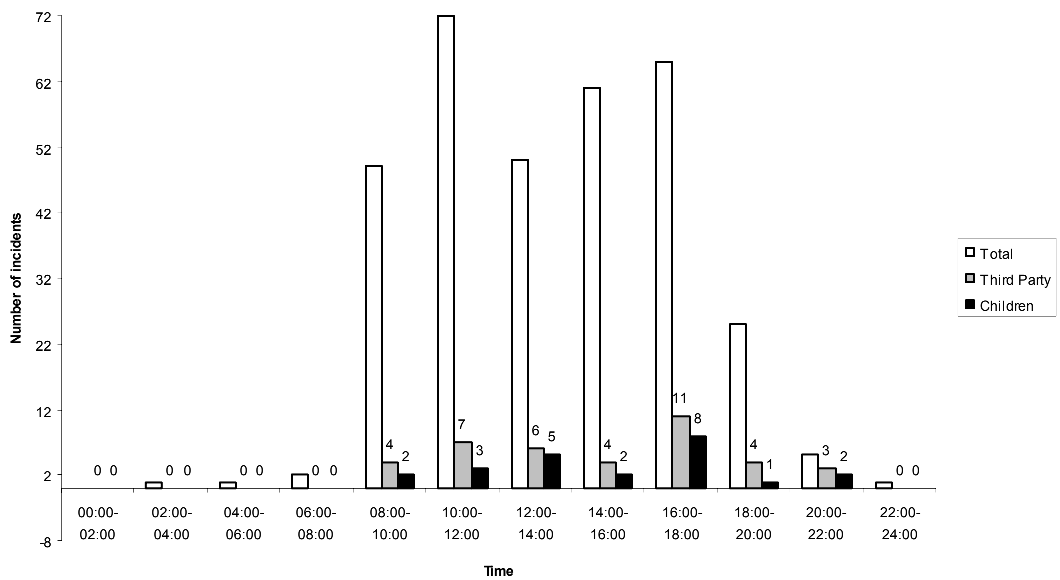

Figure 1. Distribution of the investigated cases by hour

4. DISCUSSION

As Hinze et al (1998) state, the causes of construction accidents can be characterized in greater detail with a minimum amount of effort and the level of detail that can be attained provides much more valuable information by which accident prevention programs can be made more effective. The collection of data in the U.S performed by OSHA officers when investigating construction fatalities or serious injuries have occurred and is recorded in OSHA's Integrated Management Information System. On the contrary, the data collection is a great problem in Turkey and the method of investigation of expert witness reports is a unique source of data especially on third party or children involved incidents. The study may create an inspiration for researchers from other countries where data collection systems and official records are poor.

Apart from the causation of the accidents, the legislative aspects of the accidents are also important and at this point the question of "who is held responsible for construction accidents" appears. Because of the inherent danger of construction sites, the construction company or property owner is responsible for taking necessary precautions to prevent any accidents. Proper rules of conduct and safety practices can reduce the risks of workers or passersby being injured. If the negligence of an individual leads to a preventable construction accident, that person may be liable for the victim's injuries. Safety professionals must also know the ins and outs of construction accident litigation and can determine whether there is a case against the employer, general contractor, or subcontractors at the site. Injury victims are entitled to compensation for past and future medical expenses, wage loss, pain, suffering, and, in certain cases, punitive damages. In addition, if a victim dies and his or her survivors suffer economic loss or emotional distress as a result, the survivors may be entitled to recover full compensation. In general, when an accident occurs, the parties given below may be liable for the given reasons:

A. Employers
   Employers must ensure their employees are properly trained, personal protective equipment are provided and used and collective forms of safety measures are satisfied. A supervisor (on the behalf of the employer) at a construction site is responsible for enforcing safety measures.
B. Manufacturing Companies
   Companies that manufacture construction equipment and products that prove to be defective are held liable.
C. Other Responsible Parties
   Other parties involved in the construction process may be held liable, such as architects or scaffolding companies.
D. Victims (employee or non-employee).

On the other hand, for the protection of the general public (third parties) from the hazards associated with construction work that may be carried out in a public area or adjacent to such an area, additional legislative points should be taken into account. For example, the Occupational Safety and Health Act 2004 (OSH Act) requires that care be taken at work by employers, employees and self-employed people to ensure that no members of the public or workers are exposed to hazards as a result of their work. Refer to Section 21 of the OSH Act for more information. Regulations 3.75 and 3.76 of the Occupational Safety and Health Regulations 1996 clearly explain what must be done to protect people who are in the vicinity of, but are not on, the construction site. Australian Standard AS 2601 (Demolition of Structures) as well as Turkish regulation of Health and Safety at Construction Works requires all demolition sites to be fenced in.

Moreover, Victoria's (Australia) Occupational Health and Safety Act and Turkish legislation (Regulation of Health and Safety at Construction Works) have very similar statements. Provisions providing protection to workers in traditional or non-traditional forms of employment is the duty of care imposed upon employers for the health and safety of non-employees, including members of the general public. This duty is also imposed on the self-employed. Turkish legislation states that every employer shall ensure, so far as is practicable, that persons (other than the employees of the employer) are not exposed to risks to their health or safety arising from the conduct of the undertaking of the employer. According to the conviction of the courts, the clause in the regulation is very broad and covers independent contractors and their employees, salespersons, students visiting sites and/or in their training period (internship period required by the universities) or members of the general public. In Table 7, the liable parties are revealed.

Table 7. Liable Parties according to court decisions from the investigated files

Liable party (The party at fault)	Third parties Fatalities	Third parties Non-fatal cases	Children Fatalities	Children Non-fatal cases
Contractor (employer)	58	16	36	6
Victim	48	6	22	3
Third parties	25	3	18	2
Natural, social and other conditions, misfortune	18	1	16	1
Craftsmen	15	2	8	2
Chief Engineer on site	10	3	4	2
Other	8	2	7	2
Sub-contractor/Trade contractor	6	2	3	
Chief of workmen crew	8	6	5	4
Public bodies (municipality, concerning directorate, ministry et al.)	6	3	3	1
Technical superintendent	5	1	2	1
Head formen, formen	4	1		
Equipment operator	4		3	
Security guard of the site	2		2	
Site Engineer	1	1	1	
Drivers	1		1	
	219	47		

Only in nine cases a single party is fully responsible for the accident. In one incident of natural conditions, in six cases the victim and in two cases the employer were deter,omed by the court to be fully responsible for the accident.

In 120 fatal and non-fatal third party involved accidents, the courts determined that 266 parties were at fault with only nine cases resulting in a single party being declared to be fully responsible for the accident. As mentioned before, in criminal and labour courts, the final verdict is regularly based on an expert witness report that distributes the responsibility (or liability). Table 7 shows that employers, namely prime contractors, have a principal role in the third party accidents. In 58 cases, in other words nearly half of the investigated incidents, the verdict of the courts was that the employers were liable. On the other hand, in 48 incidents the courts, with the aid of the expert witnesses, determined that the fault was placed on the non-employees including children, namely accidents caused by the direct actions of the injured person. In Table 7, the "third parties" ranks third, however here, the term does not refer to the third party victims but persons who have no relation to the construction work. Parents of the children, neighbors of the construction site or an ordinary driver passing nearby the construction site are examples of third parties. It should be also pointed out here that, the public body such as a municipality, concerning directorate or ministry are regarded as a third party in judicial terms. A separate line in Table 7 accentuates the role of the "government" in its broad definition. Researchers and safety professionals should consider all aspects of the accidents. When investigating an accident, consideration should be given to not only the immediate causes of accident, namely unsafe acts or conditions, but also the contributing causes such as safety management and government inspection or control.

5. CONCLUSION

This study presented another point of view of construction accidents. Although in a broader study that will be held in the near future by the authors, the faulty acts of the liable parties will be examined in detail. The data of this study reveal that the liability of the contractors and subcontractors, especially in non-employee or third party involved accidents, emanates from negligence of the basic safety rules. Every effort must be made to prevent the public, especially children, from encroaching on construction site activities. The first step in any construction project with regard to public protection is the identification of hazards and the planning of the best methods of eliminating or controlling the hazards. In their safety management plan for the construction effort, contractors, project managers, safety professionals and supervisors must incorporate the evaluation of the risk of harm that is present for third parties., It is important to define the proper methods and mitigation/abatement techniques for accidents and prevention of property damage. The safety management plan has to inform all levels of management of the degree of risk and ensure appropriate training is implemented.

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ASSESSING SAFETY RISKS ON CONSTRUCTION PROJECTS USING FUZZY ANALYTIC NETWORK PROCESS (ANP): A PROPOSED MODEL

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ABSTRACT

Construction injury accidents are associated with moral, productivity and financial problems. Past research on construction safety management has been mainly focused on either improving site conditions, establishing comprehensive legislative mandates or promoting a safety culture. With the strong emphasis currently being placed on safety performance, a challenging task for the construction industry is to develop and employ an effective method to assess safety risks on construction projects. The aim of this research is to develop a model for assessing construction safety risk based on the fuzzy analytic network process (ANP). This paper first presents a comprehensive literature review of safety risk management and then discusses the reasons why ANP is a suitable and effective method to assess construction safety risk and why fuzzy set theory is introduced in the assessment model. The paper also argues that the assessment of safety risk should be carried out from a project life cycle perspective. Finally, a prototype ANP-based life cycle model for assessment of construction safety risk, together with future work for this research, is presented.

Keywords: Safety, Risk Assessment, Life Cycle, Fuzzy Set Theory, Analytical Network Process (ANP), Construction Projects

1. INTRODUCTION AND RESEARCH AIMS

Apart from being a significant contributor to the national gross domestic product (GDP), the construction industry offers substantial opportunities for employment. At the same time, the risky nature of construction places a potential negative impact on the health and safety of project personnel. For example, in Australia, the construction industry employed 837,000 workers in 2004-2005 representing 9% of the country's workforce, which incurred an injury incidence rate of 27.3 per 1000 employees which was substantially above the national rate of 17 injuries per 1000 employees (ASCC 2007a). Similar statistics tarnish the reputation of the construction industry in the United States (Huang and Hinze 2006). The situation in China has been even worse (Zou et al 2007a). Therefore, improvements in the health and safety performance of the construction industry are clearly needed. Past research has been focused on such topics as the following:

- developing guidelines for managing health and safety (Fu and Lee 2006) or defining a prescriptive legislative framework and helping construction firms establish and adopt a self-regulated safety and health management system (Shang et al 2006);
- developing safety management systems, safety procedures and standards, improving physical working conditions such as design of plant and machinery and site access, training site workers, developing better planning and work methods and providing personal protective equipment (Holmes et al., 1998; Reese, 2003, Biggs et al., 2005; Chan et al. 2006); addressing 'unsafe behaviour' (Sawacha et al. 1999), and poor attitudes towards safety and lack of interest towards safety (Clifford 1988);
- promoting and cultivating of a sound organizational safety culture (Ling and Teo 2007, Zou et al. 2006 and Fung et al. 2005).

To a less extend, some research has been focused on identifying and assessing safety risks (Rowlinson and Lingard 2005). Good safety performance requires an effective safety management system which includes assessment of safety risks.

Construction safety risk management is an integral aspect of construction management. Cooke and Williams (2004) stated that safety risks arise from the impact of hazards (where there is no hazard there will be no risk), but there are hazards everywhere on construction sites. Rowlinson (2004) claimed that a series of moral, production and financial problems may be caused by safety risks on construction sites. Further, construction occupational fatalities and injuries lead to considerable human suffering, not only the workers directly involved, but also their families and communities. Risk management has been a key requirement of occupational health and safety legislation in Europe, Australia and other parts of the world (Lingard and Rowlinson 2005). They have proposed that in accordance with good business practice, all construction companies should ensure that workplace risks are identified, evaluated and controlled. Santos-Reyes and Beard (2008, p15) have argued that both academics and practitioners have tended to address risks by focusing on technical aspects and looking for immediate causes of accidents after they have taken place. From this point, identifying and assessing the potential risks factors that may cause safety problems on construction projects is very important. From the safety risk management perspective, the occurrence of one safety event might lead to another risk event that could initiate a chain reaction on a construction project. Thus, the occurrence of a safety risk event may have an effect in the downstream stages of a project. Therefore it is important to understand the interdependences of different safety risks in different project stages.

The aims of this research include understanding the interdependence between various risk factors and developing a prototype assessment model which is based on fuzzy analytic network process (ANP) to assess construction safety risks. To achieve these aims, the research objective was to answer the following questions.

1. Why is ANP suitable for safety risk assessment?
2. Why is fuzzy set theory necessary and suitable for safety risk assessment?
3. What are the essential steps in the application of fuzzy ANP in order to achieve a credible safety risk assessment result?
4. Why is it necessary and effective to consider safety risks from a project life cycle perspective?

2. WHY ANP FOR SAFETY RISK ASSESSMENT

The analytical network process (ANP) was first introduced by Saaty in 1975 and he later (in 2006) postulated that ANP provides an effective tool for solving complex decision-making problems. Saaty (2006) realized that many decision problems cannot be structured in a linear hierarchy structure due to the interdependence and interaction among the various factors. In order to solve this problem, Saaty (2006) developed ANP by considering the interaction and feedback within the decision problems. He suggested that ANP can be used in many disciplines such as political, economic, social, technological, etc. According to Saaty (2006), the network system in ANP is divided into two parts. One part is a linear hierarchy including the goal, criteria and sub-criteria organized or arranged in three levels, with the sub-criteria level being called the cluster level. The other part is the feedback network consisting of the network relationships between elements and clusters. Both the relationship between the elements in the same cluster and the interdependence between the clusters should be considered when the pair-wise comparison is being conducted using ANP. The result of the pair-wise comparison forms a super matrix. Finally, the priority of the elements at the bottom level can be obtained by calculating the super matrix. ANP has been used for dealing with many problems such as assessing dispatching rules for wafer fabrication, selecting transportation infrastructure projects and assessing values of urban industrial properties, etc. (Lin et al. 2007, Wey and Wu 2007, Aragones-Beltran et al. 2006). Saaty (2006) highlighted the advantages of ANP, such as ensuring the consistency of pair-wise comparisons, reducing the subjectivity of decision-making, and providing a clear structure of the problem. A typical ANP hierarchy structure is shown in Figure 1. Due to its consideration of interdependence between the elements of the decision problems, Jharkharia and Shankar (2007) believed that the ANP method establishes a better understanding of the complex relationships between the elements in decision making, and at the same time improves the reliability of decision making.

Safety risk assessment on construction projects is a complex issue due to the uncertain nature of construction projects. As has been described, the safety risk events that occur in one stage of construction may influence the risk factors of another stage. Meanwhile, the activities carried out in the same stage may have an impact on each other which could impact safety risks. Therefore, it is important that across-the-board consideration be given to the influences of the many risk factors when assessing risk. ANP provides a solution for this problem.

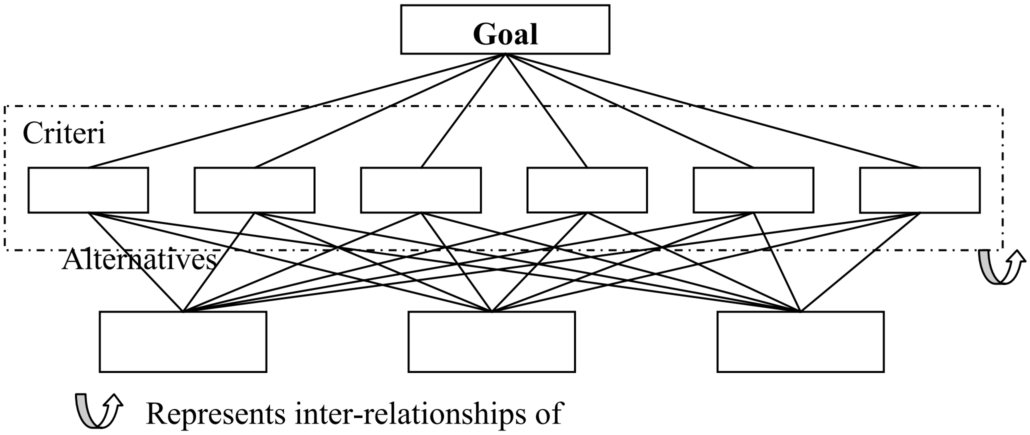

Figure 1. A typical ANP network hierarchy (modification based on Saaty 2006)

3. WHY FUZZY SET THEORY FOR SAFETY RISK ASSESSMENT

In reality, because of the complexity of the problem the decision maker may feel more confident about making a fuzzy judgment rather than in making a crisp conclusion. Safety risk as one kind of risk on construction projects is surrounded by uncertainty. Therefore, it is a complex subject to assess the level of safety risk. Tah and Carr (2000) pointed out that vague terms are unavoidable in risk assessment and put forward a proposal for construction project risk assessment using fuzzy set theory.

The proposed ANP-based model for construction safety risk assessment in this research requires the pair-wise comparison of the relative importance between the different risk factors and the assessment of the influences between them. Because most decision makers usually evaluate risk levels by linguistic values (Chen 2001), the assessment in this research will be presented in linguistic variables. Kangari & Riggs (1989) presented an integrated knowledge-based system to describe risks using linguistic variables implemented as fuzzy sets. Cheng et al. (1999) proposed that fuzzy set theory can give a much better representation of the linguistic data. Duran and Aguilo (2007) argued that by adopting fuzzy numbers decision makers will be able to achieve a better flexibility in estimating the overall importance of attributes in developing real alternatives to assess risk problems with greater confidence. Therefore, this research proposes to use the fuzzy set theory for quantifying the linguistic variables.

4. THE PROPOSED MODEL FOR CONSTRUCTION SAFETY RISK ASSESSMENT

To assess safety risks on construction projects, a six-step model based on fuzzy ANP may be used, as shown in Figure 2.

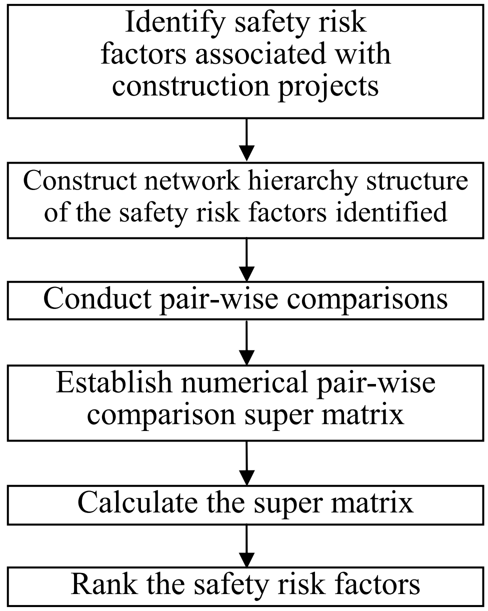

Figure 2 A fuzzy ANP-based model for assessment of construction safety risks

Step 1: Identify safety risk factors associated with the construction project

All the known factors that may affect safety on the construction project should be incorporated in the model. In order to identify safety risk factors, a comprehensive questionnaire survey or brain-storming sessions may be conducted with safety managers, project managers, designers, foremen, experienced craft workers, and other on-site management and supervisory personnel.

Step 2: Construct network hierarchy structure of safety risk factors

After the safety risk factors are identified, they are categorized into different groups in terms of project stages within the project life cycle. Then a network hierarchy structure is constructed, as shown in Figure 3. In this structure, inner dependency exists within each group and outer dependency between different groups.

Step 3: Conduct pair-wise comparison

After constructing the network hierarchy structure, the next step is to perform pair-wise comparisons to assess the relative importance of the different risk groups and the different risk factors within the same groups. The impact of one risk factor on the other risk factors (within the same group or with other groups) also needs to be judged in this step. Both the pair-wise comparison and impact judgment are undertaken by the same group of experts. In this stage, all the judgments are expressed in linguistic terms.

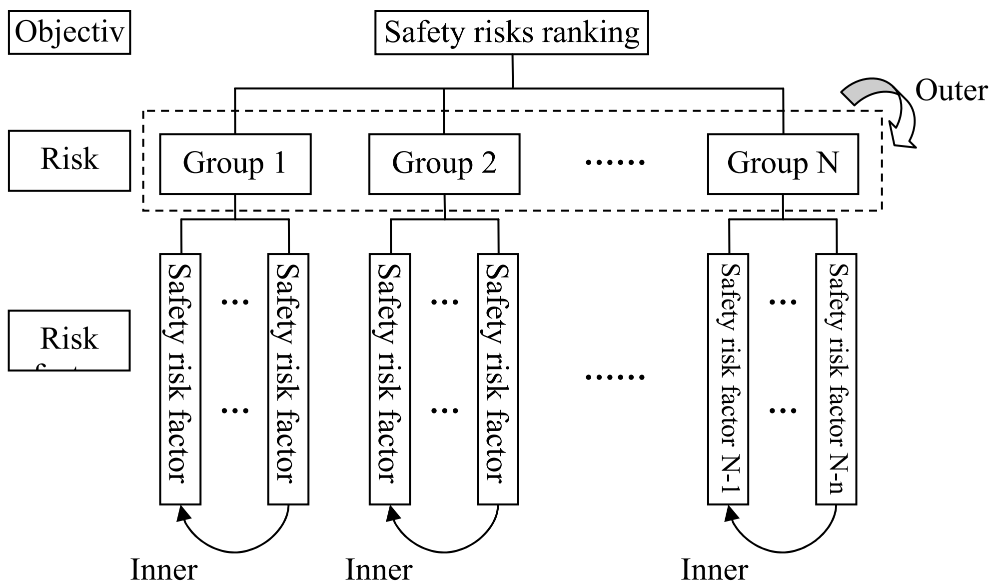

Figure 3. safety risks network hierarchy structure

Step 4: Establish numerical pair-wise comparison super matrix

In order to quantify the linguistic judgment, a fuzzy number scale is established in this research to replace Saaty's 1-9 scale (Saaty 1980). All the linguistic judgments generated in Step 3 are transferred to numerical judgment based on the fuzzy number scale. Then these numerical pair-wise comparison matrices are calculated as per the following equations as, described by Saaty (1980).

$$\varpi_i = \sqrt[n]{\prod_{j=1}^{n} a_{ij}} \quad (1)$$

Where, ϖ_i is the eigenvector of the pair-wise comparison matrix, a_{ij} is the element of the pair-wise comparison matrix.

$$\omega_i = \frac{\varpi_i}{\sum_{i=1}^{n} \varpi_i} \quad (2)$$

Equation (3) is to normalize ϖ_i .

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(A\omega)_i}{n\omega_i} \quad (3)$$

Where, $\lambda_{\max}$ is the eigenvalue.

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (4)$$

$$CR = \frac{CI}{RI} \quad (5)$$

Where, CR denotes the consistency ratio, CI denotes the consistency index, RI denotes the average random consistency index. The value of RI is decided by the order N of the matrix referring to Table 1.

Table 1 Average Random Consistency Index (Saaty 1980)

N	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.48	1.49

CR is used to test the consistency of the pair-wise comparison. If the value of CR is less than 0.1, this indicates the pair-wise comparison matrix achieves satisfactory consistency. Then the priorities of risk groups and safety risk factors can be inserted into the super matrix. The standard form of super matrix is shown as Equation (6).

$$
W = \begin{array}{cc}
 & \begin{array}{c} C_1 \quad \cdots \quad C_k \quad \cdots \quad C_n \\ e_{11}\; e_{12} \cdots e_{1m1} \cdots e_{k1}\; e_{k2} \cdots e_{k\,mk} \cdots e_{n1}\; e_{n2} \cdots \end{array} \\
\begin{array}{cc} C_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1m1} \\ \vdots \end{array} \\ \vdots & \\ C_k & \begin{array}{c} e_{k1} \\ e_{k2} \\ \vdots \\ e_{kmk} \\ \vdots \end{array} \\ \vdots & \\ C_n & \begin{array}{c} e_{n1} \\ e_{n2} \\ \vdots \\ e_{nmn} \end{array} \end{array}
& \begin{bmatrix} w_{11} & \cdots & w_{1k} & \cdots & w_{1n} \\ \vdots & & \vdots & & \vdots \\ w_{k1} & \cdots & w_{kk} & \cdots & w_{kn} \\ \vdots & & \vdots & & \vdots \\ w_{n1} & \cdots & w_{nk} & \cdots & w_{nn} \end{bmatrix}
\end{array} \qquad (6)
$$

Steps 5 and 6: calculate the super matrix and rank the safety risk factors

The outcome of step 4 is the unweighted super matrix. In order to rank the safety risk factors, the limit priority of the safety risk factors should be derived through the following process. The unweighted super matrix must first be transformed to a matrix where each of columns is a stochastic column (Saaty 2006). This is known as the weighted super matrix. Then, the weighted super matrix must be transformed to a limit matrix which contains the limit priorities of the safety risk factors. The safety risk factors can then be ranked according to their limit priorities.

5. WHY APPLY THE PROPOSED MODEL IN THE LIFE CYCLE OF A PROJECT

The life cycle of a construction project is normally divided into five stages, including conceptual stage (feasibility study), design stage, construction stage, operation stage and deconstruction or decommissioning stage. The activities carried out in one stage may have an impact on safety issues in another stage. Recent research has shown that many risks occur in the construction stage because of decisions and activities carried out at the design stage (ASCC 2006). For example, a new technology specified in the design stage may lead to construction worker injuries because the workers are unfamiliar with the proper procedures to be followed to successfully undertake the new construction process. Research has also shown that over 60 percent of fatal construction accidents were caused by decisions made before construction work commenced on site which indicates that the activities conducted in one stage may have an impact on the occurrence probability of safety risks in another stage (Lingard and Rowlinson 2005). Generally, on construction projects, the decisions made early during the life of a project, may have an impact on the safety performance in the following stages (Lingard and Rowlinson 2005). Meanwhile, the activities carried out in the same stage may also have interdependent relationships with safety. For example, in the construction stage, lack of training of the on-site workers may lead to operation errors during the construction process that could lead to on-site worker injuries and even death. The risk management of a construction project will be more effective if risks are identified and assessed in a more complete way in the project life cycle (Chapman and Ward 1997). Zou et al. (2007a) argued that identifying the possible occurrence of risks in each stage is important for the success of construction projects. Nevertheless, whether in research or construction practices related to safety risk management, most of the focus is on the construction stage. It is very important to consider health and safety planning from the beginning of the construction project (Rowlinson 2004). By conducting an investigation on various structural and cultural factors concerned with the implementation of risk management on construction projects, Uher and Toakley (1999) found that the application of risk management in the conceptual stage was very low. The design stage is an important stage in terms of its influence on safety. According to ASCC (2003), 42% of the 210 identified workplace deaths had involved design related issues. In recent years, the assessment of safety risk at the design stage has been effectively implemented by some companies, such as Risk and Opportunities Assessment at Design carried out by Bovis Lend Lease (Zou et al. 2007b). They asserted that undertaking the assessment of safety risks during the design stage is not only feasible but also should be mandated for all construction projects. They also argued that such good practice should be introduced to the entire construction industry. Loosemore and Andonakis (2007), Zou et al (2007b) and Shang et al. (2007) have demonstrated the hazardous nature of projects during the construction stage by listing the incidence rates in construction industries in Australia, China and the USA, respectively. Chapman and Ward (1997) pointed out that the risks were always considered as the single problem area, but actually the potential risks in a certain stage may often be related to weaknesses in earlier stages. Unfortunately, there is a lack of comprehensive consideration and assessment of safety risk management for the whole project life cycle. Based on the above arguments, it is clear that the application of the risk assessment model proposed in this paper will be effective for proactively assessing and controlling safety risks in the life cycle of construction projects.

6. SUMMARY AND FUTURE WORK

From the theoretical perspective, this paper has developed a fuzzy ANP-based life cycle model for assessing construction safety risks and this model is applicable throughout the life cycle of construction projects. The prototype of the proposed model is presented step by step. In the next stage of this research, the validity, usefulness and effectiveness of the proposed model will be tested on selected construction projects.

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RESEARCH STRATEGIES

11

TOP CONSTRUCTION PROBLEMS AND THE NATIONAL OCCUPATIONAL RESEARCH AGENDA (NORA) AGENDA TO ADDRESS THEM

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ABSTRACT

The National Institute for Occupational Safety and Health (NIOSH) used a decade-long National Occupational Research Agenda (NORA) process to involve stakeholders in identifying and implementing targeted research. The first NORA effort resulted in 21 cross-cutting topics. NIOSH is taking a "sector approach" for the second decade of NORA (2006-2016) and Construction is one of eight sectors developing a sector-specific national research agenda. This presentation will describe the multi-stakeholder NORA "Construction Sector Council" used to identify ten top problems, the process used to discuss candidate topics, and the resulting list of topics. It will also describe the use of a Construction Program Logic Model to guide NIOSH efforts in making an impact on end outcomes via research. Lastly, the presentation will describe the current status of efforts to develop strategic goals for each of the top problem topics including the current version of the draft goals. Each strategic goal includes an overall goal related to improved outcomes, performance measures to track progress toward outcomes, along with several intermediate research and research to practice goals. Taken together, the various strategic goals will comprise the National Construction Agenda.

Keywords: Construction, Research, Strategic Planning, Goals, Impact, Stakeholders

1. INTRODUCTION

NIOSH initiated a decade-long National Occupational Research Agenda (NORA) process in 1996 to involve stakeholders in identifying and then implementing targeted research priorities. Approximately 500 organizations and individuals provided input into the development of NORA, resulting in 21 cross-cutting topics. A variety of partners worked together over the decade to stimulate innovative research and improved workplace practices to address these priorities.

NORA entered its second decade in 2006 with a new "sector-based" orientation intended to better move research into practice within workplaces. Each of eight industry sectors[2] is creating its own national sector agenda. NIOSH acts as the steward of NORA and

[2]The 8 sectors are: Agriculture; Forestry & Fishing; Construction; Healthcare & Social Assistance; Manufacturing; Mining; Services; Transportation, Warehousing & Utilities; and Wholesale and Retail Trade

facilitates the work of multi-stakeholder "NORA Sector Councils" in developing and implementing the resulting agendas over the decade (2006-2016). The "NORA Construction Sector Council" is the group that has been working to develop the draft agenda for the construction sector.

Several other features differentiate the second decade of NORA from the original NORA effort. In comparison to the 21 "priority research areas" developed during the first NORA, the second decade priorities are structured as strategic goals targeting top sector issues and outcomes. Each strategic goal is in turn supported by a number of intermediate goals reflecting the specific changes and improvements that workers, contractors, and owners need to make in order to progress toward the strategic goals. The framework emphasizes "Research to Practice" (R2P) to promote the transfer and translation of research findings, technologies, and information into effective prevention practices and products and to further promote their adoption in the workplace (see http://www.cdc.gov/niosh/r2p/). Underlying research and R2P goals are selected based on the knowledge and activities needed to support the identified intermediate goals. The use of strategic outcome-oriented goals reflects evolving government performance planning concepts derived from the U.S Office of Management and Budget (OMB) "Program Assessment Rating Tool" (PART) initiative.
(http://www.whitehouse.gov/omb/part/)

The resulting National Construction Agenda serves as a mechanism for construction industry stakeholders to provide input on the most relevant safety and health problems in construction. Once established, it is intended to inspire decision makers to include these topics among their top priorities, and to steer researchers to relevant and cohesive topic areas for research proposals. Lastly, it is intended to encourage dialog and partnering among stakeholders on a manageable subset of key issues ---thus increasing the collective ability of the larger construction community to make an impact in reducing injuries and illnesses among construction workers.

2. METHODS

A variety of information sources were used to develop the draft goals including Town Hall meetings, solicitation of written comments, and breakout sessions at the 2006 NORA Symposium. The initial NORA Construction Sector Council kickoff meeting was held in March of 2006 and additional members were added for the September 2006 meeting. The 35 member council includes contractor and trade association, labor, researcher, owner, federal agency, state agency, safety professional, industrial hygiene professional, and non-profit and insurance organization representatives. A listing of NORA Construction Sector Council members is available at http://www.cdc.gov/niosh/nora/councils/const/planpart.html.

Council members were briefed on the NORA comments received along with available surveillance findings on construction injuries and illnesses. Group members were asked to contribute their opinions on the three top problems in construction for discussion.

NIOSH input to the NORA council was represented by a draft of NIOSH Construction Program Strategic Goals. The program had begun to develop these draft goals in 2005 in response to the OMB PART requirements.

The sector council used a variety of criteria to discuss and look at top problem candidates. These were developed as questions such as:

- What evidence supports this as a top problem?
- Why does the problem persist?
- What would be the ideal situation?
- What stage are we at in our knowledge and understanding of this construction problem?
- Can the problem be described using common priority-setting criteria such as severity, incidence or prevalence?
- How much change is needed for near-term improvement?
- What stage is the problem at from a construction practice perspective?

Discussions and multi-voting led to the selection of a list of "top ten" construction topics. This number was arbitrarily selected to allow a variety of topics without overextending the ability to provide meaningful support. The Agenda is not intended to be an inventory of all issues and it should not be viewed as suggesting that other topics are unimportant.

NORA workgroups, co-chaired by NORA Construction Sector Council members, were established to convert each top problem topic into strategic and intermediate goals. NIOSH provided a "logic model" to provide a visual picture and shared understanding of the path by which the research process contributes to impacts on reducing injury and illness. The Institute had developed a logic model to facilitate strategic planning to optimize relevance and impact. It was also incorporated into the framework developed for evaluation of NIOSH Research Programs by the National Academies. (http://www.cdc.gov/niosh/nas/framework1.html).

The logic model allows stakeholders to appreciate that researchers tend to have few direct links to construction end users such as workers, contractors, and developers. Instead, research impact is most often achieved when intermediaries such as trade associations, labor unions, and professional associations use the research information for their own products and actions which then influence end users. The logic model provided common terminology, reinforced the need for researcher and intermediary construction stakeholder partnerships, and provided a way to structure goals, since strategic goals need to reflect improved end outcomes, and intermediate goals then need to reflect the most important actions that intermediate groups can take to help contractors and workers to improve performance.

Workgroups included other interested individuals participating as "corresponding" members to the NORA Construction Council. Workgroups developed sufficient intermediate goals to address key gaps and needs. They were not limited to any specific budget or anticipated activity level. The resulting workgroup products, while varying somewhat on length and detail, all include the same basic goal and performance measure elements. The draft goals were posted for comment on December 21, 2007. Council members believe that the ten areas represent important construction topics where research and combined industry efforts are needed over the next decade.

Resulting Draft Strategic and Intermediate Goals

Each numbered strategic goal includes a performance measure, narrative, and 3 to 8 numbered intermediate goals (each including a performance measure and from 2 to 7 research or R2P goals). For sake of brevity, only strategic and intermediate goals are provided herein. The complete draft National Construction Agenda can be accessed at: http://www.cdc.gov/niosh/nora/comment/public/ConstDraftDec2007/

3. STRATEGIC GOAL #1

Reduce Construction Worker fatalities and serious injuries caused by falls to a lower level

Performance Measure: Address technical solution gaps, increase implementation of effective fall prevention measures, and utilize design approaches and social marketing campaigns to support a 33% reduction in the rate of fatal falls among construction workers over the decade.

IG 1.1 - Partner with construction stakeholders and safety professionals to identify the top three fall-related problems requiring technical engineering solutions and develop and evaluate options to fill these gaps.

IG 1.2 - Partner with Construction stakeholders to expand awareness and use of existing effective fall prevention and protection solutions by construction employers and workers

IG 1.3 - Partner with architects, engineers, and construction organizations to expand the use of "safe-by-design" practices for fall prevention via demonstration projects and guidance.

IG 1.4 - 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.

4. STRATEGIC GOAL #2

Reduce fatal and nonfatal injuries from contact with electricity among construction workers.

Performance Measure: Address technical solution gaps, and increase dissemination and use of interventions to reduce construction-related electrical injuries to support a 20% reduction in the rate of electrocutions among construction workers over the decade

IG 2.1 - Investigate ways to improve the performance of power line proximity warning alarms to protect operators of mobile vehicles and nearby construction workers.

IG 2.2 - Investigate ways to protect construction workers from electrocution hazards involving power line contact through hand-carried metallic objects and vehicle-related contacts.

IG 2.3 - Investigate ways to protect construction workers from contact with live electrical wiring and components by studying electrical installation, maintenance, and repair tasks and recommending ways to improve work practices, techniques, and tools

IG 2.4 - Investigate ways to protect construction workers from contact with live electrical wiring and components by studying electrical installation, maintenance, and repair tasks and recommending ways to improve work practices, techniques, and tools.

5. STRATEGIC GOAL #3

Reduce fatal and serious injuries associated with struck-by incidents associated with objects, vehicles, and collapsing materials and structures.

Performance Measure: Address risk factor gaps, develop new interventions, and increase dissemination and use of interventions to reduce construction-related struck-by injuries associated with objects, vehicles, and collapsing materials and structures by 33% over the decade.

IG 3.1 – Objects: Improve understanding of risk factors associated with struck-by fatalities and serious injuries associated with falling, flying, swinging, and rolling objects; and compare findings to existing regulations and guidance.

IG 3.2 – Objects: Use risk factor and gap information to develop and evaluate interventions and guidance for preventing struck-by injuries involving falling, flying, swinging, and rolling objects. Partner with construction stakeholders to disseminate resulting interventions**.**

IG 3.3 – Vehicles: Evaluate strategies to reduce worker exposure to being run over by heavy construction vehicles and equipment.

IG 3.4 – Vehicles: Promote the availability and use of operator visibility limit information for road construction equipment.

IG 3.5 – Vehicles: Evaluate worker injury risks associated with the expanded use of night work in the road construction industry.

IG 3.6 – **Vehicles:** Gain widespread usage of effective prevention measures in the road construction industry

IG 3.7 – Collapsing Materials/Structures: Characterize circumstances associated with collapsing structures (e.g. scaffolding, demolition work, partially built structures)

IG 3.8 – Collapsing Materials/Structures: Partner with construction stakeholders to greatly increase the diffusion of existing effective practices for preventing fatalities and serious injuries associated with trench collapses.

