AN ABSTRACT OF THE DISSERTATION OF

Sathyanarayanan Rajendran for the degree of Doctor of Philosophy in Civil Engineering presented on December 6, 2006.

Title: Sustainable Construction Safety and Health Rating System

Abstract approved ____
John A. Gambatese

The main objective of this research study is to incorporate construction worker safety and health into sustainable design and construction practices. This can be fulfilled by the development of an innovative construction worker safety and health planning tool, called Sustainable Construction Safety and Health (SCSH) Rating System that will:

- provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of safety and health elements; and
- unify and coordinate the safety and health efforts of the four primary parties in a project: owner, designer, general contractor, and subcontractors.

Before development of the SCSH rating system, it was necessary to analyze whether present sustainable buildings are truly sustainable from a safety and health perspective. Currently, the construction industry's sustainable practices are based on compliance with the Leadership in Energy and Environmental Design (LEED) rating system. To be truly sustainable, sustainable buildings should have superior safety performance in addition to environmental performance. A pilot study on a LEED building project revealed that there were both negative and positive impacts on worker safety and health. However, based on the analysis of 86 LEED and non-LEED construction projects, it was found that there was not a statistically significant difference in safety performance between the two types of projects. Hence, current sustainable buildings are not truly sustainable when considering worker safety and health. To be labeled as sustainable, the construction

industry should include worker safety and health in the project lifecycle. This can be achieved with the SCSH rating system.

A Delphi survey technique was used to develop the SCSH rating system. The rating system consists of 50 safety and health elements, grouped into 13 categories that should be implemented through the combined efforts of the project team. The rating system was validated based on 25 real-time construction projects and was found to accurately represent the safety performance of projects. The rating system can be used as a tool to help sustain the safety and health of construction workers. Recognition for using the rating system will be an added incentive for a project team to improve the safety and health performance of a project. Since the rating system would require the joint efforts of all of the parties involved in a project, a team effort would be another benefit that will help set in motion the sustainable safety and health drive throughout the construction industry.

Sustainable Construction Safety and Health Rating System

by
Sathyanarayanan Rajendran

A DISSERTATION

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APPROVED:

Major Professor, representing Civil Engineering

Head of the Department of Civil, Construction and Environmental Engineering

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Dean of the Graduate School

I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Sathyanarayanan Rajendran, Author

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CONTRIBUTION OF AUTHORS

Dr. Mike Behm was involved in the data collection for Chapter 2. He also assisted with the analysis of the data by providing statistical expertise and draft review for Chapter 3.

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SUSTAINABLE CONSTRUCTION SAFETY AND HEALTH RATING SYSTEM

1.0 INTRODUCTION

1.1 Background

“Green” or “sustainable” building design and construction has become prevalent in the U.S. construction industry in the recent past. Buildings that are designed, constructed, operated, maintained, and demolished in an environmentally friendly manner can be labeled as “green” buildings. The U.S. Green Building Council (USGBC) recognizes buildings designed and constructed using these techniques by means of its Leadership in Energy and Environmental Design (LEED) rating system released in 2000. The number of buildings registered and certified using the LEED rating system is on the rise.

The primary purpose of USGBC LEED certification is to make buildings greener, i.e., to reduce the environmental impacts of the building’s lifecycle and to protect the health of the building’s occupants. Let us consider some of the environmental impacts caused during a building’s lifecycle. Internationally, the construction and operation of the built environment has been estimated to account for: 12-16% of fresh water consumption; 25% of the wood harvested; 30-40% of energy consumption; 40% of the virgin materials extracted; 20-30% of the greenhouse emissions and 40% of the total waste stream of countries (CIB 2002). Does LEED address these issues? Yes. Does this make LEED certified buildings “green” or “sustainable”? These two terms are often used interchangeably. However, there is a difference between the terms “green” and “sustainable”.

“Green” is a term used to address primarily the design and construction practices that impact the environment. For example, a green practice is reusing or recycling the material waste generated during construction. Sustainability is a broader concept which, in addition to the environmental aspect, addresses the continuity of economic and social aspects of human society. A building can be called sustainable only if green principles are applied throughout its lifecycle, which includes the end of life stage of the building.

Because of the long lifespan of a building, however, planning and control are only possible until the penultimate (maintenance and operations) stage of a building. Knowledge about a building's end of life stage or its life span is not available. Therefore it is difficult to identify a building as truly sustainable. A building can only be identified as more or less sustainable than another building, similar to the different levels of LEED certification. For each and every green design and construction feature added during the early stages (design, construction, and operation) of a building, the building only takes a step closer towards sustainability, but not necessarily becomes fully sustainable.

When considering the LEED rating system and its various green features, a question comes to mind: *How can the buildings certified by LEED be taken one step closer to sustainability?* One way to enhance the sustainability of buildings is to consider construction worker safety and health in addition to the health of the final occupants. Since sustainable concepts address the environmental, economic, and social well being of human society, considering the safety and health of the construction workers who are part of the building's lifecycle would take green buildings one more step towards sustainability. We call this concept "sustainable construction safety and health". This research introduces the concept of sustainable construction safety and health and presents the findings of the application of this concept in this dissertation.

1.2 Problem Statement

Construction worker safety continues to be a major concern for the U.S. construction industry. It has historically employed about 5 percent of the country's workforce, yet has accounted for a disproportionate number of occupationally related fatal and non-fatal injuries as shown in Figure 1.1 (NSC 2006).

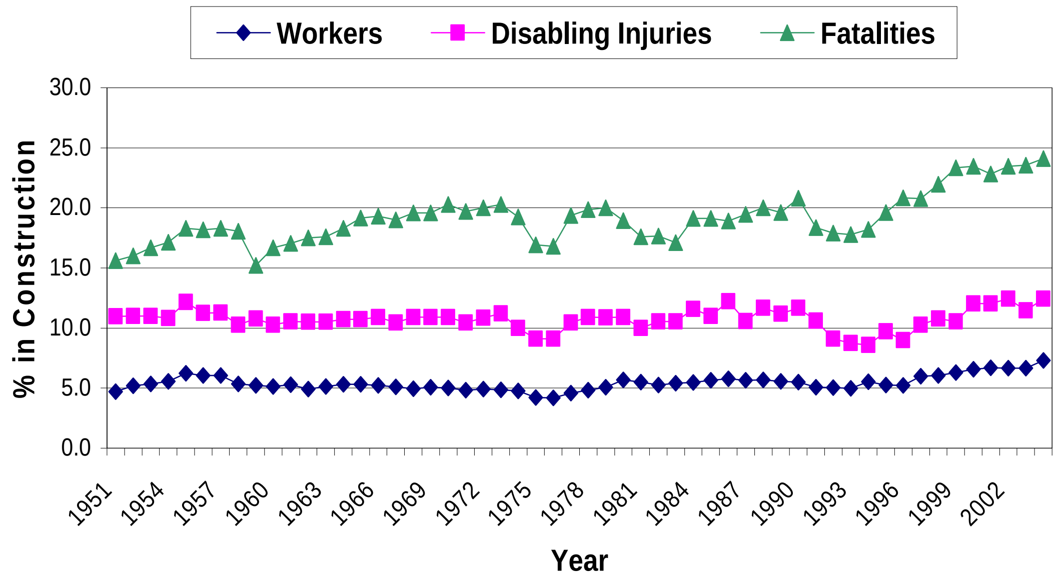

Figure 1.1: Comparison of Construction Worker, Fatality, Disabling Injuries as a Percent of Total U.S. Workforce (Source: "Injury Facts", National Safety Council, 1952-2004)

The construction industry has consistently experienced higher fatality and injury/illness rates. The National Safety Council reports that from 1951-2004 the construction-related fatality rate has decreased, but still is higher than all other industries combined. Figure 1.2 compares the fatality rate of the construction industry with all industries in the United States from 1951 - 2004 (NSC 2006). The same trend is present for disabling injury rates. Figure 1.3 compares the disabling injury rates of the construction industry with all industries in the United States from 1951 - 2004 (NSC 2006). It should be noted that both the fatality and disabling injury rates have declined during the period shown. (It is important to note that changes in fatality and injury rates from 1991 to 1992 are not to be construed as indicating major changes in the safety trend. Beginning in 1992, the National Safety Council employed different means of measuring fatalities and injures, and no comparison of the data prior to 1992 should be made with data accumulated in 1992 and later). Even though there has been a decline, the fatality and disabling injury rates in construction are severe compared to other industries, and the actual number of fatalities in the construction industry has increased in the past decade. Increased control of construction site hazards is needed to lower the level of risk and improve worker safety.

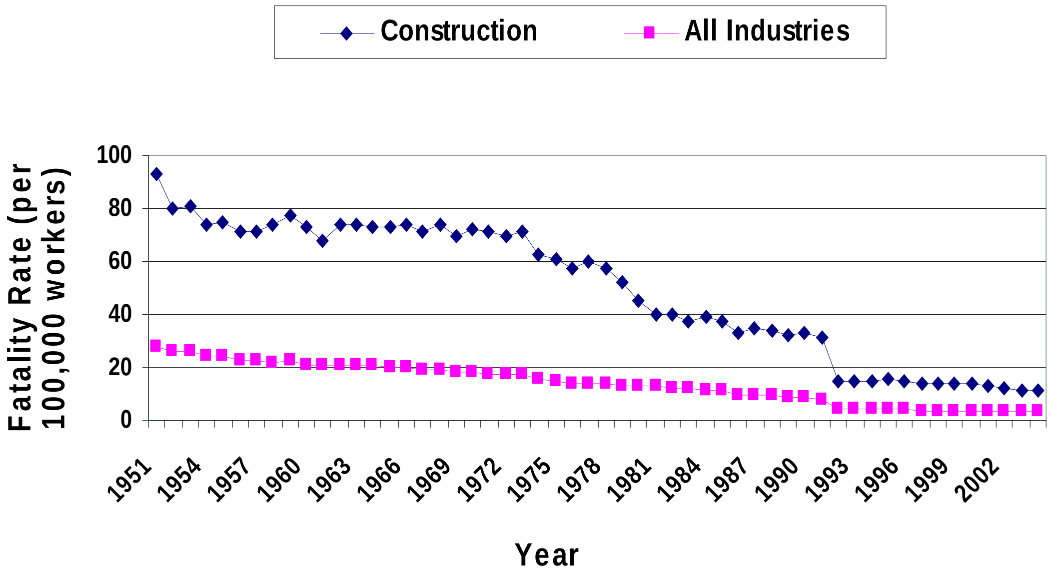

Figure 1.2: Annual Fatality Rate of Construction versus All Industries (Source: "Injury Facts", National Safety Council, 1952-2004)

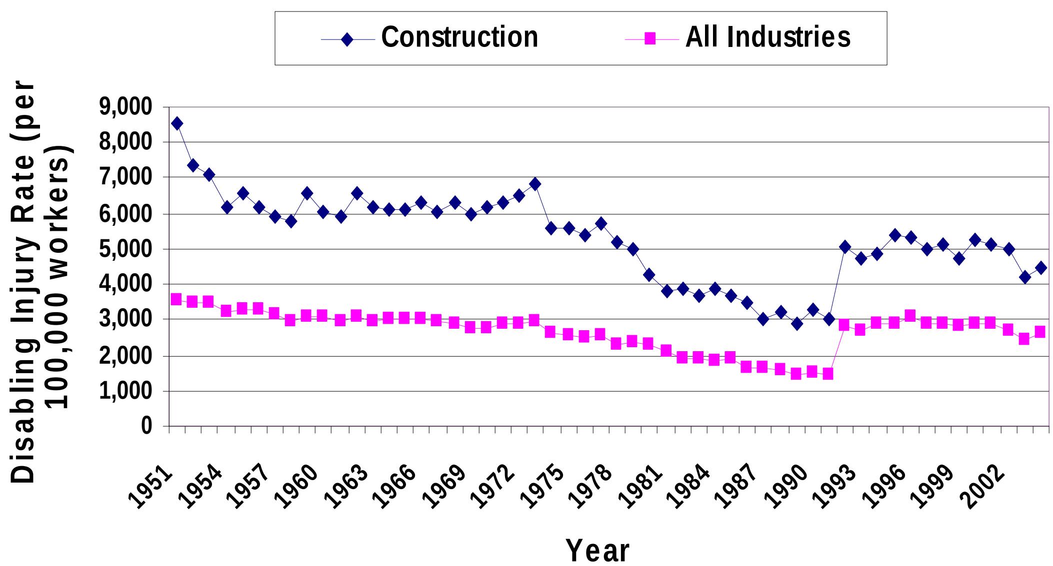

Figure 1.3: Annual Disabling Injury Rate of Construction versus All Industries (Source: " Injury Facts", National Safety Council, 1952-2004)

The causes of injuries and illnesses in construction have long been recognized and their persistence continues to frustrate construction safety and health practitioners and researchers. Traumatic injuries have historically been caused by falls, electrocution, being struck by objects, or being caught in or between objects. The work lives of many employed in the construction industry have been shortened by repeated physical hazards posed by exposure to lead, silica, solvents, heat and cold, and a plethora of other chemical and environmental challenges (Hill 2003).