6. STRATEGIC GOAL #4

Reduce hearing loss among construction workers by increased use of noise reduction solutions, practices, and hearing conservation programs by the construction community

Performance Measure – A performance measure cannot be set for this strategic goal until better baseline information can be obtained and analyzed. Intermediate goal 1 will address this need and is expected to support a performance measure such as "Increase use of noise reduction solutions, practices, and hearing conservation programs by the construction community by 33% over baseline in ten years."

IG 4.1 - Use existing information supplemented by survey research to develop a baseline on current noise control and hearing loss practices in construction.

IG 4.2 – Increase awareness about noise hazards and solutions among construction workers, contractors, owners, and suppliers.

IG 4.3 – Increase the availability and adoption of quieter tools and equipment in the construction industry via research and implementation of a "Buy Quiet" campaign.

IG 4.4 – Develop and promote the use of model programs and practices by construction owners, governmental groups, professional groups, and best practice employers.

7. STRATEGIC GOAL #5

Reduce silica exposures and future silicosis risks among construction workers by increasing the availability and use of silica dust controls and practices for tasks associated with important exposures.

Performance Measure – A performance measure cannot be set for this strategic goal until better baseline information can be obtained and analyzed. Intermediate goal 1 will address this need and is expected to support a performance measure such as "Increase use of silica control solutions and exposure reduction practices by the construction community by 33% over baseline in ten years."

IG 5.1 - Use existing information supplemented by survey research to develop a baseline on current silica control practices and programs in construction.

IG 5.2 – Increase awareness about silica hazards and known solutions among construction workers, contractors, owners, and suppliers

IG 5.3 – Increase the availability of engineering and work practice options for reducing silica exposures

IG 5.4 – Develop model practices and programs and promote their use by construction owners, governmental groups, professional groups, and best practice employers.

IG 5.5 – Evaluate hazard and exposure assessment research gaps associated with silica in construction

8. STRATEGIC GOAL #6

Reduce welding fume exposures and future related health risks among construction workers by increasing the availability and use of welding fume controls and practices for welding tasks

Performance Measure – A performance measure cannot be set for this strategic goal until better baseline information can be obtained and analyzed. Intermediate goal 1 will address this need and is expected to support a performance measure such as "Increase use of welding fume exposure reduction solutions and practices by the construction community by 33% over baseline in ten years".

IG 6.1 - Use existing information supplemented by survey research to develop a baseline on current welding control practices and programs in construction.

IG 6.2 – Increase awareness about welding fume hazards and known solutions among construction workers, contractors, owners, and suppliers

IG 6.3 – Increase the availability of engineering and work practice options for reducing welding exposures.

IG 6.4 – Develop model practices and programs and promote their use by construction owners, governmental groups, professional groups, and best practice employers.

IG 6.5 – Evaluate hazard and exposure assessment research gaps associated with welding fumes in construction

9. STRATEGIC GOAL #7

Reduce the incidence and severity of work-related musculoskeletal disorders among construction workers in the U.S.

Performance measure: Increase the number of effective interventions (e.g., technologies and 'best practices') to reduce construction workers' exposures to WMSD risk factors and develop effective methods to improve and expand intervention adoption and diffusion in the construction industry

IG 7.1 - Develop and evaluate practical field exposure assessment methods for use by contractors to prioritize the effectiveness of workplace interventions.

IG 7.2: Conduct studies, including short-term prospective studies, to characterize the effects of work activities on the musculoskeletal systems among workers in different trades and construction divisions and help identify high-risk activities/trades.

IG 7.3 – Expand the availability of effective interventions to prevent WMSDs in Construction.

IG 7.4 – Improve the acceptance, diffusion, and adoption of MSD interventions and solutions by contractors, owners, and workers**.**

10. STRATEGIC GOAL #8

Increase understanding of factors that comprise both positive and negative construction safety and health cultures; and, expand the availability and use of effective interventions to maintain safe work practices 100% of the time in the construction industry.

Performance Measure: This goal will be successfully achieved if by 2016, NIOSH, along with its stakeholders and the construction industry as a whole, increases its recognition and understanding of the complexity of safety and health culture and strives to use successful measurement and intervention tools to create a positive culture at the worksite.

IG 8.1- Develop an understanding of factors that contribute to a positive or negative safety and health culture in the construction industry and a working definition and framework**.**

IG 8.2 - Develop a set of validated measurement methods of safety culture in the construction industry.

IG 8.3 - Develop effective intervention measures that result in an improved safety and health culture in the construction industry.

11. STRATEGIC GOAL #9

Improve the effectiveness of safety and health management programs in construction and increase their use in the industry.

Performance Measure – Form partnerships with successful companies, unions, and associations to learn which management practices promote job safety and health. Then build products (training and promotion materials in a variety of media), hold conferences, and reach 25% of the construction industry with these messages by 2012**.**

IG 9.1 – Develop a baseline to describe and understand the current use of safety and health management programs in construction.

IG 9.2 - Improve understanding of the effectiveness of best practice construction safety and health management programs and program elements

IG 9.3 – Partner with best practice contractors, on best practice sites or projects, to develop and expand safety and health management program elements that address important emerging issues

IG 9.4 – Partner with best practice small employers to identify the most important safety and health management elements and increase the use of programs tailored to small construction employers.

IG 9.5 – Partner with trade associations, management associations, and other construction stakeholders to disseminate new information and practices and to expand the use of effective safety and health management programs.

12. STRATEGIC GOAL #10

Improve understanding of how construction industry organization factors relate to injury and illness outcomes; and increase the sharing and use of industry-wide practices, policies, and partnerships that improve safety and health performance.

Performance Measure – Increase the recognition of the external and internal characteristics of the organization of the industry that may impact (e.g., reduce or contribute to) injury and illness outcomes, and increase the availability and use of best practices in the construction industry to improve health and safety performance.

IG 10.1 - Characterize the connections between construction industry organization and safety and health performance and identify changes that might improve performance.

IG 10.2 – Evaluate and improve current construction system mechanisms used to define and influence safety and health roles.

IG 10.3 - Study how subcontractors and small construction employers affect construction system safety and health performance. Develop and disseminate model practices for improving subcontractor and small employer safety performance on multi-employer construction projects.

IG 10.4 - Study and improve the effect of various workers' compensation arrangements and mechanisms on construction injury and illness at the system level.

IG 10.5 - Study and enhance the role of regulatory, consultative, consensus and other organizations and policies for improving construction safety and health at the industry level.

IG 10.6 Evaluate the nature of construction work and the inherent work organization factors that can influence the risk of injuries and illnesses. Develop recommendations and solutions to address impacts.

IG 10.7 - Integrate the findings from the previous intermediate goals to provide an overarching safety and health framework, logic model, and management system for the construction industry.

13. STRATEGIC GOAL #11

Increase the recognition and awareness of construction hazards and the means for controlling them through broad dissemination of quality training for construction workers, including non-English speaking workers.

Performance Measure: Demonstrate a minimum set of safety and health competencies required for all workers on construction sites to recognize hazards and the methods to control or avoid them through access to quality training and educational materials.

IG 11.1 – Perform a construction training needs analysis**.**

IG 11.2 – Survey current training programs, models, materials and best practices to identify the scope of training resources available.

IG 11.2 – Survey current training programs, models, materials and best practices to identify the scope of training resources available.

IG 11.3 – Develop new or improved training programs, models, materials, and methods.

IG 11.4 – Promote the dissemination and use of construction training best practices, materials, and methods.

14. STRATEGIC GOAL #12

Increase understanding of how vulnerable worker groups experience disproportionate risks in construction work and expand the availability and use of effective interventions to reduce injuries and illnesses among these groups.

Performance Measure: This goal will be successfully achieved if by 2016, there is improvement in the understanding of what constitutes worker vulnerability; expansion of the existing knowledge base of injury, illness, and exposure of vulnerable worker populations; and increased distribution of effective interventions.

IG 12.1: Improve surveillance of work-related injuries, illnesses, hazards and related costs among vulnerable workers in construction in order to set intervention priorities, guide future research, and evaluate progress in reaching prevention goals.

IG 12.2 - Improve our understanding of conditions and risk factors that contribute to the vulnerability of workers and the mechanisms though which vulnerability places workers at increased risk for work-related injury (or illness) in the construction trades, and their longitudinal effects.

IG 12.3 - Develop and disseminate materials on effective interventions so as to increase the utilization of these methods by construction stakeholders and influence policy-makers. Based on existing information, Hispanic workers should be an important target group, but efforts should not neglect other vulnerable groups including other immigrant groups and inexperienced workers.

15. STRATEGIC GOAL #13

Increase the use of "prevention through design (PtD)" approaches to prevent or reduce safety and health hazards in construction.

Performance Measure: Increase the use of "Construction Hazards Prevention through Design" (CHPtD) by 33% over the next 10 years.

IG 13.1 – Characterize the current use of CHPtD and coordinate efforts to promote its use.

IG 13.2 – Confirm the most prevalent obstacles to acceptance and implementation of CHPtD: fear of liability; lack of expertise in safety and in designing for safety; and increased costs associated with CHPtD.

IG 13.3 - Develop tangible products and methods to address identified CHPtD obstacles and challenges.

IG 13.4 - Expand the use and evaluation of CHPtD practices.

IG 13.5 - Develop incentives for architects and engineers to include the following in facility design plans and specifications: methods for: safer project erection, safe operation, safe service and maintenance, and for safety of the public

16. STRATEGIC GOAL #14

Improve surveillance at the Federal, State, and private level to support the identification of hazards and associated illnesses and injuries; the evaluation of intervention and organizational program effectiveness; and the identification of emerging health and safety priorities in construction.

Performance Measure – Increase available surveillance resources, construction information products, strategies for improving surveillance, and use of surveillance resources by construction stakeholders to meet the intermediate goal performance

IG 14.1 – Partner with surveillance researchers and federal and state surveillance programs to support, enhance, and expand collection of traditional surveillance information relevant for the construction sector

IG 14.2 – Partner with professional associations, surveillance experts, insurance companies, regulatory and consultation organizations to explore, develop, and implement new types of construction-sector hazard, exposure, and performance indicators to supplement current surveillance approaches.

IG14.3 – Partner with best practice employers, labor organizations, and project owners to explore, develop and implement model safety and health surveillance measures to support improved safety and health performance at the enterprise and project level

17. A PLAN FOR THE DECADE AHEAD (2006-2016)

Because NORA is intended to provide an agenda for the nation, we strongly encourage construction stakeholders to participate and partner on specific strategic and intermediate goals. To provide comments either use the online form at: http://www.cdc.gov/niosh/NORA/comment/public/ConstDraftDec2007/comments.html ; or send an email with the subject line **"ConstDraftDec2007: Comments"** to noracoordinator@cdc.gov . Comments will be accepted through April 30, 2008.

Membership in the NORA Construction Sector Council will rotate over time. Please share any interest in participating on the Council or as a corresponding member by emailing the author. The NORA goals, along with recommended topics arising out of the National Academies review of the NIOSH Construction Program, will be incorporated into future research funding mechanisms to drive the direction of construction research towards these strategic goals. All of the goals include performance measures. These will be tracked over the decade starting from initial baselines (some baselines need to be created as early intermediate goals).

In conclusion, the National Construction Agenda provides a mechanism for construction sector stakeholders and researchers to work together on shared priorities to make a difference for employee safety and health. Please join us.

IMPROVEMENT OF RESEARCH IN CONSTRUCTION SAFETY: A PROPOSAL FOR THE APPLICATION OF QUANTITATIVE APPROACHES

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ABSTRACT

The construction industry is one of the most dangerous industries in the U.S. Some of the incidents leading to construction injuries and fatalities can be attributed to collisions between workers and equipment, workers falling from roofs, scaffolds or trench edges. Traditionally, research conducted in construction safety has focused on the analysis of historical data from federal agencies, such as Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and the Bureau of Labor Statistics (BLS); interviews with industry practitioners, and qualitative assessments. Even though these research endeavors have identified important trends and issues associated with construction safety, they lack a proactive approach that can take advantage of available quantitative techniques. In this paper, several quantitative approaches are described, based on statistical techniques, design of experiments, and information technology that may assist in the process of identifying the root causes of construction accidents and opportunities for improvement of safety in construction operations. All these approaches are founded on extensive field data collection and data analysis utilizing novel techniques. The techniques presented in this paper should be used as a complement to existing qualitative approaches due to the complex nature of the analysis of safety in the construction industry, which involves the interaction of equipment, human behavior, and risky construction operations.

Keywords: Construction Safety, Information Technology, Simulation, Data Analysis

1. BACKGROUND

In the year 2006, there were 1,226 fatalities associated with the construction industry in the U.S. This accounts for almost 24% of all the fatalities of the private sector (BLS 2007). However, the construction industry accounts for only 5% of the United States' workforce (Abdelhamid and Everett 2000). This high proportion of construction injuries and fatalities is perhaps an indication that the industry needs new approaches in order to improve safety environments for workers on construction sites. Traditionallty, research in construction safety has been conducted based on the analysis of historical data, interviews, and qualitative evaluation of safety initiatives. Although these approaches assist in the process of identifying safety issues on the job site, the authors believe that more quantitative techniques should be utilized in order to identify safety management practices and their success in preventing construction worker injuries. This paper is organized as follows: (1) description of traditional safety research approaches; (2) proposed integrated methodology to conduct safety research, and (3) expected outcomes of the combination of qualitative and quantitative approaches to safety research.

2. TRADITIONAL SAFETY RESEARCH APPROACHES

Qualitative Approaches

Interviews and Focus Groups. Interviews and focus groups have traditionally been used to assist in the process of identifying factors that may affect safety performance. The purpose of the interview is to investigate and/or validate some of the prior knowledge by researchers about safety issues. During the interviews, construction practitioners are asked to describe how a specific set of factors, job site conditions, construction processes, management attitudes, external factors, and human behavior may or may not affect safety performance.. The research hypotheses are stated prior to the start of the field observation, then data is collected in the form of frequencies of accidents or near accidents, work cycles, resource analysis, safety practices, etc. After collecting a representative number of data points in the sample, then each hypothesis is tested using statistics or other tools for data analysis. Statistical validity is important for testing the hypotheses, since the data points collected must be representative of the population being analyzed. Findings from the interviews and the direct observation on the field can assist in the process of refining the original hypotheses, including new factors and/or project attributes.

Safety Behavior Evaluation. Prior research has found that the causes of accidents can be attributed to factors such as human error, unsafe behavior, and the interaction of humans with materials, tools, and environmental factors (Lehto and Salvendy, 1991). Accident reports have been used to find the causes of injuries and fatalities (Abdelhamid and Everett, 2000; Huang and Hinze, 2003; Edwards, 2003; Hide et al., 2003; Arboleda and Abraham, 2004; Chua and Goh, 2004). However, research based on the information obtained from these reports focuses mainly on after-the-fact information and stops at a premature level or ignores important steps to identify the root causes of accidents (Abdelhamid and Everett, 2000). Brown (1995) suggests that accident investigation should be based on theories of accident causation and human error, resulting in a better understanding of the relationship between the “antecedent human behavior” and the accident at a level that enables the root causes to be determined. This could result in more effective accident prevention strategies directed at the root causes of accidents and not at its symptoms.

Quantitative Approaches

Historical Data Analysis. The analysis of fatality and injury reports has been utilized by safety researchers to identify the major causes of construction injuries and fatalities. For example, Arboleda and Abraham (2004), Suruda et al. (2002), and Hinze (1997) analyzed fatality reports from federal agencies such as the Occupational Safety and Health Administration (OSHA) to determine the major causes of trenching fatalities. Based on these analyses, the major causes of fatalities were identified and safety practices were suggested. These suggestions were not evaluated in a systematic mode to determine the effectiveness and success of the different strategies. This means that the analysis of historical data should be followed by a comprehensive experiment to verify whether the proposed strategies to reduce injuries and fatalities have been successful. There are difficulties that may hinder experimental research in construction safety, such as cost of conducting the experiments, access to the construction site, and ethical issues. However, these difficulties are also present in the experimental research of other domains, constituting a challenge that may be overcome with novel ideas, collaboration from the industry, and a robust design of experiments.

Field Data Collection. Site layout organization is an important part of the planning process and can help make this process more effective. Tawfik and Fernando (1999) developed a simulation tool for organization of the site layout that considered productivity and safety. This tool could help productivity and safety by minimizing travel times for activities such as material delivery, movement of equipment and materials, and movement of labor. Also, safety could be improved by minimizing risks associated with hazard areas near equipment and work processes. Various methods, such as genetic algorithms, isovists, space syntax, and Virtual Reality (VR), were used in the development of the simulation tool. Genetic algorithms can perform a fast and efficient search through a very large number of possible solutions for enhanced site layouts according to multiple criteria that would otherwise be computationally too expensive. Virtual Reality uses computer graphics technology to produce realistic and interactive representations of buildings. Space syntax are techniques for analyzing the spatial patterns of access and visibility that are used in design decision support. It is an approach for mathematically representing and analyzing spatial patterns and properties. Isovists, or fields of vision, are used to analyze the space layout of the site. The isovist of a point in space is the visible field from that space and can be thought of as the geometry obtained by casting light rays in all directions from that point (Tawfik and Fernando 1999). The result of the analysis using isovists is the identification of regions in the site that offer higher visibility than others.

Tools like the one developed by Tawfik and Fernando (1999) could be used to assess environmental impacts on productivity and safety by taking into consideration the environmental characteristics of the job site when planning the job site layout. Computer-aided software is available to assist in the layout and visualization of construction sites. However, the lack of a layout evaluation technique that works in sufficient detail to search for good layout solutions prevents the integration between visualization modeling technologies and the layout evaluation procedure. Other approaches, such as the simulation of project environments (weather, elevation, etc.), could be used to assess the impact of project characteristics on the productivity of workers. In such simulated environments, workers would perform various tasks under a predetermined set of conditions and then be evaluated on their performance. Simulation of construction operations, including factors that affect productivity, could be employed to evaluate the impact of the factors selected.

Practices with Potential Applications in Safety Research

Risk-taking behavior and accident causation. There are many definitions of risk, including the following: the existence of threats to life or health (Fischhoff et. al, 1981), exposure to the chance of injury or loss (Hertz and Thomas, 1983), and the likelihood that harm will occur (Health and Safety Commission, 1995). Risk- taking can be defined as following a course of action selected at the end of a probabilistic process. Risk-taking behavior has been identified as a leading cause of accidents (Wagenaar, 1990). In many accident reports, the causes of accidents are attributed to irresponsible underestimation or acceptance of risk. This fact leads to the hypothesis that a misperceived risk, or a consciously accepted risk, constitutes a major cause of accidents.

Two risk theories that have been used in the study of safety issues in steel erection work (Irizarry, 2005) are the risk homeostasis theory (Wilde, 1982) and the zero-risk theory (Näätanen and Summala, 1974, 1976). The risk homeostasis theory states that an individual's behavior in risky situations is determined by a desire for cost minimization. It explains how behavior can be in accordance with risks, even subjectively perceived risks, without an ever-repeated process of conscious risk evaluation. This theory suggests that no safety measure will ever help to reduce risk and that risk control measures should be replaced by cost control measures. The zero-risk theory states that people seek situations in which there is no risk. Forces that play a role in this model are perceptual, experimental, and motivational. Perception of risk involves individual differences that cause someone to consider a situation to be risky or not risky. The aspects of skill and chance play an important role in risk perception. People who think that their skills can control the risk involved in a given situation may perceive less risk in that situation and completely ignore the chance of being injured. A person's experience is a factor that can influence the risk perceived in a situation; for example, a person who has had an auto accident while driving on wet pavement would perceive a higher risk in driving on a rainy day. Atkinson (1957) argued that the motivation to perform an act combines one's motivations to approach and to avoid the situation. The motivation to achieve success or avoid failure can influence a person's decision to engage or not in an action that has a high level of risk. These theories are important to the study of risk perception of construction workers because they relate the different dimensions of the risk perception with resulting behaviors in risky situations. Understanding these relationships can contribute to the development of safety training programs that target worker risk perception as a method of hazard prevention and avoidance.

There are many research aprocahes for the evaluation of risk on construction sites. An example is a study by Zimolong (1985), which found that accepted risk levels are established as a result of previous experiences and cognition. This study used information about accident-causing factors obtained by investigating the working conditions and personal behavior in harzardous situations. Zimolong concluded that workers are more likely to underestimate high-risk situations if they have had a long-term experience with these hazards.

Another example is a study by Huang and Hinze (2003), which used accident reports to find that approximately 33.3% of fall accidents are caused by the misjudgment of workers about hazardous situations. Huang and Hinze concluded that worker risk taking behavior may be influenced by their perception of what is safe or unsafe, and their subsequent decisions as to when adopt or not adopt required safety precautions are based on this perception.

All the analysis approaches described make use of experiential information or concepts that relate human behavior and accident causation. These are important since accidents are often the cause of risky behavior and the lessons learned from accident experiences can contribute to the reduction of situations that contributed to such accidents. Next, quantitative approaches that can be used in the study of construction accidents and their causes are discussed. Quantitative approaches make extensive use of data ranging from historical accident data to simulated project data to designed experiments.

Assessment of Job-Site Conditions. Another example of the use of quantitative data in construction safety research is related to data used in the planning for safety and the identification of hazards in the construcion activity. This approach has been used to help prevent accidents and costly delays (Burkart, 2002). By practicing good safety habits, a contractor can eliminate the undesirable costs of accidents. Less obvious and more advantageous to the contractor is the elimination of the uninsured costs that result from accidents, which result from delays caused by clearing an accident, damaged equipment, lost time while employees are interviewed for accident reports, cost of filling accident reports, etc. These costs have been estimated by various industry groups, including owners of construction projects, as being between four to 17 times the medical costs of the accident (Burkart, 2002).

Injuries can occur as a consequence of unsafe physical conditions, unsafe work practices, or a combination of the two (Hinze, 1997). Unsafe physical conditions are present when the construction site environment presents difficulties to performing the required tasks. For example, high winds can affect the movement of materials when a crane is used. Unsafe work practices are those that put the worker at risk because specified procedures are not followed. For example, a worker on an elevated structure who does not wear protective equipment is at an increased risk of experiencing a fall.

Job safety analysis consists of considering the various elements that comprise the project and evaluating the existing or possible hazards related to those elements. Not only is it important to conduct such an analysis before the start of the project, but also during the construction process. This kind of analysis is especially important when the work is unusual (i.e., work on irregularly-shaped surfaces or work on complexly-shaped structures), or when the methods used have not been tested before (i.e., use of new tools recently introduced to the market or use of recently developed construction methods).

General Conditions Hazards can be identified from the safety records of previous projects. The OSHA log of previous projects can be used to identify trends in injuries or illnesses, which in turn can assist in determining the root safety problems on various types of projects and operations. Hinze (1997) presents a sample list of questions that could be asked to identify the General Condition Hazards in order to develop strategies to mitigate those risks. These questions can be divided into groups of important factors to assist in the job site safety analysis. The major groups are:

- Physical obstructions (utilities, existing structures)
- Adjacent activities (existing neighbors, traffic)
- Environment (temperature, wind, lighting, ventilation, weather, noise, topography)
- Equipment (type, operational condition)

Specific Operations Hazards is the evaluation of specific procedures that will be used during the project. It is a more detailed and focused analysis of the work operations. An effective approach to this analysis is to use the construction schedule to determine the operations involved in the project. As with the General Condition Hazard identification procedure, Hinze (1997) presented an extensive list of factors that are more specific to the tasks.

- Type of exposure to hazards (falling, being struck by object, being caught in or between collapsing materials or objects, etc.)
- Availability of safety equipment for the task
- Trained workers
- Environmental hazards

Conducting the General Conditions Hazards and the Specific Operations Hazards analyses can increase the safety awareness of the workers on the construction site. By identifying the hazards before the operation starts, steps can be taken to mitigate the possible impacts on safety and productivity.

Designing for safety. Hendrickson (2000) referred to the importance of designing for construction safety. Some designs can be difficult to implement while others may provide for safer construction, thereby reducing the risks of accidents. Safety depends largely upon education, and then upon vigilance and cooperation during the construction process. Education involves training workers and managers in proper procedures and identification of hazards. Vigilance and cooperation is needed when considering the risks of different work practices and implementing strategies that mitigate the risks. This also involves maintaining temporary physical safeguards such as barricades, braces, guylines, railings, etc. Various measures can be taken to improve safety on the jobsite, including design, choice of technology, and education. An example given by Hendrickson (2000) is that parapets could be designed to appropriate heights for construction worker safety, rather than the minimum height required by building codes. Also, modifications to equipment can improve safety on the job site. Controls could be developed to prevent equipment to function under high risk conditions; for example, workers could be provided with sensors that would activate a warning signal to the operators of equipment if the worker is closer than a specified safe distance. Another example is a system to determine the stability (horizontal level) of a crane in order to permit its operation only if the position meets predetermined stability criteria.

Coble and Blatter (1999) discussed the implications of safety on design/build contracts. They focused on the role of the design firm during the design and construction process regarding their liability for safety. Various court cases are cited in which the designer was found liable for safety in the construction stage. In "United States Ex Rel Los Angeles Testing Laboratory v. Rodgers and Rodgers,"[3] it was ruled that "the power of the architect to stop the work alone is tantamount to a power of economic life or death over the contractor." In "W.H. Lyman Construction v. Village of Gurnes,"[4] it was ruled that "the relationship of the supervising engineer and the general contractor gives rise to a duty of care on the part of each party to each other". Designers can become embroiled in liability that in prior years was the responsibility of the contractor. Designers must meet the requirements of the American National Standards Institute (ANSI) and the National Fire Protection Association (NFPA) in order to ensure the safety of the end users of the constructed facility, which implies that designers must have knowledge about safety and constructability when they design structures. This knowledge could be applied to the design of structures considering the safety of the end users and the safety of the workers who will build the structures. Constructability is related to the safety of the end user because the model used to connect design documentation with construction sequence and assembly details would store important information that may be useful for HVAC, or even for considering modifications to the current building physical appearance and layout. The United States Corps of Engineers (USCOE) has stated that jobsite safety is part of the quality control function that many times is the responsibility of the designer (Coble and Blatter 1999). The selection of safe contractors has been shown to have rewards beyond jobsite safety, including increased productivity and better quality construction. The design/build concept allows the firm to give appropriate consideration to safety and other factors according to Coble and Blatter (1999).

In a CII report on the relationship between the designer and construction safety, over 400 design suggestions were identified that could be used to increase worker safety during the design process. Three ways in which the designer can contribute to the safety of the worker are:

1. Reviewing high risk areas in the construction process to determine safety implications.

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[3] 161 F. Supp. 132 (S.D. Cal. 1958)

[4] 84 III. App. 3d 28, 403 N.E. 2d 1325, 1328 (1980)

2. Designing for less worker exposure to hazards.
3. Consulting with contractors and possibly safety consultants to understand the safety implications of their designs (Hinze and Gambatese 1996).

Two important concepts were introduced. First, in design/build contracts the role of the designer is expanded to eliminate by design potential construction safety hazards during the actual construction process. Second, designers should consider the building process in their designs. This could include the incorporation of safety devices such as fall protection (higher parapets and connections for safety lines) and a design that would facilitate the construction sequence (use of similar shapes in steel structures). No methodology is presented in the study to assess the impact of a designer's efforts to improve worker safety by implementing modifications to the design, and the implications of designing for safety in other contract strategies are not addressed. The ability of the designer to influence safety in the construction process is reduced when there is no direct relationship between the designer and the contractor.

3. A DIFFERENT APPROACH TO SAFETY RESEARCH

Linking the two methodologies: Qualitative data and Quantitative Data. Previous sections described methodologies utilized to identify the major causes of construction injuries and fatalities and some of the techniques to prevent these events. In this section we propose the combination of qualitative and quantitave methodologies to determine the best safety management practices in order to anticipate and minimize construction safety injuries and fatalities (Figure 1).

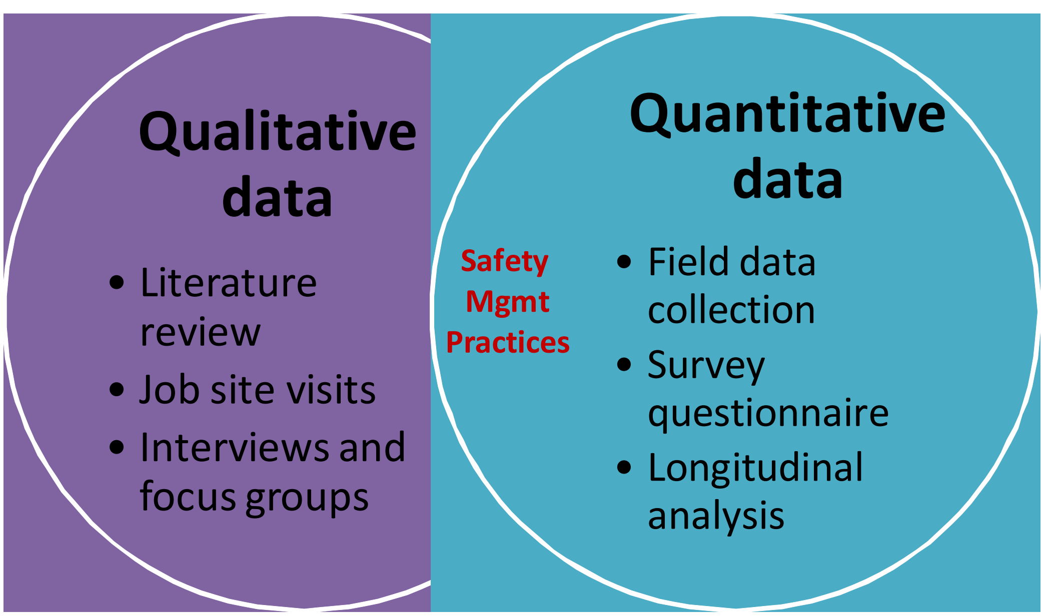

Figure 1. Combination of qualitative and quantitative approaches in safety research

Integrated Approach. A brief description of the major components of the integrated approach are as follows (Figure 2):

a) ***Assessment of safety factors***. The purpose of this phase is to identify the most relevant safety factors related to construction operations. This assessment will be performed evaluating previous studies in construction safety, focus groups with construction workers and managers, and a qualitative assessment based on job site visits.

b) ***Identification of safety practices***. The purpose of this phase is to identify the most relevant safety practices related to risky construction operations. Survey questionnaires can be deployed in order to categorize practices implemented by construction companies and their success in reducing safety incidents.

c) ***Design of experiment***. Once the most relevant practices have been identified, an experiment will be designed and conducted in order to assess whether these practices are effectively reducing near-misses, injuries, and fatalities in trenching and roofing operations. Different "treatments" can be studied to verify whether safety practice is succesful in reducing safety incidents and the variation of the safety metrics through time (longitudinal analysis) There are important challentes associated with this approach, mainly related with the complexity and variability of construction operations. However, we do consider these challenges can be overcome with a rigourous design of experiments and collaboration with the industry.

d) ***Safety practices recommendation***. The "best" practices to improve safety will be identified as a result of the comparisson of the results of the experiment in the previous phase. This comparisson will also provide information regarding the combination of practices that can be implemented on the job site.

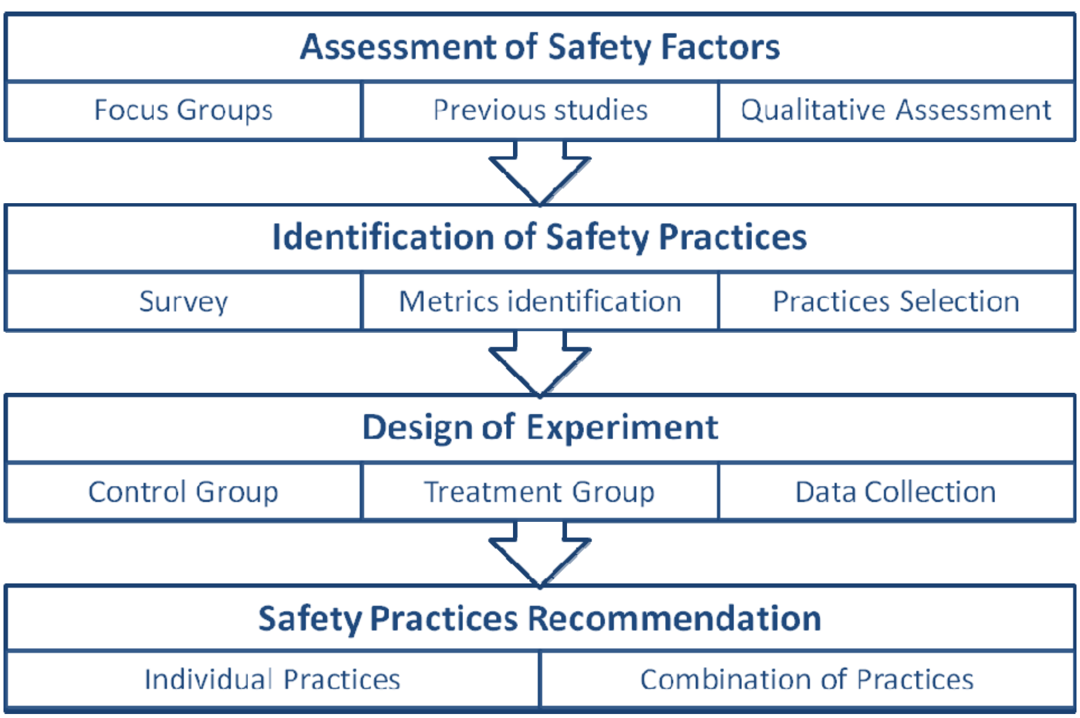

Figure 2. Integrated Approach for Construction Safety Research

Automated Safety Surveillance (iSafety). Information technologies provide the opportunity to collect very accurate data regarding jobsite safety issues. The model for automated safety survailance consists of an automated safety assessment and management system for construction workers in building construction sites using UWB and Bluetooth technologies. In this proactive safety approach, the system can be designed to monitor the location of workers in reference to equipment and work face areas and automatically determine if the workers are at risk of injury by using several decision rules related to the safety hazards previously identified in the project and the proximity of the workers to the hazard. The system can then notify the workers via Bluetooth, alerting them to be aware and remove themselves from the dangerous situation. This concept is innovative because it protects construction workers on building construction sites by automatically detecting exposure to possible hazards and alerting them of the hazard before an accident can occur. The application of this concept can be through safety specifications in construction contracts or possibly as safety requirements of government safety standards such as OSHA. The requirement for use of a system such as this could be similar to the requirements for use of personal protective equipment (PPE). Currently, protection for building construction workers is limited to the use of PPE (e.g., protective footwear, reflective vest, hard hat, fall restraint harness, etc.) and delimitation of hazard areas with tape or signs for visibility of the worker in the building site. Workers would carry a UWB tag the size of a 36 mm watch case attached to their vests. The UWB system would pinpoint the location of every tag and display it on a CAD drawing that can be seen by project participants on their computer screens. Autonomous software agents would determine whether a particular worker is too close to a hazard zone which has been previously identified by the resident engineer and/or safety competent person and entered in the CAD drawing, or to a piece of equipment that also has an attached UWB tag. If this is the case, the worker would immediately receive a warning message using Bluetooth. The message would be received by the worker's warning device, which would be programmed for communication with the server. The system, dubbed i-safe-T (Integrated Surveillance and Automated Frequency Estimation of Threats system), would continuously estimate the proximity of workers to safety threats in the job site and automatically determine if the worker is at risk of injury, taking the necessary action to reduce the risk of injury to the worker (Figure 3). The research approach for the development of the proposed concept involves several tasks. The first task is the deployment of the UWB system on a building construction site. The second task is to develop the program that will identify the safety hazards in the work zone based on previous experiences by the project management team, a set of defined decision rules, and information from standard safety regulations. The last task of the research is to develop a prototype of the system and to perform field testing that includes construction equipment and several simulated scenarios of building construction activities such as excavation, forming, rebar assembly, concrete pouring, steel erection, etc. (Castro et al, 2007). Several components are part of the proposed i-safe-T system:

UWB receivers. Receiver boards that obtain power from the central processing hub via standard CAT-5 cables, which are also used to carry data back to the hub for subsequent processing. A set of three or more receivers will be positioned at known coordinates within, or about the edge of the area to be monitored. These receivers will be placed at strategic locations around the building construction site where construction activities are being performed. The purpose of the receivers is to assist the Hazard Assessment and Management System (HAMS) to determine the relationship between the location of workers and the hazards they might be exposed to, based on the tasks they are assigned to perform.

Sensor monitored automated resource tracking vest (SMART vest). This will be a reflective safety vest fitted with an UWB tag. Short pulse, radio frequency emissions from the tags are subsequently received by each sensor and processed by the central hub CPU. This information will allow the system to determine the possible safety hazards that the worker wearing the vest can be more frequently exposed to, based on his position and the tasks he is assigned to perform, thus facilitating the calculations and decisions made by the system. The vest will also have a Bluetooth-enabled communication device such as a pager to alert the worker of a dangerous situation and that action must be taken for personal protection.

Processing hub. The hub uses a standard CPU that interprets the data sent from the receivers, and generates the identity and location of each tag within a designated area. The results are made available via the hub LAN interface to client computers for further processing and display.

Computing server running the hazard assessment and management system (HAMS). This unit will analyze the information received and processed by the central hub CPU. It will run a software application that would determine the location of each of the workers fitted with a SMART vest and also the location of the construction equipment and hazard areas within the building construction site. It will then calculate the distance of the workers to possible hazards in the work zone, including equipment. The program will them determine, based on a set of decision rules based on actual safety regulation information and equipment manufacturer's safety information, if the worker is in a risky situation and it will then notify the worker of the danger so actions can be taken for personal protection.

4. SUMMARY AND RECOMMENDATIONS

Historically safety research has being limited to the diagnosis of safety problems and limited to recommendations on how to improve safety on construction sites. More recently, a paradigm shift has occurred in which pre-construction design has been used to reduce safety hazards from construction operations. Other efforts concentrate on the development of training materials and other methods of improving safety. What this paper recommends is a step forward in that direction. It is proposed that traditional qualitative research and quantitavive research be joined in a way that will promote strategies that can be monitored and their effectiveness in reducing safety hazards evaluated.

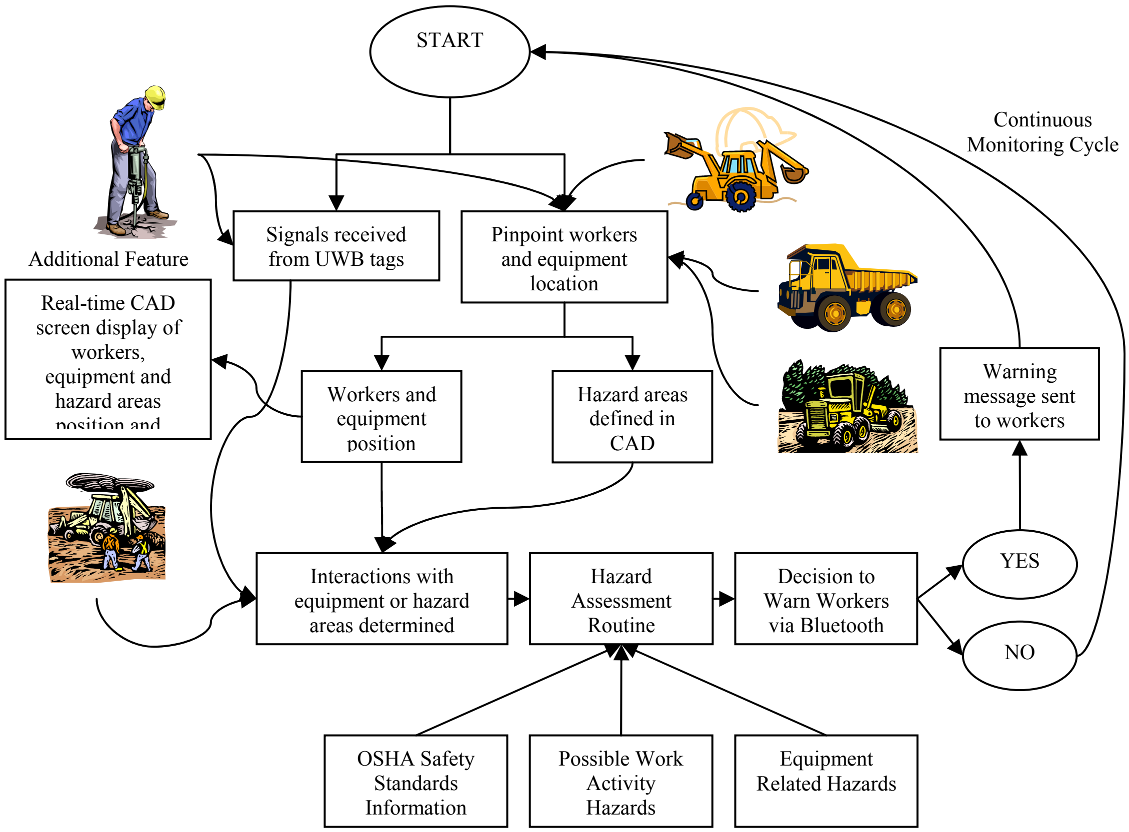

Figure 3. iSafety information processing cycle

The proposed quantitative approach will harmonize the outcomes derived from to the statistical analysis of existing data, interviews with site personnel and the combined output of simulations of different treatments and iSafety monitoring. The identification of the most relevant safety practices will be based on consistent and valid statistical considerations of data from projects completed. These safety practices will be incorporated in the experiment design, simulated using analysis of time and space and monitored using the iSafety methodology. Any perceived discrepancy between the expected behavior of the worker in terms of unnecessary proximity to equipment in motion or to predefined hazardous areas, and the current monitoring, will be reported in real time. This information will allow for a proactive identification of worker behavior, encompassing safety considerations while performing a construction task in real time.

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PRACTICES/POLICIES 12

EXTERNAL SAFETY REPORTING AMONG U.S. CONSTRUCTION FIRMS

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ABSTRACT

Increasingly, over the past decade, organizations have been capturing and formally reporting corporate sustainability data to external stakeholders in three dimensions; environmental, economics, and social. Occupational safety and health metrics, a component reported in the social dimension, have not been studied in the peer-reviewed literature as an external reporting mechanism. We evaluated the externally reported OSH metrics from the top 30 construction firms from *Engineering News Record*'s Top 400 construction firm list. The purpose of this research is to explore, describe, and quantify the extent that occupational safety and health is utilized as an externally reported metric among leading constructions firms and to recommend future directions and research within the topic. Our findings indicate that many construction firms are not fully disclosing OSH metrics as an important component of sustainability. However, we expect that external safety metric reporting will be utilized more in the future to win bids and also to ensure sustainable companies are procuring green construction contracts. The results of this research will assist construction firms measure and report OSH and sustainability metrics.

Keywords: Sustainability, metrics, corporate social responsibility

1. INTRODUCTION

Over the past decade, companies have been increasingly capturing and formally reporting sustainability and social responsibility data to external stakeholders in the three dimensions; environmental, economics, and social. Several research endeavors have focused on environmental aspects in sustainability reporting (Beets and Souther, 1999; Cerin, 2002; Hackston and Milne, 1996; Gray et al, 1995; Williamhurst and Forst, 2000), while other researchers have claimed that the sustainability reporting is too narrowly focused on the environment while ignoring important social aspects, such as occupational safety and health (Gilding et al, 2002; Newport et al, 2003). We find no specific research endeavors that evaluate construction companies' sustainability reporting efforts, and none that focus on external reporting specific to construction safety and health. The purpose of this research is to explore, describe, and quantify the extent that occupational safety and health is utilized as an externally reported metric among leading construction firms and to recommend future directions and research within the topic. We expect the results to provide an improved understanding of the value of voluntary and transparent sustainability reporting. The results should help construction firms as they go about formulating a strategy for sustainability implementation and reporting. For project managers within construction firms, they will have a better understanding of the types of activities that will improve decision-making to influence sustainability. This strategy can extend to supply chain relationships which can be enhanced and assured they are in line with sustainable principles.

2. LITERATURE REVIEW

While occupational safety and health (OSH) is a recognized component of the social dimension within the construct of sustainability, we find no peer-reviewed literature specifically evaluating the role of OSH in construction companies' sustainability strategies. Because sustainability and corporate social responsibility (CSR) reporting are contemporary issues, no formal universally accepted standards exist to guide construction companies seeking to report OSH metrics externally. However, we found three guidance documents in the literature that provided general good practices for external occupational safety and health reporting. The Australian National Occupational Health and Safety Commission (2004) and the Royal Society for the Prevention of Accidents (2003) provide guidance documents related to the contents of externally reported OSH metrics. Epstein and Roy (2003) provide an evaluation strategy to determine the extent that OSH is integrated into the core business strategy of the organization.

3. METHODS

The companies utilized for this research were the Top 30 construction firms from *Engineering News Record*'s Top 400 construction firm list (ENR, 2007). We utilized these firms because they are large companies; Yongvanich and Guthrie (2005) reported that larger firms are more likely to externally report compared with smaller companies because they are under greater pressure to demonstrate that they conduct their activities in accordance with social values.

The three guidance documents found through the literature review (the Australian National Occupational Health and Safety Commission, the Royal Society for the Prevention of Accidents, and Epstein and Roy) were utilized to direct this research. Each is described in detail in the next section. Content analysis was utilized to gather OSH reporting data in Annual Reports and from company websites relating the content to the details and guidance from the three aforementioned sources. This form of data collection was previously accomplished with environmental reporting in accounting research (Williamhurst and Forst, 2000; Hackston and Milne, 1996; Gray et al, 1995). The unit of analysis is the individual firm.

4. RESULTS

Australian National Occupational Health and Safety Commission

The Australian National Occupational Health and Safety Commission (2004) provides guidance on specific items organizations should include in their OSH section of a financial, sustainability, or social responsibility annual report. Specific recommended items include policy statement, CEO statement, safety statistics, safety goals, how the organization manages OSH, contribution of employees, training, OSH program and initiatives, awards, contribution to industry sector OSH, description of OSH incidents, how OSH is integrated into business planning, and any employee health surveillance programs. We utilized all thirteen recommendations as guidelines and during the review of the constructions firms' websites and annual reports made a yes/no determination whether they were reporting on these criteria. The results are shown in Table 1.

Table 1: Results of the 13 recommended elements for OSH reporting

Component	Yes	No
OSH Policy Statement	10	20
CEO Statement on OSH	7	23
Safety Statistics and indicators	15	15
Safety Goals or targets	11	19
Description of how firm manages OSH	5	25
Employee contributions to OSH	3	27
Description of OSH training	2	28
Description of OSH programs and initiatives	7	23
OSH Awards	10	20
Contribution to OSH in construction industry	4	26
How OSH is integrated into the business	3	27
Description of significant OSH incidents	4	26
Employee health surveillance programs	1	29
Totals	82	308

For the thirty companies analyzed across thirteen components, there were 390 possibilities for a yes/no designation. Eighty-two (21%) yes responses were recorded indicating that the company reported a recommended OSH component. Half of the companies reported safety statistics and eleven (37%) reported safety goals or targets. Of the eleven that reported safety goals or targets, nine mentioned a goal of zero accidents as their primary goal. Table 2 summarizes the aggregate sum of "Yes" responses for the thirty companies. Nine companies (30%) reported no OSH information; this was the mode. One company reported eleven of thirteen possible recommended OSH metrics. The mean number of yes responses per company was 2.73; the median was 2.0. The majority of construction firms are not reporting OSH metrics to the extent possible.

Table 2: Summary of 'Yes' Responses per Company

Number of Yes Responses	Frequency	Percentage
0	9	30.0
1	5	16.7
2	2	6.7
3	5	16.7
4	2	6.7
5	2	6.7
6	1	3.3
7	2	6.7
9	1	3.3
11	1	3.3
Total	30	100.0

Royal Society for the Prevention of Accidents

The Royal Society for the Prevention of Accidents (RoSPA) investigated the types of OSH items reported on company web sites and in annual reports (2003). They provide a rating system as guidance for evaluators of externally reported OSH information and categorize OSH information into three categories: Principles, Performance, and Targets. Principles apply to goals, mission statements, employee representation, and policies. Performance includes seven items looking at several traditional safety metrics including costs. Targets refer to improvements measures and stated goals. Each category was operationally defined in the RoSPA guidance document and measurements are provided to classify each level of reporting as low, medium, and high. A category of "None" was added as many of the companies' evaluated did not report OSH metrics. We evaluated each company according to the RoSPA recommended guidelines. The results are summarized in Table 3.

Table 3. Results using RoSPA recommendations

	None	Low	Medium	High
Principles	10	8	6	6
Performance	12	13	4	1
Targets	17	8	3	2

Linking OSH metrics to business

Epstein and Roy (2003) contend that sustainability measures must be explicitly linked to business performance or they will become meaningless and not integrated as important metrics. They provide guidance on categorizing 'levels' of business integration for a variety of sustainability issues, including OSH. Four levels are described and range from "descriptive information not linked to financial performance" to "monetized information fully linked to financial performance". In their research, Epstein and Roy (2003) found that most companies do not make the strategic connection between occupational safety performance and financial performance. However, not one of the twenty companies evaluated by Epstein and Roy was a construction company.

Among the thirty construction firms, nine (30%) made no references to any OSH information and no level was assigned. Six companies' (20%) reporting strategy can be classified as Level 1 or descriptive information not linked to financial performance. Fourteen companies' (47%) reporting strategy can be classified as Level 2 defined as quantified information not linked to financial performance. Only one firm could truly be classified as a Level 3 firm, reporting monetized information partially linked to financial performance. No firms demonstrated Level 4 strategy in their OSH reporting fully linking OSH to financial performance. Several construction firms mentioned their Experience Modification Rate (EMR) as being below the industry average, and went on to say that this helps them be competitive. This description is classified as Level 2 because the information is limited to quantified, not monetized information. The information on EMR was too vague to classify higher than a Level 2. In contrast the lone company classified as Level 3 described several OSH investments including training costs and safety's influence on schedule which impacted total project cost savings. In this example, they were not classified as Level 4 because the OSH information was not directly linked within the text of the report to financial performance.

This struggle to link OSH performance with financial performance is not limited to the construction industry. Colbert (2006) reported that the typical approaches and metrics of OSH professionals are too focused on regulatory aspects and that this minimalist type of philosophy is not congruent with sustainability. The topic of linking OSH with financial performance, or making a business a case for safety, is becoming increasingly a topic of discussion amongst safety professionals; the American Society of Safety Engineers has created a Business of Safety Committee with the goal of being a clearinghouse for information on how safety is linked with financial performance and how safety performance is good for business.

Leading and Lagging OSH Indicators

Lagging OSH indicators are those associated with measurements after an accident occurs, such as injury rates, experience modification rates, accident costs, etc. They are reactive measurements. Leading indicators are those measures which are activity-based and are proactive measures and, if researched and constructed adequately, are predictive of lagging indicators. Research and practice have recognized lagging indicators may not accurately reflect a firm's safety performance and can be misleading (O'Brien, 1998). This is due to the rare number of accidents or lagging indicators which results in a low level of confidence. Toellner (2001) recommends using a combination of leading and lagging indicators as safety performance metrics. We evaluated each company as to whether they were quantifying and describing OSH leading indicators. Surprisingly, we found none of the companies quantify leading indicators. Many described activity based initiatives, such as behavior based safety and training. Compared to the firms which quantified and tracked lagging measures, we hypothesized that at least some of the companies would be tracking and reporting leading OSH measurements.

Reporting Methods

Three construction firms created separate sustainability or ESH reports as .pdf files on their website. Two others had specific sustainability sections within their financial report. It is not surprising that these were also the companies who scored the highest on the three metrics utilized in this research. For example, in the Yes/No analysis from the Australian National Occupational Health and Safety Commission, these five companies 'yes' scores ranged from 3 – 11, averaging 7 yeses compared with 2.73 for all companies. One of the companies with an integrated sustainability/financial report was the firm classified as the level 3 company according to the Epstein and Roy scale. This data demonstrates that only a few construction companies are taking leadership roles in external OSH reporting and overall sustainability reporting.

Rikhardsson et al (2003) evaluated sustainable reporting on the Internet. As an indicator of the ease and availability of sustainability information, they found that to access social reporting from company web pages required an average of 2.75 clicks. In our sample, the average was 1.82 clicks; moreover, seven firms had safety links direct from their company homepage. This could either be an indication that safety is an important indicator to report or overall web page browsing enhancements since the Rikhardsson et al study. Because of the other results within this study, we believe it is the latter.

5. DISCUSSION

The data revealed that very few construction companies are reporting OSH information and they, for the most part, are not embracing sustainability reporting overall. When construction firms are reporting, the amount is limited compared to available guidance. It appears that occupational safety and health is not an important factor for construction to be externally reporting. They may be a perception that external stakeholders are not interested in OSH, as OSH is an internal issue, rather than an external one.

Gilding et al (2002) and Newport et al (2003) posit that sustainability reporting is too narrowly focused on the environment while ignoring important social aspects, such as occupational safety and health. Safety is an important component for companies who want to operationalized sustainability; Gilding et al (2002) recommend excellence in OSH as a starting point to truly understand sustainability. Dentchev (2004) goes one step further and contends that occupational safety and health to be so important that its measures are recommended to be utilized as a proxy for overall CSR performance. If construction firms want to begin or enhance current sustainability initiatives, ensuring excellence in, and the reporting of, occupational safety and health is a critical component.

It was surprising that none of the companies reported quantified OSH leading indicators. Lagging indicators have been subject of concern with regards to their accuracy in the desire to maintain a perfect safety record (CPWR, 2002) and can be viewed as corporate rhetoric. Reporting and quantifying leading indicators portrays a much more holistic picture of an organization and how they manage OSH and sustainability. This is an area of future research to enhance current construction practice.

6. RECOMMENDATIONS

This formative research provides a foundation for future research regarding external reporting in the construction industry. We recommend that external reporting on OSH and the broader topics of sustainability and corporate social responsibility be investigated more thoroughly by comparing construction industry reporting to other sectors such as manufacturing, oil and gas, and healthcare. Green (sustainable) construction is becoming increasingly popular (Post, 2006). For publicly traded companies, the quality and accuracy of external social reporting may become investment decisions or even serve as proxy for investment decisions (Barnea et al, 2005). Because the disclosures made are voluntary, the quality and auditing of social, OSH, and other external reporting will be an important area for future research. The construction industry must be careful and mindful about forms of 'green washing', since there is skepticism about voluntary disclosures and their intent (Ramus and Monteil, 2005). This, however, provides an opportunity for research into quality and auditing of OSH and social external reporting. In addition, because green and sustainable construction is increasing (Post, 2006), we contend that, in the future, the firms who are to be selected to bid on green and sustainable construction projects will need to be pre-qualified to do so. Therefore, a construction's firm verifiable and accurate social and environmental scorecard will be necessary to award green/sustainable projects based on factual data. This reporting structure should include leading OSH indicators to ensure a complete and transparent disclosure strategy.

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SAFETY PRACTICES OF SMALL CONSTRUCTION SPECIALTY CONTRACTORS

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ABSTRACT

Little research has been conducted concerning the safety practices of small construction contractors. These tend to be firms with limited budgets for safety. Since these small contractors constitute a significant proportion of the construction industry, greater understanding is needed about how these firms address construction safety issues. In the past few years construction safety studies focused on these contractors have been conducted at the University of Florida. The research, conducted with specialty contractors or subcontractors, indicated that for the most part small construction firms implement very basic safety practices when compared to those of the larger firms. While the safety practices of the smaller firms vary, they all have to battle the limitations imposed by their budgetary constraints, size, and companywide feelings towards safety. This paper will explore the current safety practices of smaller construction firms and will describe a set of best safety practices that are currently implemented by some of these firms.

Keywords: Safety Programs, Small Contractors, Specialty Contractors

1. INTRODUCTION

Research in the area of construction safety has identified a number of factors that influence safety performance. These include programs such as drug testing, construction site inspections, incident investigations, pre-task planning, worker orientation, and many other techniques. Despite the enlightenment that past research has provided, little has been researched concerning the extent that smaller firms utilize these safety techniques. While some programs can be just as economically implemented in small firms as in large firms, this has not been previously examined. It has been shown however, that some fixed expenditures of a safety program tend to become prohibitive when few employees are involved (Hinze 2002). The research reported here was conducted to establish which safety programs or techniques are more widely employed among smaller construction firms, especially the specialty contractors.

2. BACKGROUND

Several studies have been conducted in the United States to identify the safety techniques or approaches that were being employed to reduce injuries. These studies showed that fewer injuries were noted on projects where specific programs were implemented. For example, a study of facility owners showed that safer project performances were realized when the owner restricted the short bidders list to contractors who met prescribed safety credentials, when owners required contractors to employ full-time safety representatives on the projects, when contractors were required to submit site-specific safety programs, and when the construction contract included additional safety requirements that were more stringent than the OSHA regulations (Huang and Hinze 2006).

Several studies involving construction firms showed that certain safety approaches were consistently associated with better safety performances. For example, better safety performances were noted in firms where pre-screening drug tests and random drug tests were conducted, when a full-time safety manager was assigned to a project (Hinze 1999), when pre-task planning was implemented, when a robust worker orientation program was in place, when workers were actively involved in the safety process, when workers were recognized for safe behaviors, and others (Hinze 2006). These studies showed that the Occupational Safety and Health Administration (OSHA) recordable injury rates were significantly better (lower) on those projects where the practices were in place. The results of these research efforts were obtained through studies involving large construction projects and large construction firms.

A previous study had been conducted at the University of Florida on small contractors involved in residential construction. That study showed that, in general, residential contractors were not very sophisticated in their approach to safety (Madigan 2001). The following findings for that study demonstrated clearly that residential contractors generally are not aggressive about promoting safety in a formal manner: 81% of the firms had written safety plans, 67% of the firms provided new worker orientation, 71% of the firms had a drug testing program, and 63% of the firms required workers to wear hard hats. The second part of the study asked the residential contractors to estimate the percentage of their subcontractors who used a specific safety practice. The results showed that 28% of the subcontractors attend preconstruction safety meetings, 19% had written safety plans, 2% had site-specific safety plans, 14% supplied material safety data sheets, 35% required workers to wear hard hats, 40% required workers to wear protective shoes, 19% required workers to wear safety glasses, and 38% had a drug testing program.

Another construction safety study was conducted at the University of Florida that was also focused on small contractors involved in residential construction. That study also showed that, in general, residential contractors are not very sophisticated in their approach to safety. The study asked contractors to identify the most common types of accidents that had occurred on their jobsites. The study identified falls from an elevated surface, minor cuts and bruises, misuse of power tools, muscle strains from lifting materials, and failure to use proper personal protective equipment (PPE) as the most common types of accidents. The second part of the study asked the residential contractors to identify the safety practices currently utilized by the firms. The results are as follows: 46% of the firms provided new worker orientation, 8% had a safety incentive plan for workers, 70% had a formal safety plan, 32% had site specific safety plans, 30% conducted weekly "toolbox meetings," 32% required workers to wear hard hats, 38% had a drug testing program, and 30% of the firms investigated accidents that did not involve injuries. (Glenn 2000)

3. RESEARCH METHODOLOGY

The objective of this study was to assess the extent that safety programs or safety techniques are employed in small construction firms. Since there was no funding for this study, it was determined that the research would be done on a localized basis. To conduct the study, a questionnaire was developed that inquired about the common elements of safety programs known to be commonly used in the construction industry.

Because of various circumstances, this resulted in three different studies being conducted. While the objectives of each of these studies were the same, the nature of the samples necessitated the data from each to be regarded as being distinct and different from the other studies.

The objective of the first two studies was to determine the extent to which safety was formally addressed by specialty contractors involved in building construction. In one study, the survey was mailed, handed out personally, or distributed via email to specialty contractors working in the Gainesville, Florida area. A total of 90 responses were received from specialty contractors in the Gainesville area. In the second study, the surveys were distributed to specialty contractors working in the vicinity of Martha's Vineyard, an area where one of the authors was employed. This study resulted in 32 Martha's Vineyard firms responding. While these were not random samples of the construction industry, they did provide a good representation of two geographic areas.

While the first two studies were focused on specialty contractors of all types working in two localized areas, the third study was focused on roofing contractors in the state of Florida. The objective of this study was to examine the safety practices implemented by roofing contractors involved in Florida's construction industry. In addition to the questions pertaining to safety practices, this study was also focused on the safety practices of the contractors who employed Hispanic workers; however, that aspect of the research results are not presented here. To conduct the study, a questionnaire was developed that inquired about the common elements of safety programs known to be used by many construction firms. This survey was "fax blasted" to 500 members of the Florida Roofing, Sheet Metal, and Air Conditioning Contractors Association. A total of 68 firms responded.

4. RESULTS

The respondents of the firms to these studies can be classified as being small. The median size of the responding firms from Gainesville, Florida employed 10 workers, the firms in Massachusetts employed fifteen workers, and the responding roofing contractors employed a median of nineteen employees. The specialty contractors were involved in a wide variety of work ranging from mechanical, electrical, and plumbing (MEP) to site work. The Occupational Safety and Health Administration (OSHA) recordable injury rates (RIR) of the respondents were 7.4 for the Gainesville contractors, 3.6 for the Massachusetts contractors, and 9.0 for the Florida roofing contractors.

The specialty contractors were asked a number of questions pertaining to their efforts to improve their safety performances. One such question related to whether the firms employed a full-time safety officer or safety director. Results show that full-time safety officers are not employed by most of the responding specialty contractors (see Figure 1). Few of the Martha's Vineyard contractors employed full-time safety officers while over half of the Gainesville and 40% of the roofing contractors employed full-time safety officers.

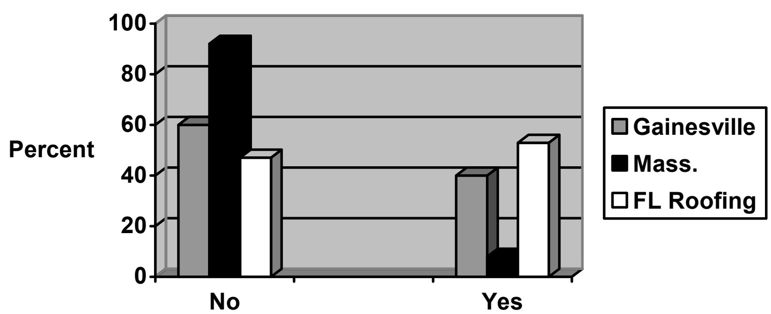

Figure 1. The firm employs a full-time safety officer

The specialty contractors were asked if they regularly prepared site specific safety plans for their projects. Most of the respondents stated that they did not prepare site specific safety plans. Among the roofing contractors, nearly half (46%) prepared site specific safety plans (see Figure 2).

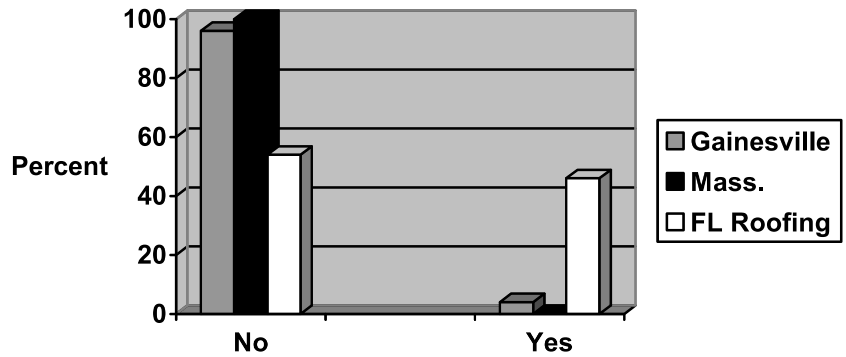

Figure 2. The firms regularly prepares a site specific safety plan

The specialty contractors were asked if they had implemented a drug testing program. Approximately 40% of the Gainesville and half of the Martha's Vineyard respondents had implemented such programs. For the roofing contractors, 85 percent of the respondents had established a drug testing program (see Table 3)

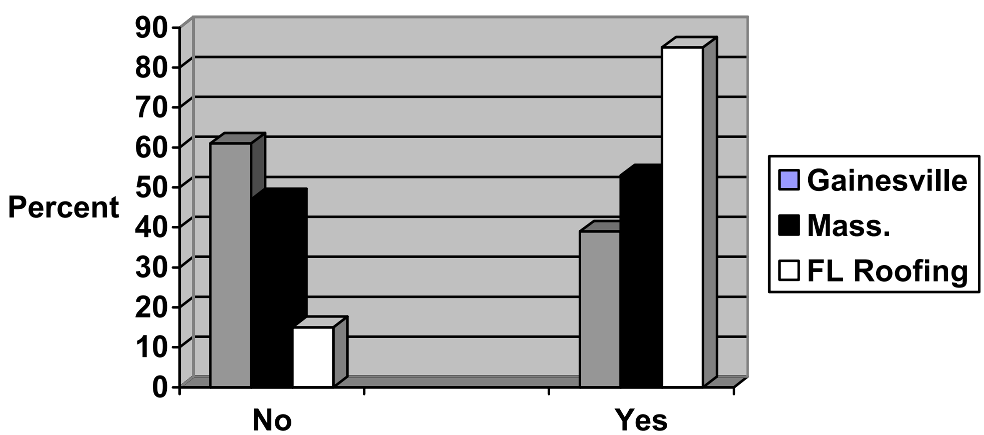

Figure 3. Firm has implemented a drug testing program

The survey also asked about new worker orientation. Less than a third of the Gainesville contractors and even fewer of the Martha's Vineyard contractors (19%) provided orientation training for their new employees. On the other hand, over half of the roofing contractors provided new worker orientation training (see Figure 4).

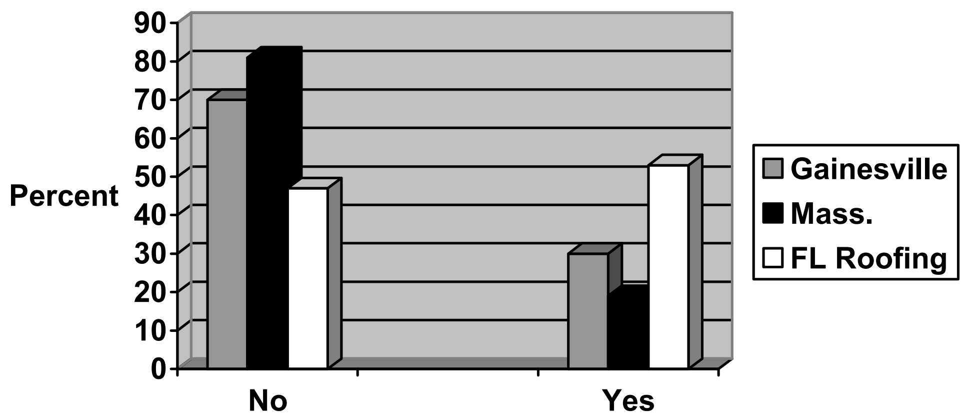

Figure 4. The company provides orientation training for new employees

Jobsite safety meetings, commonly called toolbox meetings or "tailgate" meetings were also examined in this study. These toolbox meetings were conducted by 14% of the Gainesville contractors, 3% of the Martha's Vineyard contractors, and 67% of the roofing contractors (see Figure 5).

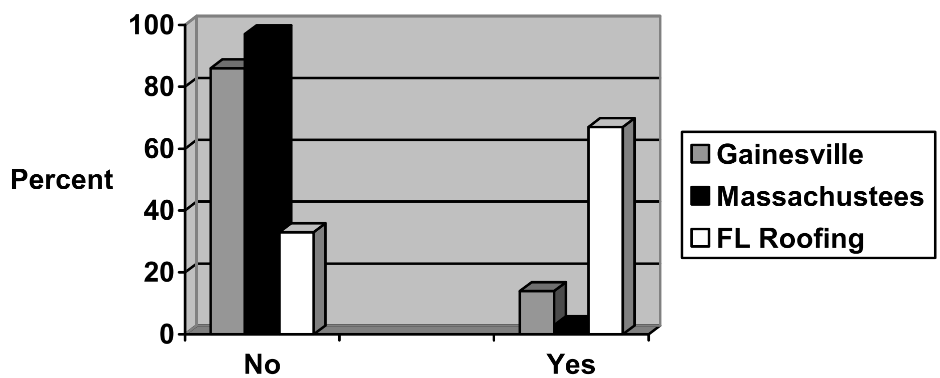

Figure 5. The firm conducts weekly toolbox safety meetings.

Safety incentives have historically been employed to increase worker awareness about safety; however, the use of incentives was small among the contractors. Specialty contractors were asked whether such programs were implemented on their construction project sites. Almost none of the Gainesville and Martha's Vineyard responding firms employed any type of incentive programs. Over forty percent of the roofing contractors did have some type of safety incentive program.

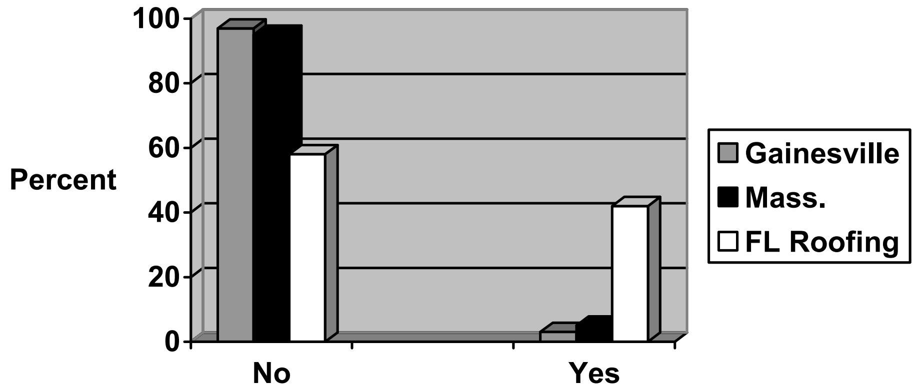

Figure 6. Safety incentive programs are implemented to promote safety

Questions were asked about requirements related to wearing personal protective equipment (PPE), especially hard hats and safety glasses. Regarding the requirements about hard hats, 86 percent of the Gainesville contractors required their employees to wear hard hats on the job, while approximately half (55%) of the Martha's Vineyard contractors required hard hats to be worn. Approximately a third of the roof contractors (36%) required hard hats to be worn (Figure 7). The practices regarding the wearing of safety glasses were considerably different from the practices related to requirements for wearing hard hats. For example, few of the Gainesville contractors (8%) and none of the Martha's Vineyard contractors required workers to wear safety glasses. Over half of the roofing contractors (56%), on the other hand, required workers to wear safety glasses (see Figure 8).

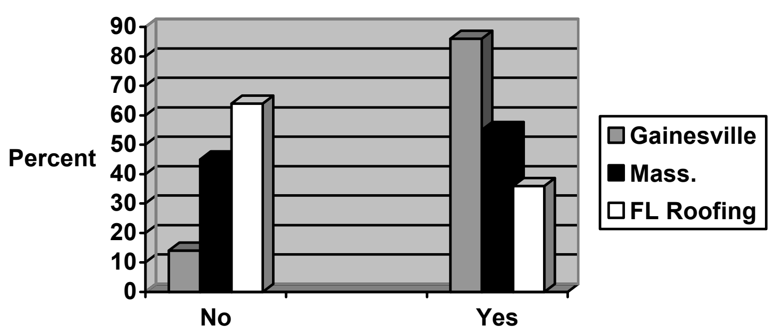

Figure 7. Workers are required to wear hard hats

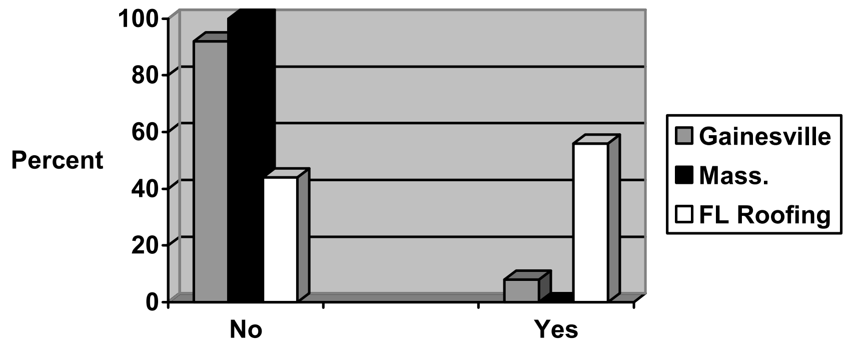

Figure 8. Workers are required to wear safety glasses

The results show a wide range in the safety practices of specialty contractors. In each study, correlations were run between each safety item identified and the RIR to identify a set of best safety practices that favorably impact safety performance. The study of the Gainesville specialty contractors found, with a level of significance of 0.05, that the employment of fulltime safety officers and implementing drug testing were significantly correlated with the RIR. That is, safety performances were better in firms employing those practices.

The study including the Martha's Vineyard contractors had a limited number of respondents, resulting in difficulty in identifying firm relationships between safety performance and the implementation of specific safety programs. There were two noteworthy findings that were identified. One found that safety performances were significantly better in those firms where the safety officers or safety directors spent more of their time (generally over 50% of their time) on the jobsites. The second finding showed that safety performances were better in those firms where more time (especially over 8 hours) was devoted to orientation training. The average injury incident rates were lower among those firms that prepared site specific safety plans, conducted toolbox safety meetings and those that required hard hats to be worn, but these findings were not statistically significant.

The Florida roofing contractors study found, with a level of significance of 0.05, that conducting pre-task planning meetings and preparing project specific safety plans were significantly correlated to RIR. The findings suggest that firms should implement these practices into their safety procedures to reduce injuries. Some of these safety practices will result in a moderate cost to the firm while others can be implemented at nearly no cost at all. The contractors must ultimately decide which practices they will implement but there is only a nominal cost associated with conducting pre-task planning meetings and preparing site specific safety plans. In combination with proper training and PPE, these safety practices can help to reduce the number of injuries on job sites.

5. CONCLUSIONS

The results of this study provide compelling evidence that the average sized specialty contractors do not have sophisticated safety programs. This may stem from a lack of understanding by smaller firms of the impact that the various types of programs have on safety performance or it may simply be a lack of a safety culture that is essential before such programs can be truly successful. The safety culture is dependent on the commitment of top management to the safety agenda. The results indicate that safety has not become a core company value in many small firms.

Despite the lack of sophistication in regard to safety programs in small firms, evidence still suggests that some small firms have quite outstanding safety records. One conclusion that might be drawn is that small firms do not achieve world-class safety results through the same means as large firms. It can be further concluded that there is still insufficient information by which to determine how best to achieve world-class safety performance in small companies.

6. RECOMMENDATIONS

While the study's findings are reasonably compelling, a larger study covering various regions of the United States and including many types of specialty contractors should be conducted. It is possible that safety performance can be achieved in a smaller firm through different means than those that have been proven successful on large projects and in larger firms. A large scale study could help determine if there are different dynamics that can result in good safety performances in the different sizes of firms.

Despite the recognition that safety performance might be better achieved through different means in small firms, there is little doubt that the requirement to wear hard hats and the requirement to wear safety glasses will contribute to better safety performance. Consequently, all small firms should seriously assess the level of compliance that the workers have with the use of basic personal protective equipment, and to make appropriate adjustments where weakness are noted.

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EVALUATION OF SAFETY PROVISIONS IN SUBCONTRACTS

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ABSTRACT

The roles played by firms on a construction project are generally defined in the various contract provisions. When a firm elects to address safety in a specific manner, the verbiage of the contract can be a major factor in ensuring that certain safety techniques are implemented. The goal of this study was to evaluate and enumerate the inclusion of safety provisions found in construction subcontracts. To examine the existence of a possible trend regarding the inclusion of safety provisions in subcontract agreements, 16 subcontracts from 1988-1990 were evaluated and compared to 31 subcontract documents from 2004- 2006. It was found that while the inclusion of safety provisions has increased from 1988-1990 to 2004-2006, they generally do not mandate any stricter requirements than those already imposed by existing laws, namely those of the Occupational Safety and Health Administration (OSHA). No definitive conclusions could be made due to the scale of the study as well as the lack of corresponding safety data. However, the construction industry's recognition of the importance for implementing proactive safety measures is becoming increasingly widespread and the discussions of the safety provisions would be beneficial to any contractor who is seeking new ways to improve job site safety.