Not only are the construction injuries a great cause of humanitarian concern, but the high cost associated with injury/death is a motivation for a more sustaining safety performance in the construction industry. Construction site accidents are very expensive. In 1979, the Business Roundtable (BR) commissioned a study to determine the true costs of accidents and injuries in the construction industry. At that time, the BR concluded that accidents and injuries account for 6.5% of the total cost of industrial, commercial, and utility construction (as cited in Everett and Frank Jr. 1996). Another study by Everett and Frank Jr. (1996) re-examined the costs of construction injuries and revealed that the total cost of accidents has risen to somewhere between 7.9% and 15.0% of the total cost of non-residential, new construction.

In 2004 the construction industry experienced 460,000 disabling injuries. The cost of these disabling injuries was estimated to be $15.64 billion (NSC 2006). NSC estimates the cost per death to be $1,150,000. The construction industry experienced 1,194 deaths in 2004. With approximately 10.3 million employees in the construction industry the average total cost for injuries and deaths was $1,656 per construction employee. Table 1.1 outlines the estimated cost of injuries and deaths in the construction industry.

Table 1.1: Cost of Injury/death per Construction Employee, year 2004 (NSC 2006)

	Number in 2004	**Cost per fatality/injury**	**Total cost**
Fatalities	1,194	$ 1,150,000	$ 1,373,100,000
Disabling injuries	460,000	$ 34,000	$ 15,640,000,000
Total Cost			$ 17,013,100,000
Construction workers	10,272,000		
Total cost per employee			$ 1,656

Safety has traditionally rested primarily on the constructor's shoulders. Over the past few decades, efforts have been made to improve worker safety and health in the construction industry. Construction companies have developed positive safety cultures and are committed to creating an "injury free work environment" on all of the projects they perform. However, no industry-wide recognition exists, such as a Gold or Platinum safety certification, for those projects which stand out in their commitment to reduce workplace fatalities and injuries. Such recognition would provide a motivation to constructors to sustain safety and performance on all projects.

Past research has exposed the influence that owners, designers, and subcontractors have on construction worker safety and health. An owner can impact safety through the selection of safe contractors, inclusion of safety requirements in the contract, and active participation in safety during project execution (Hinze 2003). Designers dictate the configuration and components of a facility and thereby control, to a large extent, how the project will be constructed (Hinze and Gambatese 1996). Subcontractors also significantly impact safety, since they perform the majority of the on-site work on a project. Research has been conducted in the past to assess the role of the four critical players (owner, designer, constructor, and subcontractors), individually in the project development process (PDP). Today, however some projects involve one or more of the four parties in addressing safety and health in the PDP. Research on the combined efforts of some or all of these parties is lacking. There exists a gap in research aimed at identifying the safety performance if all four parties are involved.

As discussed previously, stimulus for this research is LEED. LEED projects are proposed by the owner at the start of the PDP and implemented by the designer, constructor and subcontractors. The LEED rating system lacks a construction worker safety and health component. LEED's negligible consideration of construction worker safety and health, and the potential significant impact of increased LEED presence in the industry, leads to a question of its impact on construction worker safety and health.

Minimal research and knowledge exist on applying the concept of sustainability to construction safety and health. However, the inclusion of safety and health in sustainability concepts and practices is recognized within the occupational safety and health community as imperative in order for sustainability to be addressed and achieved. In addition to watching the financial "bottom line", corporations and other organizations are expected to pursue an acceptable "social bottom line," in terms of social equity (Elkingon 1998). Organizations concerned about social equity often foster a culture that respects diversity, considers the health of local communities when making outsourcing and other strategic decisions, and ensures employee access to healthcare and a safe work environment. Occupational safety and health issues are a part of the social dimension in sustainability agendas (Gilding 2002). No entity that presides over avoidable workplace deaths, injuries, or illnesses can ever claim to be sustainable (DJSI 2006).

1.3 Sustainable Construction Safety and Health

Sustainable development can be defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (the Brundtland Report 1987). As mentioned previously, sustainability or sustainable development is about much more than just the environment. This is exhibited in the following definitions of sustainability as:

- "improving the quality of human life while living within the carrying capacity of supporting ecosystems" (Caring for the Earth, IUCN/UNEP 1991)
- "development that delivers basic environmental, social, and economic services to all residences of a community without threatening the viability of natural, built,

> and social systems upon which the delivery of those systems depends" (ICLEI 1996)

Construction worker safety and health plays a major role in achieving sustainable socio-economic development of the workers in the industry. The sustainable safety and health concept, which considers the social and economic well being of the construction workers, is a new approach to boosting the safety and health performance of construction workers. The sustainable safety and health concept aims to sustain the construction worker's safety and health:

- from start to finish of a single project;
- for each future project a worker is involved in; and
- during the worker's remaining life time after retirement.

For example, the work lives of many construction workers have been shortened by repeated physical hazards posed by exposure to lead, silica, asbestos, and many other chemical and environmental hazards. The condition may persist even after the exposure has been stopped when the worker quits the job or is reallocated to a different project. The construction worker's health could have been sustained if he or she were properly protected from the exposure in the first place. Many safety and health elements, if properly implemented in a project development process, can help sustain worker safety and health. The sustainable safety and health concept approaches the consideration and implementation of safety and health measures from a different perspective.

1.4 Scope and Objectives

The overall goal of the proposed research is to help the construction industry sustain the safety and health of construction workers. To meet this goal, the research involved three main objectives.

The first objective (Phase I) was to determine the difference, if any, in safety and health performance of green and non-green building projects as identified by LEED. Two research activities were planned to fulfill this objective. The first activity was a pilot study to serve as a preliminary investigation of the relationship between green design and construction and construction worker safety and health. Questions addressed in the pilot study were:

- Is there an impact either positively or negatively, of green building design and construction (LEED buildings) on the safety and health of the construction workers?
- If so, what are the green design and construction practices that affect worker safety and health?
- What are the project members' perspectives on the relationship between green building design and construction practices and construction worker safety and health?

The second activity undertaken to meet the first research objective involved the determination of the difference, if any, in safety and health performance (based on OSHA recordable and lost time injury/illness rates) of LEED rated projects and non-LEED rated projects. A quantitative research approach was adopted for this task involving the development and distribution of a short questionnaire. The questionnaire was sent to construction contracting firms located in the Pacific Northwest and across the U.S. Safety and health performance data was collected for both LEED rated and non-LEED projects. This data was used to compare the safety performance between these two types of projects. The scope of the projects studied as part of the research includes all building projects built by the participating firms in the last five years. This criterion is based on the fact that the LEED rating system was introduced in 2000 and, therefore, no LEED rated projects exist which are more than 5 years old.

The second objective of the research (Phase II) was to develop a sustainable construction safety and health rating system that will provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of safety and health elements. The Delphi survey technique was used in the development of the rating system. Delphi uses a highly structured and focused questionnaire approach in order to establish a consensus opinion from "experts" geographically dispersed.

The final objective (Phase III) of the research study was to validate the sustainable construction safety and health rating system developed based on real-time projects. The scope of validation was limited to building projects, but was left open to other types of projects as seen pertinent during the course of the study.

A detailed study design was developed at the start of the research study. This served as a roadmap for the author to fulfill the research objectives. The study design followed to fulfill the three objectives is presented in Table 1.2.

Table 1.2: Sustainable Construction Safety and Health Research Study Design

Phase I **Impacts of Green Buildings**	**Phase II** **Rating System Development**	**Phase III** **Rating System Validation**	**Phase IV** **Thesis Defense**
1. Pilot study 2. Comparison of LEED and Non-LEED building projects	1. Literature review 2. Plan Delphi process 3. Select Delphi panel 4. Construct Delphi process 5. Develop rating System	1. Select validation projects 2. Validate rating system	1. Write dissertation 2. Defend thesis

1.5 Research Significance

The building industry's current perspective of sustainability is based on the principles of resource efficiency and the health and productivity of the building's occupants. Before construction worker safety and health can be integrated into sustainable design and construction practices, an understanding of whether current green design and construction practices impact construction worker safety and health is required. This research provides knowledge of the difference in construction worker safety and health performance between LEED and non-LEED construction projects. The findings will indicate the presence/absence of any relationship between injury incidents and green building design and construction practices. Specific green building design and construction practices that influence the safety and health of construction workers are identified. If there is a negative impact, or even no impact of green building design and construction on construction worker safety and health, the building industry's sustainability philosophy and principles should be modified to incorporate construction worker safety and health. This is based on claims that: (1) a building cannot be called sustainable if it leads to injuries/illnesses, and (2) consideration should be given to the entire project lifecycle, as opposed to current practice that focuses primarily on the phases after construction is complete. The proposed research aims to contribute to the existing body of knowledge with the purpose of driving such change.

The major outcome of the research is the incorporation of construction worker safety and health into the sustainability concept. To implement the sustainable safety and health concept in the construction industry, a sustainable construction safety and health model/rating system is developed. The sustainable safety and health rating system incorporates the safety and health elements to be implemented to sustain worker safety and health from project-to-project. The rating system will provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of safety and health elements. The rating system could be used as a tool to help sustain the safety and health of construction workers. Recognition for using the rating system will be an added incentive to the project team to improve the safety and health performance of the project. Since the rating system would require the joint efforts of all of the parties involved in the project, a team effort would be another benefit that will help set in motion the sustainable safety and health drive in the construction industry.

1.6 Dissertation Organization

This dissertation is composed of four manuscripts addressing a common theme. Four papers have been envisioned to be published of these four manuscripts.

The first manuscript (Chapter 2), titled "Impacts of Green Building Design and Construction on Worker Safety and Health – A Pilot Study," was published in the conference proceedings of the American Society of Safety Engineers Professional Development Conference and Exposition in June 2006 (Gambatese et al. 2006). This paper presents the findings of a pilot study that served as a preliminary investigation of the relationship between green design and construction worker safety and health.

The second manuscript (Chapter 3), titled "Impacts of Green Building Design and Construction on Worker Safety and Health," will be submitted for publication to the ASCE *Journal of Construction Engineering and Management.* This paper compares the difference in safety performance (OSHA recordable and lost time injury/illness rates) between green and non-green buildings as defined by the LEED rating system.

The third manuscript (Chapter 4), titled "Sustainable Construction Safety and Health Rating System," will be submitted for publication to the ASCE *Journal of Construction Engineering and Management.* This paper presents a rating system that will provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of safety and health elements.

The fourth manuscript (Chapter 5), titled "Validation of Sustainable Construction Safety and Health Rating System," will be submitted for publication to the ASCE *Journal of Construction Engineering and Management.* This paper presents the findings of the research undertaken to validate the SCSH rating system. Additional information gained as part of the research in developing the four manuscripts (Chapters 2 to 5) is presented in the Appendices to this document.

1.7 References

DJSI (2006). "Dow Jones Sustainability Indexes", SAM Indexes GmbH, Zurich, Switzerland. <www.sustainability-indexes.com/default.html> (December 7, 2005).

Elkington, J. (1998). *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*. New Society Publishers, Gabriola Island, BC, Canada.

Everett, J.G., & Frank, P.B. (1996). "Costs of accidents and injuries to the construction industry". *Journal of Construction Engineering and Management,* 122(2), 158-164.