Keywords: Construction Safety, Subcontract

1. INTRODUCTION

According to the Census of Fatal Occupational Injuries (CFOI) and the Survey of Occupational Injuries and Illnesses published by the Bureau of Labor Statistics, there were 1,186 fatalities and 1,766,600 injuries and illnesses in the construction industry in 2005. More than half of these fatalities and injuries were sustained by the employees of specialty contractors or subcontractors. These findings are not surprising since a large portion of the construction put in place is performed by subcontractors, putting their employees at greater risk of sustaining injuries and fatalities than the employees of the general contractors.

So what role do general contractors have in ensuring the safety of all on-site construction workers, including those of the subcontractor? General contractors have a responsibility for worker safety, even when no employees are on site. For example, according to the Occupational Health and Safety Administration (OSHA), general contractors are not relieved of their responsibilities for ensuring the safety of everyone on a jobsite, including the employees of the subcontractor and the subcontractors' subcontractors' employees, et cetera.

While the role of general contractors for the safety of all workers is assumed by virtue of being the controlling contractor, subcontractors are also responsible for the health and safety of their employees. This creates a joint role and responsibility for both the general contractor and the subcontractor in ensuring the health and safety of the subcontractors' employees. This role may be altered contractually. Most general contractors include provisions and in some cases additional addenda and exhibits in their subcontract agreements that pertain specifically to safety. These are designed to shift risk or they may be included in contracts to help ensure safe work performance.

Almost all subcontract agreements include indemnity clauses whereby the subcontractor agrees to hold harmless the general contractor for any injuries or fatalities that may be sustained on the jobsite either through the fault or no fault of the general contractor's actions. Nevertheless, some contractors take more proactive steps for ensuring a safe jobsite by including provisions directly in their subcontracts that address the protection of the health, safety, and welfare of all employees.

The trend towards the inclusion of safety provisions in subcontract agreements can probably be attributed to the decline of self performed work by the general contractors and an increase of subcontracted labor, as well as a concerted effort to improve safety performance. General contractors are beginning to evaluate their own safety standards and practices and demanding that the same safety standards be complied with by their subcontractors. The safety provisions may simply demand that subcontractors comply with existing rules and regulations such as those of OSHA, the Environmental Protection Agency, or other applicable state and local laws or ordinances. However, in some instances the contractor will even include its own company policies that are stricter than existing governing laws.
While some general contractors still do not include safety clauses in their subcontract agreements for fear of inadvertently assuming greater liability (taking control of means and methods), studies have shown that a proactive and demanding employer for the protection of the health and safety of employees, results in safer jobsites with less injuries and fatalities than jobs where employers are not involved with safety (Huang and Hinze, 2006).

This study is an examination of the extent to which general contractors address safety, both now and historically, within their subcontract provisions and the implication for safety on jobsites.

2. CONSTRUCTION INDUSTRY SAFETY

In 2004, the construction industry accounted for 22,360, or 57.1 percent, of all Occupational Safety and Health Administration’s (OSHA) inspections. This was followed by manufacturing with 8,755 inspections (22.4 percent). Of the construction violations found, 71.1 percent were classified as serious "where there is substantial probability that death or serious physical harm could result and that the employer knew, or should have known, of the hazard" ("OSHA Facts," 2005). The construction industry also accounts for approximately 20 percent of all industrial worker fatalities and 9.8 percent of the non-fatal injuries. These statistics are particularly staggering when it is taken into account that the construction industry only employs five percent of the industrial workforce (Hinze, 1997; "2004 Survey," 2005).

The construction industry's safety record has not improved as much as it needs to and it still accounts for a disproportionately high percentage of worker fatalities and injuries. The construction industry has approximately 50 percent higher injury rates than all other industries (Huang and Hinze, 2006).

Occupational Safety and Health Act (OSH Act)

A major step towards creating a safe working environment was the passage of the OSH Act of 1970. This act provides specific prescriptive safety measures to be complied with by the employers in the private sector with specific regulations for the construction industry. In Section 5a, the OSH Act outlines the ethical duties of the employer, stating:

(1) Each employer
    (1) shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees…

The OSH Act also created the Occupational Safety and Health Administration (OSHA), which has the following mission:

> OSHA's mission is to assure the safety and health of America's workers by setting and enforcing standards; providing training, outreach, and education; establishing partnerships; and encouraging continual improvement in workplace safety and health (www.osha.gov).

OSHA accomplishes this mission by investigating workplaces and enforcing the regulations stipulated under the OSH Act. Violators are subject to fines, the amount of which is determined by the severity of the offense. OSHA also assists companies in compliance through various programs and safety training and education centers (www.osha.gov).

Contractual Agreements

The Occupational Safety and Health Administration defines the responsibilities of subcontractors and general contractors in OSHA standard 1926.16(c):

> To the extent that a subcontractor of any tier agrees to perform any part of the contract, he also assumes responsibility for complying with the standards

> in this part with respect to that part. Thus, the prime contractor assumes the entire responsibility under the contract and the subcontractor assumes responsibility with respect to his portion of the work. With respect to subcontracted work, the prime contractor and any subcontractor or subcontractors shall be deemed to have joint responsibility.

In the somewhat conflicting OSHA standard 1926.16(a), the general contractor and the subcontractor are allowed some flexibility for determining the obligations of each party; but it is clear that the general contractor's obligations remain intact in the event the subcontractor fails to suitably execute the contracted requirements.

> The prime contractor and any subcontractors may make their own arrangements with respect to obligations which might be more appropriately treated on a jobsite basis rather than individually. … In no case shall the prime contractor be relieved of overall responsibility for compliance with their part for all work to be performed under the contract.

The reason OSHA allows the contractor and subcontractor to determine obligations and roles on site concerning safety is because of the dynamic nature of construction projects. The responsibilities are usually outlined in the subcontract agreements and are established before the start of construction. Whether a portion of the work is subcontracted or not, the prime contractor is held accountable to OSHA for compliance with the regulations. Often, the subcontract agreement includes provisions that are addressed in the contract that exists between the general contractor and the owner. The intent of such provisions is to "shuffle, shift, and ultimately allocate primary responsibility" for safety on the jobsite (Smith et al., 2005). While the ultimate goal of the contractual agreements is to assign liability to one or more parties, the inclusion and more importantly the execution of some safety provisions does aid in better safety performance.

Subcontracts and Safety

The application of proven safety methods is particularly important for subcontractors, especially because they generally perform 80-90% of the actual construction work. As mentioned before, the general contractor can have a positive impact on subcontractor safety performance by implementing proven safety techniques. The general contractor can initially address safety issues in the subcontract agreement. A subcontract agreement, once mutually agreed upon, effectively becomes enforceable by law. Therefore, including safety provisions in a contract (as long as they are not in conflict with existing laws) essentially creates a new 'law'.

Most subcontract agreements address safety to some extent, and it is common for contractual agreements to reference existing laws and regulations. One of the most common provisions found is for the subcontractor to comply with the OSHA regulations. However, such provisions only require compliance that is already demanded by law.

Most subcontract agreements do not include substantial provisions that place more rigorous safety standards on the subcontractors and their employees (Hinze, 1997).

3. METHODOLOGY

Laws that were created, or whose importance were reinforced by contractual agreements between a general contractor and subcontractor were the main focus of this study. The following details describe how the study of safety in subcontract agreements was conducted.

Obtaining Subcontract Agreements

Since this study was focused on the topic of safety as addressed in subcontract agreements, it was necessary to obtain a collection of subcontracts that would reflect a good cross-section of the construction industry. Subcontract agreements were collected through different means to evaluate and enumerate the inclusion of safety in their provisions. A total of 35 subcontract agreements were solicited from willing participants of The Florida Roofing, Sheet Metal and Air Conditioning Contractors Association (FRSA) as well as local Gainesville, Florida subcontractors. Some subcontract agreements were also provided by general contractors in Jacksonville and Orlando, Florida areas.

Historical subcontract agreements were obtained to perform a historical comparison with the agreements that are currently being used in the construction industry. These documents were obtained from an archival record maintained at the M.E. Rinker Sr. School of Building Construction at the University of Florida. A select 16 documents were chosen from the years 1988-1990.

Establishing the Validity of the Subcontract Agreements

After evaluating the 2005-2006 subcontract agreements, it was found that only 31 out of the 35 agreements were valid for this study. Four contracts were determined to be invalid for the purpose of this study because:

- one was a contractual agreement between an owner and a general contractor,
- two subcontract agreements were found to be incomplete as they only included the scope of work, and
- one subcontract agreement consisted of only the odd numbered pages.

No subcontract agreements were discounted because of their lack of safety provisions as the purpose of this study was to determine the current trends for the inclusion, or lack thereof, of safety provisions in subcontract agreements.

The general contractors who had adopted the subcontract agreements were found to vary in size. Of the 31 current agreements used in this study, ten general contractors were on the Engineering News Record's Top 400 Contractors list. The remaining general contractors varied in size from local area state contractors to regional contractors.

Data Coding Sheet Development

To quantify the various safety provision inclusions in the subcontract agreements, a data coding sheet was developed. After the categories were all identified, the subcontract agreements were examined again and all safety provisions were coded in the data base. This made the data conducive to analysis.

In order to create a list of safety provisions to be analyzed, each subcontract was read in its entirety and all safety provisions were highlighted. A list of provisions was then generated of all those that were found within the subcontracts. All provisions that were obscure and only occurred in one subcontract agreement were set aside as extraneous, and were noted as anomalies found within agreements.

The safety provisions found in multiple agreements were organized into categories. The categories that the safety provisions were divided into were as follows:

- Provisions Not Included in 'Safety' Subsections
- General Provisions Directly Addressing Safety
- Compliance with Laws and Regulations
- General Contractor's Rights
- Programs, Submittals, and Requirements by Law
  - General Safety
  - Drugs and Alcohol
  - Hazardous Substances
- Safety Meetings and Training
- Detailed Safety Requirements
  - Personal Protective Equipment
  - Barricading
  - Other

All 66 of the safety provisions coded in this study were placed into the appropriate category. Each subcontract agreement was evaluated and all safety-related provisions were examined. These safety related provisions were noted as being incorporated in the respective subcontract agreements. A matrix was created detailing if the provisions were included in a particular subcontract agreement or not. Because the wording of the subcontract agreements did vary, the *exact* wording of these provisions was not included, but only the overall intention.

Safety Programs

Some of the subcontract agreements also included additional safety requirements in the form of addenda. Some of these addenda included: company safety programs, site specific safety policies, drug and alcohol policies, and hazardous communication and substances policies. These safety documents were not included in the coding because some of the subcontract agreements mentioned the inclusion of additional addenda, however, these were not submitted with the subcontracts making them incomparable. In order to make note of additional safety criteria in the subcontract, one of the provisions coded for was the mention of the inclusion of additional safety documents.

OSHA Standards

After the subcontract agreements were compiled and coded for the inclusion of safety provisions, they were compared to the requirements set by the Occupational Safety and Health Administration (OSHA) Standards for the Construction Industry, Part 1926, and Industry in general, Part 1910. It was then determined whether or not the provisions established by the general contractors compelled safer work practices than those required by OSHA.

4. RESULTS

To examine the existence of a possible trend regarding the inclusion of safety provisions in subcontract agreements, sixteen subcontracts utilized during the period from 1988 to 1990 were evaluated and compared with subcontract documents from 2004-2006. It was recognized that the number of subcontracts that were evaluated provided insufficient information to provide conclusive trend information, but that reasonable inferences could be drawn.

Of the 66 safety provisions that were coded, only 24 were found in the historical subcontract agreements. Table 1 shows the number of historical and current subcontract agreements that contained the 24 provisions. The other 42 provisions are shown as ‘other’ under each main section and are there to show the distribution of provisions found in the current subcontracts and demonstrate the statistical findings. Due to the numerous provisions coded, select provisions will be discussed in subsequent sections.

Because only 16 historical subcontracts were evaluated and coded compared to the 33 current subcontract agreements, a statistical analysis (table 2) and a two-sample t-test (table 3) were conducted to deduce if the increase in provisions was statistically significant. The mean for the 2004-2006 subcontracts was 15.27 and for the 1988-1990 subcontracts it was 3.88. After conducting the student t-test the means were found to be significantly different. The significant increase in the number of provisions found in modern subcontract agreements could be a contributing factor to the decrease in construction industry accidents and injuries. Some of the more commonly occurring (standard) provisions found in both the historical and current subcontract agreements are discussed as well as some of the more proactive provisions found in the 2004-2006 subcontracts.

General Provisions

The provisions coded for in this section included who the responsible party was for providing potable water, toilets, electricity, and trash removal/dumpsters. These provisions are peripherally related to safety in that all these utilities and services are necessary to maintain a clean and healthful work environment. OSHA mandates that employers provide potable water in 29 CFR 1926.51(a) stating "an adequate supply of potable water shall be provided in all places of employment." OSHA also requires the supply of adequate toilet facilities in 29 CFR 1926.51(c) based on the number of employees on site and states in 29 CFR that 1926.25(c) that "garbage and other waste shall be disposed of at frequent and regular intervals." There are no specific safety provisions related directly to providing electricity, however a certain level of light and ventilation, dependent on the task, is required.

Only one historical subcontract agreement contained any provisions from this section of the coding sheet and it stipulated that the general contractor would provide the potable water, toilets, electricity, and trash removal/dumpsters. Fifteen of the 33 current agreements were divided about equally between the general contractor and the subcontractor providing the necessary utilities and services. The inclusion of these provisions is not particularly progressive, as the services and facilities mentioned are already mandated by law.

General Safety Provisions

The study of the historical subcontract agreements revealed that the indemnity clauses and the housekeeping provisions occurred more frequently than any other safety provision. Nine historical subcontract agreements contained a housekeeping provision with no specific mention of safety and one that did specifically mention safety. The current subcontracts had 30 with a housekeeping provision and 8 that specifically mentioned safety. Again, a clean and healthful work site is already required by OSHA.

Table 1- Provision Enumeration

Subcontract Provisions	1988-1990 Subcontracts	2004-2006 Subcontracts
General Provisions		
Contractor provides potable water.	1	4
Contractor provides toilets.	1	7
Contractor provides electricity.	1	4
Contractor provides trash removal/dumpsters.	1	6
Other	0	12
General Safety Provisions		
Subcontractor:		
a) will bear costs and hold harmless the Contractor for any violations.	10	28
b) will bear costs and hold harmless the Contractor for any *safety* violations.	0	15
c) and Contractor mutually indemnify one another for violations for which the other is not responsible.	0	2
Subcontractor will require all of its subcontractors and suppliers to comply with:		
a) the subcontract agreement.	3	5
b) with the safety clauses in the subcontract agreement.	0	3
Subcontractor must comply with:		
a) the contract between the general contractor and the owner.	6	26
b) the safety requirements of the contract between the general contractor and the owner.	0	2
Subcontractor is responsible for health and safety at all times.	4	14
Subcontractor will stop work if Contractor deems it unsafe.	1	4
Subcontractor will remove all trash and debris (daily). *No specific mention of safety.	9	30
Subcontractor must maintain work site in safe and clean condition.	1	8
Subcontractor shall notify contractor of injuries:		
a) immediately.	0	6
b) within 24 hours.	0	2
c) within 3 days.	1	1
Other	0	33
Compliance		
Subcontractor must comply with:		
a) applicable laws, ordinances, rules and regulations.	0	12
b) applicable *safety* laws, ordinances, rules and regulations.	7	21
Subcontractor must comply with OSHA.	3	21
Subcontractor must comply with reasonable safety recommendations of insurance companies.	1	2
General Contractor's Rights		
Contractor not enforcing:		
a) a provision is not a waiver of the provision.	2	4
b) a *safety* provision is not a waiver of the provision.	1	6
Contractor may provide safety personnel and services and backcharge the subcontractor if subcontractor is unwilling or unable to maintain a safe work site (or withhold payments until the subcontractor complies.)	1	7
Other	0	14
Programs, Submittals, and Requirements by Law		
Subcontractor must submit:		
a) their company's safety program.	0	9
b) a project specific safety program.	1	3
Subcontractor must comply with Contractors safety policy.	2	18
Subcontractor must:		
a) abide by Contractors hazardous communication program.	1	3
b) provide its own hazardous communication program.	0	3
Subcontractor must comply with MSDS requirements on toxic materials (Ch 422 of Florida Statutes).	1	16
Subcontractor must give written notice of hazardous substances it will bring on site.	1	3
Other	0	39
Safety Meetings and Training		
Subcontractor must conduct weekly safety/toolbox meetings.	1	10
Subcontractor must supply copy of safety meeting minutes to Contractor.	1	10
Other	0	13
Detailed Safety Requirements		
Other	0	78
TOTAL	**62**	**504**

Table 2- Descriptive statistics

	2004-2006 Subcontracts	*1988-1990 Subcontracts*
Mean	15.27	3.88
Standard Error	1.35	0.875
Median	15	2.5
Mode	17	2
Standard Deviation	7.76	3.5
Sample Variance	60.14	12.25
Kurtosis	-0.918	2.18
Skewness	0.012	1.57
Range	28	13
Minimum	2	0
Maximum	30	13
Sum	504	62
Count	33	16
Confidence Level(95.0%)	2.75	1.87

Table 3- Two sample t-test assuming unequal variances at 95% confidence level

	2004-2006 Subcontracts	*1988-1990 Subcontracts*
Mean	15.27	3.88
Variance	60.14	12.25
Observations	33	16
Hypothesized Mean Difference	0	
df	47	
t Stat	7.08	
P(T<=t) one-tail	< .0001	
t Critical one-tail	1.68	
P(T<=t) two-tail	< .0001	
t Critical two-tail	2.01	

Ten of the historical subcontracts required the subcontractor to "bear costs and hold harmless the Contractor for any violations." This indemnity provision was also found in 28 of the 2004 to 2006 subcontracts. In addition, 15 of the 2004-2006 subcontracts also specifically stated that the subcontractor would hold the contractor harmless for any *safety* violations and 2 contained a mutual indemnification clause. The indemnity provisions are not included as a worker safety measure, but as a way to prevent legal action that may be taken against the general contractor should an accident occur. The increase in their rate of occurrence could be a sign of the increasingly litigious nature of the construction industry.

Six of the historical subcontract agreements required the subcontractor to comply with the prime contract and three required lower-tiered subs to comply with the provisions of the subcontract document. However in these instances, this was mentioned only as a general clause and not in direct relation to safety. Twenty-six of the 2004-2006 subcontracts required compliance with the prime contract, and two stipulated directly that this included the safety provisions. When such provisions are mandated in subcontract agreements they may also be found within the prime contract, or the contract between the general contractor and the owner. This creates a chain of responsibility, from the general contractor to the lowest tiered subcontractor/supplier, to abide by the contents of the prime contract. Should the owner or general contractor have an especially stringent safety program, requiring compliance could greatly benefit worker site safety.

Four of the 16 historical agreements also stated that the subcontractor was responsible for safety. In two of these instances, this was only mentioned in regard to providing a "safe and convenient environment for testing." Fourteen of the 2004-2006 subcontracts also said that the subcontractor was responsible for safety, however the focus on safety varied among them. For instance, one contract focused more on responsibility (and therefore liability) in stating, "Subcontractor is fully responsible for, and shall ensure, the safety of persons and property in connection with the Work." A more proactive provision that focused on worker safety stated, "The subcontractor agrees to take all necessary steps to promote safety and health on the job site."

Another provision that was found in one of the older subcontracts stated that the subcontractor shall notify the contractor of injuries within three days. Nine of the modern subcontracts also had provisions stipulating the notification of worker injuries; however, 6 required immediate notification, 2 required notification within 24 hours, and one within 3 days. This provision could be included because the general contractor may want to be advised of any injuries for insurance purposes, to perform an accident investigation (and take any corrective measures to prevent further accidents), or to have the data available should OSHA investigate. Also, provisions requiring the immediate notification of injuries could dissuade the practice of under-reporting of injuries.

One historical and four current subcontracts contained a provision that required the subcontractor to stop work in the contractor deems it unsafe. The lack of significant increase in the inclusion of this provision is probably due to fear of liability for tampering with the subcontractor's 'means and methods.' One subcontract went so far as to include that "failure on the part of Contractor to stop unsafe practices shall, in no way, relieve Subcontractor of its responsibility." While many general contractors attempted to assign to the subcontractors the responsibility for safety, according to the Occupational Safety and Health Administration Standards (29 CFR 1926.16(a)) this is not entirely possible.

> The prime contractor and any subcontractors may make their own arrangements with respect to obligations which might be more appropriately treated on a jobsite basis rather than individually. ...

> …In no case shall the prime contractor be relieved of overall responsibility for compliance with the requirements of this part for all work to be performed under the contract.

The provisions that probably most effectively aid in the cause of safer work practices are those which address safety in a more proactive manner and less as an obligation which one party is trying to evade.

A more proactive provision coded in this section that was not found in the historical agreements was one which required the subcontractor to immediately notify the contractor of hazardous or unsafe work conditions. One such provision that took a very proactive stance concerning safety was, "Safety is a concern to all of us. If you feel there is a problem in some area, please notify Contractor's Superintendent immediately." The purpose of immediately notifying the general contractor assures that prompt corrective measures can be taken to abate the hazards and/or unsafe conditions.

Compliance

The most frequently occurring safety provision in the older subcontract agreements was one which required the subcontractor to comply with existing safety laws and regulations. Seven out of the 16 agreements contained this provision, while three others specifically cited OSHA as a safety standard to comply with. One also stated that the subcontractor must comply with reasonable safety recommendations of insurance companies. The 2004-2006 subcontracts contained 21, 21, and 2, respectively. While the first two provision requiring compliance with safety and health laws and OSHA does not further aid in creating a safe work environment, but requiring compliance with insurance company recommendations may. Some insurance companies take a proactive stance on safety and offer their clients job site safety inspections and recommendations. While they may offer insights overlooked, contractually demanding compliance with their recommendations may shift the burden of liability to the general contractor.

General Contractor's Rights

One provision was found in the 1988-1990 agreements that stated:

> In any emergency affecting the safety of persons or property, the Contractor shall act, at his discretion, to prevent threatened damage, injury, or loss. Any additional compensation or extension of time claimed by the Contractor on account of emergency work shall be determined as provided in Paragraph 14 for Changes in the Work.

Similar provisions were also found in 7 of the 2004-2006 agreements allowing the contractor to provide safety personnel and services and back-charge the subcontractor if subcontractor is unwilling or unable to maintain a safe work site (or withhold payments until the subcontractor complies.) The general contractor's right to remedy safety deficiencies and back-charge for them makes it more likely that subcontractors would be cognizant of maintaining a safe work environment, especially under threat of incurring extra costs that can be avoided.

Two historical and four modern agreements also contained a provision that stated the contractor's failure to enforce a provision is not waiver of that provision. One historical and six current agreements contained a similar provision that specifically mentioned safety provisions. The purpose for including provisions such as this is to reduce liability for the general contractor should the subcontractor fail to abide by any of the provisions, specifically if the general contractor fails to demand compliance with the provision. However, the inclusion of such provisions does not do anything to enhance job site safety performance.

Programs, Submittals, and Requirements by Law

Two of the historical subcontracts required compliance with the general contractor's safety policy and one required that they submit their own safety program to the contractor. The inclusion of both of these provisions increased significantly in the 2004-2006 provisions with 18 requiring compliance with the general contractor's safety policy and 12 requiring the subcontractor to submit their own safety program, 3 of which required the policy to be site specific. Job site safety could be greatly increased depending on the efficacy and extent of the contractor's safety program. Also, job specific safety programs result in safer job performance.

One historical subcontract agreement contained three provisions related to hazardous substances:

- Subcontractor must comply with MSDS requirements.
- Subcontractor must abide by hazardous communication program.
- Subcontractor must give written notice of hazardous substances it will bring on site.

The 2004-2006 subcontracts also contained these provisions, 16, 3, and 3 respectively. However, 3 more agreements also required the subcontractor to submit their own hazardous communication program. The handling and disposal of hazardous substances, as well as proper documentation, is heavily regulated by law and local statutes. The compliance with MSDS requirements isn't particularly progressive as it only emphasizes what is already required by law.

OSHA also states in 1926.65(b(1)(i) that, "Employers shall develop and implement a written safety and health program for their employees involved in hazardous waste operations." Again, the provision requiring a hazardous communication program is not particularly progressive; however where the general contractor requires compliance with their program the provision provides for a uniform response from all workers and employees on the job site. The last provision, giving written notice of hazardous substances to the general contractor, would provide enough time for all other workers and subcontractors to receive notice and proper safety training for dealing with the hazardous substances, helping to create a safer job site.

Safety Meetings and Training

One of the1988-1990 and 10 of the 2004-2006 subcontract agreements required the subcontractor to conduct weekly safety/toolbox meetings and they also required the subcontractor to provide a copy of the meeting minutes to the general contractor. Scheduled safety meetings are not specifically required by OSHA. As such, this was an increased safety measure enforceable and effectively made a law through the subcontract agreement. Safety meetings are an effective means of communicating information about hazards or safety rules that may have become applicable to the project. By requiring the subcontractor to furnish proof of the meeting, the general contractor ensured that the safety meetings were conducted. The proof of the meetings to be included in the contractor's records manual served to decrease the contractor's liability since the subcontractor has purportedly reported necessary safety information to its workers. Furthermore, should the subcontractor have neglected necessary safety information, the general contractor is able to bring it to the subcontractors attention for remediation.

Detailed Safety Requirements

None of the historical subcontract agreements contained any detailed safety requirements. The 17 provisions coded for in this section are listed below preceded by the number of 2004 to 2006 subcontracts in which they were included.

Personal Protective Equipment

- (8) Subcontractor must supply or subcontractor's employees must have all required PPE and dress appropriately.
- (11) Hard hats are mandatory.
- (2) Hard sole/steel toe shoes are required.
- (1) Safety glasses are mandatory

Barricading

- (7) Subcontractor must maintain traffic control for its own agents and operations: includes flagmen, barricades, and closure permits.
- (4) Subcontractor must post danger signs and other warnings against hazards.
- (8) Subcontractor shall provide and/or maintain all perimeter barricades or safeguards required for safety and/or keep them in place.

Other

- (4) When hoisting, Subcontractor must meet or exceed safety requirements including those of OSHA.
- (4) Subcontractor will safely and efficiently unload materials.
- (7) Subcontractor will provide their own task lighting.
- (3) Subcontractor must provide their own ground fault interrupters for electrical equipment.
- (2) Subcontractor is responsible for the location of underground objects/existing facilities, including electric lines.
- (3) Subcontractor will provide all fall protection required by OSHA.
- (4) OSHA approved safety kits must be provided.

- (5) When using equipment (contractor's, rented, or own), subcontractor shall ensure it is in safe condition, takes all responsibilities for safety, and shall provide a competent operator.
- (2) No radios or sound-making devices not used for jobsite communication are allowed.
- (3) Subcontractor shall provide fire extinguishers/protection.

All of these provisions merely stipulated what was already required by OSHA. However, by including them within the body of the subcontract, the general contractor emphasized safety matters that were of a particular concern or that were noteworthy. All of these provisions were only found in the modern subcontracts, demonstrating an increased dedication to worker safety and better safety performance.

5. CONCLUSION

The inclusion of safety provisions within subcontract agreements could help lead to safer work practices on construction sites. While restating existing laws and regulations will only stress or emphasize safety practices that are already mandatory; stressing compliance with existing safety laws demonstrates a general contractor's commitment to jobsite safety. The level of management commitment to safety is very influential for overall jobsite safety and specifically for subcontractor safety. It is very important that the general contractor place the same emphasis on safety as say, cost and schedule, because this could lead to safer worker performance.

Nonetheless, due to the lag the construction industry still experiences with regard to worker safety when compared to other industries, more proactive measures need to be taken to aid in jobsite safety. As shown with the historical comparison, it is becoming a more common practice for general contractors to include safety provisions in their subcontract agreements. Fifteen years ago, it was hardly widespread for subcontract agreements to contain safety provisions requiring compliance with existing safety laws. Now, not only do most subcontract agreements contain such provisions, but some also include project or task specific safety measures. Continuing to include provisions that require safety measures that go above and beyond what is required by OSHA or other regulatory agencies is one way to help improve the construction industry's safety record. Requiring safer work practices than those necessitated by law is probably the most effective demonstration of a general contractor's commitment to safety (always assuming that they are regularly and strictly enforced).

6. RECOMMENDATIONS

This study was limited to using the generalized improvement of the construction industry's safety record as a comparison for the effectiveness of safety provisions found in subcontract agreements, as well as factors that are known to have an effect on worker safety. Further studies evaluating the inclusion of safety provisions in subcontract agreements in comparison with other safety related data (contractor and subcontractor safety records, company size, project size, etc.) are needed. More conclusive statements with regard to the effectiveness of safety provisions could then be made. The general contractor's commitment and enforcement of its own policies must also be evaluated. However, due to the nature of the construction industry and its variable environment such conclusions would still only be generalizations, albeit more accurate ones. Comparison of the size of the project and company and the most effective provisions would probably provide the most insight into worker safety performance. Publishing the enumeration of the most effective safety provisions and measures that general contractors have used could benefit worker safety in the construction industry.

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ANALYSIS OF CARPENTER INJURIES FROM A WORKERS' COMPENSATION DATABASE FROM 1992 TO 2006

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To identify the profiles of the types and severity of occupational injuries experienced by construction workers, this paper describes injuries sustained by carpenters at various occupational experience levels (e.g., laborers, apprentices, foremen). For this study, workers' compensation (WC) claims information, furnished by a large WC insurance provider, was examined for 46,056 construction worker injuries. Around 14% (n = 6,488) of these claims specifically identified the injured worker as injured while performing work directly associated with the carpentry trade. Injury frequencies and injury severity levels were calculated and compared across demographic variables which included: gender, age, time of day at which the injury occurred, day of the week, month of the year during which the injury occurred, and job tenure (e.g., the time between date of hire and date of injury). Claims data were reported by the provider according to the National Council on Compensation Insurance job classifications. Carpenter injuries were further examined as to the specific body region(s) impacted by the injury (head, neck, trunk, upper extremities, lower extremities, and multiple body regions), specific body part within each region injured, nature of injury (e.g., fracture, puncture, myocardial infarction, etc.), and cause of injury (e.g., slip, fall, struck by -, caught in/between, etc.).

Keywords: Construction Worker Injuries, Carpenters, Workers' Compensation, Injury Severity, Head Injuries, Neck Injuries, Trunk Injuries, Injuries to the Upper Extremities, Injuries to the Lower Extremities.

1. INTRODUCTION

Fatal and non-fatal injuries in the construction trades continue to rank among the highest in the United States (Kisner, SM & Fosbroke, DE, 1994; Soroack, GS, Smith, EO., & Goldoft, M., 1993; USDOL BLS, 2008). Construction workers are difficult to study because of the organization of their work, constantly changing work sites, jobs of relatively short duration, and, for many workers, frequently changing employers. These issues are particularly significant for workers in carpentry, who often work in small crews of four to five workers. Workers' compensation coverage is provided, in most states, by multiple carriers, making access to claims data for large groups of workers difficult to obtain. Consequently, there are relatively few published reports that address work injury experiences of the carpenter sector of the construction industry (Salminen St., 1994; Lipscomb, HJ, Dements, J, & Behlman, R., 2003; Lipscomb, HJ, et. Al., 1997). Reported here are frequency and injury severity analyses of over 6,400 injuries among carpenters based on workers' compensation claims over the 12-year period from 1995 to 2006. The database, provided by a large private provider, contained information on 46,056 construction worker injuries representing multiple trade groups.

2. METHODOLOGY

The focus of this investigation was twofold; first, to examine the frequency of injuries experienced by carpenters relative to several demographic and occupational factors, and second, to explore possible relationships between the severity of injuries to construction workers and several demographic and occupational factors.

The research was based on workers' compensation data records provided by a large private insurance company. The data provided information on the nature of the construction injuries, along with demographic information on the injured workers. The data were well suited to satisfy the objectives of this study. The use of insurance claims data can be especially valuable for population-based studies and are particularly well-suited for occupational injury surveillance studies (Connell, F., Diehr, P. and Hart, L.G., 1987). This insurance provider maintains a proprietary information management system that contains patient demographic and injury data, as well as outpatient treatment, diagnostic, and billing information. For this study, only claims from individuals working in the construction industry (N = 46,056) from 1992 through January 2006 were analyzed.

Some information, such as race and other "sensitive" data were not made available for this research. Job tenure was computed by calculating the number of days between the date of hire of the injured worker and the date of injury occurrence. The data set included information on the injured workers' "occupational work area" (the type of work being performed by the worker at the time of the injury), "nature of injury," specific "body part" affected, "injury type" (converted to injury severity score), and "cause of injury". The nature of injury or illness describes the principal physical characteristics of the injury or illness. Examples of "nature of injury" include amputation, burn, contusion, etc. Examples of the "body part" affected by the injury include brain, skull, arm, finger, shoulder, toes, etc. A "general body region" code was then generated by assigning specific body parts affected, as described within the USDOL-BLS Occupational Injury and Illness Classification Manual (1992).

The original data set provided information regarding the relative severity of the injuries through information given in an "injury type" field. The system for the classification of an injury complied with the National Counsel on Compensation Insurance (NCCI) classification system. Based on payments made to claimants, injuries were assigned an "Injury Severity Score" value from one to five, with five being the most severe injury (medical only = 1; Temporary injury = 2; Permanent partial disability = 3; Permanent total disability = 4; Death = 5).

The “cause of injury” variable indicates the identified cause of the injury. There were seventy-five possible causes that could be assigned to an injury. Each of these specific causes of injury was subsequently assigned to one of eight “general cause of injury” categories.

In an attempt to reflect the workers’ experience levels the variable “experience level “ was generated by extrapolating the experience level (e.g., laborer, helper, apprentice, journeyman, etc.) from information provided in the original data set. The following four categories were applied to this variable for carpenters:

- Laborer - this indicated workers who assisted other construction workers to build or repair buildings, roads, bridges, dams, and other construction projects, and perform other unskilled tasks at construction sites.
- Apprentice - include workers who are learning the craft or trade through on-the-job training and a formal apprenticeship training program.
- Journeyman - this included any craft workers who have completed an apprenticeship program.
- Foreman - this included any worker who is in charge of a construction crew. Generally a construction worker with many years of experience and talent. The foreman is a wealth of knowledge and a key asset to the project.

Statistical Analysis. The statistical analysis of the data were conducted at three levels; (1) the data set for injuries to carpenters was examined for the injury distribution by basic variables (age, age group, gender, general nature of injury, nature of injury, general cause of injury, general agent of injury, agent of injury, job tenure on date of injury, year of injury, month of injury, day of the week of injury, and occupational experience levels), (2) chi square analysis was conducted to detect high risk groups for injuries to each of the body regions (this included the generation of proportional incident rates (PIR)), and (3) an analysis of these injuries specific to “body region” (head, neck, truck, upper extremities, and lower extremities).

Means comparisons were performed for the continuous variables of age and injury severity. For two independent groups of subjects (such as gender, and new hires and non-new hires) the independent t-test was performed to determine whether the groups came from populations with the same mean for the variables of interest (age or injury severity) (Norusis, M.J., 2005). Figure 1 shows the protocol for multiple comparisons of age and injury severity means; analysis of variance (ANOVA) or the Welch robust test was used to assess equality of means. Subsequently, the Tukey’s b range test, was utilized for a pair-wise multiple comparison of means (Aspelmeier, 2002). The decision to conduct either an ANOVA or the Welch test was made based on the results of the Levene test for equality of variances (age or injury severity scores) between the classifications of a given variable (Aspelmeier, 2002). All statistical analysis was performed using SPSS® for Windows® Graduate Pack 13.0.

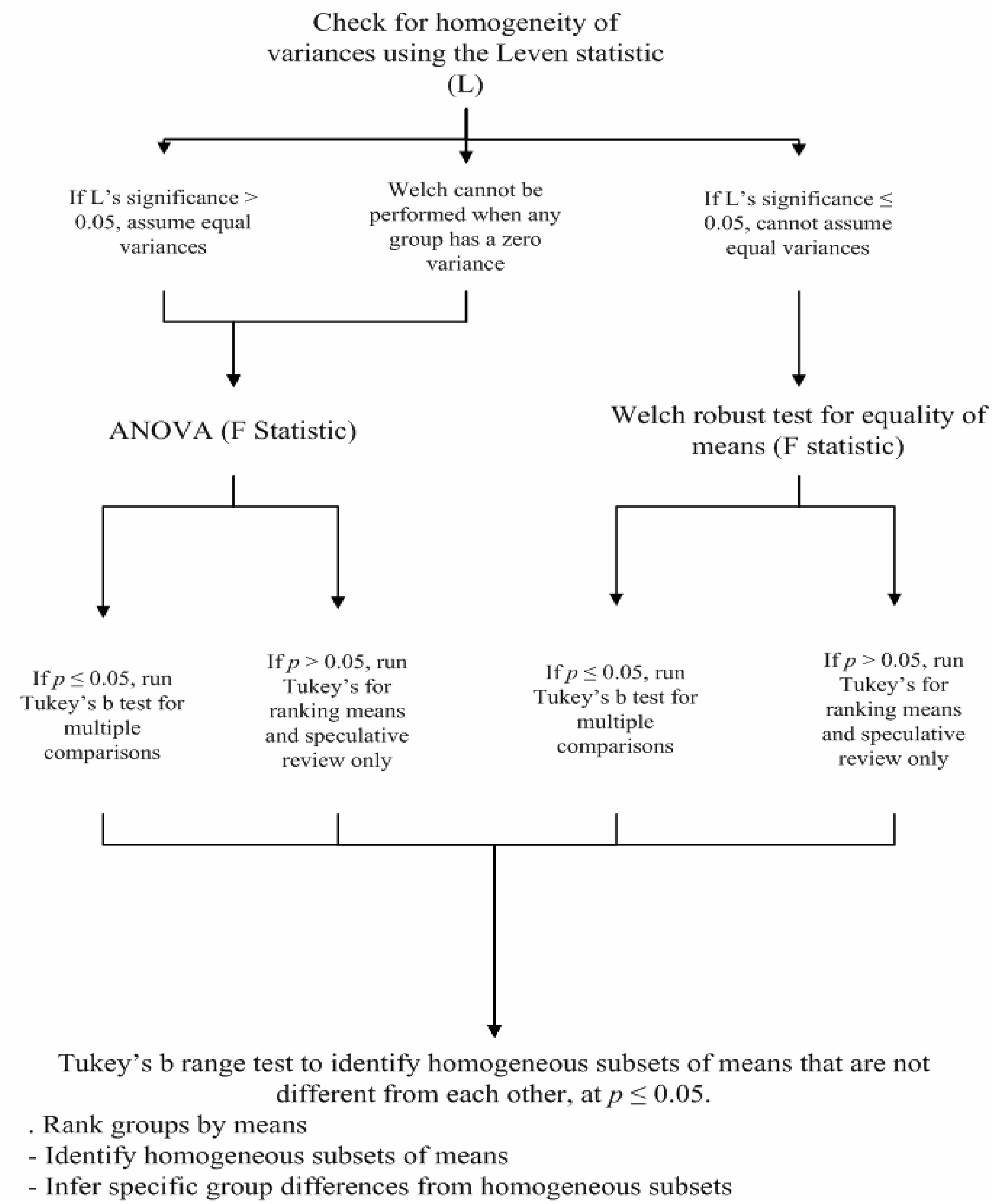
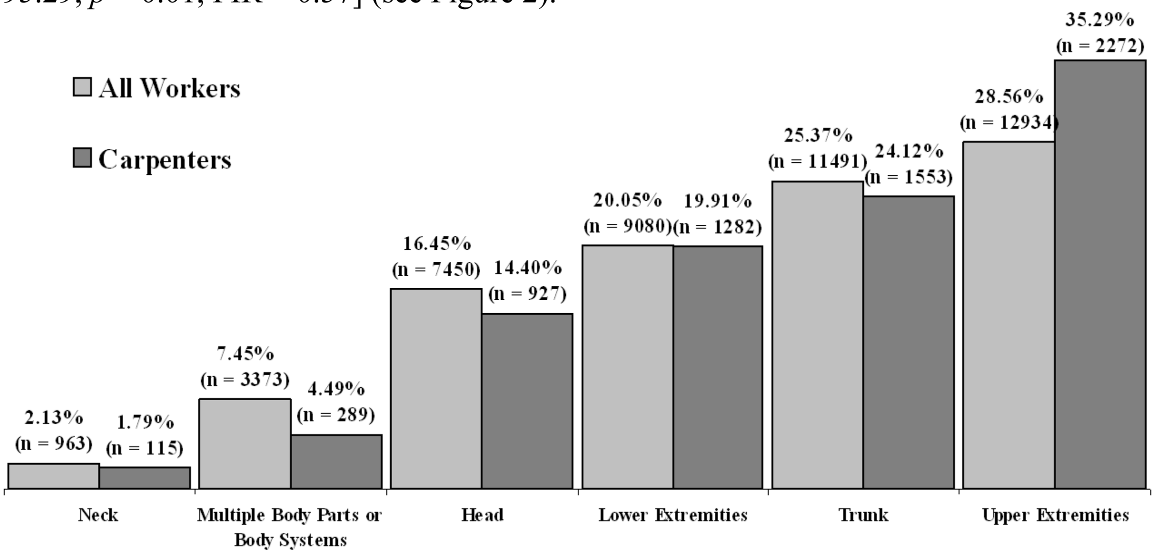


Figure 1. Protocol for statistical multiple comparison of means (Aspelmeier, 2002).

3. RESULTS

Body Region Injured. Results of the chi-square analysis showed that carpenters were more likely to have had an injury to the upper extremities than other construction workers [X^2 ^{2}(1, 45291) = 166.75, p < 0.01, PIR = 1.29]. Carpenters were less likely than other workers to have had injuries to the trunk [X^2 ^{2}(1, 45291) = 6.18, p < 0.02, PIR = 0.94], head [X^2 ^{2}(1, 45291) = 22.955, p < 0.01, PIR = 0.86], neck [X^2 ^{2}(1, 45291) = 4.17, p < 0.05, PIR = 0.82], or injuries multiple body parts or body systems [X^2 ^{2}(1, 45291) = 95.29, p < 0.01, PIR = 0.57] (see Figure 2).



X^2 (1, N = 45,291)

X^2 = 4.17	X^2 = 95.294	X^2 = 22.955	X^2 = 0.085	X^2 = 6.184	X^2 = 166.750
***p* < 0.05**	***p* < 0.01**	***p* < 0.01**	*p* > 0.10	***p* < 0.02**	***p* < 0.01**
PIR = 0.82	**PIR = 0.57**	**PIR = 0.86**	PIR = 0.99	**PIR = 0.94**	**PIR = 1.29**

Figure 2: Comparison of injury frequency (Valid %) by "General Body Region" between Carpenters (N = 6,438) and All Workers (N = 45,291). (Chi-square values and proportional incidence rates (PIR) comparing carpenters with non-carpenters, significant at $p \leq 0.05$).

The least severe injuries for all workers (μ = 1.12) and for carpenters (μ = 1.13) were head injuries which were less severe than upper extremity injuries and these were less severe than the lower extremity injuries. For both groups, head injuries were significantly less severe, at $p \leq 0.05$, than injuries to any of the other "General Body Region" groups. The most severe injuries experienced by carpenters were to multiple body parts or body systems (μ= 1.63); significantly greater (at $p \leq 0.05$) than injuries to the other five regions. Among all workers, injuries to the neck (μ = 1.48) were the most severe, but only significantly more severe (at $p \leq 0.05$) than injuries to the head, lower and upper extremities.

Demographics

Gender and Marital Status. Gender designation along with severity score was provided for 6,368 of the injury cases. Over 97% of the injured workers were male (n = 6198). A comparison of proportional incident rates (PIR) did not show any significant difference between male and female carpenters with respect to likelihood of experiencing an injury to any of the six body regions.

The effect of gender on injury severity was not statistically significant, F = (1, 6,326) = 0.28, $p > 0.50$. Gender had no significant effect, at $p \leq 0.05$, on the severity of injuries to any of the six "General Body Region" groups.

The marital status, along with severity score, was provided for 4,494 of the carpenter injury cases. Over 58% of the injured workers were married while almost 38% of the injured workers were single. Among all injuries to carpenters the effect of marital status on injury severity was statistically significant, F = (4, 4,489) = 2.75, $p < 0.\ 05$. A Tukey's b range test analysis could not identify specific differences in severity means between marital status groups significant at $p \leq 0.05$, for all injuries to carpenters.

Age Band. Age was provided for 2,564 cases involving carpenters. The mean age of injured carpenters was 36.57 years, with age ranging of 15 and 73 years. Among all injuries and for each body region, over 80% of the workers injured were between the age of 20 and 59 years. Over 46% of the injuries for all injuries and among injuries to each of the body regions were to carpenters between 20 and 39 years of age.

Carpenters between 20 and 39 years of age were nearly twice more likely to have an injury to the head than an injury to any of the other body regions [X^2 ^{2}(1, 2564) = 89.32, $p < 0.01$, PIR = 2.17]. Carpenters between 40 and 49 years old were slightly more likely to have an injury to the lower extremities than to any of the other body regions [X^2 ^{2}(1, 2564) = 72.14, $p < 0.01$, PIR = 1.95]. Carpenters 60 to 69 years old were almost four times more likely to have had an injury to multiple body parts or body systems than to any other body region [X^2 ^{2}(1, 2564) = 14.59, $p < 0.01$, PIR = 1.50].

Results from further ANOVA analysis suggest significant, at $p \leq 0.05$, injury severity mean differences existed between age-bands for all injuries, head injuries, and injuries to the lower extremities. However, results from subsequent Tukey's b range tests comparing injury severity means across age bands for all injuries, head injuries and injuries to the lower extremities of carpenters did not reveal specific differences between age-bands, significant at $p \leq 0.05$.

Month of Injury. The month during which the carpenter experienced the injury was provided for 6,443 injured carpenters. Figure 3 shows that carpenters experienced the most injuries during the months of August (10.26%, n = 661), October (9.27%, n = 597), July (9.20%, n = 593), and June (9.14%, n = 589). The least amount of injuries to carpenters occurred during the winter months of November, December, January, and February.

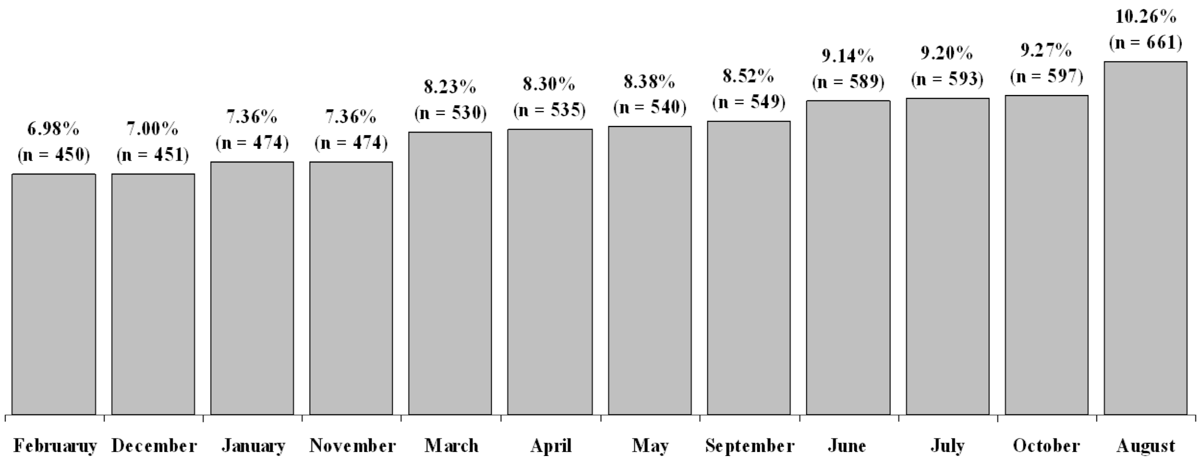


Figure 3. Comparison of injury frequency (Valid %) by "Month of Injury" for all injuries to carpenters (N = 6,443).

Results from a chi square analysis showed carpenters, during the month of July, were more likely to have had a neck injury than an injury to any of the other body regions [X^2 ^{2}(1, 6443) = 5.83, *p* < 0.05, PIR = 1.86]. During the month of May carpenters were more likely to have had a trunk injury than to any of the other regions [X^2 ^{2}(1, 6443) = 11.20, *p* < 0.01, PIR = 1.39]. Lower extremity injuries were more likely to occur to carpenters than to other body regions during the month of January [X^2 ^{2}(1, 6443) = 8.02, *p* < 0.01, PIR = 1.37]. Further ANOVA and Tukey's b range analysis did not reveal any significant injury severity mean differences between months of injury.

Day of the Week and day of the Month of Injury. The day of the week during which the injury occurred was provided for 6,443 cases involving carpenters. Almost 95% of all injuries to carpenters occurred between Monday and Friday. Table 1 displays the distribution of all the injured workers by the day of the week on which they occurred for all injuries and across each of the six "General Body Regions" effected.

Table 3. Frequencies and relative frequencies of injuries to carpentry workers by day of the week of injury for all injuries and injuries to each "General Body Region".

	All Injuries		**Head Injuries**		**Neck Injuries**		**Trunk Injuries**		***UE Injuries**		****LE Injuries**		*****MBPBS Injuries**	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Sunday	86	1.33%	9	0.97%	0	0.00%	46	2.96%	22	0.97%	5	0.39%	4	1.38%
Monday	1265	19.63%	174	18.77%	17	14.78%	320	20.61%	433	19.06%	267	20.83%	53	18.34%
Tuesday	1269	19.70%	196	21.14%	23	20.00%	318	20.48%	442	19.45%	219	17.08%	70	24.22%
Wednesday	1205	18.70%	179	19.31%	23	20.00%	277	17.84%	407	17.91%	272	21.22%	47	16.26%
Thursda	1253	19.45	195	21.0	21	18.26	261	16.81	478	21.04	244	19.03	53	18.34

y		%		4%		%		%		%		%		%
Friday	1114	17.29 %	145	15.6 4%	26	22.61 %	268	17.26 %	408	17.96 %	221	17.24 %	44	15.22 %
Saturday	251	3.90 %	29	3.13 %	5	4.35 %	63	4.06%	82	3.61%	54	4.21%	18	6.23%
Total	6443	100.0 0%	927	100. 00%	115	100.0 0%	1553	100.00 %	2272	100.00 %	1282	100.00 %	289	100.0 0%

* UE = Upper Extremities, ** LE = Lower Extremities, *** MBPBS = Multiple Body Parts and Body Systems

Carpenters were four times more likely to have had a trunk injury than an injury to any other body region on Sundays [X^2 ^{2}(1, 6443) = 41.14, p < 0.01, PIR = 3.70]. Injuries to multiple body parts or body systems were almost twice more likely to occurred to carpenters than any other injury on Saturdays [X^2 ^{2}(1, 6443) = 4.40, p < 0.05, PIR = 1.69] while they were slightly more likely to occur than other injuries on Tuesdays [X^2 ^{2}(1, 6443) = 3.92, p < 0.05, PIR = 1.32].

Results from further ANOVA analysis suggest no significant (at $p \leq 0.05$) injury severity mean differences between days of the week. The day of the month (e.g., 1, 2, 28, or 31) on which the injury occurred was provided for 6,412 cases involving carpenters. Results from an ANOVA analysis suggested no significant injury severity mean differences between days of the month on which the injury to carpenters occurred. This was the case for all injuries as well as specific to injuries to each of the “General Body Regions”.

Job Tenure & New Hires. Job tenure was generated by calculating the number of days between the date of hire of the injured worker and the date of injury occurrence. Table 2 displays the distribution of all the injured workers by their respective membership to one of nine job tenure bands for all injuries and across each of the six “General Body Regions” affected.

Carpenters with more than four years of job tenure were more likely to have had an injury to the trunk than to any of the other body regions [X^2 ^{2} (1. 6443) = 5.65, p < 0.02, PIR = 1.39].

Results from further ANOVA analysis suggest significant. (at $p \leq 0.05$) injury severity mean differences existed between job tenure bands for head injuries to carpenters. However, subsequent Tukey’s b range tests comparing injury severity means across job tenure bands for head injuries to carpenters could not identify significant differences specifically between any of the job tenure bands.

Table 2. Frequencies and relative frequencies of injuries to carpenters by job tenure band for all injuries and injuries to each "General Body Region"

	All Injuries		Head Injuries		Neck Injuries		Trunk Injuries		*UE Injuries		**LE Injuries		***MBPBS Injuries	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
0 to 15 Days	599	11.97%	91	13.13%	17	18.28%	141	11.34%	196	11.26%	119	11.90%	34	14.91%
16 to 30 Days	420	8.39%	50	7.22%	10	10.75%	89	7.16%	152	8.73%	93	9.30%	25	10.96%
31 to 60 Days	631	12.61%	79	11.40%	13	13.98%	143	11.50%	221	12.69%	136	13.60%	38	16.67%
61 to 90 Days	460	9.19%	68	9.81%	9	9.68%	123	9.90%	157	9.02%	81	8.10%	22	9.65%
91 to 180 Days	796	15.91%	108	15.58%	17	18.28%	208	16.73%	283	16.26%	148	14.80%	30	13.16%
181 to 365 Days	859	17.17%	130	18.76%	8	8.60%	215	17.30%	312	17.92%	160	16.00%	34	14.91%
366 to 730 Days (1 to 2 Years)	587	11.73%	73	10.53%	11	11.83%	154	12.39%	200	11.49%	123	12.30%	26	11.40%
731 to 1460 Days (2 to 4 Years)	390	7.80%	62	8.95%	5	5.38%	89	7.16%	139	7.98%	83	8.30%	12	5.26%
> 1461 Days (> 4 Years)	261	5.22%	32	4.62%	3	3.23%	81	6.52%	81	4.65%	57	5.70%	7	3.07%
Total	5003	100.00%	693	100.00%	93	100.00%	1243	100.00%	1741	100.00%	1000	100.00%	228	100.00%

*UE = Upper Extremities, ** LE = Lower Extremities, *** MBPBS = Multiple Body Parts and Body Systems

General Occupational Experience Level. Injury information was provided on four categories of worker occupational experience level for 1468 carpenters. Among all injuries laborers (n = 833) made up just over 56% of the injured carpenters. Apprentice level workers (n = 352) accounted for almost 24% of the injured carpenters. Together, injuries to Journeymen (n = 122) and Foremen (n = 161) comprised just under 20% of all the injuries to carpenters.

Chi-square analysis showed that carpenter laborers were more likely to have had injuries to the lower extremities [X^2 (1, 1468) = 4.94, $p < 0.05$, PIR = 1.34], or to multiple body parts or systems [X^2 (1, 1468) = 4.60, $p < 0.05$, PIR = 1.69] than to other body regions. Apprentice carpenters were more likely to have had an injury to the upper extremities than an injury to any of the other body regions [X^2 (1, 1468) = 18.69, $p < 0.01$, PIR = 1.72].

Results from further ANOVA analysis suggest significant (at $p \leq 0.05$) injury severity mean differences existed between "General Occupational Experience" levels for all injuries [$F(3, 1464) = 2.79$, $p < 0.04$] to carpenters and more specifically lower extremity injuries [$F(3, 358) = 1.00$, $p < 0.02$] to carpenters.

Results from the Tukey's b range test suggested that journeymen ($\mu = 1.52$) had the highest injury severity mean for all injuries to carpenters followed by foremen ($\mu = 1.43$), apprentices ($\mu = 1.41$), then laborers ($\mu = 1.36$). Journeymen carpenters had a significantly greater injury severity mean (at $p \leq 0.05$) for all injuries than that for injuries to carpentry laborers. Journeymen also had the highest injury severity mean among carpenters for trunk injuries (($\mu = 1.81$), followed by apprentices ($\mu = 1.60$), laborers ($\mu = 1.45$), and foremen ($\mu = 1.42$).

Body Parts Injured, Nature, Cause, and Agent of Injury

Body Parts Injured. Injury information was provided on 46 body parts for 6327 carpenters. Among all injuries to carpenters, injuries to the fingers (n = 758) and to the lower back area each made up almost 12% of the injured carpenters. Injuries to the eyes (n = 571) and soft tissue (n = 174) combined to account for over 80% of the head injuries to carpenters.

Soft tissue injuries (n = 75) made up slightly over 65% of carpenters' neck injuries followed by 20% to a disc (n = 23). Forty-seven percent (n = 732) of trunk injuries to carpenters were specific to the lower back area, followed by almost 20% to the shoulders (n = 301) and around 10% to the abdomen (including groin) area (n = 163).

Table 3 illustrates those injuries within the wrist-hand region comprised over 77% of upper extremities (UE) injuries to carpenters. Injuries to fingers made up 33% (n = 758) of the UE injuries followed by nearly 25% of these injuries to the hand (n = 561), 12% to the thumb (n = 284), nearly 10% to the lower arms (n = 220), nearly 10% to the wrist and wrist-hand (n = 224), and almost six percent to the elbows (n = 132).

Over 32% of the upper extremities (UE) injuries to carpenters were specific to the knee (n = 415). Foot injuries (n = 295) and ankle injuries (n = 232) combined for 41% of the UE injuries to carpenters. Among those injuries to carpenters which directly compromised multiple body parts or body systems (MBPBS) nearly 92% impacted multiple body parts (n = 159) (e.g., hand and knee; eye, neck, and finger) while eight percent involved body systems (n = 14) (e.g., respiratory or circulatory).

Table 3. Frequencies and relative frequencies of injuries to carpenters by “Body Part” for all injuries and injuries to each “General Body Region”

	All Injuries		Head Injuries		Neck Injuries		Trunk Injuries		* Injuries		UE** Injuries		LE*** MBPBS Injuries	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Multiple Head Injuries	8	0.13%	8	0.86%										
Skull	7	0.11%	7	0.76%										
Brain	7	0.11%	7	0.76%										
Ear(s)	27	0.43%	27	2.91%										
Eye(s)	571	9.02%	571	61.60%										
Nose	27	0.43%	27	2.91%										
Teeth	46	0.73%	46	4.96%										
Mouth	45	0.71%	45	4.85%										
Soft Tissue	250	3.95%	174	18.77%	75	65.22%								
Facial Bones	15	0.24%	15	1.62%										
Multiple Neck Injuries	9	0.14%			9	7.83%								
Vertebrae	4	0.06%			4	3.48%								
Disc	23	0.36%			23	20.00%								
Spinal Cord	4	0.06%			4	3.48%								
Multiple Upper Extremity Injuries	16	0.25%							16	0.70%				
Upper Arm(s)	77	1.22%							77	3.39%				
Elbow(s)	132	2.09%							132	5.81%				
Lower Arm(s)	221	3.49%							220	9.68%				
Wrist(s)	209	3.30%							209	9.20%				
Hand(s)	561	8.87%							561	24.69%				
Finger(s)	758	11.98%							758	33.36%				
Thumb(s)	284	4.49%							284	12.50%				
Shoulder(s)	302	4.77%					301	19.38%						
Wrist(s) & Hand(s)	15	0.24%							15	0.66%				
Multiple Trunk Injuries	9	0.14%					9	0.58%						
Upper Back Area	58	0.92%					58	3.73%						

Lower Back Area	733	11.59%					732	47.13%						
Chest	127	2.01%					126	8.11%						
Sacrum & Coccyx	4	0.06%					4	0.26%						
Pelvis	5	0.08%					5	0.32%						
Internal Organs	42	0.66%					42	2.70%						
Heart	6	0.09%					6	0.39%						
Multiple Lower Extremities Injuries	14	0.22%									14	1.09%		
Hip(s)	42	0.66%									42	3.28%		
Upper Leg(s)	77	1.22%									77	6.01%		
Knee(s)	415	6.56%									415	32.37%		
Lower Leg(s)	150	2.37%									150	11.70%		
Ankle(s)	232	3.67%									232	18.10%		
Foot/Feet	295	4.66%									295	23.01%		
Toe(s)	44	0.70%									44	3.43%		
Great Toe(s)	13	0.21%									13	1.01%		
Lungs	16	0.25%					16	1.03%						
Abdomen Including Groin	163	2.58%					163	10.50%						
Buttocks	9	0.14%					9	0.58%						
Lumbar and/or Sacral Vertebrae	82	1.30%					82	5.28%						
Multiple Body Parts	159	2.51%											159	91.91%
Body Systems	14	0.22%											14	8.09%
Total	6327	100.00%	927	100.00%	115	100.00%	1553	100.00%	2272	100.00%	1282	100.00%	173	100.00%

* UE = Upper Extremities, ** LE = Lower Extremities, *** MBPBS = Multiple Body Parts and Body Systems

Results from further ANOVA analysis suggest significant (at $p \leq 0.05$) injury severity mean differences existed between specific body parts injured by carpenters. Significantly different (at $p \leq 0.05$) severity means were also detected between specific body parts injured within each of the body regions except MBPBS.

Results from subsequent Tukey's b range tests comparing injury severity means across specific body parts for all injuries to carpenters suggest significantly (at $p \leq 0.05$) greater severity to the heart, pelvis, and spinal cord than to most of the other body parts (see Figures 4). As Figure 10 shows, following injuries to the heart and to the pelvis, carpenters experiencing injuries to nervous system (spinal cord, vertebrae, brain and disc) were associated with the highest severity means. The least severe injuries to carpenters were to the mouth, facial bones, teeth, and eyes.

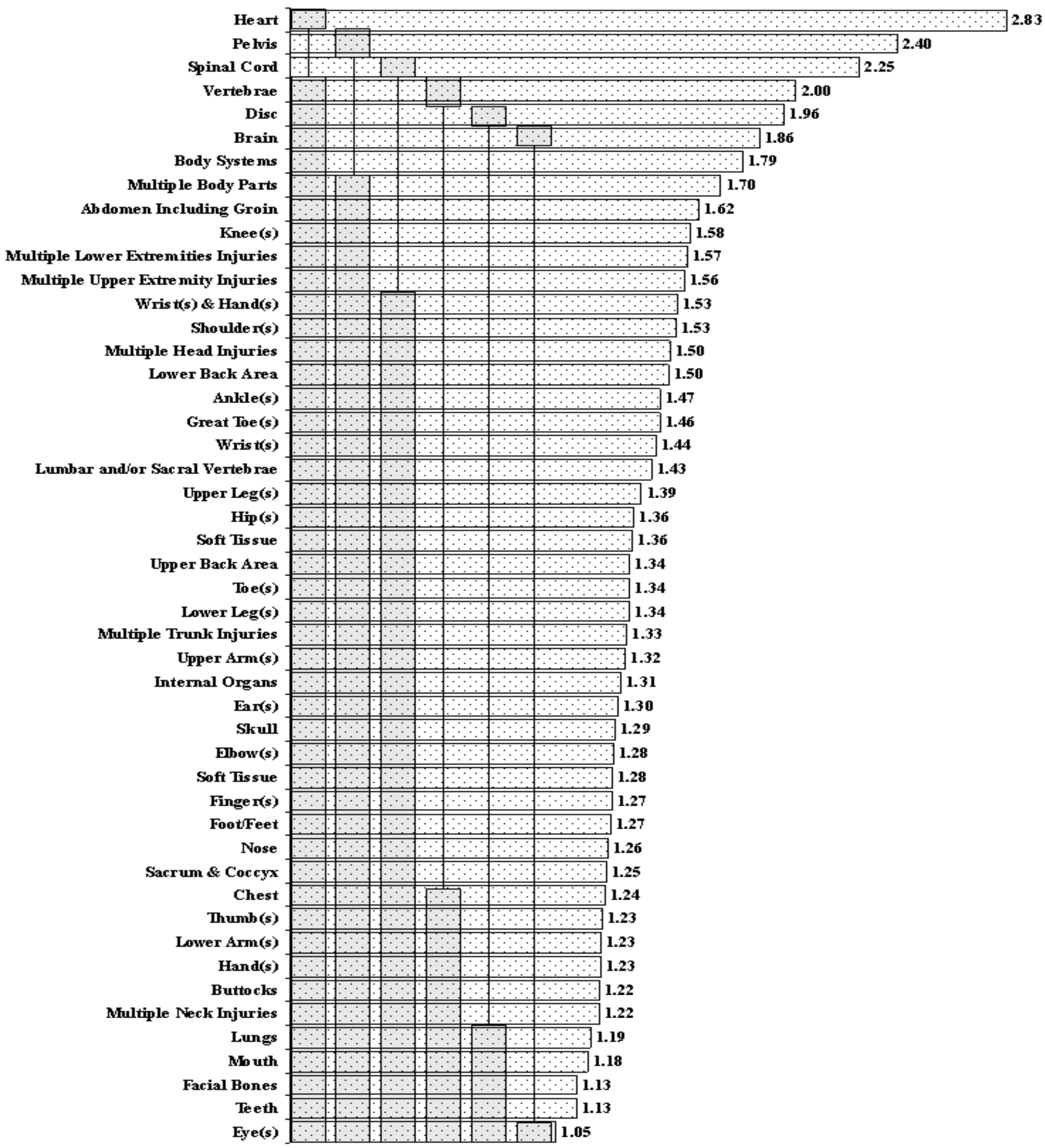


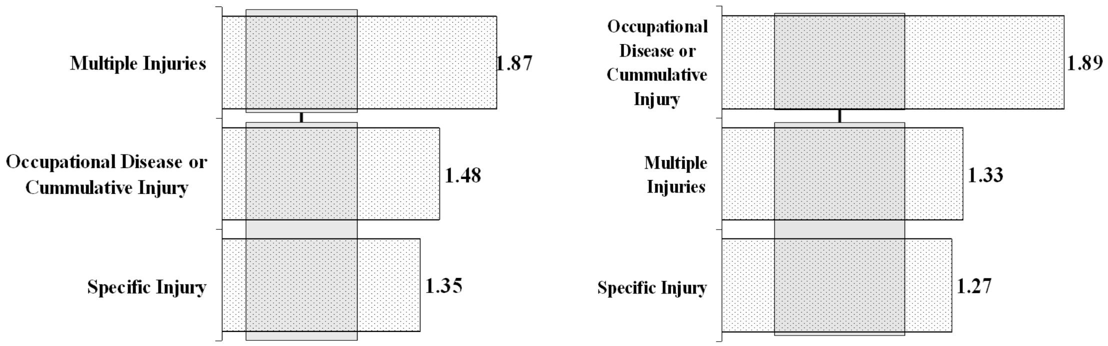
Figure 4. Differences of injury severity means between "Body Parts" for all injuries to carpenters.

General Nature of Injured. Injury information was provided on three categories of "General Nature of injury" for 6443 injured carpenters (see Table 16). Among all injuries to carpenters, specific injuries (e.g., fracture, puncture, rupture) (n = 6291) made up almost 98% (n = 6291) of the injuries to carpenters. Injuries or illnesses associated with an occupational disease or cumulative injury (n = 90), comprised the slightly more than one percent of all injuries to carpenters by general nature of injury. Less than one percent (n = 62) of all the injuries were identified as a result of multiple injuries (e.g., laceration and puncture, multiple fractures). Over 96% of carpenters' injuries specific to head (n = 918), neck (n = 113), trunk (n = 1504), upper extremities (n = 2247), and lower extremities (n = 1275) were specific types of injuries. Around one percent of the head injuries to carpenters were associated with occupational disease or cumulative injury (n = 9). Similarly, an occupational disease or cumulative injury accounted for less than one percent of the lower extremities (n = 2), and upper extremities, injuries (n = 19) to carpenters. MBPBS was the only body region to exhibit more than one percent of its injuries as multiple injuries. Multiple injuries constituted over 16% of all MBPBS injuries to carpenters (n = 47).

Results from chi-square analysis showed that injuries to carpenters' head [X^2 (1, 6443) = 9.06, $p < 0.01$, PIR = 2.71], upper extremities [X^2 (1, 6443) = 24.14, $p < 0.01$, PIR = 2.82], and lower extremities [X^2 (1, 6443) = 22.84, $p < 0.01$, PIR = 5.27] were more likely to be specific injuries (e.g., fractures, contusions, punctures) than injuries to other body regions. Occupational diseases or cumulative injuries were more likely to occur to the trunk [X^2 (1, 6443) = 36.39, $p < 0.01$, PIR = 3.36] or multiple body parts or body systems [X^2 (1, 6443) = 21.13, $p < 0.01$, PIR = 3.72] of carpenters than to other body regions. Multiple injuries were 80 times more likely to cause MBPBS injuries to carpenters than to cause an injury to any of the other body regions [X^2 (1, 6443) = 743.27, $p < 0.01$, PIR = 79.49].

Results from further ANOVA analysis suggest significant (at $p \leq 0.05$) injury severity mean differences existed between specific body parts injured by carpenters. Significantly different (at $p \leq 0.05$) severity means were also detected between "General Nature of Injury" groups within each of the body regions except MBPBS. Carpenters head injuries were identified as either a specific injury or an occupational disease of cumulative injury. A subsequent independent t test suggested that occupational diseases or cumulative injuries to the head were significantly more severe (at $p \leq 0.05$) than for carpenters than specific injuries. For neck injuries to carpenters a comparison of injury severity means between "General Nature of Injury" (GNI) groups could not be conducted because GNI information was provided for less than two cases within the occupational disease or cumulative injury group and within the multiple injuries group.

Results from subsequent Tukey's b range tests comparing injury severity means across "General Nature of Injury" groups for all injuries and for injuries to each body region were conducted (see Figure 5). Among all injuries to carpenters, multiple injuries were significantly more severe (at $p \leq 0.05$) than those associated with a specific injury and those identified as either an occupational disease or cumulative injury. Occupational diseases or cumulative injuries to the upper extremities of carpenters were significantly more severe (at $p \leq 0.05$) than both multiple injuries and specific UE injuries to carpenters.



All Injuries **Upper Extremities Injuries**

Figure 5. Differences of injury severity means between "General Nature of Injury" groups for all (left), and upper extremities (right) injuries to carpenters.

Nature of Injury. Injury information was provided on 34 categories of "Nature of Injury" for 5915 injured carpenters. Strains (n = 1509), lacerations (n = 1228), and contusions (n = 782) combined for almost 60% of all the injuries to carpenters. Lodged foreign bodies (n = 481) and punctures (n = 579), sprains (n = 347), and fractures (n = 372) combined to account for around 30% of all the injuries to carpenters. There were only single cases of freezing and enucleations (dislocation of the eyeball from the eye socket). Only two carpenters were reported to have experienced syncope (i.e., fainting). Three cases each were reported for hearing loss, myocardial infarction, and mental stress/disorders.

Foreign bodies constituted 55% (n = 462) of the head injuries to carpenters followed by 20% lacerations (n = 1228). The leading nature of injury to the neck among carpenters was strains (54.21%, n = 58), followed by contusions (8.41%, n = 9), and ruptures (7.48%, n = 8). Strains were the leading nature of injury to carpenters for trunk injuries (69.05%, n = 993), and LE injuries (22.20%, n = 266). Lacerations were attributed to almost 43% (n = 930) of the UE injuries to carpenters. Punctures (n = 333), contusions (n = 291), and fractures (n = 181) combined to make up 37% of all the UE injuries to carpenters. Punctures (n = 225), contusions (n = 211), and fractures (n = 115) were the second, third and fourth most frequent LE injuries to carpenters. Multiple injuries (n = 47) made up slightly over 30% of MBPBS injuries to carpenters, followed by strains (18.83%, n = 29) and contusions (16.23%, n = 25).

Results from Chi-square analysis suggested that carpenters were at significantly greater risk of amputations [X^2 ^{2}(1, 5915) = 10.53, $p < 0.01$, PIR = 13.80], crushings [X^2 ^{2}(1, 5915) = 44.53, $p < 0.01$, PIR = 0.01], fractures [X^2 ^{2}(1, 5915) = 24.12, $p < 0.01$, PIR = 1.69], infections [X^2 ^{2}(1, 5915) = 11.45, $p < 0.01$, PIR = 2.97], lacerations [X^2 ^{2}(1, 5915) = 1011.86, $p < 0.01$, PIR = 8.63], punctures [X^2 ^{2}(1, 5915) = 118.77, $p < 0.01$, PIR = 2.57], and severances [X^2 ^{2}(1, 5915) = 17.76, $p < 0.01$, PIR = 12.11] to the upper extremities than to any of the other body regions. Carpenters showed a higher risk of lodged foreign bodies [X^2 ^{2}(1, 5915) = 2882.76, $p < 0.01$, PIR = 326.17], or inflammation [X^2 ^{2}(1, 5915) = 19.78, $p < 0.01$, PIR = 2.46] to a part of the head than to any of the other body regions. The neck of carpenters was significantly more susceptible to inflammations [X^2 ^{2}(1, 5915) = 11.89, $p < 0.01$, PIR = 3.66], ruptures [X^2 ^{2}(1, 5915) = 54.43, $p < 0.01$, PIR = 10.59], or strains [X^2 ^{2}(1, 5915) = 47.21, $p < 0.01$, PIR = 3.55] than other body regions. The trunk of carpenters was significantly more vulnerable than other body regions to strains [X^2 ^{2}(1, 5915) = 1895.55, $p < 0.01$, PIR = 17.13], respiratory disorders [X^2 ^{2}(1, 5915) = 11.37, $p < 0.01$, PIR = 15.62], and chemical poisoning [X^2 ^{2}(1, 5915) = 4.78, $p < 0.05$, PIR = 3.90]. The lower extremities of carpenters were significantly more vulnerable than other body regions to contusions [X^2 ^{2}(1, 5915) = 25.26, $p < 0.01$, PIR = 1.55], fractures [X^2 ^{2}(1, 5915) = 27.93, $p < 0.01$, PIR = 1.84], punctures [X^2 ^{2}(1, 5915) = 137.57, $p < 0.01$, PIR = 2.85], ruptures [X^2 ^{2}(1, 5915) = 21.79, $p < 0.01$, PIR = 3.42], and sprains [X^2 ^{2}(1, 5915) = 245.12, $p < 0.01$, PIR = 5.07]. The nature of injury to multiple body parts or body systems of carpenters were significantly more likely than any of the other body regions to be electric shock [X^2 ^{2}(1, 5915) = 115.14, $p < 0.01$, PIR = 34.24], heat of prostration [X^2 ^{2}(1, 5915) = 154.37, $p < 0.01$, PIR = 193.29], a disease not otherwise classified [X^2 ^{2}(1, 5915) = 89.67, $p < 0.01$, PIR = 29.15], or multiple injuries [X^2 ^{2}(1, 5915) = 1324.08, $p < 0.01$, PIR = 168.26].

Results from further ANOVA analysis suggest significant (at $p \leq 0.05$) injury severity mean differences existed between specific “Nature of Injury” groups for all injuries to carpenters. Significantly different (at $p \leq 0.05$) severity means were also detected between “Nature of Injury” groups within each of the body regions except MBPBS.

Because several “Nature of Injury” groups contained less than two cases for all injuries and for each of the body regions Tukey’s b range tests could not be made to compare injury severity means. Among all injuries to carpenters, myocardial infarctions ($\mu = 4.00$) ranked as the nature of injury with the highest severity mean (see Figure 6), followed by ruptures ($\mu = 2.40$), mental stress/disorders ($\mu = 2.33$), carpal tunnel syndrome ($\mu = 2.27$), amputations ($\mu = 2.22$), and hernias ($\mu = 2.16$). Burns ($\mu = 1.08$), electric shock ($\mu = 1.070$, lodged foreign body ($\mu = 1.06$), respiratory disorders ($\mu = 1.00$), syncope ($\mu = 1.00$), freezing ($\mu = 1.00$), and enucleation ($\mu = 1.00$) were associated with lowest injury severity levels for all injuries to carpenters.

Mental stress/disorders and concussions displayed the highest severity means among head injuries to carpenters. Burns, foreign bodies, strains, inflammations, respiratory disorders, and had the lowest severity means among head injuries to carpenters. Fractures, ruptures, crushing, and infections were associated with the highest injury severity means among neck injuries to carpenters, while neck contusions, lacerations, burns, multiple injuries, and inflammations, had the lowest severity means. Myocardial infarctions, ruptures, and hernias, had the highest injury severity means among trunk injuries to carpenters. Poisonings, heat of prostration, dermatitis, foreign bodies, respiratory disorders, infections, and multiple injuries had the lowest severity means among trunk injuries to carpenters. Differences of injury severity means between “Nature of Injury”, head (left), neck (middle), and trunk (right) injuries to carpenters.(* Unable to conduct Tukey’s b range test because one group had $n < 2$).