Gambatese, J.A., Rajendran, S., and Behm, M., (2006). "Building Towards Sustainable Construction Safety and Health." *ASSE Professional Development Conference & Exposition*, Seattle, WA, June 12-14, 2006.

Gilding, P., Humphries, R., and Hogarth, M. (2002). *Safe companies: A practical path for 'operationalizing' sustainability*. ECOS Corporation Publications, Sydney, New South Wales, Australia.

Hill, Darryl C. (2003). *Construction safety management and engineering*. American Society of Safety Engineers, Des Plaines, Illinois.

Hinze, J. (2003). *The Owners Role in Construction Safety*. Construction Industry Institute Research Summary 190-1. The University of Texas at Austin.

Hinze, J. and Gambatese, J.(1996). *Addressing Construction Worker Safety in the Project Design.* Construction Industry Institute Research Report 101-11. The University of Texas at Austin.

International Council for Research and Innovation in Building and Construction (CIB). (2002). *Construction Site Waste Management and Minimization.* Report Prep. by Dennis S. Macozoma. Report No. BOU/C361.

IUCN/UNEP/WWF (1991). *Caring for the Earth. A strategy for sustainable living.* IUCN, UNEP and WWF, Gland, Switzerland, and Earthscan, London.

International Council for Local Environmental Initiatives (ICLEI) (1996). *Local Agenda 21 Planning Guide: An Introduction to Sustainable Development Planning.* ICLEI, Toronto.

National Safety Council (NSC) (2006). *Injury Facts 2005-2005 Edition.* Itasca, Illinois.

The Brundtland Report (1987). *World Commission on Environment and Development—Our Common Future.* Oxford University Press, New York.

Impacts of Green Building Design and Construction on Worker Safety and Health – A Pilot Study

Sathyanarayanan Rajendran
John Gambatese

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2.0 IMPACTS OF GREEN BUILDING DESIGN AND CONSTRUCTION ON WORKER SAFETY AND HEALTH – A PILOT STUDY

2.1 Abstract

This paper presents the findings of a pilot study to serve as a preliminary investigation of the relationship between green buildings and construction worker safety and health. The purpose of the study was to assess whether there is an impact, either positively or negatively, of green building design and construction (LEED buildings) on the safety and health of the construction workers. If so, the study aimed to determine the green design and construction practices that affect worker safety and health. A preliminary literature search did not uncover any documents discussing the impacts of green design and construction on the safety and health of construction workers. For the purpose of this study, a LEED-NC "Gold" registered building construction project was used as the focus of the pilot study. Data used for the pilot study was collected through: focus group interviews of project personnel and review of project documentation. Some features of LEED buildings, such as construction material recycling programs, appear to negatively impact the *safety* of construction workers, while others, such as the use of low VOC materials, help to eliminate construction site *health* hazards. Project personnel felt that green building projects were "a little safer" than conventional building projects. One of the OSHA recordable injuries experienced on the project (foot punctured by nail) was related to a green feature of the project (material recycling).

2.2 Introduction

Green building design and construction has become more prevalent in the U.S. construction industry over the past decade. Green buildings are those whose design and construction employ techniques that minimize environmental and resource impacts, and contribute to the safety, health, and productivity of their occupants. The U.S. Green Building Council (USGBC) recognizes buildings designed and constructed using these techniques by means of its *Leadership in Energy and Environmental Design* (LEED) rating system released in 2000. This recognition is leading to changes in the way owners, designers, and constructors approach the design, construction, and operation of buildings.

Currently in all 50 states and in 13 countries around the world, 2,069 new construction projects have been registered with the USGBC and 289 new construction projects have received LEED certification (USGBC 2005a). This amounts to approximately 235 million gross square feet of building space (USGBC 2005a). Analysts predict the number of registered projects will grow to 5,000 by the end of 2007 with more than 1,000 LEED-certified projects during the same time, more than a ten-fold increase over year-end 2003 (Yudelson 2004). This intense movement toward green design represents a major portion of the building industry's activity, and *might* have major impacts on the health and safety of those who construct the buildings – the construction workers.

Past research has focused on the impact of green design and construction on the health and productivity of the final occupants (end-users) of the facility. Literature indicates that green building concepts, applied to the design, construction, and operation of buildings, can enhance both the economic well-being and environmental health of a building's final occupants (USGBC 2005). However, questions exist regarding whether the inclusion of green concepts in the building development process has positive or negative impact on construction worker safety and health.

The objective of this pilot study is to serve as a preliminary investigation of the relationship between green design and construction and construction worker safety and health. The following questions were addressed in the pilot study:

- Is there an impact of green building design and construction (LEED buildings) on the safety and health of the construction workers?
- If so, what are the green design and construction practices that affect worker safety and health, either positively or negatively?
- What are the project members' perspectives on the relationship between green building design and construction practices and construction worker safety and health?

Evidence of a link, either positive or negative, from the pilot study will help to plan and conduct subsequent research to answer the following questions:

- Is there a difference in the safety and health performance (based on OSHA recordable and lost time injury/illness rates) of LEED rated projects and non-LEED rated projects?
- What is the relationship between construction worker injuries and illnesses on LEED building projects and the green design and construction aspects implemented on the projects?

An understanding of whether current green design and construction practices impact construction worker safety and health will provide the construction industry with the knowledge required to move forward and develop green design and construction practices, and green building rating systems, that benefit construction worker safety and health.

2.3 Literature Review

A preliminary literature search did not uncover any documents discussing the impacts of green design and construction on the safety and health of construction workers. This may be attributed to the fact that the LEED Rating System is relatively new, introduced by USGBC in 2000, and studies of its impact on construction safety have yet to be completed and published.

2.4 Research Methodology

2.4.1 Project Description

A construction project on the Oregon State University (OSU) campus was used as the focus of the pilot study. The project was the construction of a new, four-story, 146,000 square foot, electrical engineering/computer science building. The building was designed and constructed to the LEED "Gold" specifications for sustainability. Some of the green features of the building include:

- Natural ventilation: interior spaces provided with fresh air
- Indoor air quality management during construction
- Use of low emitting materials
- Energy efficiency: building systems designed to require 35% less energy than the minimum allowed by the building code
- Atrium/day lighting: classrooms, labs, and offices supplied with natural light, cutting energy costs by as much as 40%
- Earth-friendly concrete: reduces CO_2 emissions
- Bio-planters: "recycle" water runoff and provide outdoor seating
- Bicycle parking and showers: encourages alternative transportation use
- Use of local construction materials: reduces transportation costs
- Low-toxicity finishes, fiberboard, and flooring: minimizes VOC (volatile organic compounds) off-gassing
- Demolition materials: over 90% of original materials on site were recycled

The primary reasons for the selection of this project for the pilot study were:

- It was being built to achieve a LEED "Gold" certification;
- Close proximity to the researchers;
- It was a building project; and
- Full cooperation by the general contractor on the project was provided.

2.4.2 Data Collection and Analysis

Data used for the pilot study was collected in two ways: focus group interviews of project personnel, and reviews of project documentation. The participants in the focus group interviews (typically 4-6 per group) included on-site representatives, both management and labor, from the general contracting and subcontracting firms working on the project. Focus group interviews were conducted periodically during the course of construction (approximately once every 3-4 months) to obtain the participants' perspectives and input on the impact of the project's green building design and construction features on worker safety and health. Five rounds of interviews were conducted throughout the entire construction phase to obtain the views of different subcontractors who worked on the project at different times during the project. Overall, 24 participants were interviewed in the pilot study, some participating in more than one focus group.

The researchers used a written questionnaire to conduct the focus group interviews. The questionnaire was composed of questions that solicited information regarding: the participant's awareness, knowledge, and experience with constructing LEED buildings; the participant's knowledge of the green features included in the pilot building project; the perceived negative and/or positive impacts of green features on construction worker safety and health; the relative safety and health performance between conventional and green buildings; and any impacts of the green building on their regular tasks. The questionnaire used during the data collection process contained the following questions:

1. What type of work do you perform on this project (e.g., masonry, concrete, steel, etc.)?
2. How long have you been working on this project?
3. Did you know that this building is being commissioned as a green building?
4. Have you worked on other green building projects in the past?
5. Do you know of any particular aspects of this construction project that are being implemented as part of the green building process? If so, please describe.
6. Do the aspects listed in Question 5 affect construction site safety or health in any way? If so, how?
7. With regards to construction site safety and health, green building construction when compared to conventional construction is:
   ❐ Much safer ❐ A little safer ❐ Same ❐ Less safe ❐ Much less safe
8. Do you think that green designed buildings should consider construction worker safety and health as part of the LEED accreditation process? Why or why not?
9. Has the fact that the building is a green building impacted your work in any way? If so, please describe.
10. Are there any aspects of the design that have made it safer to perform the work? If yes, describe.

11. Are there any aspects of the design that make it difficult to work safely? If yes, describe.

The interviews were conducted in the general contractor's office trailer on the jobsite. Questionnaires were handed out to the participants at the start of the interview, allowing them time to read through the questions. The researchers then asked each question to the group and solicited responses. The participants were also asked to record their answers on the questionnaire forms where appropriate to ensure that their responses were recorded. Furthermore, the participants were individually given a chance to answer each question verbally. The respondents were asked to provide their responses based on their experience on this project and, where relevant, the projects they have worked on in the past. All responses to the questions were recorded by the researchers.

In addition to the focus group interviews, project documentation was obtained from the general contractor and reviewed to find any evidence of a connection between green features and construction site hazards. Project documentation reviewed included: job hazard analyses (JHAs) prepared by subcontractors; a LEED matrix showing the categories in which each of the LEED points is obtained; and OSHA recordable and lost time injury/illness data.

The data collected in the study was analyzed using both quantitative and qualitative methods. Quantitative analysis involved simple statistical analyses. Since most of the questions were closed-ended, frequency statistics were used to evaluate the responses of the participants. Open-ended questions were analyzed qualitatively to assess the participants' perspectives of the construction worker safety and health differences between LEED and non-LEED building projects.

2.4.3 Limitations

One limitation of the methods chosen for this study is the presence of confounding variables that might affect worker safety and health even in the absence of the building being LEED registered. The two most significant variables are described here. The general contractor managing the project is certified to the ISO 14001 standard. This requires the contractor to implement environmentally friendly practices on not only LEED projects, but on all of its jobsites. Secondly, the general contractor is one of the safest contractors in the U.S., with a very good safety program in place. These two variables could possibly impact the effect of LEED on construction worker safety and health on the studied project.

2.5 Results

The focus group participants had varied backgrounds representing a variety of trade specialties. The breakdown of participants based on trade is shown in Table 2.1. Of those interviewed, the majority represented the general contractor (29.2%) followed by mechanical (16.7%) and concrete (16.7%) subcontractors. The length of time spent on the project of those interviewed ranged from one to 24 months (mean = 7.3 months; median = 5.5 months).

Table 2.1: Distribution of Participants by Trade/Profession (n = 24)

Trade/Profession	Frequency	Percent of All Participants (%)
General Contractor	7	29.2
Mechanical	4	16.7
Concrete	4	16.7
Drywall	2	8.3
Electrical	2	8.3
Excavator	1	4.2
Structural Steel	1	4.2
Window	1	4.2
HVAC Controls	1	4.2
Carpenter	1	4.2
Total	24	100.0

General knowledge of LEED and experience constructing LEED projects among the focus group participants was evaluated utilizing the responses to three different questions. In the initial stage of the interview, the participants were provided the opportunity to state their understanding of the green concept and the LEED rating system. The specific questions and a summary of the responses are provided in Table 2.2. Most of those interviewed had knowledge about the LEED rating system and only a few did not know about LEED. Twenty respondents (83%) indicated that they knew that the current project was being built to be a LEED certified building. Eight respondents (33%) stated that they had previous experience working on a LEED certified building project, while one respondent reported that he had previously worked on several LEED buildings.