Ruptures were among the two most severe UE, LE, and MBPBS injuries to carpenters. Amputations ranked as the second most severe injury to the extremities of carpenter, followed by carpal tunnel syndrome, general poisoning, and fractures. Dislocations and general poisoning ranked first and third, respectively, among the most severe LE and MBPBS injuries to carpenters. Electric shock, dermatitis, burns, and infections were among the least severe UE, LE, and MBPBS injuries to carpenters. Figure 16. Differences of injury severity means between "Nature of Injury for upper extremity (left), lower extremity (middle), and multiple body parts or body systems (right) injuries to carpenters.(* Unable to conduct Tukey's b range test because one group had n < 2).

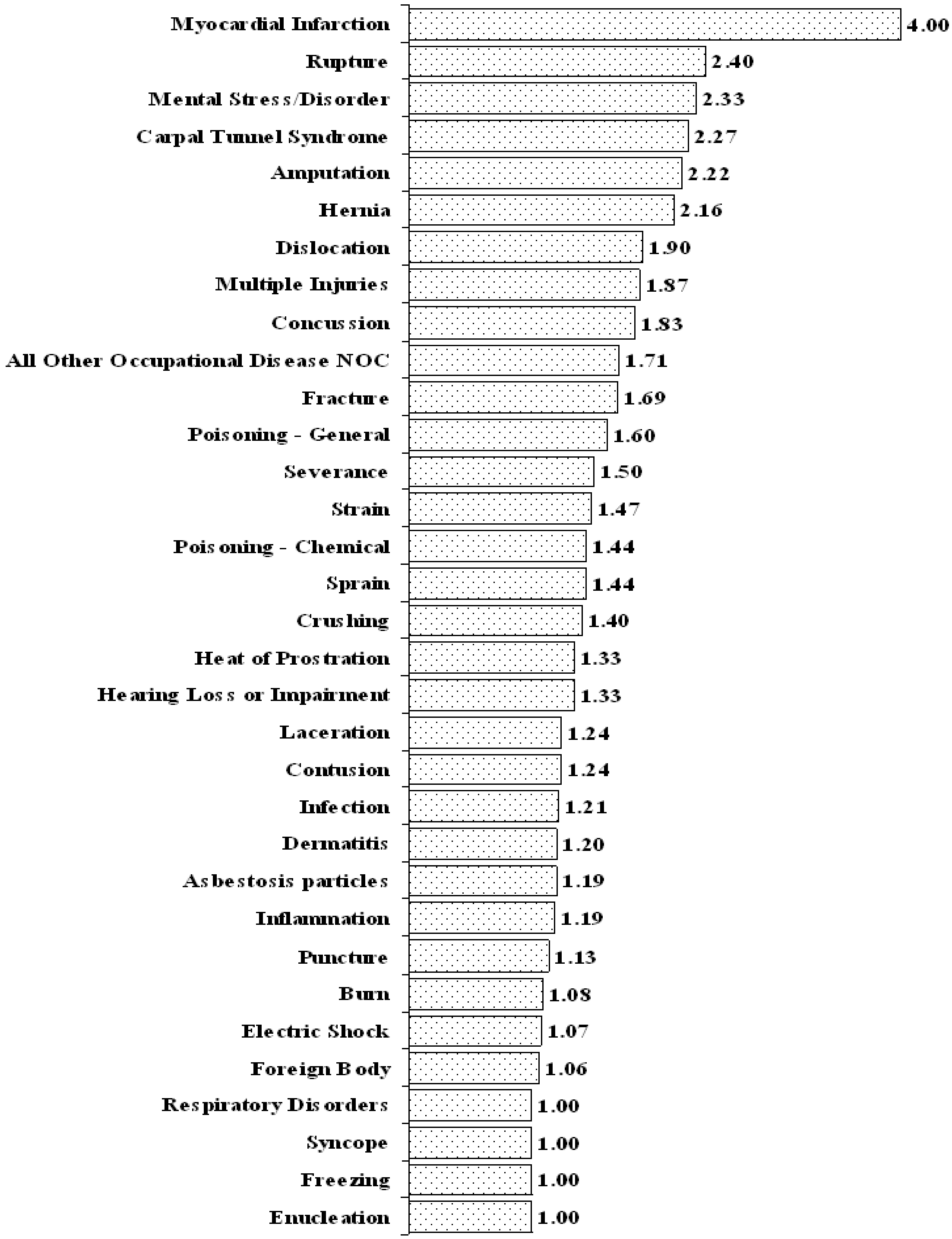


Figure 14. Differences of injury severity means between "Nature of Injury" for all injuries to carpenters.

General Cause of Injury. Injury information was provided on 11 categories of "General Cause of Injury" (from this point on referred to as "the cause" or "cause") for 6244 injured carpenters (see Table 4). Slightly over 25% (n = 1590) of all injuries to carpenters were attributed to some type of straining activity (e.g., lifting, pulling, pushing). This was followed by injuries due to the carpenter being cut, punctured or scraped (20.50%, n = 1280), struck by an object (16.26%, n = 1015), and falls or slips (16.19%, n = 1011). Absorption, ingestion, or inhalation of a substance (1.15%, n = 72), burns (0.86%, n = 54), and animal bites or stings (0.62%, n = 39) caused the least amount of injuries to carpenters.

Table 4. Frequencies and relative frequencies of injuries to carpenters by "General Cause of Injury" for all injuries and injuries to each "General Body Region"

	All Injuries		Head Injuries		Neck Injuries		Trunk Injuries		* UE Injuries		** LE Injuries		*** MBPBS Injuries	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Burn	54	0.86%	12	1.33%	3	2.63%	2	0.13%	16	0.71%	8	0.63%	13	5.83%
Caught In or In Between	277	4.44%	5	0.56%	0	0.00%	8	0.53%	231	10.31%	28	2.22%	5	2.24%
Cut, Puncture, or Scrape	1280	20.50%	45	5.00%	4	3.51%	13	0.87%	999	44.60%	212	16.77%	6	2.69%
Fall or Slip	1011	16.19%	44	4.89%	15	13.16%	301	20.09%	199	8.88%	359	28.40%	92	41.26%
Motor Vehicle	19	0.30%	1	0.11%	0	0.00%	3	0.20%	4	0.18%	4	0.32%	7	3.14%
Strain	1590	25.46%	9	1.00%	32	28.07%	969	64.69%	243	10.85%	295	23.34%	41	18.39%
Striking Against or Stepping On	388	6.21%	55	6.11%	14	12.28%	33	2.20%	143	6.38%	133	10.52%	10	4.48%
Struck By	1015	16.26%	213	23.67%	37	32.46%	138	9.21%	385	17.19%	211	16.69%	29	13.00%
Foreign Matter In Eye(s)	499	7.99%	499	55.44%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Absorption, Ingestion or Inhalations	72	1.15%	8	0.89%	3	2.63%	29	1.94%	7	0.31%	7	0.55%	18	8.07%
Animal Bite/Sting	39	0.62%	9	1.00%	6	5.26%	2	0.13%	13	0.58%	7	0.55%	2	0.90%
Total	6244	100.00%	900	100.00%	114	100.00%	1498	100.00%	2240	100.00%	1264	100.00%	223	100.00%

*UE = Upper Extremities, ** LE = Lower Extremities, *** MBPBS = Multiple Body Parts and Body Systems

Results from the subsequent chi-square analysis suggested that the injuries to the head [X^2 ^{2}(1, 6244) = 41.43, $p < 0.01$, PIR =1.76] or neck [X^2 ^{2}(1, 6244) = 22.39, $p < 0.01$, PIR

= 2.53] were at higher risk being due to being struck by an object than injuries to other body regions of carpenters. Multiple body parts or body systems [X^{2} ^{2}(1, 6244) = 66.49, p < 0.01, PIR = 9.03] and the neck [X^{2} ^{2}(1, 6244) = 4.23, p < 0.05, PIR = 3.22] of carpenters were significantly more vulnerable to injury due to burns than other body regions. Being caught in or in between objects [X^{2} ^{2}(1, 6244) = 284.52, p < 0.01, PIR = 9.89] and cuts, punctures, or scrapes [X^{2} ^{2}(1, 6244) = 1244.75, p < 0.01, PIR = 10.67] were more likely to cause injuries to the upper extremities than to any other body region of carpenters. Falls or slips were more likely to cause injury to the trunk [X^{2} ^{2}(1, 6244) = 22.11, p < 0.01, PIR = 1.43], lower extremities [X^{2} ^{2}(1, 6244) = 174.12, p < 0.01, PIR = 2.63], or multiple body parts or body regions [X^{2} ^{2}(1, 6244) = 107.06, p < 0.01, PIR = 3.90] of carpenters than to any of the other body regions. Contact with a motor vehicle was more likely to cause injury to multiple body parts or body systems of carpenters than to any of the other body regions [X^{2} ^{2}(1, 6244) = 61.26, p < 0.01, PIR = 16.23]. Straining was significantly more likely to cause injuries to the trunk rather than to any of the other body regions of carpenters [X^{2} ^{2}(1, 6244) = 1597.40, p < 0.01, PIR = 12.17]. The neck [X^{2} ^{2}(1, 6244) = 7.33, p < 0.01, PIR = 2.14] and the lower extremities [X^{2} ^{2}(1, 6244) = 50.47, p < 0.01, PIR = 2.18] of carpenters were at significantly higher risk of being injured by striking against or stepping on an object than any of the other body regions. The absorption, inhalation, or ingestion of a substance was more likely to cause injuries to the trunk [X^{2} ^{2}(1, 6244) = 10.60, p < 0.01, PIR = 2.16] or multiple body parts or body systems [X^{2} ^{2}(1, 6244) = 97.12, p < 0.01, PIR = 9.70] than to any of the other body regions of carpenters. The neck of a carpenter was more vulnerable to animal bites or stings than any of the other body regions [X^{2} ^{2}(1, 6244) = 40.25, p < 0.01, PIR = 10.26].

Results from further ANOVA analysis suggested significant (at $p \leq 0.05$) injury severity mean differences existed between specific "General Cause of Injury" groups for all injuries to carpenters (see Table 5). Significantly different (at $p \leq 0.05$) severity means were also detected between "General Cause of Injury" groups within each of the body regions except MBPBS.

Results from subsequent Tukey's b range tests comparing injury severity means across "General Cause of Injury" groups for all injuries and for injuries to each body region were conducted (see Figure 7). Among all injuries to carpenters, contact with a motor vehicle, falls or slips, and straining caused injuries with the highest severity means. Each of these caused significantly more severe (at $p \leq 0.05$) injuries to carpenters than most of the remaining causes. Injuries caused by burns, animal bites or stings, or foreign matter in the eyes were the least severe to carpenters.

The Tukey's b range test was conducted to compare injury severity means across "General Cause of Injury" groups for neck, trunk, UE, LE, and MBPBS injuries to carpenters (see Figures 8). "General Cause of Injury" groups were ranked by descending severity mean levels for each of the six body regions.

The most severe head injuries to carpenters were caused by contact with a motor vehicle, followed by a fall or slip, or being struck by an object. The least severe head injuries to carpenters were caused by the absorption, ingestion or inhalation of a substance, foreign matter in the eyes, or by a cut, puncture or scrape. Because there was only one case of a head injury caused by contact with a motor vehicle significant severity mean differences between specific "General Cause" groups could not be determined (see Figure 8, left).

Table 5. Comparison of carpenters' injury severity means across '"General Cause of Injury" for all injuries and each of the six "General Body Region" groups.

	All Injuries Severity Mean	**Head Injuries Severity Mean**	**Neck Injuries Severity Mean**	**Trunk Injuries Severity Mean**	***UE Injuries Severity Mean**	****LE Injuries Severity Mean**	*****MBPBS Injuries Severity Mean**
F (d1, d2) or t(df)	(10, 6233) = 56.187	(9, 889) = 9.55	(7, 106) = 1.463	(20, 1414) = 9.772	(9, 2230) = 10.426	(9, 1254) = 10.701	(14, 133) = 1.347
*****p*	**0.000**	**0.000**	**0.188**	**0.000**	**0.000**	**0.000**	0.161

*UE = Upper Extremities, ** LE = Lower Extremities, *** MBPBS = Multiple Body Parts and Body Systems

**** Bold indicates significant, $p \leq 0.05$, differences occurred between groups (note: slightly higher values may justify further investigation).

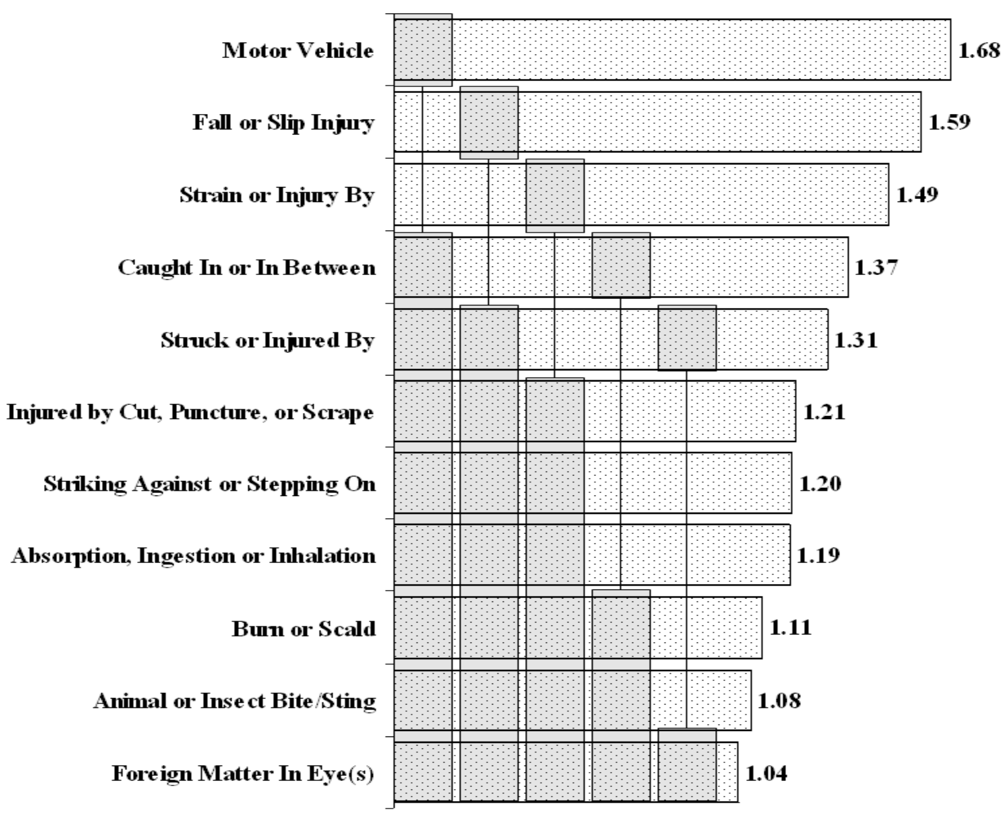
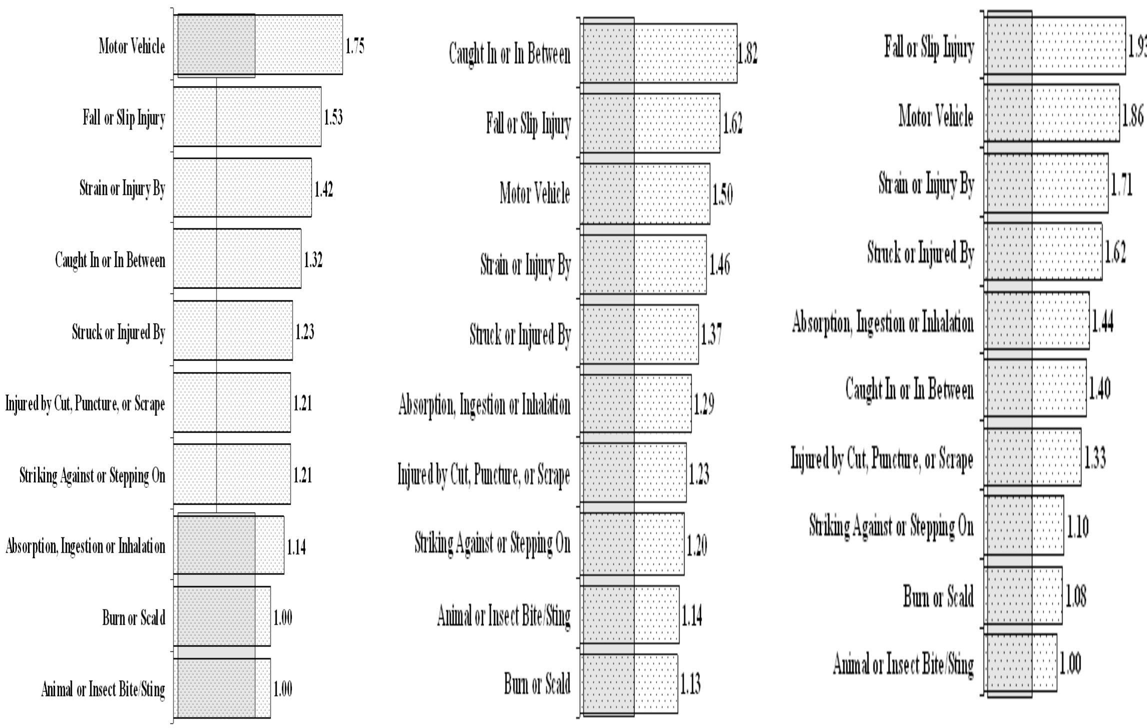


Figure 7. Differences of injury severity means between "General Cause of Injury" for all injuries to carpenters.

The Tukey's b range test could not detect significantly (at $p \leq 0.05$) different injury severity means between specific causes of injury for either neck nor trunk injuries to carpenters.

Contact with a motor vehicle caused the most severe UE injuries to carpenters. The Tukey's b range test did show that motor vehicle related UE injuries to carpenters were significantly (at $p \leq 0.05$) more severe than UE injuries to carpenters causes by either absorption of a substance, burning, or animal bites or stings (see Figure 8). The Tukey's b range test could not detect significantly (at $p \leq 0.05$) different injury severity means between specific causes of injury for neither LE nor MBPBS injuries to carpenters. Being caught in or between objects caused the most severe LE injuries to carpenters followed by injuries caused by falls or slips, or contact with a motor vehicle.



Upper Extremities Injuries **Lower Extremities Injuries** **Multiple Body Parts or Body Systems Injuries**

Figure 8. Differences of injury severity means between "General Cause of Injury", head, neck, trunk (top row) and upper extremity, lower extremity, and multiple body parts or body systems (bottom row) injuries to carpenters.(* Unable to conduct Tukey's b range test because one group had n < 2).

4. CONCLUSION AND RECOMMENDATIONS

The study's purpose was to demonstrate that data from a large provider of workers' compensation insurance could generate insights about the relative frequency and severity of various occupational injuries and diseases sustained by carpenters. The study examined data relative to worker experience levels, age, gender, job tenure, year, month, and day of the week of occurrence. With the slight exception of age, none of these demographic factors showed any significant impact on the severity of injuries to carpenters. Results suggested a possible association between age and the severity of an injury for all injuries to carpenters. The results of a Kendall's *tau* test for correlation between injury severity and the age of the injured carpenter indicated a slight, though significant, at $p \leq 0.01$, correlation of $\rho = 0.134$. Similar results were found for carpenters' neck ($\rho = 0.442$, $p \leq 0.01$), trunk ($\rho = 0.102$, $p \leq 0.01$), LE ($\rho = 0.156$, $p \leq 0.01$), UE ($\rho = 0.134$, $p \leq 0.01$), and MBPBS ($\rho = 0.221$, $p \leq 0.01$) injuries. The severity of head injuries to carpenters was not significantly correlated (at $p \leq 0.05$) with age.

Carpenters seem to have a greater likelihood of experiencing an occupational injury to the upper extremities than other construction workers. However, carpenters are less likely to experience neck, head, trunk, or MBPBS injuries than other workers. The injury severity profile of carpenters was similar to that of all the workers, with injuries to the neck and MBPBS showing the highest severity levels. However, where neck injuries may be the most severe among injuries to all the workers, injuries to multiple body parts or body systems may be at risk for being the most severe to carpenters.

Among all the injuries to carpenters, those to the fingers, lower back and eyes were the most frequent. Injuries to the heart, brain, vertebrae, spinal cord, pelvis, and disc were among the least frequent but were also among the most severe injuries to carpenters. Injuries directly impacting the heart, ranked as the most severe injury to carpenters, and were significantly more sever (at $p \leq 0.05$) than injuries to all other body parts except to the pelvis, which ranked second and spinal cord (3^{rd}). Other injuries to carpenters which are of potential higher severity levels included injuries to the discs, brain, body systems, knee, abdomen, and multiple body parts.

Injured carpenters are far more likely to experience specific injuries than either occupational disease (e.g., asbestosis) or cumulative injuries (e.g., carpal tunnel syndrome), or multiple injuries. Overall, carpenters' with multiple injuries risk having the most severe injuries. Results suggest that the most severe upper extremities injuries to carpenters will be those related to an occupational disease or cumulative injury; most likely a cumulative injury such as carpal tunnel syndrome or various repeated vibration disorders.

Among all the injuries to carpenters heart attacks (myocardial infarctions) are likely to have the most sever outcome, followed by ruptures, mental stress/disorders, carpal tunnel syndrome, amputation, and hernia. Each of these seems to have a relatively low likelihood of occurrence. However, among neck injuries to carpenters ruptures may exhibit a greater likelihood of occurrence and potential for high severity levels. This may be due to fact the neck is probably the most unprotected, by personal protective devices while at the same time the region highly prone to severe injury from minimal impact.

Overall, carpenters seems to be at the greatest risk of injury from being cut, punctured or scraped by an object, straining, a fall or slip, and from being struck by an object. Contact with a motor vehicle though infrequent causes the most severe injuries to carpenters. Falls or slips should be a high priority for design and prevention efforts since they are the fourth most frequent cause of injuries to carpenters as well as the second most lethal, behind contact with a motor vehicle, cause of injury to carpenters. Similarly, straining is the most frequent cause of injury to carpenters, especially trunk injuries, while generating the third most severe types of injury to carpenters.

These data provided information that is useful for surveillance purposes, documenting rates and allowing internal comparisons for groups of carpenters at known high risk of various types, causes, and agents of injury. As with any claims analysis, the findings are based on events that were reported. Anything that influenced whether a worker filed a workers' compensation claim will be reflected in the findings. No information was available about the time the worker was exposed to any given risk factor, such as tools, ladders, scaffold, and manholes. No details were available on the circumstances surrounding the injuries beyond what was available from the first reports, which could have been more revealing. For example, from the brief text-field descriptions the weight and dimensions of weighted objects, associated with lifting, straining or struck by injuries could not be determined, nor could the number of workers involved, or the site conditions. An accurate measure of total work hours was not possible.

Despite these limitations the methods allowed insight into the experiences of a group of construction workers, who are particularly challenging to study. The workers compensation data source provided events of interest and person-time at risk information over more than a decade, allowing the examination of patterns of injury and associated severity over time.

It is clear from these analyses that there are a group of activities, or tasks associated with particularly severe injuries among carpenters. The serious nature of falls from elevations is well documented among these workers (Sorock, GS, et. al., 1993; Dement, JM, et. al., 1999) but without incorporating severity data into the analyses of these injuries, circumstances associated with the more uncommon, but severe, injuries (e.g., ruptures to the neck) would not be noted. Engineered innovations could potentially reduce the frequency and severity of these injuries. Attention to adequate crew sizes, planning, training, and supervision would also be prudent.

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Agent assistance for interrogating safe and healthy methods of working.

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Keywords: Collaboration; Integration; Inter-disciplinary Teamwork; Safety, Construction Knowledge; Intelligent Computer Agents

Abstract

This paper outlines a decision support environment that actively supports collaboration during decision making and problem solving. A complementary partnership is formed between computer agents and human agents; the one bringing selected intelligence to the solution process from "unlimited" multi-domain knowledge sources, the other bring human cognitive rationality. In particular the system proposed articulates how domain knowledge and know-how can be shared thereby creating a truly integrated construction team. The author's investigation measured the views of practitioners in the main building professions; architecture, engineering and construction management before proposing the decision support system. The conclusion of the work is a conceptual model; a definition of the contractors' construction management computer agents and a specification based on scenarios of how these agents would interact with design agents. Apart from assisting the design process the decision support environment created will assist interrogation of the design in regard safety erection procedures and help reduce unsafe practices.

1 Introduction

Over the past decade a succession of strategic reports (Latham, 1994; Egan, 1998; UK National Audit Office, 2001) reported on the inability of the UK construction industry to deliver a high quality product to its clients at acceptable cost and within an acceptable time. In the USA (Wright, et al, 1995) also suggested that greater value should be offered to the clients of construction services. Their concerns centered on an industry that is under-achieving, recommending that substantial improvements in quality and efficiency were required. Central to the challenge is finding a better way in which all the key participants could work together with the client being core to the process. The improvements targets set for both the USA and UK construction industries are indicated in table 1:

Table 1 - Construction Sector Performance Improvement Targets for the USA and UK

Construction Sector Performance	USA		UK
	Target	Rank	Target
Total Project Delivery Time	Reduce by 50%	First	Reduce by 25%
Lifetime Cost (Operations Maintenance Energy)	Reduce by 50%	Second	
Productivity and Comfort Levels of Occupants	Increase by 50%	Fifth (equal)	Improve by 20%
Occupants Health and Safety Costs	Reduce by 50%	Sixth	
Waste and Pollution Costs	Reduce by 50%	Fifth (equal)	
Durability and Flexibility in Use over Lifetime	Increase by 50%	Third	
Construction Worker Health and Safety Cost	Reduce by 50%	Fourth	
Costs			Reduce by 30%
Construction Quality			Zero Defects

The source of this information is: USA – Wright Rosenfield Fowell; UK - The Engineering and Physical Science Research Council's Innovative Manufacturing Initiative Programme.

To achieve these improvements deficiencies will have to be found throughout the supply chain.

2 The Design Process

To understand how to build an effective decision support environment we need to first understand how architects, engineers, construction managers and all the other inter-related construction disciplines carry out their work. What are their processes? How dependent is one disciplines process to another or how reliant should it be to get to the best solution? How can they be best supported? What do they need?

Building design is a complex group problem solving process that Whitney (1990) describes as involving the simultaneous evolution of both the requirements and the artifact specification. However design-in-practice consists of many additional problems such as requirements analysis, negotiation, communication and conflict resolution.

Fundamentally the process of design is a complex activity involving a number of tasks that are generally broken into sub-tasks, with a number of alternative methods potentially available for each sub-task. Those design tasks are driven by certain input parameters, goals, preconditions, to produce some output parameters, e.g. layout, resources, constraints, etc. Chandrasekaren (1989) proposed that design be defined as a hierarchy of sub-tasks that can be solved by conducting a task analysis. A task-structure is then developed that lays out the relationship between tasks, applicable methods for solving the task, the knowledge requirements for the methods, and the sub tasks generated.

How to break the design activity down into tasks forms a key area of research in task-oriented methodologies especially for knowledge-based systems and can be referenced in Pohl (1993) work who concluded that the architectural design process could be characterized by five functional elements:

- Information - a search for proper information that includes past experience of other projects;
- Representation - the methods and procedures designers utilized to solve design problems relied on their ability to identify, understand and manipulate objects. Objects have a representable form that encapsulates knowledge that is conveyed as factual data, algorithms, rules, exemplar solutions and prototypes.
- Visualization - is important since traditionally some form of graphic media is used to convey design intention; generally this is in the form of drawings. Drawings however are often inadequate in portraying information and can lead to erroneous conclusions, with many misinterpretations and inappropriate conclusions resulting.
- Reasoning - that is central to the design activity. The ability of designers to solve problems is dependent on their interpretation of the issues and the dynamic changing relationship between these issues.
- Intuition - which in the design process is often the spontaneous reaction to a thought process that diverts too many areas of the human brain.

It is within these five areas that the partnership between machine and human agents could be one that each is complimented by the strengths of the other in an intelligent way. Humans use complex cognitive skills whereas machines are indefatigable in their mechanistic search for information that they can then bring to the decision environment.

Intelligence in the context of this work implies that the design system has some means that allows it to anticipate the data needs, information needs or knowledge needs of the human designer. The system would act as an intelligent assistant to the evolving design, aiding the designer and freeing them from being overwhelmed with untimely knowledge. Providing such assistance to all problem solvers in the design environment requires an understanding of the various participants' knowledge, factors that constrain their decisions and criteria they work under. Pohl (1993) called this an Intelligent Computer Assisted Design System (ICADS).

The ICADS approach is supported in several working models (ICADS-DEMO1 (Pohl, 1989), ICADS-DEM0 2 (Pohl, 1991), AEDOT (Pohl, 1992). These have provided computer scientists with a useful test bed for the development of a body of knowledge relating to software and hardware computer architecture, theoretical concepts and technical implementation issues. By linking the design objects to information they represent (e.g. functions, relationship to other objects, cost) the information value of drawings can be significantly increased. This information could be contained as attribute data in relational databases. Advances in the object-oriented modeling paradigm advanced this concept. Having this ability to view the artifacts used in the design model as a series of objects, which have implicit attributes and features, gives scope to analyze the design with regard to such aspects as manufacture, constructability, cost, quality, safety, etc. Almost unlimited definition of machine agents could be specified that are the caretakers of knowledge pertaining to most of the constraints and criteria related to a new building project.

3. Team problem solving

Team problem solving is characterized by more than two people being involved in attempting to reach a collective decision, each with their own perceptions, expertise and commitment towards that problem which they all recognize in varying degrees. However, many problems solved in construction are resolved by a single domain rather than an inter-disciplinary team. Architects and engineers are used to working in relative isolation when proposing a solution. Construction Managers on the other hand make their decisions based on a team approach. This is well documented and construction industry research efforts over the past twenty five years have sought to find ways of effectively integrating project decision making into a team approach with timely knowledge support across all the building professions associated with a project from start to completion. ‘Buildability’ and ‘Constructability’ are terms used in earlier attempts, then came a wave of expert system shells, then intelligent computer agents. The one common purpose was to find ways to share domain knowledge thereby developing a more cost effective solution; solutions that are developed concurrently across multi-disciplinary teams rather than sequentially by isolated domains.

The research carried out by the author, Jones (2004, 2003, 2002, 1998, 1995), conceptualized such an environment. In it the inter-disciplinary team could be supported by computer agents to work towards building solutions in a collaborative way. The human/machine environment would be used to fully consider issues that effect bringing the best solution based on best practice to the client; issues such as production, quality, safety, cost, environmental factors, life-cycle effectiveness, performance, etc.

4 Collaborative Agent Partnerships

The advances in the concept of an object as a high-level information source led to the paradigm of object-oriented modeling and the development of object-oriented computer languages. The premise is that a crucial element in the decision making process that human designers utilize to solve problems is the reliance they place on their ability to identify, understand and manipulate objects, e.g. architects develop solutions by reasoning about location, sites, buildings, floors, spaces, walls, windows, doors, and so on; the contractor does likewise.

Each of these objects encapsulate knowledge about its own nature, its relationships with other objects, its behavior within a given environment, what it requires to meet its own performance objectives and how it might be manipulated by the designer within a given design problem scenario. This knowledge is contained in the various representational forms of the object (e.g. factual data, algorithms, rules, etc.).

Within the computer agent environment proposed by the author; problem solving is seen as a co-operative process with mutual sharing of information across an inter-disciplinary project team to produce a solution. The resulting project solution is seen as an assembly of construction objects, e.g. bricks, walls, floors, windows, etc., to satisfy project specific criteria, e.g. quality, environmental, cost, safety, etc.

Whereas, objects are information entities only, computer agents are active and have knowledge of their own nature, needs and global goals. Objects are therefore accessible by agents but cannot take action. However, for the system to interact effectively between the interactive project team there has to be a full description of the objects. This description should resemble as closely as possible the designer's real world by including the objects physical appearance, attributes, context and relationship to other objects.

Within the computer environment the "agents" also have the ability to communicate and take action. Typically, each agent is represented at a level of detail sufficient to facilitate the project team's decision making. The frames in such a project model could represent geometric, physical and administrative attributes of a project's components together with their topological structure. All of this information about the structure of a project and the local values of its component attributes are then available in a representation easily accessible by computer tools for solving or assisting with design and production tasks.

5. Construction Computer Agents

There is an inevitable need for interaction between all the participants who input to complete the final project. Pohl (2000) suggested that the computer system should reflect the more realistic situation of a team that interacts by co-operation and persuasion. The concurrent engineering concepts apply here. Therefore, complete families of computer-agents that represent a particular domain could be built e.g. architect, interior designer, civil engineer, landscape architect, safety manager, quality manager, environmental manager, mechanical and electrical engineer, construction manager, project manager, etc. and within each family specific agents would monitor and offer assistance regarding criteria and constraints imposed in the areas of environmental, quality, safety, cost, production time, etc. For instance there could be a 'Safety' agent residing in a number of domains i.e. Architect, Engineer, Construction Manager, Project Manager, Quality manager, each would be representing the criteria and constraints of that domain.

It must be stressed that project solution development assisted by computer agents is not intended to automate the design process. Agents would initially assist the designer in the partnership by acting as co-operative search agents having the ability to liaise with knowledge bases in the search for alternative solutions. They are evaluators and solution proposers acting as system agents who operate in a defined domain. They exist to first express opinions about the current state of the design solution. The intention is to change incrementally the current state of the design through the interaction among the various agents within the environment. As pointed out previously this environment would include representation from all the built environment disciplines, agencies and client. This interaction enriches the environment with information about the current design state and how it relates to the project requirements. It should support the project team by providing adequate information about the current design state, its design objects (i.e., data-objects and object-agents), their relationships and how they satisfied the various project criteria and constraints.

Each agent would provide two kinds of support; intermittent foreground responsiveness to requests for information initiated directly by the designer and other members of the project team, and continuous background monitoring that evaluates the evolving design/project solution. Operating in such an environment would be computer agent types that include: expert-agents; query-agents; co-ordination agents; activation/ deactivation – agents; CAD-agents; designer as agent; application support agent and the human agent (Pohl, 1994).

The human agent's role in such an environment is seen as:

1. Evaluating the current state, independently or with the support of other agents,

2. Participating in the process of changing the design state by manipulating the design objects, i.e. introducing new data-objects to the CAD environment, modifying attributes, etc.
3. Modifying the design goals if seen necessary,
4. Directing and guiding the effort of the other agents to advance the current state towards an acceptable design.

In such an environment the facilitator's role would be one of searching, evaluating and modifying initially the current design state with the support of different domain computer agent families (Jones, 1994). In this process the facilitator would direct and guide the efforts of all computer agents to advance the current state of the project solution towards a best design and construction process that is acceptable to all domains computer agents' and the inter-disciplinary project team. The role of the designer or project leader would be that of principal long term or strategic planner while agents would focus mainly on short-term activities. Families of computer agents and objects would represent each domain and their problem solving activities associated with the design and production problems of a specific project. As other problems arise so the agent environment would extend or should the project be of a different construction then a new agent family would be appropriately designed. An agent hierarchy in the domain of Construction Management is shown at the end of this paper. Sub-tasks resulting from decomposing the problem would be distributed to different domain agent families with the intention that these agents assist the human agent. We can see clearly how 'Safety' agents can be used in this environment.

Each domain family of agent would operate in a narrow domain providing support to requests for assistance. Agents would range from simple to complex processing units each rationally working toward a single global goal or towards separate individual goals that interact. Acting independently in a self-regulating manner their common purpose is to change the current design state towards meeting a common set of goals. The goals are set by the human agent(s) with advice from various autonomous agents that include agent representation of the client.

Agents would use their local expertise and available resources to work in parallel on different or co-coordinating tasks to arrive at a solution by searching knowledge bases for alternative solutions; evaluating to express opinions about the current state of the design solution; background monitoring and evaluation of the evolving design solution; carry implicit domain knowledge, knowledge of their own needs, knowledge of global goals, the ability to communicate and the ability to take action; represent the level of detail at which the design facilitator or human agent wishes to reason about the designed system.

6 Conclusions

The integrated partnership environment proposed is one that fully utilizes the strengths of a multi-agent collaborative computer environment and the human domain built environment experts. A total project decision making and problem solving environment, where the knowledge and intelligence of all domain-contributing agents can be used to create better opportunities to arrive at the project solution. All contributors to the project are collaboratively drawn into the design process and then continue through all phases of the project life-cycle. Time is saved because a concurrent problem solving approach is adopted rather than a sequential problem solving approach. Experts can still be geographically or functionally distributed taking advantage of recent advances in technology in communication systems (co-operative distributed, broad band, etc.). Importantly, the environment proposed could be extended to continually monitor and assist decision making throughout the life cycle of the project.

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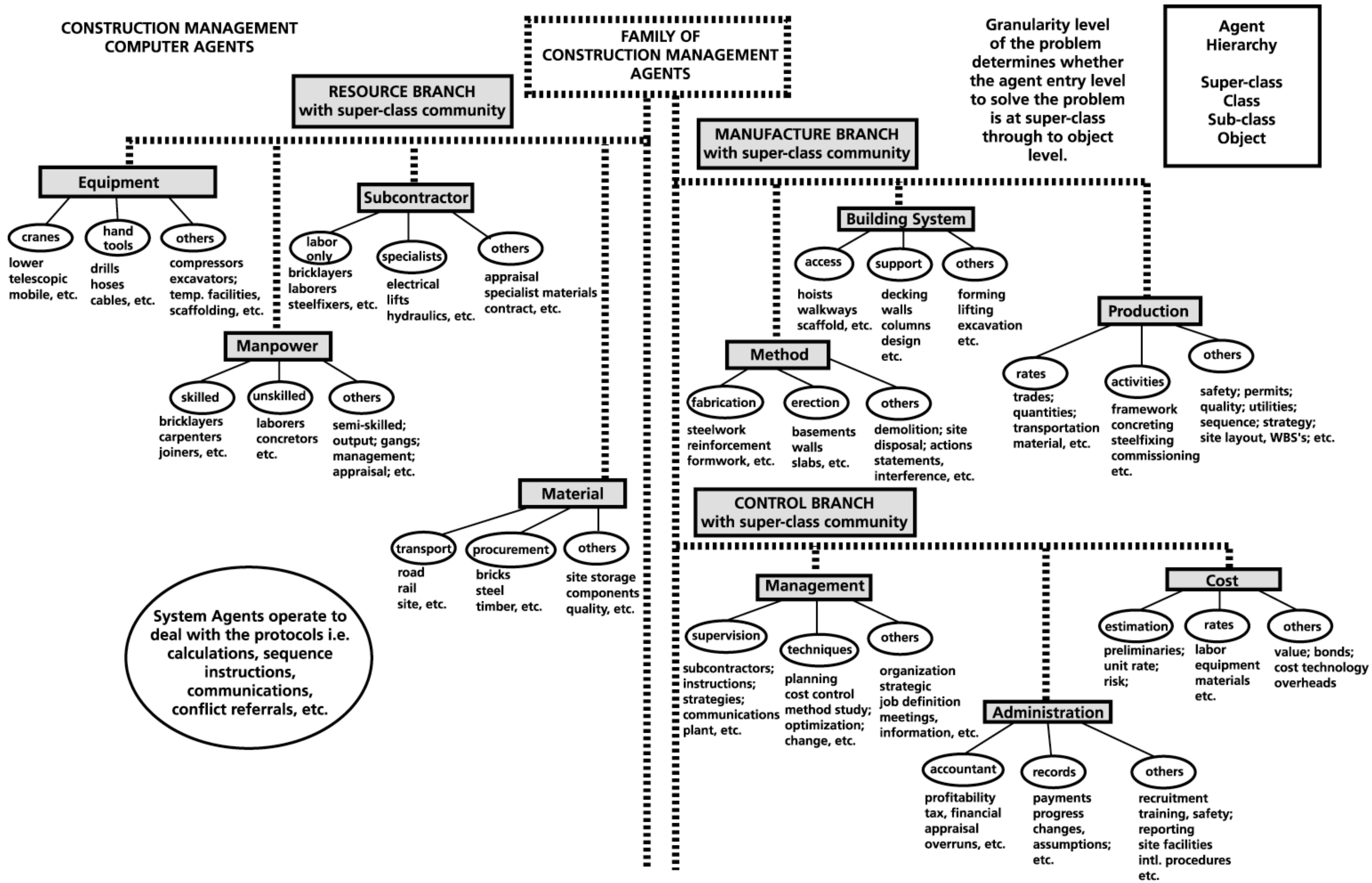
CONSTRUCTION MANAGEMENT
COMPUTER AGENTS
FAMILY OF
CONSTRUCTION MANAGEMENT
AGENTS
Granularity level of the problem determines whether the agent entry level to solve the problem is at super-class through to object level.
Agent Hierarchy
Super-class
Class
Sub-class
Object
RESOURCE BRANCH
with super-class community
Equipment
cranes
lower
telescopic
mobile, etc.
hand tools
drills
hoses
cables, etc.
others
compressors
excavators;
temp. facilities,
scaffolding, etc.
Subcontractor
labor only
bricklayers
laborers
steelfixers, etc.
specialists
electrical
lifts
hydraulics, etc.
others
appraisal
specialist materials
contract, etc.
Manpower
skilled
bricklayers
carpenters
joiners, etc.
unskilled
laborers
concretors
etc.
others
semi-skilled;
output; gangs;
management;
appraisal; etc.
Material
transport
road
rail
site, etc.
procurement
bricks
steel
timber, etc.
others
site storage
components
quality, etc.
System Agents operate to deal with the protocols i.e. calculations, sequence instructions, communications, conflict referrals, etc.
MANUFACTURE BRANCH
with super-class community
Building System
access
hoists
walkways
scaffold, etc.
support
decking
walls
columns
design
etc.
others
forming
lifting
excavation
etc.
Method
fabrication
steelwork
reinforcement
formwork, etc.
erection
basements
walls
slabs, etc.
others
demolition; site
disposal; actions
statements,
interference, etc.
Production
rates
trades;
quantities;
transportation
material, etc.
activities
framework
concreting
steelfixing
commissioning
etc.
others
safety; permits;
quality; utilities;
sequence; strategy;
site layout, WBS's; etc.
CONTROL BRANCH
with super-class community
Management
supervision
subcontractors;
instructions;
strategies;
communications
plant, etc.
techniques
planning
cost control
method study;
optimization;
change, etc.
others
organization
strategic
job definition
meetings,
information, etc.
Administration
accountant
profitability
tax, financial
appraisal
overruns, etc.
records
payments
progress
changes,
assumptions;
etc.
others
recruitment
training, safety;
reporting
site facilities
intl. procedures
etc.
Cost
estimation
preliminaries;
unit rate;
risk;
rates
labor
equipment
materials
etc.
others
value; bonds;
cost technology
overheads

The Impact of the Influx of Illiterate and Foreign Construction Workers on the Effectiveness of Construction Safety Induction in South Africa

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Abstract
The South African construction industry is experiencing an increase in immigrants, many of whom are illiterate. Furthermore, South Africa has 11 official languages which create a problem of communication within the country. This study investigated whether or not there is a direct link between the language biases of the population in question and the occurrence of incidents on construction sites. If so, what recovery measures are recommended to eradicate the bias related to the foreign/illiterate workers when conducting safety inductions?

The study involved safety officers and construction workers. Interviews and questionnaires were employed for data collection that included 101 questionnaires administered and 5 interviews with safety officers. The potential limitations of the study include untruthfulness of the respondents due to fear and confidentiality of information. Data were analyzed using simple statistical methods.

Though initial findings show about 19% of the general workers are foreigners, the study could not conclude that there is any apparent link between accidents on sites and the language biases of the population in question. It was however revealed that there is a lack of commitment and dedication on the part of the employers concerning safety induction given to the workers. Large companies adhere strictly to safety practices but subcontractors do not. Medium and small contractors do not fully comply with safety rules because they think their projects are less hazardous. Therefore safety induction advocacy should be directed at small and medium contractors.

Keywords: Illiterates, foreigners, construction workers, safety inductions, small and medium enterprise, South Africa.

1. INTRODUCTION

South Africa is currently faced with the problem of high illiteracy level among the vast majority of her indigenes. This problem can be traced directly to the impact of the inferior education offered to the black majority of South African population during the abolished apartheid regime. The problem is worsened by massive influx of immigrants from neighboring countries who have less or no education seeking greener pastures; most of which end up either as general workers or sometimes skilled workers in the construction industry.

1.1. The diversity of language and culture in South African construction industry

According to census 2001, the population of South Africa was at 44.8 million which was an increment from 1996 statistics of 40.5 million. South Africa's races are comprised of black Africans constituting 79%, whites 9.6%, Asians/Indians 2.8% and coloureds at 8.4% in total. There are eleven official languages; IsiZulu being the most commonly spoken first home language with a percentage of 23.2% followed by IsiXhosa 17.6% and Afrikaans 13.3%. English comes fifth with 8.2% (Van Wyk, 2003). It has been found that almost one in every five South Africans aged 20 years or more have not received formal education. Furthermore black Africans have a rate of 22% of people aged 20 years who have received no education. This leads these people into primary industries such as agriculture, mining and construction and as a result become victims of deadly accidents and injuries (Van Wyk, 2003). This is supported by Brunette (2004), who asserts that fatality rates for Hispanic workers in the construction industry in the United States have been higher than the overall national fatality rate. He further argues that to date, very little construction safety and health research has been conducted among Hispanic workers.

It is believed that within South Africa, the number of non-citizens in the country has escalated since 1990 (Crush and Williams, 2001). The migration of non-citizens from most of the African countries has increased the population of the country. The number of such immigrants is not known, since most are illegal immigrants (Ellis, 2001). Crush and Williams (2001) citing Rogerson (1998) states that the construction industry, originally the preserve of Zimbabweans, is increasingly dominated by illegal Mozambicans recruited in South Africa as casual labourers.

The prominent reason of employing immigrants is that South African employers tend to prefer non-south African workers, who are considered hard-working, excellent workers, more disciplined and well-behaved. These migrant workers, primarily Mozambicans, are recruited by labour brokers in Gauteng and the City of Cape Town, for long-distance migrant labour in the city's booming construction industry (Crush and Williams, 2001).

It is a known fact that foreign employees immigrate to developed or developing countries in search of greener pastures. According to McConnell (2004) one of the reasons that so many foreign workers are being seen in the construction industry is due to labour shortage. With the boom currently experienced by the South African construction industry, the phenomenon of immigrant workers with its associated problems is bound to persist for some time; there is therefore need to understand how to forestall its consequent effect on health and safety.

1.2. Effect on Construction Health and Safety

One of the major effects that migration has in the construction industry is visible through non-compliance with OHS (Occupational Health and Safety). This was reported by the Department of Labour based on inspections that were conducted. Among provinces visited were Kwazulu-Natal, Free State, Western Cape and Gauteng North. Out of the 412 companies visited in greater Johannesburg (Gauteng province), 293 were found to be non-compliant with health and safety standards. The common areas of concern to the inspectors were the lack of health and safety plans, unavailability of risk assessment on site, failure by management to train workers in health and safety issues and workers not being provided with protective clothing (Department of Labour, 2007).

In an article from the department of work, in the University of Massachusetts, Brunette (2004) said: "Foreign workers come to the United State with poor understanding of health and safety, little or no participation in building (or other) trades and little or no governmental enforcement of safety regulations". Certain work related experiences in their countries of origin will also be a key determinant of these workers' level of safety awareness. These include working under poor physical environment and little or no safety and health training (Brunette, 2004). Most workers end up not reporting levels of both fatal and non-fatal injuries in an attempt to keep positive relationships with employers and also for protection purposes because some of these workers are illegal in the country (Brunette, 2004).

Vazquez (2006) citing Crockett, (2004) stated that another factor that contributes to higher fatality rates among foreigners is the fact that illegal immigrants are willing to work for less pay and work in the most dangerous conditions, as long as they do not loose their jobs. Moreover foreigners tend to be loyal subordinates and look after the group's interests rather than individual interests, if accidents might happen to one member; it might not be reported to protect the whole group (Vazquez, 2006). Foreign workers respect their employers because of the power they possess, resulting in accidents or hazards at the work place being reported by the workers, because it might provoke an unfavourable opinion from their employer. This happens to be one of the reasons that increase the risk of hazards among foreigners.

2. CONSTRUCTION SAFETY LEGISLATURES

Safety is the most dominant issue in construction and legislatures are deployed to enforce it. OSHA (Occupational Safety and Health Act) is to ensure that employers follow necessary protocol to create safe environment in all hazardous areas of work. The Act further emphasises the essence of employee education pertaining to safety of the working environment regardless of weather the employee is educated or not, illiterate or foreign. Failure to comply with the Act could result in legal prosecution of an employer by the state authorities (Hinze, 1997). The Act further stipulates duties of the employer described in "section21- safety training and education" which describes how safety inductions (Toolbox talk) should be conducted on reasonable intervals to ensure adequate understanding of safety regulations (Hinze, 1997).

In South Africa, Fester and Haupt (2006) citing Haupt (2003), the OSHAct: Construction Regulations published in Government Gazette No 25207, Regulation Gazette 7721, 18 July 2003 (CR), heralded a welcome and overdue departure in particular from previous approaches to the management of construction safety and health; providing the catalyst for a new approach (Smallwood and Haupt, 2005). The emphasis of the act is on hazard identification and risk assessment prior to the execution of construction activities (Fester and Haupt, 2006). In the words of Haupt (2005), "all parties are encouraged to eliminate risks at source, reduce exposures to risks, or protect against the consequences of unavoidable risks". The only ways to adhere to this advice of course is through appropriate safety induction and training.

OSH Act, according to Davies and Tomasin (1996) stipulates the general duty of the employer is to provide safety instruction and training as is necessary to ensure the health and safety for employees at work.

2.1. Safety Training

Laney (1982) stated that each person starting a job should be instructed to do safety induction properly. Instructions can be learned by practicing, and it will be necessary for the supervisor to acquire this skill and then pass it on to junior supervisors, trades foreman and work gangs, as they will be involved with the day-to-day job instruction of the operatives. According to Laney (1982), "accidents happen to, and are caused by people". He further stated that much can be achieved in preventing accidents by bringing about a change of attitude on the part of the workforce and by giving them a better understanding of the root cause".

Davies and Tomasin (1996) recommended that the basic introduction to health and safety should last for at least 2 hours and should include visuals aids, slides and possibly a film (motion picture). He further stated that it is the employer's duty to indicate if certain training procedures are vague or training was never received. Holt (2001) stated that three conditions need to be present for any safety training to be successful: the active commitment, support and interest of management, and the management team must also demonstrate support by setting good examples. Furthermore, trainers must be qualified to answer questions on the practical application of the knowledge in the working environment, which will include a formality with work practices, procedures and rules.

According to Hinze (1994), training should be at the core of every safety program. It is important first to identify the areas in which training is required; the most important training that can take place is the orientation of new hires. This can help the trainers to get to know the employees and their level of understanding in terms of the construction industry. Holt (2001) also recommended that newcomers to projects should receive induction before they start work, as it has been found that new arrivals are statistically the most likely to be injured soon after starting work.

2.2. Language of Safety Training

Brunette (2004) argued that English is not the first language of foreign workers and their understanding of educational materials about safety at work will be significantly lower in comparison with native English speakers. Moreover this problem is aggravated by the fact that a small, but significant portion of foreign workers are illiterate and speak only their own language. Furthermore, the author suggested the use of a worker's participatory approach when developing safety and health training materials for foreign workers. Also, because most workers in the construction industry are foreign, it becomes a challenge to the management and safety officers to create induction procedure to suit their workforce. The involvement of workers in the design, development and continuous evaluation stages of training methods is important considering that creative thinking can come from the workers themselves.

In the words of Vazquez (2006) ;
"*Language places foreign construction workers at higher risk of injury or fatality in the workplace. In the years to come, the growing foreign population will shape the construction industry's labour force and failing to recognise these changes may have serious consequences for the profitability of contractors and increases in insurance premium"*.

According to McConnell (2004), however, the level of English proficiency is not a main cause of incidents on site In fact the more English proficient one is the more likely to suffer site injuries than their counterparts, the foreigners. He however acknowledged the fact that if identical research is undertaken by somebody else looking at different companies and populations the finding might be slightly different from his findings.

3. METHODOLOGY

Nine construction companies were randomly selected within the Johannesburg area, for the purpose of the research. Five companies; 2 large, 2 medium and 1 small sized companies were willing to participate in the study.

Questionnaires were administered to construction workers from each of the five companies. Since most of the workers are either illiterates or foreigners, interpreters were employed when necessary. The main purpose of this questionnaire was to gauge their understanding of safety rules, particularly the workers who are illiterate and/or foreigners. The total number of respondents was 101 construction workers. The 5 safety officers, one from each company were further interviewed. The aims of these interviews were; to understand the safety induction methods employed on their particular sites, establish whether foreigners and illiterate workers need special or extra safety induction, understand how the issue of foreigners is addressed, and also to investigate its impact on injuries occurring on site.

Data obtained from completed questionnaires and interviews were analyzed and summarized and the findings tabulated where necessary in order to draw relevant conclusions and recommendations.

4. FINDINGS

4.1 Responses from construction workers

Demography of respondents

From all sites visited the youngest worker interviewed was 18 years old and the oldest was 65 years of age. Five percent were female and 95% were male. From all responses received, the construction workers comprised mainly of South Africans, Mozambicans, Zimbabweans and Malawians. Foreigners accounted for 19% of the sample and 81% were South Africans. Out of South African workers, 13% were Sotho related, 71% Nguni, 7% Venda, and 9% Tsonga. The summary is shown in figure 4.1 below.

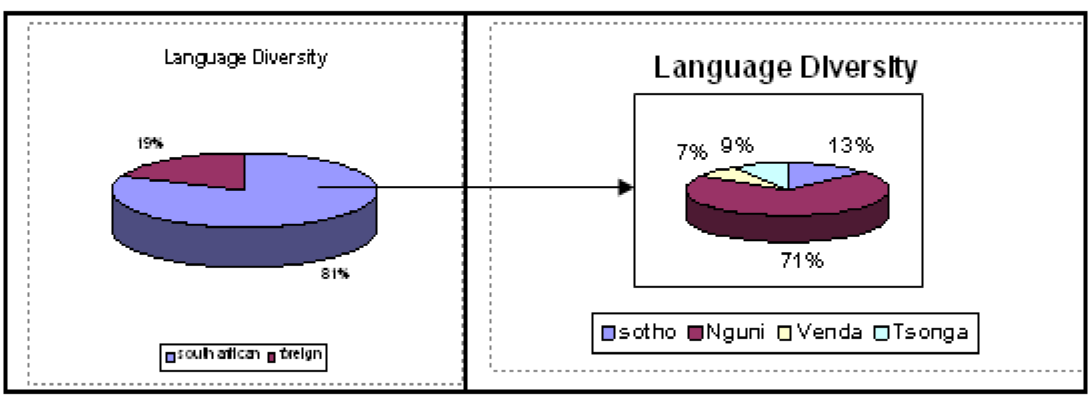

fig.4.1 – Language Diversity

Educational background

The level of education of the workers was classified into: poor, average and good. Workers with no education up to grade 7 were categorized as poorly educated; those between grades 8 and grade 10 was categorized as average; while workers with grade 11 and above were regarded as having good education. Workers considered to have poor education were 20%, while 34% and 46% were considered to have average and good education levels respectively. See fig. 4.2 below.

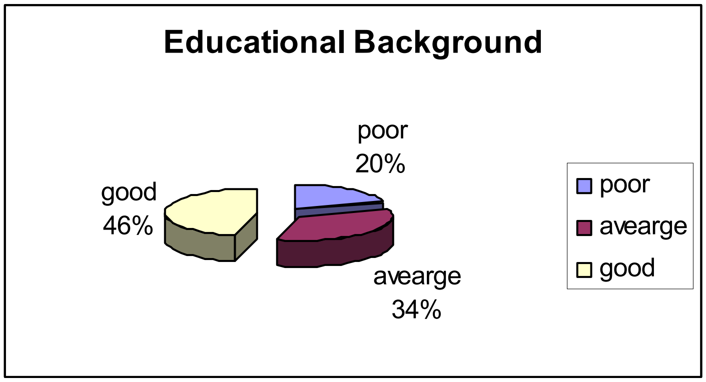

Fig.4.2 – educational background

Skills and experience level

Sixty two percent of workers interviewed were skilled and the remaining 38% were unskilled. Unskilled included cleaners, assistants, tee lady etc, while skilled workers included plasterers, bricklayers and carpenters. Experience wise, 42% of the respondents had worked for less than a year in construction industry, while 22% had 3 years experience and 36% had 5 years or greater experience.

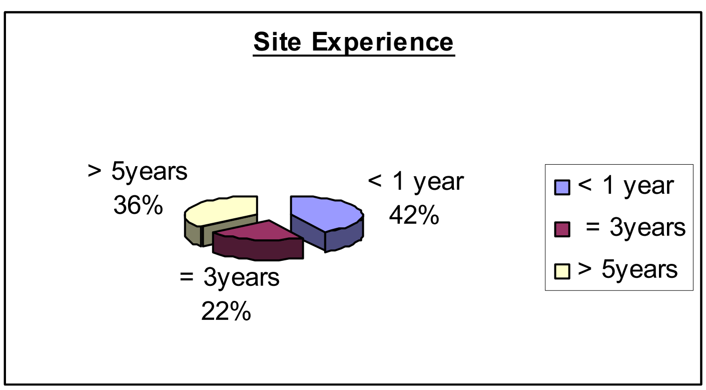

Fig.4.3 - site experience

Safety induction and practice on site

All workers interviewed confirmed that they were aware of Toolbox Talk but 81% had received safety induction training. Those who received training (50.5%) highlighted the fact that they received their induction in English, and 49.5% stated that various languages were used to conduct induction. Asked whether they understood the induction, they responded as follows:

Yes	No	Average
86%	7%	7%

Sixty six percent of workers believe that the method used to conduct safety induction training require educational background to adequately understand induction. Thirty four percent of other workers believe that with little or no education the contents and procedure of safety inductions are clearly understandable.
Safety training should be carried out as often as possible. The respondents indicated the frequency with which training is conducted on their sites as follows:

Weekly	Monthly	Quarterly	Yearly
75%	19%	2.5%	3.5%

When asked what significant improvement they would like to see happening on the safety induction the response was as follows:

- Different languages should be used when conducting safety induction
- The employer should encourage or keeps on reminding them to work on maintaining a safe environment at all times.
- Safety officers should be appointed to regularly check the workers while working e.g. alert them every time the crane is moving towards them.

The safety laws clearly state that the employer should provide, free of charge to his workers, personal protective equipment (PPE). However, 77% of the respondents stated they received all the necessary PPE from their employers while 19% didn't receive any at all.

4.2 Responses from safety officers

The safety officers interviewed expressed that on average, 40% of construction workers on their sites are either illiterates or foreigners. They however expressed that they have no language barrier in dealing with the variety of workers.

Safety induction & practice on site

Three of the five safety officers stated that safety induction on their sites is carried out in various ways but mainly through physical lectures and demonstrations and sometimes issuance of safety pamphlets and viewing of motion pictures.
However, two other safety officers stated that they mostly use motion picture and the display of warning signs as it portrays real case scenario. They believed that the use of real case scenarios would better aid the worker in remembering safe work practices and recognizing safety hazards.

All the safety officers stated that safety inductions were conducted before any worker commenced work on site. Two of the 5 safety officers further stated that safety induction was conducted for workers prior to commencing any new activity on site.
The language mostly used by the safety officers to address the workers was English, and translators helped to solve the language diversity problem. The challenge being faced, according to the safety officers, is that while the OSH Act stipulates that all workers be educated on safety, the Act offers limited clarity on how to deal with the issues of illiteracy and/or foreigners.

Safety officers believe that the safety induction discussed above is not necessarily adequate. Tool box talks, regular meetings and warning signs etc. should always be available to workers to constantly alert them to safety related issues. Generally, it was stated by all the safety officers that while every worker is susceptible to accidents on site, foreigners and illiterates are more vulnerable.

5. CONCLUSIONS

South African construction industry is governed by the OSH Act which clearly outlines the duties of the employer concerning safety procedures. The Act however does not discuss the procedure for conducting safety inductions when illiterate and foreigners contribute to the workforce. It leaves method for the implementation of safety to the employer. From the sites visited it is apparent that the big construction companies have more regimented and established safety programs as compared to medium and small companies. Subcontractors tend to relax safety rules while they focus mainly on work execution. The OSH Act stipulates the responsibilities an employer has for the appointment of a safety committee, but it was determined from the sites visited that medium and small companies tend to ignore those regulations because they regard their projects to be less hazardous.

From the study, it was determined that there is no apparent illiteracy impact on construction safety, though there is less attention given to the problem of illiterates and foreigners in construction. Nineteen percent of the workers are foreigners. In total, 20% have less than grade 7 educations; 54% have less than grade 10 educations, and 42% of the workers have worked for less than 1 year in construction.

Employers try to maximise profit by spending less on safety systems and by employing foreigners (some illegal) and illiterate workers. Although safety officers seem to have less problems with South African workers as far as interpretation is concerned, there is a communication problem with foreign workers. Contractors fail to appoint interpreters or safety representatives to accommodate foreigners; they rely merely on their low level of South African language proficiency.

Literacy and nationality are not the main determinants of accidents on site; however, it is safe to conclude that illiterates and/ or foreigners understanding of safety is not satisfactory. Although behaviour and attitude mostly contribute to thoroughly understanding safety rules, education can also have a great impact.

The following recommendations are made from this study:

- The OSH Act is active but there is a need to amend it as far as training and education for illiterates and foreigners are concerned.
- If the entire safety committee can be outsourced at the expense of the contractor, safety induction can improve.
- Adequate incentives should always be available to the workers in order to stimulate their participation when it comes to safety issues.
- The method of conducting safety induction should be reviewed to cater to the illiterate workers by using video presentation.

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The compensation mechanisms made available to injured workers on site: A study of SME contractors in South Africa

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Abstract

The South African construction industry is currently experiencing a boom. Statistics however show that there is 1 injury per 22 workers in South Africa and an average employer pays around R53, 000 in workers' compensation assessment tariffs per annum (MDA, 2001). With the increase in construction activities, there is likely a higher level of accident occurrence on sites. This paper presents the results of an exploratory investigation into the effectiveness and /or efficiency of a mechanism of compensation to injured workers on construction sites in South Africa. The study also ascertained whether the workers on site are knowledgeable about the workings of the compensation mechanisms.

The study applied a combination of both quantitative and qualitative methods of research. Two sets of questionnaires were administered to contractors and construction workers from 15 different small and medium companies operating within the Johannesburg metropolitan area. The data were analyzed using simple statistical methods.

Results show that though the mechanisms are effective, they are not efficient due to poor accident reporting on site, low levels of worker literacy, and the fact that most workers are from the homelands. The study elucidates on how these factors affect efficiency of the mechanisms. It was also discovered that knowledge of the workings of the compensation mechanisms is very limited for both workers and employees. Recommendations on improvement are suggested.

Keywords: Compensation mechanisms, construction industry, injured workers, SME, South Africa.

1. INTRODUCTION

1.1 Background Information

Workmen's compensation laws have existed since the beginning of the century. Initially, in South Africa, various provinces passed their own workmen's compensation legislation, such as the Workmen's Compensation Act 36 of 1907 of the Transvaal. Over time, these acts were repealed. The current statutory regulation in South Africa is covered in the '*Compensation for Occupational Injuries and Diseases Act 130 of 1993'* (COIDA).

According to the Act (COIDA), the construction industry employer is expected to register with and contribute to the Compensation Fund as a form of insurance for workers. Workers' compensation insurance is closely associated with employer's liability insurance and accident prevention. Employer's liability deals with civil claims being brought by an employee against his or her employer.

Besides insuring with the Compensation Fund, the employer can choose to take out coverage with the Federated Employers Mutual Assurance Company Limited (FEMA). FEMA was formed in 1936 by the building industry as a mutual insurer to ensure compensation liability of employers in the industry. It is one of only two mutual insurers granted a license to perform compensation functions by the government, the other being the Rand Mutual which is for the Mining Industry. FEMA thus operates as a supplement to the Compensation for Occupational Injuries and diseases Act 130 of 1993 (COIDA). According to the Act (COIDA), employers who are covered under FEMA do not need to pay assessment tariffs to the Compensation Commissioner and are regarded as 'employers individually liable.' Construction industry employers in South Africa thus have an option of either insuring with the Compensation Fund or FEMA.

It might therefore be worth stating that proper legislation for workman's compensation has been adequately enacted to cater for the wellbeing of construction workers in South Africa. A few questions are however plaguing the mind, which prompted this study: are the current compensation structures effective? Are the workers aware of the way the compensation mechanisms work? Do the workers have access to the required compensation when necessary? Would there be a benefit to the workers and the entire industry if there is an increase of worker awareness about the compensation mechanisms?

According to Mda (2001), every year in the workplace about 27000 workers get permanently disabled, 2200 fatalities take place, 1100 workers are blinded and about 250000 workers are exposed to noise leading to deafness. There is 1 injury per 22 workers per annum in South Africa. In other countries like Germany however, the rate is 1 injury per 7000 workers per annum. In USA (Ahmed et al, 2006), the accident rate in construction is reported as the highest in comparison to other industries. There were 1,224 fatal occupational injuries and 421,400 nonfatal injuries and illnesses in construction in the year 2004.

Mda (2001) further stated that an average employer pays around R53 000 in workers compensation assessment tariffs. Taking a profit margin of 10%, this means that the construction company has to do a turnover or R 530 000 just to cover the costs of these claims. This shows an enormous impact that workers compensation has on the South African economy. In the words of Ahmed et al (2006) "the total cost of occupational injuries/illnesses and fatality incidents can threaten the survival of a construction company in a highly competitive environment". In the US construction industry, a company operating at a 4% profit margin would have to increase contract prices by $400,000 to pay for a $16,000 injury, such as the amputation of a finger. In the study of costs of construction injuries in USA, Ahmed et al (2006) found out that the total cost of occupational fatal and non-fatal accidents in 2004 was $48.7 billion representing 10.72% of the total turnover.

Quoting Haupt and Smallwood (2005), "during 1999, the latest year for which comprehensive occupational injury statistics are available, a total of 14,418 medical aid cases, 4,587 temporary total disablements, 315 permanent disablements, and 137 fatalities were reported to the Compensation Commissioner relative to construction in South Africa. These equate to 1 temporary disablement for every 102 workers, 1 permanent disablement for every 1,041, and 1 fatality for every 3,925 workers. Injuries and fatalities can result in considerable pain and human suffering, and does not only affect the injured employee, but their families and extended families, with huge costs of aftercare and rehabilitation". With the current increase in construction activities in South Africa, with a likely resultant higher level of accident occurrence on sites, more attention needs to be paid to what happens to the injured worker after their misfortune.

1.2 Why Focus on SMME?

In the words of Nicholas and Watson (2004), while reporting on their study on the SMEs in UK, "The rationale for investigating SMEs is that over 95% of construction companies employ fewer that10 people, and over 50% of the labour force is self employed". They further stated that Small and Medium sized organisations account for 96% of the number of all organisations in the construction industry by employment; furthermore (quoting from DTI, 2002), that on a national scale in UK, SMEs account for approximately 99.9% of total business and supports approximately 87.2% of the UK employment and 72% of turnover. In the same vein, according to Dlungwan and Rwelamila (2000), the Singapore Construction Industry Development Board (1996) found that 73% of construction industry employees were employed by small and medium-sized contractors. Similar trends have been reported in many other countries, and are also true of South Africa.

The South African government has put in place policies and plans to develop construction SMEs within the country. For the SME contractors to be sustainable and competitive, however, they have to embrace an effective human resource management program. An efficient and effective workmen's compensation mechanism will enhance this.

2. RESEARCH METHODOLOGY

Both qualitative and quantitative research methods were employed for this study. Primary data were obtained through questionnaires and interviews. Two sets of questionnaires were administered to contractors and construction workers from 15 different small and medium companies operating as sub-contractors on three (3) randomly selected major construction sites within the Johannesburg metropolitan area. The primary aim of the questionnaires was to obtain the views and opinions of both employers and employees with regards to the current compensation structures. There were instances where it was necessary to assist the illiterate respondents in reading and completing their questionnaires. Informal interviews were conducted with the workers while they were busy responding to the questionnaires; this further assisted in assessing the personal feelings and perspectives of the respondents. An average of 4 workers was randomly selected from each of the sub-contracting companies. A total of 60 workers and 15 employers were involved with the survey.

Secondary data was obtained through a review of the workers' compensation legislation (COIDA) and its application. The literature review also included a historical overview of the workings of the compensation mechanisms to establish the progress that has been made over the years. A correlation was made between the two primary types of workers compensation insurers, FEMA and the State run Compensation Fund.

Data obtained were analyzed and summarized and the findings tabulated where necessary in order to draw relevant conclusions and recommendations.

3. THE COMPENSATION FOR OCCUPATIONAL INJURIES AND DISEASES ACT 130 OF 1993 (COIDA)

All Workers' Compensation claim settlements are payable from the compensation fund established under section 15 of the Compensation for Occupational Injuries and Diseases Act 130 of 1993. The main sources of finance for the fund is the assessed tariffs paid by the employers, any interest on investments of the compensation fund, and any penalties and fines imposed on employers by the terms of the Act. The Compensation Fund is headed by the Compensation Commissioner who reports to the Director General who retains responsibility for the administration of the fund. The fund is valued at three year intervals by an actuary appointed by the Minister of Labor to determine if it is sufficient to meet current liabilities. In 2003, the fund's total assets are recorded at over R 13 billion (Annual report of compensation Commissioner, 2003/4).

In terms of Section 29 of the COIDA, "an *employee* who meets with an *accident* while operating *out of and in the course of their employment* resulting in *personal injuries or death* is entitled to receive compensation". In compliance with COIDA, all construction site operatives who are on site to further the interests of their employer's business are deemed to be employees and this requirement is almost automatically complied with. An accident is an outward, unplanned incident at least from the point of view of the victim. It could be argued that the phrase *'out of and in the course of employment'* is ambiguous and open to interpretation. For the purposes of the Act, an accident need not be caused by an external factor, but has to arise 'out of and in the course of the workers employment'. In terms of section 22(5) of COIDA, Workers who also meet with an accident and are injured while in–transit to work in any transportation provided by the employer are deemed to have met with an accident out of and in the course of their employment. The employee who met with an accident must also show that the accident resulted in him/her suffering personal injuries. The injury must be exact, clear, and capable of exact formulation and must be quantifiable in monetary terms. This means a worker cannot claim for pain and suffering since they cannot be quantified in monetary terms.

3.1 Claiming for Compensation

Claiming for compensation generally consists of the following main stages:

- Notice of accident by worker to the employer
- Notice of accident by employer to the Compensation Commissioner
- Inquiry into accident by the Office of the Commissioner (Director General)
- Claim Consideration

Section 38 of COIDA places a duty upon the worker to notify the employer of the occurrence of the accident as soon as possible. This is the first step to the entire process of claiming for workers compensation. COIDA stipulates that notification of accident can be either written or verbal.

According to section 39 of COIDA, after the worker has made proper notice to the employer, the employer has an immediate duty to notify the compensation commissioner within seven days after having received the worker's notice of the accident.
Even if the employer believes that the accident concerned did not arise '*out of and in the course of employment'* he is still under a duty to notify the Commissioner of the accident.
Failure to comply with the above requirement, the employer shall be guilty of an offence and will be subjected to a fine which will not be more than the full amount of compensation payable for the unreported accident. The employer is also required to furnish the worker with copies of such notice.

The office of the Commissioner, Director General, shall make inquiries into the accident after having received the notification from the employer to enable him/her to decide upon the validity of the claim and liability. The worker will be required to submit a medical report conducted by a professional medical practitioner designated by the Director General or employer.

The Director General shall then consider and adjudicate the claim for compensation and is also entitled to carry out any further investigations that may be deemed necessary.

3.2 Prescription of Claim

In terms of section 43 of COIDA, a claim for compensation must be lodged on behalf of the worker in any prescribed manner within 12 months after the occurrence of the accident or, in the case of death of worker, 12 months after the date of death. The right to the benefits will lapse if the accident is not brought to the attention of the commissioner or employer or any mutual associate within 12 months after the date of accident

3.3 Calculating Compensation Payable

The amount of compensation payable depends on the nature and degree of the injury suffered by the worker. Degree of injury ranges from 100% for injuries like loss of two limbs or eyesight, to around 1% for loss of a toe. It is also important to note that total permanent loss of the use of a limb will be treated as a loss of the whole limb. Compensation shall be awarded in the form of periodical payments at given intervals or in a form of a lump sum.

3.4 Compensation if worker dies

If the worker dies as a result of the occupational injury, compensation shall be payable to the dependants of the deceased, widow or widower and children. Compensation in these cases will not exceed 100% of total compensation that would have become available to the worker had he lived. Compensation will be made available in a lump sum or in monthly payments for the widow or widower and will be made periodically or in monthly pension for the children. Payment to the child shall lapse on the month that the child turns 18 years old except in cases where the child is unable to earn an income for himself due to a physical or mental disability, marries before 18, or until the Director-General believes that the worker would no longer have contributed towards the maintenance of that child.

If the worker leaves no widow or widower or child, but a dependant who was wholly dependant upon the worker for financial support, a monthly pension that does not exceed 40% of the total compensation that would have become available to the worker had he lived would be made available to such dependant. The Director-General may also pay such compensation to contribute towards the funeral costs of the worker

3.5 Federated Employers Mutual Association (FEMA) Scope of cover

The scope and method of compensation through FEMA for temporary total disablement and permanent disablement are briefly highlighted as follows.

- Temporary total disablement

Compensation is payable to injured employee during temporary disablement by way of periodical payments of 75% his monthly earnings. No compensation is payable in respect of the first three days of such disablement if injury lasts for three days or less.

- Permanent Disablement

Compensation for permanent disablement where degree of injury is 30% or less, takes the form of a lump sum based on 15 times the workers monthly earnings. If degree of injury is 31% or more, compensation takes the form of a monthly pension. All medical bills and transportation to hospital are also covered.

4. FINDINGS

4.1 Problems with Workers' Compensation Mechanisms

The first major problem with workers' compensation mechanisms relates to the reporting of accidents (Schroeder 1984). Under the present scheme, it is the employer's duty to report accidents. However, given the principle of reduced premiums and rebates with increase in a particular employer's accident reporting rate, it can be assumed that the current number of accidents reported is only a fraction of the actual number of accidents.

The second major problem is that when compensation is paid, it is calculated based on the wages of the worker. This places the lower earning workers who are predominantly black, unskilled or semi skilled workers at an enormous disadvantage considering they ultimately are the ones most exposed to injury. Furthermore, the total compensation received by the worker does not equal the total amount of wages lost during injury (Schroeder 1984).

Another problem is that no compensation payouts are made within the first 12 months after the worker submits a claim for compensation. It could be argued that this is the time when the injured worker will need the money the most. The worker must also finance medical bills upfront which he might not have the necessary resources to do.
Also, workers are only compensated for the types of injuries that are stated in the Schedule of Injuries in the COIDA. Any other type of injury is not compensated for. Mda (2001) found that burns and fractures are the most common types of injuries that occur on site. Burns and fractures are not present in the Schedule of Injuries in the Act. Thus we are left with a situation were the COIDA is not doing what it is intended to do. It does not cover the majority of accidents that occur on site.

With free medical aid provided by the COIDA, most workers are not even aware that they have been awarded compensation; this is confirmed by the long list of unclaimed benefits in the Annual Report of Compensation Commissioners 2003/2004. This applies particularly for workers from the homelands who return home after injury with no forwarding address, these workers never receive the compensation that is rightfully theirs. Initially, the compensation is sent to the employers, after which payouts are made directly to the workers or their representatives.