Table 2.2: Green Building Awareness and Experience (n = 24)

Survey Question	# Answering "Yes"
Did you know that this building is being commissioned as a green building?	20 (83.3%)
Have you worked on other green buildings before?	8 (33.3%)

The focus group interviews solicited input from the participants regarding the specific green design and construction features actually implemented on the project as part of its design. The following are the features recognized by the participants as being part of the building's green design:

- Recycling program
- Rain water collection system in the basement
- Use of low emitting paint
- Energy efficiency
- Heaters attached to windows
- Natural light through atrium
- Solar panels on the roof
- Use of regional materials
- Waste diversion
- Use of permeable paving
- Use of a reflective roof coating
- Indoor air quality plan

Two questions were aimed directly at the impacts of green design and construction practices on construction worker safety and health. Impact was considered to be either positive (improving safety and health) or negative (making the construction work more hazardous). Those interviewed reported some positive and some negative aspects of the building being commissioned as green. The responses are summarized below:

- *Positive aspects:*
  - Good housekeeping – less chance for trips, slips, and falls. The recycling program resulted in a cleaner project site. They felt this was one of the cleanest projects that they have worked on.
  - Low VOC (volatile organic compounds) materials – cleaner air provides a reduced health hazard to workers.
  - Painting – more consideration is being given to the time and location of where to paint in order to minimize the impact of the paint odor.

- *Negative aspects:*
  - Increased material handling – Waste materials from the construction process are gathered on the ground and manually separated according to the type of material (e.g., wood, steel, plastics, and glass). In some cases material assemblies must be dismantled piece-by-piece before separation. Once separated, the materials are loaded into different containers. Recycling makes workers handle material 2-3 more times than usual. Workers spend more time separating and moving materials than in a normal project, which creates the potential for strains, sprains, and punctures.
  - More dumpsters – The presence of multiple recycling dumpsters creates congestion on the jobsite near the material lay down and entry/exit areas.
  - Atrium design – While the atrium provides natural light to interior areas of the building, it increased the duration of the work due to the need for scaffolding up to the top of the 4-story atrium. There was also an increased risk of workers falling from the extensive scaffolding system required.

In response to the comments of increased materials handling and congestion, the project LEED documentation was reviewed to see if material handling was included. It was found that the project goal was to divert 90% of the project's waste from landfills. At one time, the contractor reported that the project had managed to divert 99% of construction and demolition waste from landfills. This reinforces the participants' claims of intensive material handling on the project.

The project site contained several large dumpsters to collect the respective waste materials which the participants identified as causing congestion on the project site. One such dumpster is shown in Figure 2.1. Figure 2.2, taken from the building being constructed, shows all of the five dumpsters placed at the entrance of the project site and their distance from the work location. The workers had to walk a long distance to dump the materials. With regards to materials selection, the project incorporated low-emitting materials that include adhesives/sealants, paints/coatings, and carpet systems. The project also attempted to avoid all materials containing added urea-formaldehyde.

Figure 2.1: Dumpster Used to Collect Waste Materials

Figure 2.2: Project Offices and Material Lay down/Storage Area and Dumpsters (top right corner of the picture)

One survey question solicited the participant's judgment as to how green buildings compared to conventionally-designed buildings in terms of construction site safety and health. A summary of the responses is presented in Figure 2.3. Of those interviewed, twelve (50%) felt that green buildings were a little safer, seven (29.2%) stated that they were much safer, and five (20.8%) reported that they were the same as conventional buildings in terms of construction safety. None of the respondents felt green buildings were less or much less safe to construct than conventional buildings.

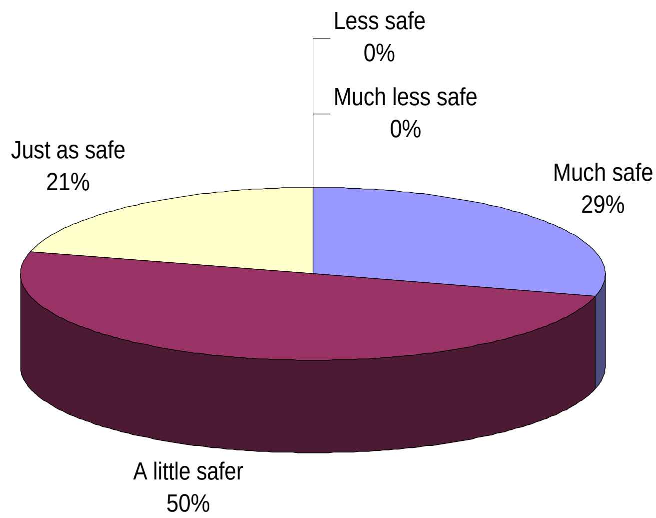

Figure 2.3: Safety and Health of Green Building Construction Compared to Conventional Buildings (n = 24)

Another question elicited their opinion of including construction worker safety and health in the LEED rating system in addition to that of the final occupants. Nineteen participants (79.2%) felt that construction worker safety and health should be considered during the LEED accreditation process, four (16.7%) responded “no”, and one participant did not answer the question. Responses to this question are, of course, dependent on the participant’s extent of knowledge of sustainability concepts, the LEED rating system, and the certification process.

One survey question asked: “Has the fact that the building is a green building impacted your work in any way?” Most of the comments received were directed at the extra effort needed to separate and recycle the waste materials generated on the project. Some of the comments received include:

- Yes, separating recyclable materials takes time.
- Yes, shop for different sources of materials, intangible value to owner, LEED documentation required and more awareness.
- Yes, more cleaning required like vacuuming.

- Yes, cleaner and safer which means more production.
- Yes, longer to clean-up and separate material.

The last two questions of the survey were aimed at soliciting the participants' input on the design for safety and health concept. One question asked: "Are there any aspects of the design that have made it safer to perform the work?" Five participants (20.8%) felt that none of the design aspects improved the working conditions, six (25.0%) responded "yes", and thirteen participants did not answer the question. Two design aspects which they felt made it unsafe for them to work included: windows with heaters to prevent fogging, and use of less hazardous materials on the project.

The last question of the survey asked the participants whether any aspects of the design made it difficult for them to work safely. Ten participants (41.7%) felt that none of the design aspects made the working conditions difficult for them to work safely, four (16.7%) responded "yes", and ten participants did not answer the question. Some of the design aspects that had made it unsafe for them to work safely included:

- No engineered anchor points on roof.
- Rebar spacing in columns/walls was small. This made it tougher to use vibrators to consolidate the concrete.
- No tie-offs for steel workers when placing trusses on the roof.
- Support walls for raised floor areas that are short create falling hazards. Many floor openings also triggered trip hazards. The raised floor system used in the building is exhibited in Figure 2.4.
- Brick cleaning liquid has acid and is hazardous to eyes.
- Atrium design made it difficult for workers due to the fall exposure while working on the atrium.
- Large pieces of stone and pre-cast for flooring and veneer were very heavy.
- Two story rebar cages for basement columns created obstructions for crane when moving materials. This especially did not allow for splicing cages in lower floors.

- The continuous footings below the shear walls in the basement were too narrow. It was difficult to work around the walls because there was no place to walk with the forms in place. Design the footings to be wider
- Parapet heights should be 42" to act as guardrails.
- Atrium skylight area has exposed floor edges (no adjacent walls). Hard to install temporary guardrails because all of the surrounding concrete will be exposed and must have a smooth, finished surface without holes. Nothing to attach guardrails to.

Figure 2.4: Raised Floor Areas Increase Chance of Trip Hazards

Project documentation was also reviewed as part of the data collection process. Job hazard analyses (JHAs) prepared by subcontractors describe the hazards recognized by subcontractors and how they plan to mitigate the hazards in the performance of their work. JHAs for the following work on the project were reviewed as part of the pilot study:

- Concrete forming and placement

- Erection of tower crane
- Underground utilities (steam, firewater, waste, and vent piping)
- Interior partition walls
- HVAC duct installation
- Waterproofing
- Generator placement

While the JHAs identified the hazards associated with the work, none of the identified hazards could be attributed specifically to the green design and construction features on the project. While not confirmed, it is unlikely that those who prepared the JHAs participated in the focus group interviews. Therefore it is not known whether those who prepared the JHAs were aware that the building was designed as a green building.

Project safety performance data was obtained from the general contractor at the end of the project. Safety data obtained included the number of OSHA recordable and lost time injuries on the project and the details of each incident. The total number of worker hours was also obtained in order to calculate the recordable and lost time injury rates. The project safety performance data is summarized in Table 2.3.

Table 2.3: Injury Data on the Project

Metric	Pilot Project	Construction Industry
Total worker-hours worked on the project	265,000 hrs	--
Number of minor incidents (non-recordable)	6	--
Number of OSHA recordable injuries	3	--
OSHA recordable rate (# of recordable injuries per 100 workers per year)	2.3	6.3
Number of lost time injuries	0	--
Lost time rate (# of lost time injuries per 100 workers per year)	0.0	3.4

The researchers gathered information on the three recordable injuries that occurred during the project for the purpose of evaluating the injuries in terms of their relation to the green building design and construction features. The three recordable injuries were as follows:

1. Hand scalded – A pipe fitting was not put on tight enough and came off with the flow of hot water.
2. Slip on concrete roof – Slippery surface caused by morning dew on the roof (not caused by the reflective roof coating).
3. Foot punctured by nail – Worker was "breaking down" a wood pallet for separation of waste materials into different recycling bins.

The puncture injury to a worker during waste material handling reinforces the concern raised by the project personnel during the focus group interview process. The added effort required by the LEED certification process increases the amount of material handing required, creating a hazard that would not be present on construction sites that do not have recycling programs.

2.6 Conclusions and Recommendations

The pilot study provided a preliminary view of the impacts of green design and construction practices on construction worker safety and health. The following findings can be drawn from the study:

- Current literature does not provide evidence of the impact of green design and construction on the safety and health of construction workers.
- Some features of green buildings designed and constructed to meet the LEED Rating System, such as the construction material recycling programs, may negatively impact the safety of construction workers, while others, such as the use of low VOC materials, may help to eliminate construction site health hazards. It should be noted, however, that these hazards may occur as well on any project and not just on a LEED project.
- Project personnel predominantly felt that green building projects were a little safer than conventional building projects.

- One of the OSHA recordable injuries experienced on the project (foot punctured by nail) was related to a green feature of the project (material recycling). As noted above, this type of injury may also occur during general housekeeping on any project and not just on a LEED project.

The pilot study described above revealed that there might be some impact on construction worker safety and health on the project due to the fact that the building was designed as a green building and a LEED rating was desired. This finding suggests a need for a larger study of many projects to determine if the relationship between green design and construction features and construction worker safety and health exists throughout the construction industry or whether it is project-specific. The study undertaken for this purpose is explained in the following manuscript of this dissertation titled “Impact of Green Design and Construction on Worker Safety Performance.”

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2.7 References

United States Green Building Council (USGBC) (2006). “Leadership in Engery and Environment.” <www.usgbc.org> Washington, D.C. (July 2006).

United States Green Building Council (USGBC) (2005a). *An Introduction to the U.S. Green Building Council and the LEED Green Building Rating System*. United States Green Building Council, Washington, D.C., Oct. 2005.

Yudelson, Jerry (2004). “Perspective: Forecasting Market Demand for Green Buildings 2004-2007.” *Environmental Design and Construction.*

Impacts of Green Building Design and Construction on Worker Safety and Health

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3.0 IMPACTS OF GREEN BUILDING DESIGN AND CONSTRUCTION ON WORKER SAFETY AND HEALTH

3.1 Abstract

This paper presents the findings of a research study on the impact of green building design and construction practices on construction worker safety and health. Sustainable rating systems, such as the U.S. Green Building Council's *Leadership in Energy and Environmental Design* (LEED) rating system, are leading to changes in the way owners, designers, and contractors approach the design, construction, and operation of buildings. Questions exist regarding whether these "changes" to include green concepts in the building development process have positive or negative impact on construction worker safety and health. For instance, what is the difference in injury rates between LEED-rated projects and non-LEED rated projects? Does the injury rate differ based on the level of LEED certification (Certified, Silver, Gold, or Platinum) and/or numerical rating (actual LEED points received)? This study was conducted to answer these questions.