4.2 Responses from employers

All the employers responded that they do offer insurance for occupational injuries and diseases. However, 20% of them expressed dissatisfaction with the assessment tariffs that they pay to the insurer; they felt that the tariffs were too expensive for SME's. For the workers' compensation system to be efficient, all interested parties need to feel that they are not being treated unfairly so that everyone will contribute to its success. 60 % of the employers are registered with the Federated Employers Mutual Assurance Company

Limited for workers' compensation insurance and 40% responded that they were insured with the Compensation Fund. 86.7% of employers have had accidents on site over the past year; this is due to the current increase in construction activity in South Africa. Only 1 respondent had a zero accident rate last year. 66.7% of respondents reported only major accidents to the insurer. Accidents like fractures, bruises and sprains which have a high frequency rate on sites generally go unreported. However, according to COIDA, all accidents that result in the worker being absent from work for more that three days should be reported.

Although all the employers responded that they inform their workers of the purpose and procedures of the compensation fund, they stated that this has not helped improve the situation. They stated that workers do not read the pamphlets and notices provided on site due to the low literacy level. The workers' responses to questionnaire reveal that only 8% of them understand English very well.

40% of the employers acknowledged that they knew only a little about workers compensation and 80% of them expressed the need for increased awareness on the procedures required to submit a claim for workers' compensation. The information they make available to their employees was inadequate. Meanwhile 33.3% of them did not have the necessary forms needed to record accidents on site increasing the likelihood that accidents would not be recorded and reported on time.

4.3 Responses from construction workers

Over 53% of workers who responded are from the homelands and 18.3% were immigrants. In the homelands, there are no formal street addresses or contact numbers. This poses a problem because workers who return to their home after suffering an injury cannot be contacted. So, even if proper compensation is claimed and awarded, the worker can not be contacted to collect the money. 75% of them did not provide the employer with their homelands contact details because they don't have them.

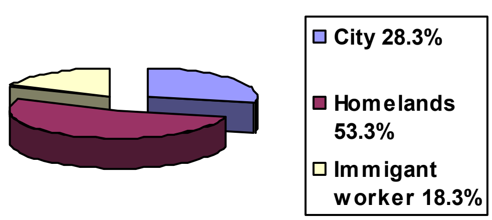

Fig. 1 Origin of the workers

While 45% of the respondents said that they have a fair understanding of the English language, only 8% stated that they have very good understanding.

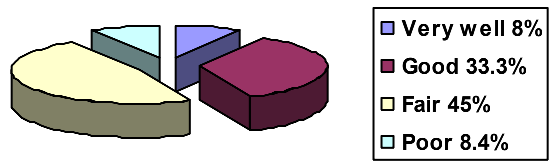

Fig. 2 Workers' English literacy level

This poses a problem because awareness and administration of the workers compensation mechanism is primarily done in the English language. The worker thus cannot actively participate in the entire workers' compensation process, discouraging them to pursue the claims process.

Among the respondents, 36.4% said that they have met with an accident while at work and 63.6% responded that they have not had any accident yet. Of those with accident experience, 62.5% have experienced an accident once, with over 4% of them having the experience more than three accidents (See fig 3 below). 83.3% of them reported the first accident they suffered; this number seemed to decrease the more accidents that the worker experiences on site. 75% of the workers who have suffered up to 3 accidents responded that they did not report the third accident (Table 1). Reasons for this is fear of victimization or job loss should the employer believe that the worker is prone to accidents. All accidents that occur on site which lead to the worker missing three days or more should be reported as soon as possible. However, this clearly is not happening.

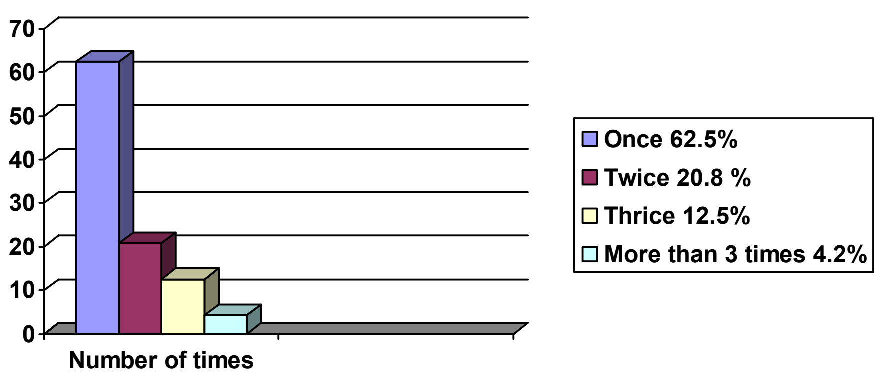

Fig. 3 Frequency of workers' accident on site

Table 1 Frequency of accident reporting to employer

Was accident reported?	First Accident	Second Accident	Third Accident	More than three accidents
YES	83.3%	66.7%	25%	0%
NO	16.7%	33.3%	75%	100%

50% of the workers who reported their accidents are not sure if the claim was submitted to the insurer. Their responses are as shown in table 2 below. 87.5% of them said that they do not personally inquire on the progress of their claims (table 3). These workers are assisted by their family members or anyone that they trust who is more literate in the English language. 92% of the respondents knew very little to nothing about workers' compensation mechanism. The respondents who said that they knew something about workers' compensation credited careful observation of the experience of others as a learning curve for them; only 7.7% credited their employers as a source of information. This contradicted the responses made by the employers, where 60% responded that they speak to workers themselves.

Table 2 Workers compensation claim made

	Percentage	Respondents
YES	20.8%	5
NO	0%	0
SOME	29.2%	7
I DON'T KNOW	50%	12

Table 3 Knowledge of progress of claim

Response	Percentage	Respondents
YES	12.5%	3
NO	87.5%	21

The responses from the workers indicated the perception they held which is mainly attributed to their personal experiences and that of their colleagues:

1. 77% of workers felt that even if they receive the compensation payouts, it will not be adequate. The worker has a lot of upfront medical bills and transport costs to

hospitals that they have to pay for out of pocket. Although FEMA and Compensation Fund provide cover for these costs, payouts are only made a year after claiming for compensation.

2. 72.7% of the workers do not expect to have prompt response from the insurers while only 27.3% are slightly hopeful.

All the workers agreed that there is a need for increased awareness on the workings of the compensation mechanisms. When asked the preferred medium of awareness improvement, 45% prefer through their employer (Figure 4).

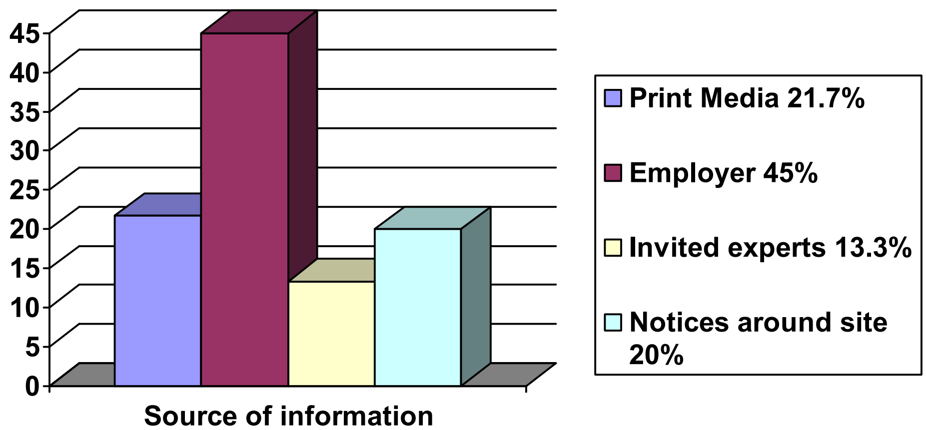

Figure 4 Worker favorable source of information

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The current workers' compensation mechanisms are effective but not necessarily efficient. If the worker meets the requirements as stipulated in COIDA, proper compensation will be given regardless of the availability resources (like time and money). This means that workers are effectively, but not efficiently, compensated. The worker should be paid compensation with the most minimal waste of resources. The current compensation mechanisms are not adequate for the following reasons:

- Accident reporting is poor. This is evident because employers do not have the necessary form readily available on site to record and report accidents. This means that accidents are either not being reported or are being reported late.
- Literacy levels amongst workers on site were not good. The compensation mechanisms are presently administered in English, therefore communication problems arise between the insurers and the workers.
- It was also found that most workers on site are from the homelands. There are no formal addresses in the rural areas, so workers cannot be contacted even if compensation claims are awarded.

- Previous researchers found that most accidents that occur on site are fractures and burns and yet these types of injuries are not included in the schedule of injuries in the COIDA.

Is there a need to increase the awareness on the workings of the compensation mechanisms? Both workers and employees knowledge of the workings of the compensation mechanisms is very limited. Both parties agreed that there is a need for increased awareness.

5.2 Recommendations

- The system of giving rebates to employers with a low claims history should be reconsidered. The main purpose of the system of rebates was to try and encourage employers to enforce health and safety at the workplace. Although this does happen, the system is now exploited by employers who do not report accidents that occur on site with hopes of getting rebates in their assessment tariffs. This defeats the entire purpose of the COIDA.
- The workers responded that they would prefer to learn about the compensation mechanisms from their employers. Increased awareness can be accomplished by inviting representatives from the insurers to give presentations to workers on workers' compensation. Also, workers would benefit from print media and publications that are distributed in a language that they will understand. Notices in all languages should also be made and put around the construction sites. This could also eliminate negative attitudes harbored by workers on site.
- Another method of calculating the amount of compensation paid out should be created. The current system based solely on wages earned is inadequate and does not fully compensate the workers.

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OTHER

13

PERSONS WITH DISABILITIES: AN UNDERUTILIZED CONSTRUCTION RESOURCE!

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ABSTRACT

South African legislation in the form of *inter alia*, the Employment Equity Act requires that designated groups such as persons with disabilities be considered and employed. This requirement presents a challenge to the construction industry, as construction sites are often undulating, work occurs at elevated heights, and the work environment places continually change in terms of layout and physical features. In South Africa there is a growing interest in possible inclusion of disabled people in construction. Globally, the issue has received attention and the key issues have been regularly debated.

This paper reports on the exploratory phase of a study conducted among Skills Development Facilitators (SDF) registered with the Construction Education Training Authority (CETA) in South Africa to determine perceptions of key industry stakeholders relative to the involvement of disabled people in construction.

The key findings suggest that there is a general lack of knowledge relative to the employment of disabled people in construction; disabled people have a role to play in and could contribute to the construction process; certain physical impairments preclude disabled people from fulfilling certain functions; disabled people are more suited to administrative and off-site functions; government must provide incentives for employing disabled people, and employing disabled people will not negatively affect the productivity of an organisation.

This paper concludes that most respondents have positive perceptions relative to the employment of disabled persons in construction. These perceptions constitute a foundation for the development and implementation of endeavours to promote the integration of disabled persons in construction.

The paper recommends that all built environment academic programmes, particularly construction management, address the issue of disabled people in construction, that guidelines be developed, and that the employment of disabled people be incentivised.

Keywords: Construction, Disabled People

1. LITERATURE
Participation of disabled people in construction

Laws exist in many countries that prohibit discrimination against disabled persons and the denial of their rights. However, persons with disabilities are still poorly treated. Their potential contribution to the mainstream economy is overlooked. Notably, the rate of unemployment of disabled persons is twice or three times that of other able-bodied persons (Aiken, 2003). Their employment is generally concentrated in low-level, low-paid jobs. Consequently, they are not adequately represented at the higher levels of management within construction firms. Various studies have been undertaken to investigate the cause of high unemployment among disabled persons. Reasons proffered include, *inter alia,* reference to large numbers of unemployed able-bodied persons (Thornton and Lunt, 1997); stigma related issues and discrimination against disabled persons (Savtschenko, 2002); perception of disabled persons as incompetent and sharing certain negative characteristics; and cultural related issues (Dainty, 2003).

In South Africa, the status quo has been exacerbated by several impacting factors, a few of which are discussed in the following sections.

Legislation

The system of *apartheid* had an incapacitating impact on disabled persons of further marginalization and exclusion. Consequently, post-apartheid South Africans with disabilities are both under-represented and under-utilized in the workforce (Strasheim, 1998). The South African government in endeavouring to redress this legacy has introduced enabling legislation, such as, in general the Labour Relation Act 66 of 1995, Basic Conditions of Employment Act 75 of 1997, particularly the Employment Equity Act 55 of 1998 (EEA), and the Promotion of Equity and Prevention of Unfair Discrimination Act of 2000 (PEPUDA). Further, the South African Constitution reputed to be one of the most progressive in the world addresses most of the needs and rights of all South African irrespective of diversity in colour, race, gender and health status (McClain, 1999). It is founded on the fundamental values of equality, freedom and non-racism. As such, it specifically prohibits any form of discrimination on the basis of race, disability, gender and sex. Notably, the Integrated National Disability Strategy of 1997 acknowledges the existence of disabled persons. It prohibits any form of unfair treatment designed to make disabled persons feel like objects of pity. Instead persons with disabilities should be regarded as capable persons who can contribute immensely to the development of society. The strategy supports the changing of the perception and attitude of society towards disabled persons (McClain, 1999).

The EEA was designed to protect disabled persons against unfair discrimination while entitling them to affirmative action measures (Strasheim, 1998). These measures include eliminating employment barriers, diversifying the workplace and making reasonable accommodation for disabled persons to ensure equitable representation in workplaces. While 10 to 14% of the South Africans are disabled, less than 1% of this group is employed. In terms of the EEA the penalty measures for non-compliance range from

R500 000 for a first offence to R900 000 for repeated offences of the same type within a three-year period. To date there has not been a single employer, particularly in construction, who has been convicted despite large-scale non-compliance with the EEA.

Additionally, schedule 8, item 11 of the Labour Relations Act 66 of 1995 addresses the issue of unfair dismissal of any employee on account of disability (Strasheim, 1998). It requires that prior to dismissing an employee with a disability, the person charged with determining the unfairness or fairness of such a dismissal should consider the extent to which the work conditions of that employee could be adapted to accommodate the disability, or, if this is not possible the extent to which the duties of the particular employee might be adapted.

Given that typically South African construction sites remain dominated by able-bodied workers and a shortage of disabled persons who are capable of working on project sites, there has been growing pressure from the business community and other (define NGO) NGO's for amendments to the Labour Relation Act 66 of 1995 and Basic Conditions of Employment Act 75 of 1997. These amendments are sought to work against the perception that South Africa has an inflexible labour market and to create a more enabling environment for the creation of jobs, especially for disabled persons as one of indigenous or minority groups (International Marketing Council of South Africa, 2003).

The greatest challenge facing SA, therefore, in relation to the goals of the Integrated National Disability Strategy policy is to transform or change the mindset of able-bodied people to accept disabled persons as persons who have a role to play in society (McClain, 1999). The Promotion of Equity and Prevention of Unfair Discrimination Act of 2000 (PEPUDA) promotes the needs and rights of disabled persons and is committed to a vision of equality and non-discrimination (Schriner, 2001). Further it addresses issues around environmental accessibility as well as reasonable accommodation in the workplace. PEPUDA expressly prohibits any unfair discrimination on the basis of disability.

Culture and Diversity

Arguably, the construction industry lags behind other industrial sectors in South Africa on the issue of diversity. Poole (1997) argues that diversity and equality cannot be judged by numerical targets, but through visible equal representation of all people. Diversity does not only level the playing field but also unearths rooted prejudices and stereotypes that discriminate against disabled persons. Perry (1992) suggests that the opportunity for all employees, including disabled persons, to achieve their maximum potential at work is something that needs to be widely recognized as a fundamental human right (Perry, 1992). Several construction firms have embraced diversity in their workplaces as a competitive necessity. Consequently, the pursuit of workplace diversity has become a strategic organizational response to the globalization of a company's activities and the growing multiculturalism of workforces and marketplaces. Diversity recognizes the contributions that individuals with disabilities can make as individuals. It calls for management of firms to be totally inclusive, not just tolerating those who are different but also celebrating those differences. It calls for the opening of non-traditional occupations to all people and for making reasonable accommodations in the workplace and work life to enable this to happen. It calls for diversity beyond just gender, race, or physical and intellectual abilities to include diversity in opinions, and other aspects of the variations in lives and lifestyles.

Employment relationships

Construction employers have perpetuated the view that disabled persons are incapable of contributing productively to the labour force or to their firm (Unger, 2002). Because of negative stereotypes as well as architectural, communication and other barriers related to disability, disabled job seekers and workers are often denied their rights or face discriminatory practices (Perry, 1992). According to the LRA all employees have a responsibility to notify their employer of a condition that may affect their ability to do the job, or that may affect their safety or that of others. Therefore, workers have a duty to represent themselves and their abilities in an honest manner. They may request reasonable accommodation, if necessary, and accept that which is most appropriate for the situation, cost-effective and least intrusive to the workplace while still meeting their needs.

Van der Colff (1999) believes that true employment inclusion and integration means access to a range of workplace activities. In particular, without effective accessibility, individuals with disabilities will continue to face obstacles at work and in their daily lives. Yet achievement of the promise of full inclusion and equal employment participation requires more than advancing technology but rigorous efforts. It requires study of underlying attitudes and behaviors toward individuals with disabilities in all parts of construction industry.

Factors that influence the employment of disabled persons in construction are illustrated in Figure 1 together with the variables which impact on legislation, accessibility and accommodation; barriers and attitudes of employers.

In reality the labour force participation of disabled persons in South Africa languishes below the average participation rate despite government initiatives to redress this imbalance. In many instances, while appropriate occupational options may be identifiable, the reality is that disabled individuals often face significant barriers in obtaining and maintaining employment in the competitive construction labour market. Disabled persons still suffer from stigmas attached to them and extraordinarily high unemployment rates. When they are employed, they tend to be concentrated in the low paying, marginal sectors of the labour market. They typically have additional expenses that able-bodied workers do not face, such as medication, special aids and devices, and special transportation services. Disabled persons are confronted with attitudinal and physical barriers, and deliberate discrimination that prevents them from working on construction sites. Preconceived attitudes, inappropriate behaviours, and limited expectations among construction firms prevent them from achieving their full potential.

About 12.8% of the South African population is disabled, equating to about 5 238 042 persons with disabilities in South Africa. The percentages of disabled persons in South Africa's nine provinces according to the 1996 census are shown in Table 1.

Attitudinal Barriers and Societal Prejudices

The South African history of division resulted in the general perception that what is different from the prevailing norms of the day is inferior or bad (Republic of South Africa, 1998). Many employers perceive disabled persons as incompetent in one way or the other even if they are not. This perception leads to negative attitudes, which focus on what disabled persons cannot accomplish, instead of what they in reality can accomplish. Further, employers tend to underestimate the capabilities of disabled persons due to their disability status. This underestimation leads to stereotypes of incompetence or less competence. This classification in practice creates unfair, irrational and unjustifiable barriers to the employment of disabled work-seekers.

Table 1. Distribution of disabled persons in South Africa

Provinces	Type of disability (%)				
	Sight	Hearing	Physical	Mental	Others
Gauteng	3.0	0.8	1.0	0.3	0.4
Eastern Cape	2.6	1.2	1.8	0.6	0.7
Free-State	5.0	1.3	1.6	0.5	0.6
Kwazulu Natal	2.2	0.9	0.5	0.5	0.3
Northern Province	N/A	N/A	N/A	N/A	N/A
Mpumalanga	3.5	1.1	1.5	0.4	0.3
Northern Cape	2.2	0.7	1.1	0.5	0.3
North West	3.9	1.1	1.1	0.5	0.5
Western Cape	1.0	0.5	0.9	0.4	0.2

Source: Republic of South Africa (1998)

Gender, race and disability are attributes that individuals bring with them to the workforce as part of their identity (Van der Colff, 1999). These characteristics are often seen as disadvantages to the extent that they make certain groups appear to be different than others. Discrimination and racism are by-products of situations where these differences are perceived as a disadvantage or handicap.

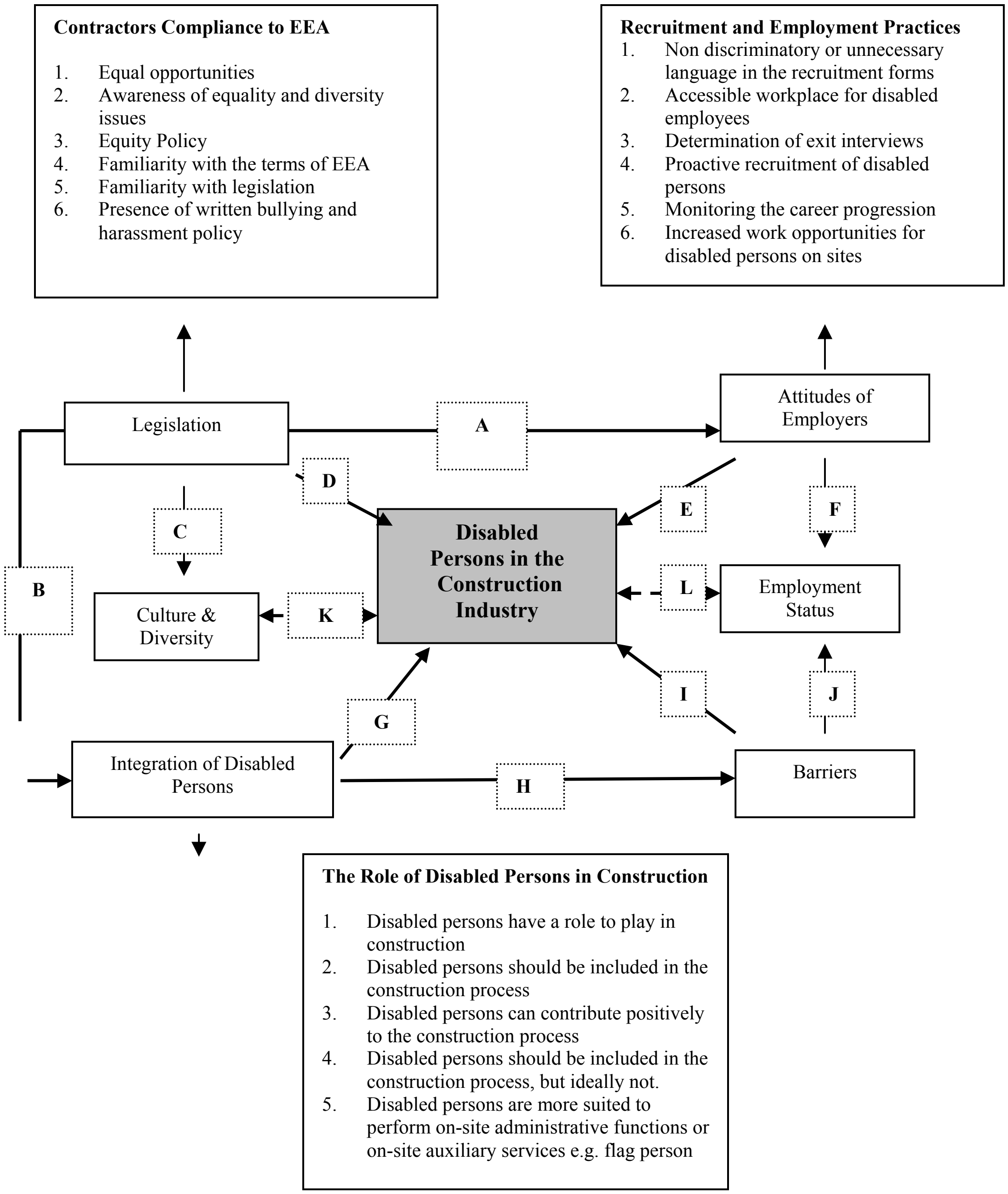

Figure1: Factors affecting the employment of disabled persons (Adapted from Tshobotlwane, 2006)

For many, the characteristics by which one judges an able-bodied person such as integrity, responsibility, sense of humor, amiability, and sensitivity, change when dealing with disabled persons. The bad characteristic becomes the focus of attention, and it is assumed that when persons are disabled their physical or mental impairment completely affects their lives. Able-bodied persons tend to create consistently negative impressions about these persons who are then necessarily viewed as inferior in terms of all possible attributes simply on the basis of their disability. For example, many mistakenly link epilepsy to physical unattractiveness. They shout at the blind as if they are deaf. They incorrectly assume that persons with physical disabilities are mentally impaired, and that persons with psychiatric conditions are violent. They speak to persons with physical disabilities as if they were children. These assumptions typically create negative attitudes about other unrelated characteristics of persons with disabilities. (Reference??)

The factors that impact the employment of disabled persons in construction in South Africa and the relationships between these factors are highlighted in Figure 1, namely:

A. Current legislation contributes to the prevailing attitudes of employers towards disabled persons.
B. Legislation contributes to the integration of disabled persons in construction.
C. Legislation promotes and enables cultural diversity of organisations.
D. Enabling legislation enhances the employment of disabled persons in construction.
E. Attitudes of employers prevent disabled persons from being part of construction industry.
F. Employment status of disabled persons in construction is caused by unfriendly attitudes of employers.
G. Integration of disabled persons improves their status in the construction industry.
H. Integration of disabled persons eliminates some of the barriers in construction.
I. Barriers result in the low status of disabled persons in construction.
J. Removal of barriers contributes positively to the employment status of disabled persons.
K. Unappealing cultural diversity of organisations leads to the low status of disabled persons in construction.

Newton and Ormerod (2005) contend that there are numerous opportunities for disabled people to become involved in the construction industry. They argue that where disabled persons may not be able to directly work on a construction site, by broadening the scope and role they may be easily accommodated within a wider job function.

2. RESEARCH

The sample stratum consisted of approximately 800 Skills Development Facilitators (SDFs) registered with the Construction Education and Training Authority (CETA). Given that CETA facilitated the survey, the authors were unable to quantify the exact sample stratum size. Seventy-one responses were included in the analysis of the data, which constitutes a minimum net response rate of 8.9%.

Findings

From Table 2 it is evident that most respondents (45,1%) were engineers, followed jointly by contractors (21,1%) and private sector clients (21,1%).

Table 2: Stakeholder group.

Stakeholder	Response (%)
Engineer	45.1
Contractor	21.1
Private sector client	21.1
Public sector client	14.1
Project Manager	7.0
Quantity Surveyor	4.2
Architect	2.8
Other	2.8

Table 3 presents the degree of concurrence with statements related to the integration of disabled persons in construction.

The mean score of 4.22 relative to "There is a general lack of knowledge relative to the employment of disabled people in construction" indicates that the degree of concurrence is between agree to strongly agree. This mean score amplifies the need for awareness relative to the integration of disabled persons in construction. This is reinforced by the degree of concurrence with "Knowledge of the potential contributions by disabled people will promote their employment." with mean scores $> 3.40 \leq 4.20$ which indicate that the degree of concurrence is between neutral to agree. Significant findings include the degree of concurrence relative to "Disabled people could contribute to the construction process", "Disabled people have a role to play in construction", and "Disabled people should be included in the construction process", which reflect the findings of the study conducted in the UK by Newton and Ormerod (What is Newton and Ormerod conclude about the acceptance or unacceptance of disabled people in construction? Doesn't hurt to restate it) (2005). Furthermore, it should be noted that the degree of concurrence relative to the first statement is 7.3% higher than that relative to the more emphatic third statement. However, it can be argued that the positive disposition to the integration of disabled persons in construction is 'qualified' by the degree of concurrence relative to: "Certain physical impairments preclude fulfilling functions such as on-site supervision e.g. concrete face" and "Disabled people are more suited to on-site administrative functions – the concurrence all within 0.09 on the mean score range. A further 'qualification' is in the form of the concurrence relative to "Certain physical impairments preclude fulfilling functions such as production." The degree of concurrence relative to "Employing disabled people constitutes an organization meeting its socio economic responsibilities" reflects subscription to the concept of corporate social responsibility (Stephens, Collins and Dodder, 2005).

Table 3: Degree of concurrence related to the integration of disabled persons in construction.

Statement	Response (%)						Mean score
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
There is a general lack of knowledge relative to the employment of disabled people in construction	1.4	0.0	1.4	10.0	52.9	34.3	4.22
Knowledge of the potential contributions by disabled people will promote their employment	1.4	0.0	2.9	5.7	67.1	22.9	4.12
Disabled people could contribute to the construction process	2.8	1.4	7.0	5.6	63.4	19.7	3.96
Certain physical impairments preclude fulfilling functions such as on-site supervision e.g. 'concrete face'	2.8	2.8	7.0	2.8	71.8	12.7	3.87
Disabled people are more suited to on-site administrative functions	0.0	1.4	10.1	10.1	58.0	20.3	3.86
Disabled people have a role to play in construction	1.4	1.4	8.6	11.4	62.9	14.3	3.81
Employing disabled people constitutes an organization meeting its socio economic 'responsibilities'	4.2	1.4	7.0	14.1	59.2	14.1	3.81
Disabled people are more suited to off-site functions	0.0	4.4	8.8	8.8	60.3	17.6	3.78
Disabled people should be included in the construction process	4.2	1.4	12.7	12.7	49.3	19.7	3.76
Accommodating the needs of disabled people is problematic e.g. access and ablutions	1.4	2.8	14.1	11.3	56.3	14.1	3.66

Employing disabled people will enhance the image of an organization	4.3	0.0	12.9	30.0	37.1	15.7	3.58
Certain physical impairments preclude fulfilling functions such as production	4.3	4.3	18.6	4.3	61.4	7.1	3.51
Government must provide incentives to employ disabled people	2.9	1.4	18.6	20.0	44.3	12.9	3.50
Certain physical impairments preclude fulfilling functions such as site management	4.3	2.9	25.7	4.3	57.1	5.7	3.39
Disabled people are more suited to on-site auxiliary services e.g. flag person	2.8	2.8	31.0	15.5	38.0	9.9	3.22
Employing disabled people can alleviate the skills shortage in construction	5.7	5.7	21.4	24.3	35.7	7.1	3.18
The Employment Equity Act relative to employing disabled people is unrealistic	14.1	2.8	23.9	31.0	26.8	1.4	3.00
Disabled people could be included in the construction process, but ideally not	2.8	14.1	42.3	8.5	31.0	1.4	2.62

Statement	**Response (%)**						**Mean score**
Disabled people are a threat to the H&S of their fellow workers	4.3	12.9	55.7	11.4	12.9	2.9	2.34
Employing disabled people is cost prohibitive	9.9	12.7	47.9	21.1	7.0	1.4	2.30
Disabled people are less productive than able bodied people	7.0	16.9	47.9	22.5	4.2	1.4	2.20
Disabled people affect the profitability of an organization	1.4	30.4	52.2	11.6	4.3	0.0	1.90
Employing disabled	2.8	38.0					

people will create a negative image among clients / customers			50.7	8.5	0.0	0.0	1.70
Disabled people will offend other workers	4.2	39.4	53.5	2.8	0.0	0.0	1.62

Although the degree of concurrence relative to the former (Comment: It is not clear what the "former" is???) is 8.9% higher than that relative to "Employing disabled people will enhance the image of an organization", the degree of concurrence relative to the former may well also be attributable to the benefits that accrue to the image of the organisation. The degree of concurrence relative to "Accommodating the needs of disabled people is problematic e.g. access and ablutions" reflects the findings of the study conducted in the UK by Newton and Ormerod (2005). The degree of concurrence relative to "Government must provide incentives to employ disabled people" constitutes a plea for recognition that there are implications arising from the employment of disabled people, which is also reflected in the degree of concurrence relative to the former statement.

The concurrence relative to the statements with mean scores $> 2.60 \leq 3.40$, which indicate that the degree of concurrence is between disagree to neutral, are discussed below.

Although "Certain physical impairments preclude fulfilling functions such as site management" falls within this range of mean scores, it is 0.02 below the range between neutral to agree. Therefore it could be concluded to be a further 'qualification' to the positive disposition to the integration of disabled persons in construction reflected in the high degree of concurrence relative to other statements. A notable finding is the degree of concurrence relative to "Disabled people are more suited to on-site auxiliary services e.g. flag person." However, the degree of concurrence can be interpreted in two ways. Firstly, that the deployment of disabled people is not constrained to on-site auxiliary services such as flag person, and secondly that there is discordance with the statement. The concurrence relative to "Employing disabled people can alleviate the skills shortage in construction" is notable due to firstly, the current skills shortage in South Africa, and possibly due to the possibility of disabled people not being as skilled as non-disabled people, which was a finding of a study conducted in the UK (Newton and Ormerod, 2005). The degree of concurrence relative to "The Employment Equity Act relative to employing disabled people is unrealistic" is notable in that the Act constitutes the second tier of legislation impacting the employment of disabled persons. The degree of concurrence relative to "Disabled people could be included in the construction process, but ideally not" further reinforces the earlier finding that respondents have a positive disposition to the integration of disabled persons in construction.

The concurrence relative to the statements with mean scores $> 1.80 \leq 2.60$, which indicates that the degree of concurrence can is between strongly disagree to disagree, are discussed below. A significant finding is the degree of discordance relative to "Disabled people are a threat to the H&S of their fellow workers", significant in that the findings of the study conducted by Newton and Ormerod (2005) in the UK determined that H&S of disabled people and that of their fellow workers is a consideration relative to the employment of the former. Similarly, the discordance relative to “Employing disabled people is cost prohibitive” is significant as the perception exists that employing disabled persons has financial implications. According to Kochran et al. (2003), integrating disabled workers adds costs to everyday operations and administrative processes. However, in their study Stephens, Collins and Dodder (2005) found that employing persons with disabilities provided economic benefits not only to the person employed but also the broader community. Therefore while there might be an initial “cost” the socio-economic benefits far outweigh this cost. Spataro (2005) argues that employing persons with disabilities offers great potential benefits to the product quality, market reputation and bottom line of organizations. Therefore, employing disabled persons is an investment opportunity.

The discordance relative to “Disabled people are less productive than able bodied people” and the even higher degree of discordance relative to “Disabled people affect the profitability of an organization”, reinforce the degree of concurrence relative to “Disabled people could contribute to the construction process.” A study of Habitat International found that disabled workers had higher rates of productivity than the industry norm, practically no absenteeism, and minimal attitudinal problems. This study confirms the positive and productive role that disabled workers can play in construction

Only two statements achieved mean scores $> 1.00 \leq 1.80$, which indicates that the degree of concurrence is between strongly disagree to disagree. The discordance relative to “Employing disabled people will create a negative image among clients/customers” reinforces the concurrence relative to “Employing disabled people will enhance the image of an organization.” It is notable that the highest level of discordance is relative to “Disabled people will offend other workers”, which correlates with the findings of a study conducted by Flynn, Chatman and Spataro (2001) who found that disabled workers suffered more from negative impressions from their fellow workers. Further, Kochran et al. (2003) found that employing disabled persons increased labour turnover and conflict. This finding was echoed by Brostrand (2006).

Just less than half (41.2%) of the respondents stated that they would be prepared to work on the average construction site as a disabled person, 23.5% stated ‘no’ and 35.3% were unsure.

Respondents were posed a concluding question: “Do you have any comments in general regarding disabled people and construction?” 50.7% had no comment, 25.4% had one, 15.5% had two, 5.6% had three, 1.4% had four, and 1.4% had five, which equates to a mean of 0.86 comments per respondent. Selected comments include:

- “We have one employee with an artificial leg who is so capable; people forget he only has one leg! He is as productive (and more) than the next employee.”
- “Wheelchair bound employees will have enormous difficulty (if not impossible) on a site but could do admin work on site.”
- “Disability covers a wide sector of the population, and whilst, for instance, a blind site telephone operator is acceptable, a blind crane operator is not.”

- “Having disabled people on the site can be more costly and time consuming, but I believe we have a responsibility to try.”
- “I have worked on a Project (Fast Track Casino) valued +/- R727 million in which disabled persons worked supervising specialist painting applicants. They performed outstandingly.”
- “We have 5 deaf employees and we find that they are very good workers.”
- “While there may be some problems with access and ablutions this depends on the disability and creative thought can be used to accommodate certain disabilities”
- “What is your definition of disabled people? We have employed people with callipers on their legs as carpenters.”
- “A one-armed foreman was less problematic.”
- “Incentives will allow companies to improve working conditions for disabled persons and increase the percentage of disabled persons employed.”
- “Disabled are motivated and more positive, focused, and willing to achieve, to overcome their disability.”

3. CONCLUSIONS

Respondents had positive perceptions relative to the employment of disabled people in construction. However, there is a lack of knowledge relative to the employment of disabled people in construction. Although the positive perceptions constitute a foundation for the development and implementation of endeavours to promote the integration of disabled persons in construction, enhanced knowledge relative to the subject area would engender such promotion and integration.

The perception exists that disabled persons are more suited to on-site administrative functions, on-site auxiliary services, and off-site functions, than to on-site supervision, site management, and production. However, the responses indicate that the nature of the disability will determine the suitability to a particular function.

Respondents perceive there to be potential benefits from the employment of disabled people, namely enhanced image and mitigation of the skills shortage in construction.

There is potential for incentives for the employment of disabled people. Although, it can be argued that doing so is a statutory requirement, the realities of construction are such that the provision of incentives may engender further employment of disabled persons.

Negative perceptions relative to the employment of disabled people, in the form of disabled people being a threat to the H&S of their fellow workers, being cost prohibitive, poor productivity, reduced profitability, negative client perceptions of employers, and non-disabled employees being offended by disabled employees, do exist to a degree. However, these are outweighed by the positive perceptions.

4. RECOMMENDATIONS

If construction employers want to make jobs accessible for disabled persons – and they should – they will need to move beyond the role of physical architect and consider the role of social architect, namely the organizational culture that values and encourages fair treatment of persons with disabilities.

It is recommended that all built environment programmes, particularly construction management, address the issue of disabled people in construction, that related guidelines are developed, and that the employment of disabled people be incentivised. Consideration should be given to adopting aspects of the Tilting at Windmills curriculum that has 11 modules[5] that have exercises relative to everyday world of work as well as information regarding legal requirements and accommodation relative to the employment of persons with disabilities.

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[5] This program has been in use in the United States since 1982.

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