The study consisted of two major research activities: (1) Gather and analyze OSHA recordable and lost time injury/illness data on green and non-green building projects (as identified by LEED) through a structured questionnaire survey; and (2) Interview industry personnel to obtain their input on the impacts of green building design and construction on construction worker safety and health. The project data collected was analyzed to test the presence of any difference in OSHA recordable incident rates (RIR) and lost time case rates (LTCR) between LEED and non-LEED building projects. It was found that there was suggestive, but inconclusive evidence of a statistically significant difference between the RIR of LEED and non-LEED projects. The LEED projects had higher mean and median RIR's than the non-LEED projects. There is not a statistically significant difference between the LTCR's for the LEED and non-LEED projects included in the current study. The study did not reveal any difference in RIR and LTCR for the different levels of LEED certification.

3.2 Introduction

Past research has focused on the impact of green design and construction on the health and productivity of the final occupants (end-users) of the facility. Literature indicates that green building concepts, applied to the design, construction, and operation of buildings, can enhance both the economic well-being and environmental health of a building's final occupants (USGBC 2006). However, questions exist regarding whether the inclusion of green concepts in the building development process has positive or negative impact on construction worker safety and health. For instance, what is the difference in injury rates between LEED rated projects and non-LEED rated projects? Does the injury rate differ depending on the number of green features incorporated into the building (actual LEED credits received)? What is the industry's perspective on green design as it relates to construction worker safety and health? What accidents or injuries are prevented, or may occur, due to the implementation of green design and construction features?

The building industry's current perspective of sustainability is based on the principles of resource efficiency and the health and productivity of the building's occupants. However, if a building is labeled as "sustainable", it should be sustainable across its entire lifecycle, including construction, and design and construction practice should also consider the construction workers. Based on this belief, the building industry's sustainability philosophy and principles should be modified to incorporate construction worker safety and health. This will ensure that consideration is given to the entire project lifecycle, as opposed to current practice that focuses solely on the phases after construction is complete. The proposed research aims to contribute to the existing body of knowledge with the purpose of driving such change.

3.3 Research Objectives

The pilot study described in manuscript one, "Impacts of Green Building Design and Construction on Worker Safety and Health – A Pilot Study" suggested that there was an impact on construction worker safety due to the fact that the building was designed as a green building and a LEED rating was desired. This finding suggested a need for a larger study of many projects to determine if the relationship between green design and construction features and construction worker safety and health exists throughout the construction industry. Hence, the objective of this study was to examine the relationship between green building design and construction practices and construction worker safety and health by answering the following research questions:

- Is there a difference in safety and health performance (based on OSHA recordable and lost time injury/illness rates) between green and non-green building projects (as identified by LEED)?
- Does the injury rate differ based on the level of LEED certification (Certified, Silver, Gold, or Platinum) and/or numerical rating (actual LEED points received)?
- What green design and construction practices impact, positively or negatively, construction worker safety and health?

An understanding of whether current green design and construction practices impact construction worker safety and health will provide the construction industry with the knowledge required to move forward and develop green design and construction practices, and green building rating systems, that benefit construction worker safety and health.

3.4 Literature Review

A detailed literature review was conducted to examine some of the world's leading sustainable building ratings systems and any research discussing the impacts of green design and construction on the safety and health of construction workers. The results of the search are presented in this section.

3.4.1 Sustainable Building Rating Systems

Three sustainable rating systems that are used around the world are: Leadership in Energy and Environmental Design (LEED) administered by the U.S. Green Building Council (USGBC); Building Research Establishment Environmental Assessment

Methodology “BREEAM” of the United Kingdom; and Green Star certification of Australia.

3.4.1.1 LEED

The most common and widely used certification is the LEED rating system. USGBC was formed in 1993, as a coalition of leaders from every sector of the building industry working to promote buildings that are environmentally responsible, profitable, and healthy places to live and work (USGBC 2006). USGBC's core purpose is to transform the way buildings and communities are designed, built, and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life (USGBC 2006). USGBC released the LEED rating system as a voluntary, consensus-based national standard for developing high-performance, sustainable buildings. According to USGBC (USGBC 2006), LEED was created to:

- define "green building" by establishing a common standard of measurement;
- promote integrated, whole-building design practices;
- recognize environmental leadership in the building industry;
- stimulate green competition;
- raise consumer awareness of green building benefits; and
- transform the building market.

The pilot version of the first LEED rating system, for new construction (LEED-NC 1.0) was released in 1998. The official version, LEED-NC 2.0, was released in March of 2000. Currently there are seven different kinds of rating systems that include: new commercial construction and major renovation buildings, existing buildings operations, commercial interior projects, core and shell projects, homes, neighborhood development, and application guides (currently in pilot). The most commonly used one is LEED-NC.

LEED is organized based on a point system consisting of a total of 69 possible points in six categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design process. Buildings which satisfy or exceed the green requirements posed by the LEED rating system are formally certified by USGBC. There are four levels of formal certification based on the number of points a project receives: certified, silver, gold, and platinum. LEED has been accepted as the national standard for green building design and construction in the U.S., Canada, and many other countries.

A detailed review of the LEED rating system was conducted to identify any formal incorporation of construction worker safety and health. There are 67 elements leading to a total of 69 points that are part of the LEED rating system. Of the 67 elements, it was found that 19 of the elements (28.4%) and 19 of the total points (27.5%) impact the constructor's scope of work. Primarily designed to reduce environmental impacts, the LEED rating system contains only minimal focus on construction worker safety and health. Only one element, Indoor Air Quality (IAQ) management during construction, addresses construction worker safety and health. The intent of this element is to protect the construction workers and building occupants from potential air quality problems during the construction or renovation process. For example, the plan might include protection against dust formation in the HVAC duct systems that could trigger the growth of mold during construction. On successful implementation of this IAQ plan, the project will receive one LEED credit. Considering that the total number of possible LEED credits for a project is 69, one credit is almost negligible and underscores the minimal consideration of construction worker safety and health in the LEED Rating System.

It should be noted that other elements designed to improve the safety and health of the end-user may benefit the construction workers as well. For example, the element low-emitting materials (Paints and Coatings), improves the health of the construction workers compared to other paints.

3.4.1.2 BREEAM

United Kingdom's Building Research Establishment Environmental Assessment Methodology (BREEAM) is another commonly used sustainable building rating system. BREEAM assesses the performance of buildings in the following areas: management, energy use, health and well-being, pollution, transport, land use, ecology, materials, and water (BREEAM 2006). Credits are awarded in each area according to environmental performance of the building. A set of environmental weightings then enables the credits to be added together to produce a single overall score. The building is then rated on a scale of pass, good, very good or excellent, and a certificate is ultimately awarded. BREEAM covers a range of building types: offices, homes (known as EcoHomes), industrial units, retail units, and schools (BREEAM 2006). The rating system was reviewed for the presence of worker safety and health elements. Similar to LEED, BREEAM does not consider construction worker safety and health. The "health and well-being" is targeted towards end-users.

3.4.1.3 GREEN STAR

Green Star is administrated by the Green Building Council of Australia (GBCAUS). Green Star certification identifies projects that have demonstrated a commitment to sustainability by designing, constructing, or owning a building to a determined standard. Green Star certification is given to projects that have demonstrated they meet all requirements detailed in the relevant Green Star Technical Manuals for each of the rating tools. Currently, there is a suite of Green Star rating tools for commercial office buildings at all phases of development - design, construction, and operations. By the end of 2006, there will be Green Star tools for Retail, Health, Education, Convention, and Residential buildings. Upon award of certification, the project team is issued an award certificate and appropriate Green Star logos. Green Star rating tools use stars to rate performance: one star (10 – 19 pts), two star (20 – 29 pts), three star (30 – 44 pts), four star (45 - 59 pts, Best Practice), five star (60 - 74 pts, Australian Excellence), and six stars (75+ pts, World Leader) (GBCAUS 2006).

Green Star has built on existing systems and tools in overseas markets including the British BREEAM system and the North American LEED system. Green Star assesses the performance of buildings in the following areas: Energy Management, Water, Indoor Environment Quality, Transport, Ecology and Land use, Materials, Emissions, and

Innovation. Given its connection with LEED and BREEAM, it was obvious that Green Star does not incorporate elements addressing construction worker safety and health.

Review of the three major sustainable rating systems reveals the absence of construction worker safety and health consideration. This indicates that the building industry’s current perspective of sustainability is based on the principles of resource efficiency and the health and productivity of the building’s occupants. Of the three systems, the most recognized is the LEED rating system administrated by the USGBC. Owing to its popularity and widespread use, for the purpose of this research, green buildings were defined as those that are identified/certified by USGBC’s LEED. Any reference herein to green and non-green buildings refers to LEED and non-LEED buildings, respectively.

3.4.2 Impact of Green Building Design and Construction

A detailed literature search was performed to identify any research that has investigated the impacts of green building design and construction on construction worker safety and health. The search did not uncover any studies discussing the impacts of green design and construction on the safety and health of construction workers. This may be attributed to the fact that the most commonly used green building rating system, LEED, is relatively new, introduced by USGBC in 2000, and studies of its impact on construction safety have yet to be completed and published. However, the inclusion of safety and health in sustainability concepts is recognized within the occupational safety and health community as imperative in order for sustainability to be addressed and achieved. Occupational safety and health issues are a part of the social dimension in sustainability agendas (Gilding et al. 2002). No entity that presides over avoidable workplace deaths, injuries, or illnesses can ever claim to be sustainable (DJSI 2006).

3.5 Research Methodology

Based on the conclusion of the pilot study described in manuscript one, “Impacts of Green Building Design and Construction on Worker Safety and Health – A Pilot Study” and the literature review, a detailed study was performed to identify the impacts of green building design and construction on the safety and health of construction workers. The premise for the research approach is that a difference in safety and health performance (based on OSHA recordable and lost time injury/illness rates) exists between green and non-green (as identified by LEED) construction projects. A two-pronged research design was used for the research that included: (i) the collection of safety and health performance data for both green and non-green projects, and (ii) informal interviews of construction safety representatives on "whether green buildings have any impact on construction worker safety and health."

A quantitative research approach was adopted for the first task. This involved the development and distribution of a short questionnaire as the survey mechanism. The questionnaire consisted of three sections requesting information on project demographics, safety performance, and LEED. The first section was aimed at gathering information such as the project type (new construction, major remodel or mixed), facility type (education, healthcare, condominiums, office, mixed use, laboratory etc), project cost, size, type of ownership, location, etc. The second section solicited information on the safety performance of the project: total project work hours (self performed or subs included), number of OSHA recordable and lost time injuries/illness on the project, and number of near misses, if recorded. The last section focused on LEED information: certified or registered, type of certification, level of certification, number of points, and whether the project LEED documentation was available for review by the researchers.

The questionnaires were sent to construction contracting firms located in the Pacific Northwest and nationally. Fifteen construction firms were contacted as part of the study via email, written correspondence, and telephone call. The construction firms included in the study consisted of medium- to large-sized companies which construct buildings, including green buildings. Firms selected for the study were primarily those with which the researchers have personal contact and which have expressed an interest in helping out with the research. The study sample included more than one firm in order to help eliminate possible bias that one single firm might have with respect to safety and its green or non-green projects. The 15 firms have offices in the Pacific Northwest (Portland, Seattle, and/or the S.F.-Bay Area) and other parts of the country.

The respondents were asked to compile the survey information for as many projects as possible, limited to building projects constructed in the past five years. This information normally exists in the firms' OSHA logs and company historic project databases. The firms' safety directors/managers were contacted to obtain the safety performance information. The firms' LEED professionals or project specific managers were contacted to obtain information regarding the LEED rating of each project designed to be sustainable. LEED information was also obtained from other sources such as the USGBC website. The USGBC maintains a list of all of the registered and certified projects on its website. The information includes the project name, owner, level of certification, number of points, and the final LEED scorecard. The questionnaire form and other documents used in the data collection process can be found in Appendix A.1 and A.2 to this manuscript.

A qualitative approach was followed for the second task to seek safety experts' opinions on the affects of green building design on construction worker safety and health. This involved an informal, unstructured open-ended interview to provide an opportunity for the experts to put forth their thoughts on this issue.

3.6 Results and Discussions

3.6.1 Survey Response

A total of nine firms responded to the questionnaire survey. Of the firms that responded, seven provided data from their projects, one firm was not interested in providing the information due to confidentiality purposes, and the other was just in the process of building a LEED certified building and therefore was not able to contribute data. Several follow-up emails to the respondents were unsuccessful in increasing the response rate. It was discovered as mentioned previously, that the information requested was, in some cases, difficult to obtain as it required the efforts of more than one department within a company such as the safety, finance, and sustainable building division. In some cases, companies either did not maintain historic records of their work or some only tracked safety records for self-performed work. The survey response rate for the study is 46.6% (7 out of 15), which is reasonable considering the sensitivity of the data being collected.

3.6.2 Survey Results

3.6.2.1 Demographic Information

A total of 86 building projects from the seven construction firms were received and utilized in this research study. All of these projects were constructed (some in progress) in the period 2000 to 2006. The study sample included projects built in the United States (83) and Canada (3). Canadian projects were provided by a general contracting firm that performs work in U.S. and Canada. The geographic locations of the 86 sample projects are exhibited in Figure 3.1. Of the 86 sample projects, the majority of the projects (82.6%) were built in Oregon and Washington. It should be noted that Oregon and Washington are two of the top 5 states that have the leading number of LEED registered/certified projects in the nation as of October 2005 (USGBC 2006). According to the Cascadia Region Green Building Council, Oregon and Washington together contain 54 certified and 324 registered LEED projects. There are less than 300 certified and 2,500 registered projects in the country. This would provide a rough estimate that 13.5% of all certified/registered LEED projects in the U.S. are from Oregon and Washington.

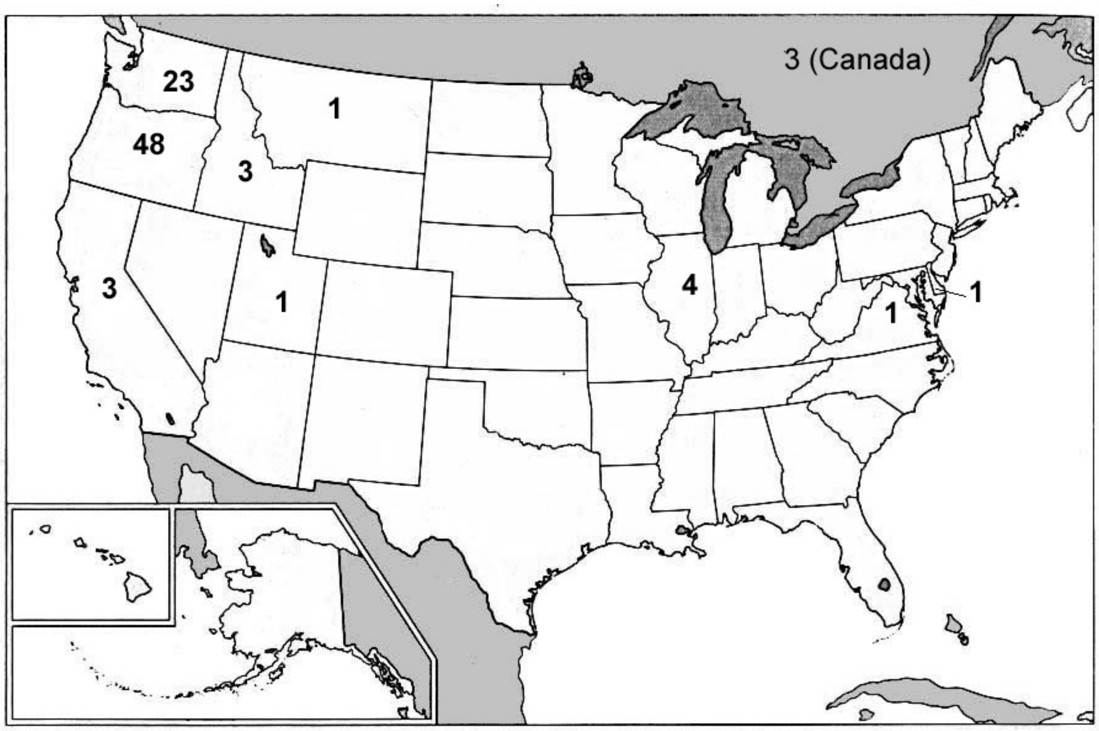

Figure 3.1: Locations of the Projects Included in the Research

The responding firms were promised that the information provided would be kept confidential, including their name and the individual project identities. Hence, this paper does not reveal any information about the responding firms or the project names. The responding firms' annual volume of work ranged from 220 million to 1 billion dollars. All of the firms had an Experience Modification Rate (EMR) less than 1.0. This shows that all of the firms are safe by industry standards. The breakdown of the construction firms based on the number of projects contributed to the study sample and the corresponding number of green/non-green projects is presented in Table 3.1.

Table 3.1: Categorization of Projects based on Responding Firms (n = 86)

Firm ID	No. of Projects	Percent of Study Sample Projects	Green	Non-Green
A	46	53.5	17	29
B	6	7.0	4	2
C	10	11.6	6	4
D	2	2.3	1	1
E	4	4.7	2	2
F	8	9.3	3	5
G	10	11.6	5	5
Total	86	100.0	38	48

The 86 sample projects consisted of the following three types of projects:

- 58 "New Construction" projects composed of 21 green and 37 non-green projects. New Construction is defined as any project that leads to an entirely new facility.
- 12 "Major Remodel" projects consisting of 7 green and 5 non-green projects. Major Remodel is a project in which the use or architecture of an existing building is substantially changed.
- 16 "Mixed New and Remodel" projects composed of 10 green and 6 non-green projects. Mixed New and Remodel is used for projects where a new building is constructed adjacent to an existing building and the existing building underwent a major architectural or structural remodel. This differs from Major Remodel in that it includes some entirely new construction also.

The proportion distribution of new construction, major remodel, and mixed new and remodel projects along with the proportion of green and non-green projects in each category is presented in Figure 3.2. The majority of the green and non-green projects in the study sample were new construction (67.4%) followed by mixed new and remodel projects (18.6%).

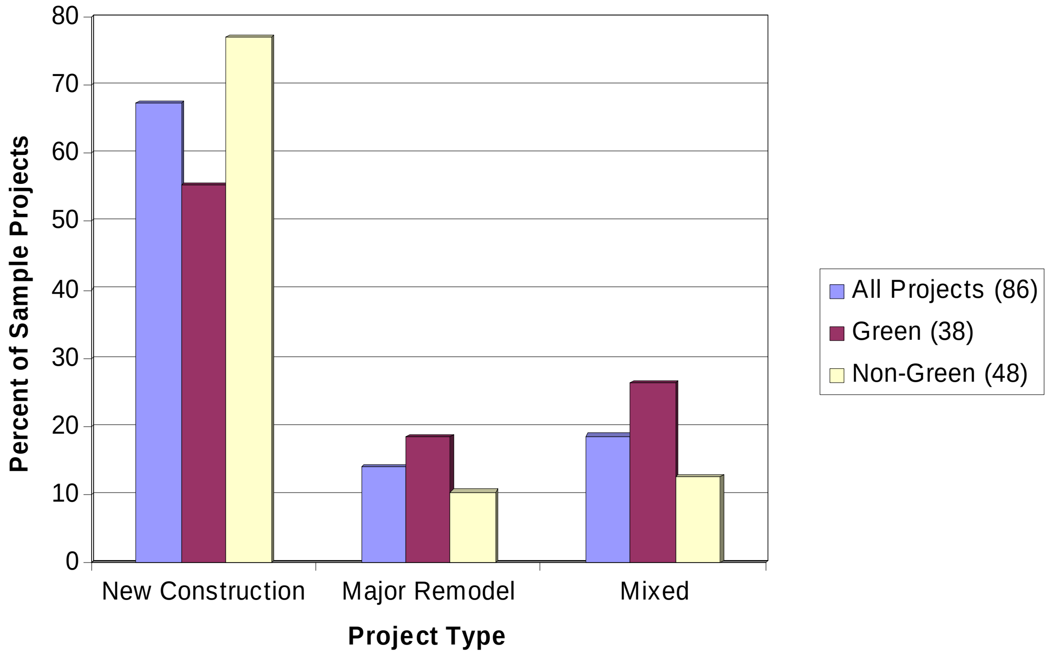

Figure 3.2: Sample Distribution by Project Type

The 86 sample projects consisted of many facility types: housing, hotels, mixed use, condominium, library, hospital or medical building, office buildings, K-12 education, higher education university buildings, and convention center. For the purposes of the study these facilities were grouped under five categories based on rough similarity in design, construction, and operation: education – 31.4% (higher and K-12 education), commercial offices – 18.6% (all private and government office buildings), public gathering – 19.8%, healthcare and lab – 16.3%, and residential high-rise – 14.0% (condos and hotels). According to USGBC, these types of buildings constituted more than 50% of the green projects as of October 2005 (USGBC 2006). Hence, the buildings included in the study sample are representative of the national green projects population. The proportion distribution of the sample projects in terms of facility type is presented in Figure 3.3. Educational buildings were found to be predominant among the green and non-green projects. All other facility types were lower in number and were evenly distributed.

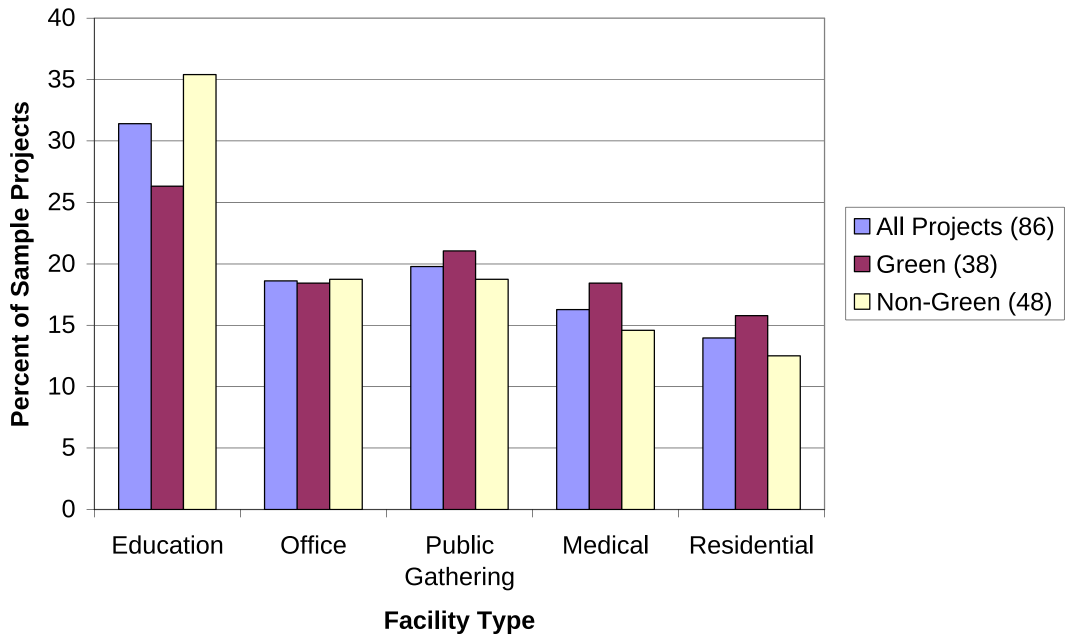

Figure 3.3: Sample Distribution by Facility Type

The cost of the 86 sample projects ranged from 4 to 271 million (M) dollars (mean = $47.86M; median = $30.0M) and the size ranged from 12,000 square feet to 1,150,000 square feet (SF) (mean = 194,140 SF; median = 139,000 SF). Unit cost was calculated for the sample projects by dividing the project cost by the project square footage to normalize the projects based on size. The unit cost of the projects included in this study ranged from 22 to 1,429 dollars per square foot (mean = $288/SF; median = $253/SF). Figure 3.4 shows the unit cost distribution of all 86 sample projects.

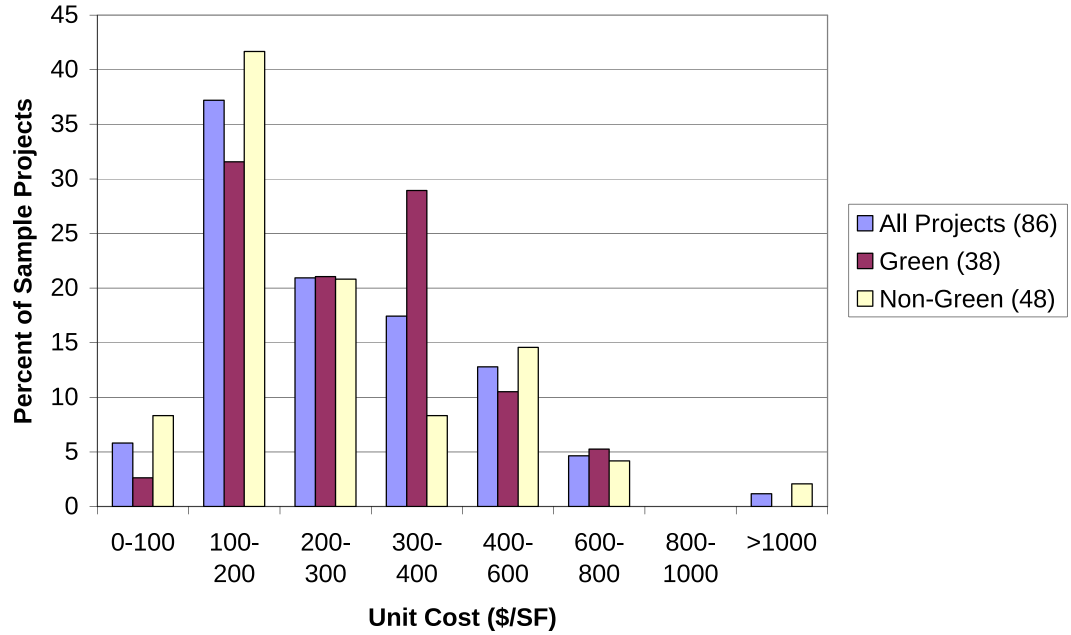

Figure 3.4: Sample Distribution Based on Unit Cost

Fifty of the sample projects (58.1%) were valued in the range of 100 to 300 dollars per square foot. Comparing the green and non-green projects, the green projects were more expensive (in terms of unit cost) than the non-green projects. This difference in unit cost might be attributed to the fact that green projects require additional cost for materials research, energy modeling, LEED documentation, registration cost, and so forth. According to Schendler and Udall (2005), advanced design and coordination involved in LEED normally raises the cost of a project by 1-5 percent.

In order to assess whether the vertical height of buildings has any impact, data on the number of stories in each building was collected. The number of stories was not provided on three projects. Based on 83 projects, the height of the buildings in the study ranged from 1 to 57 stories (mean = 7.3 stories; median = 4 stories) as shown in Figure 3.5. Considering all of the 83 projects in the sample, there was a wide variation in the heights of the buildings, with 57.8% of the buildings equal to or shorter than four stories. Seven buildings were taller than 15 stories. Among the green projects, 50% of the buildings were equal to or taller than five stories. In contrast, more than 68.8% of the non-green projects were shorter than five stories.

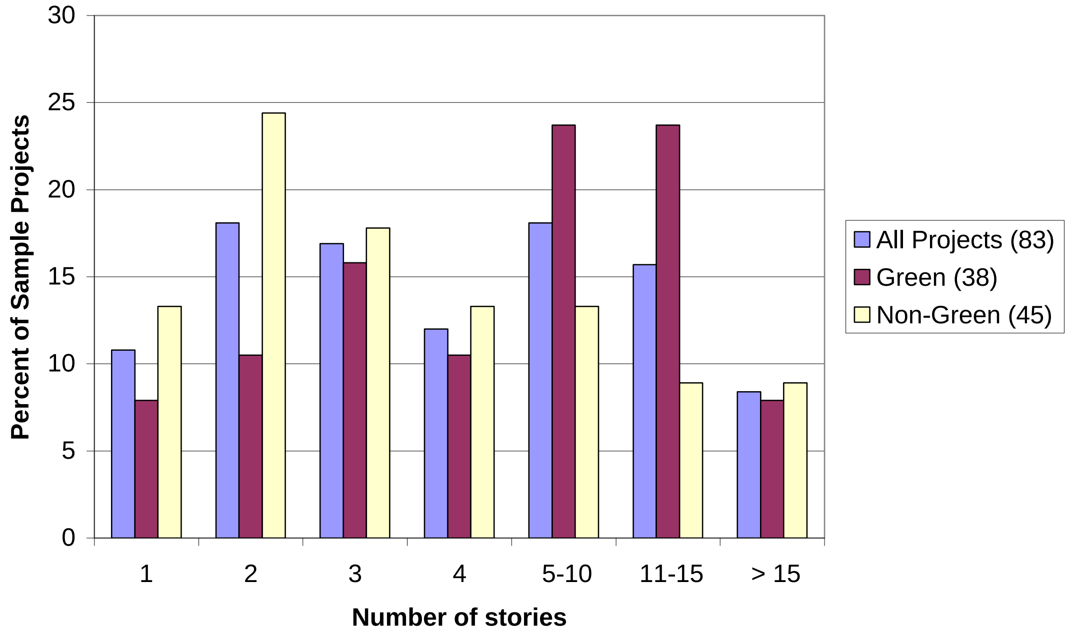

Figure 3.5: Sample Distribution Based on Project Height

Of the 86 projects, an approximately equal number of projects were funded by the public and private sectors. According to the USGBC, 42% of LEED registered projects are owned by local, state or federal governments. Thus, the study sample can be considered representative of the LEED projects in terms of type of funding. Figure 3.6 presents the distribution of projects based on type of funding.

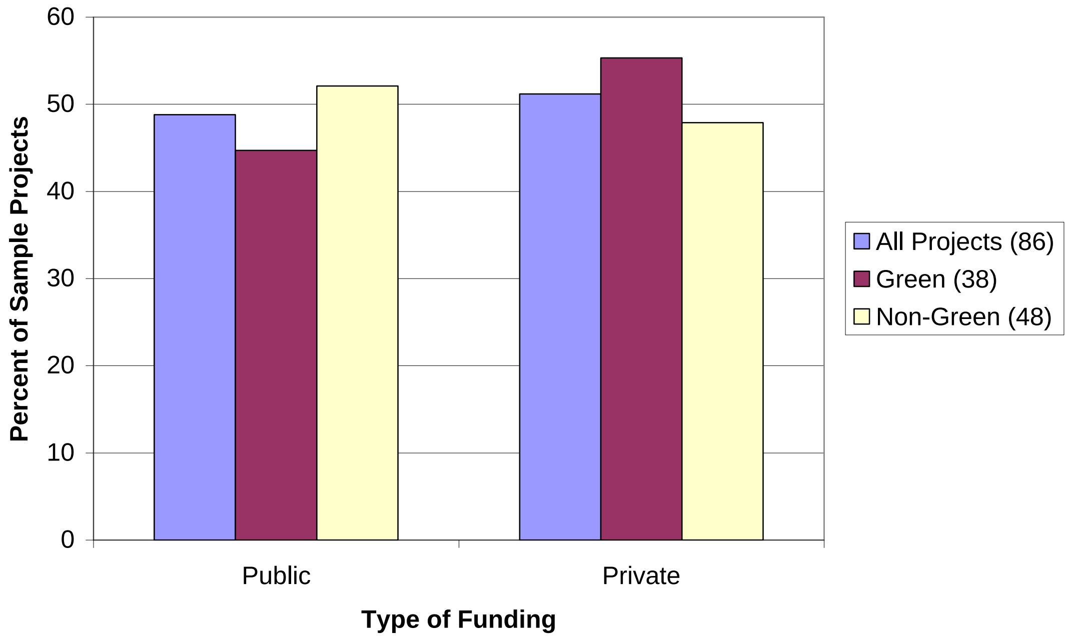

Figure 3.6: Sample Distribution Based on Type of Funding

It should be noted that for 11 of the 86 projects (12.8%) the construction work was in progress at the time of the study. Figure 3.7 presents the distribution of projects based on their level of completion. Included in the 11 incomplete projects are eight projects which were at least 60% complete. All of the incomplete green projects were close to 60% complete.

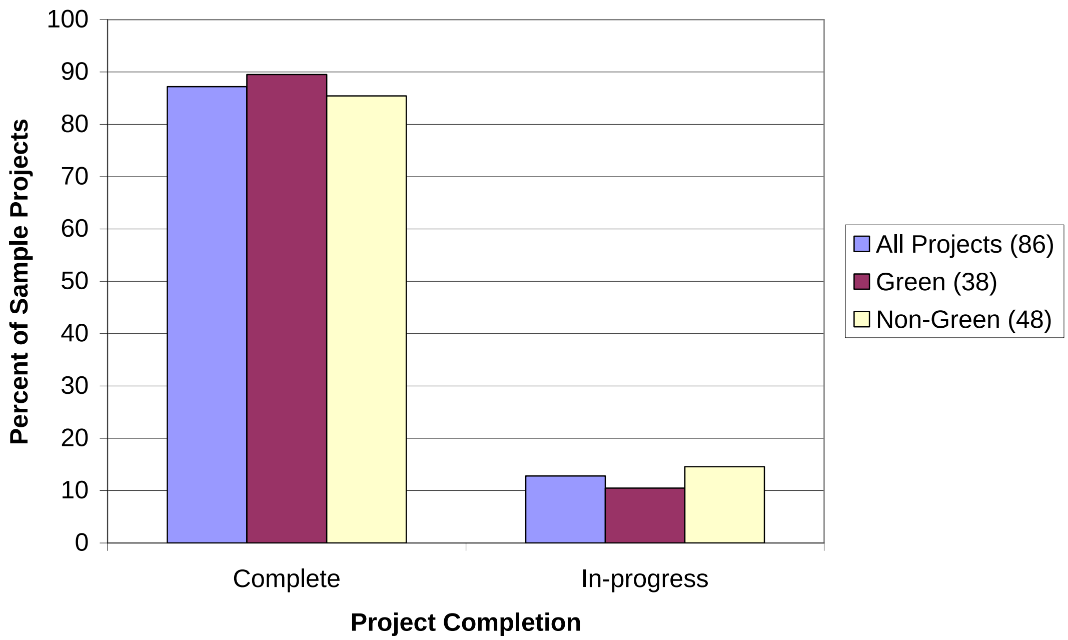

Figure 3.7: Sample Distribution of Completed Projects

3.6.2.2 Safety Information

The second section of the questionnaire survey solicited information on the safety performance of the projects. For the purposes of the study, safety performance was measured by using the OSHA recordable incident rate (RIR) and lost time case incident rates (LTCR). The definitions for the two incident rates used for the study are presented below.

OSHA recordable incidents are defined as those incidents that resulted from an exposure or event in the workplace and that required some type of medical treatment or first-aid. The OSHA recordable incident rate (RIR) is the number of recordable incidents per 100 workers per year (200,000 worker-hours). It is calculated for a project by multiplying the number of recordable injuries by 200,000 and then dividing by the number of work hours expended on the project.

$$OSHA\ \mathrm{Re}cordable\ Incident\ Rate\ (RIR) = \frac{Number\ of\ OSHA\ \mathrm{Re}cordable\ Injuries}{Total\ Hours\ Worked}\ x\ 200{,}000$$

Lost time case incidents are defined as those incidents that resulted from an exposure or event in the workplace and that required the employee to be away from work or limited to restricted work activity. Days away from work are those days in which the employee would have worked but could not due to the injury. Days of restricted work activity are those days in which the employee was assigned to a temporary job or worked at a permanent job less than full time, or worked at a permanent job but could not perform all of the duties normally required. The number of lost workdays (consecutive or not) does not include the day of the injury or onset of illness, or any days in which the employee would not have worked even though they were able to work. The lost time case incident rate is calculated in a manner similar to the RIR except that it uses the number of cases that contained lost work days.

$$Lost\,Time\,Case\,Incident\,Rate\,(LTCR) = \frac{Number\,of\;\,Lost\,Time\,Cases\,Injuries}{Total\,hours\,Worked}\,x\,200{,}000$$

The study questionnaire requested the responding firms to provide information about the number of OSHA recordable and lost time case injuries sustained on each of the projects being reported. The respondents were also asked to provide the total number of work hours that were worked on the projects. Based on these amounts, the RIR and LTCR were calculated as explained above. All of the 86 sample projects provided information on the number of OSHA recordable injuries, number of lost time cases, and the total work hours expended on the projects. However, not all of the projects tracked the subcontractor injuries/illnesses and their work hours. Of the 86 projects, only 74 projects (86%) provided information on total project employee incidents and work hours (see Figure 3.9). The remaining 12 projects (14%) provided information only on the incidents and work hours involving self-performed work of the general contracting firm. For the 86 projects, the OSHA RIR’s ranged from 0 to 52 (mean = 5.85; median = 4.98 ;), with 17 projects (19.8%) reporting zero injuries. The LTCR’s rates ranged from 0 to 52 (mean = 2.48; median = 0.7 ;), with 36 projects (41.8%) reporting zero injuries. Figure 3.8 presents the distribution of RIR’s and LTCR’s among the sample projects. Further discussion and analysis are provided in the Results section

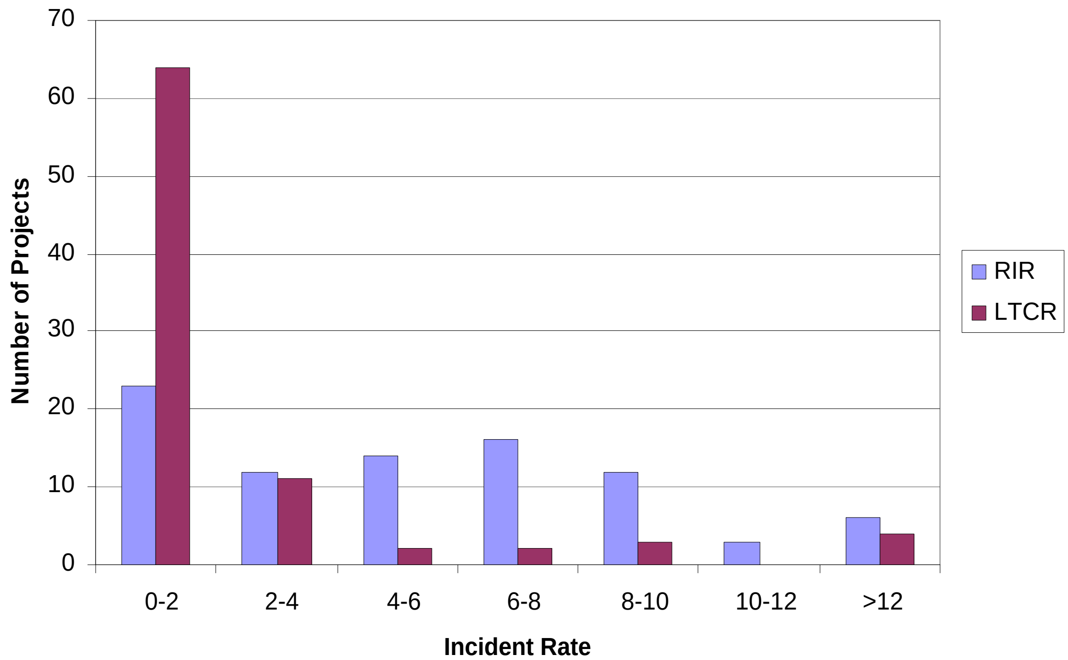

Figure 3.8: Sample Distribution Based on RIR and LTCR

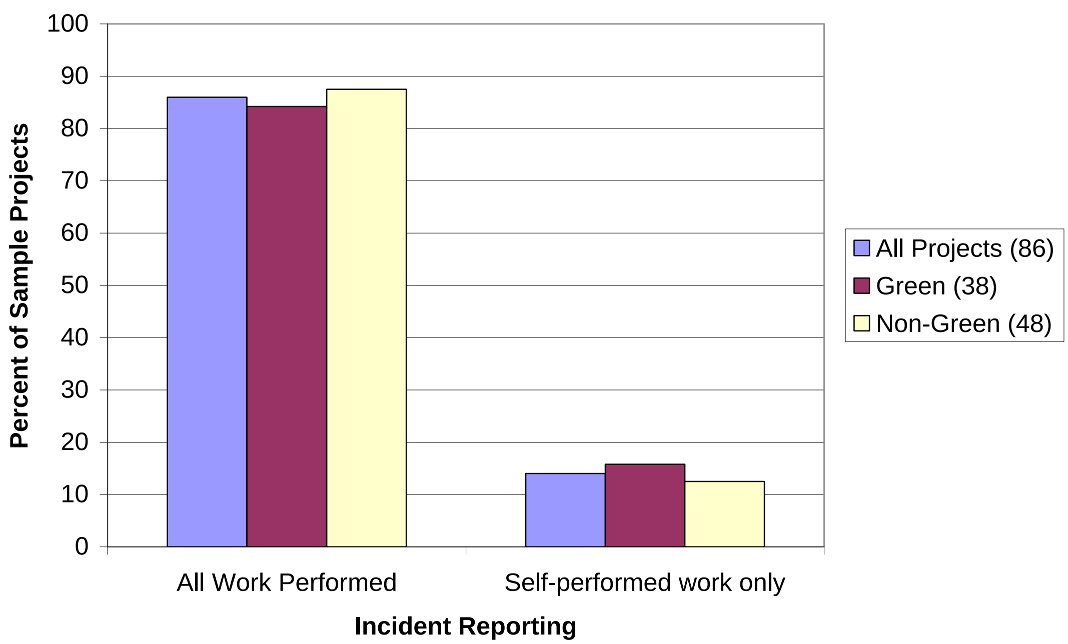

Figure 3.9: Sample Distribution Based on Incident Reporting

3.6.2.3 LEED Information

The third section of the questionnaire solicited information about the green aspects of the projects. As discussed earlier there are several types of LEED certifying categories. Of the 38 green projects present in the study sample, 34 projects (89.5%) were certified under the LEED – NC category, two (5.3%) under the LEED – CS, one (2.6%) under LEED – EB, and one (2.6%) did not have this information. Hence, the study predominately consists of one category of LEED (green) projects. This can be attributed to the fact that LEED – NC was the earliest certification category introduced by the USGBC in 2000. Currently, there are very few projects that have been certified/registered under the other types of certification categories (USGBC 2006). Hence, this sample can be considered representative of the current population of green projects. Other certification categories are slowly being introduced into the building market or are still in the pilot phase.

The LEED rating system consists of four levels of certification: certified, silver, gold, and platinum. The study sample consisted of five certified project (13.2%), 20 silver projects (52.6%), 12 gold projects (31.6%), no platinum projects, and one (2.6%) unknown level of certification. It should be noted that not all of the projects in the study sample are certified. Twenty six projects (68.4%) are certified, 11 (30%) are registered, and one (2.6%) had an unknown status. Data on the number of LEED credits received by the projects was also documented. Five of the LEED certified projects did not have the information on the credits. This information was only provided on 25 projects (both certified and registered). The LEED credits received by the projects ranged from 29 to 44 credits (mean = 36; median = 35) (Figure 3.10).

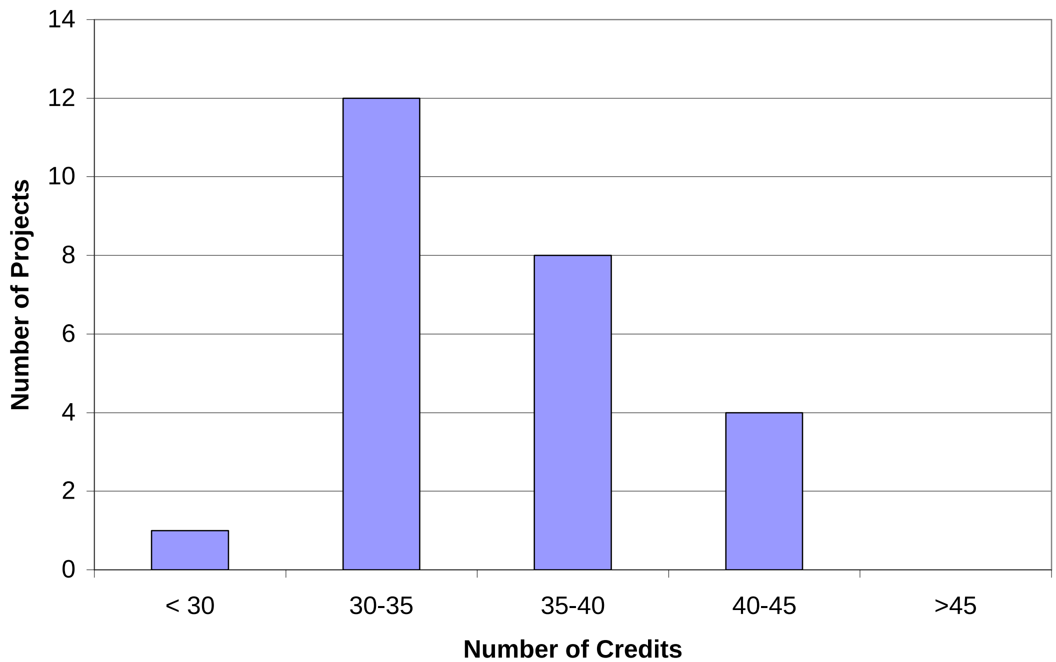

Figure 3.10: LEED Credit Distribution for the 25 Green Projects

It should be noted that the word "certified" is used in two places. The researchers would like to clarify the difference to prevent any confusion for the readers. Firstly, "certified" is used to describe completion of the entire "process" of getting a building recognized as green, by meeting the requirements set forth by the LEED. In order to get certified a project team must register their project with USGBC and follow the guidelines required by LEED rating system. The project will be labeled as a "registered" project during this process. The word "certified" is also used to describe the minimum amount of green features required by a building to be recognized as a green building. Increasing the amount of green features will lead to higher levels of certification such as silver, gold and platinum.

3.6.3 Statistical Analysis

The statistical software used for the analysis in this study was "Statgraphicsplus 5.1." The main statistical tools used to analyze the data in this research were the non-parametric Mann-Whitney and Kruskal-Wallis test. The Mann-Whitney U test examines the null hypothesis that the medians of two samples are the same (Statgraphicsplus 5.1, 2001). Mann-Whitney compares the medians of the two samples, by combining the two samples and sorting the data from smallest to largest, and comparing the average ranks of the two samples in the combined data. It provides a p-value based on which statistical significance of the difference between the medians at the 95% confidence level can be evaluated. A level of significance of 0.05 or smaller would mean that there is less than a five percent probability that the finding was due to chance. For items in which there were more than two samples to compare, the Kruskal-Wallis test was used. The Kruskal-Wallis test examines the null hypothesis that the medians of several samples are the same (Statgraphicsplus 5.1, 2001).

In the present study, a test for normality (Kolmogorov-Smirnov test) revealed that the sampling distribution for both the RIR and LTCR were non-normal ($p = 0.000$) (Statgraphicsplus 5.1, 2001). In addition there were several outliers present in the data which would make the t-test invalid. The t-test is only valid when the sampling distribution of the differences in means has a normal shape. Hence, for the present study it was decided to use the non-parametric Mann-Whitney and Kruskal-Wallis tests.

The major objective of this analysis was to identify the presence/absence of any statistically significant difference in median RIR and LTCR rates of green and non-green projects. For this purpose two separate null hypotheses were framed:

- The median RIR of green projects is equal to the median RIR of non-green projects (two-sided p-value). The alternate hypothesis is that there is a difference between the median RIR of green and non-green projects.
- The median LTCR of green projects is equal to the median RIR of non-green projects (two-sided p-value). The alternate hypothesis is that there is a difference between the median LTCR of green and non-green projects.

Before proceeding to the comparison of the green and non-green sample medians, it was necessary to address the presence of projects, which were either incomplete (in-progress) or provided information only on self-performed work. Of the 86 projects, only 63 projects provided complete information needed for the research. Twenty three sample projects had either self-performed work incidents or were incomplete. The authors felt that these projects might skew the end results if included in the analysis. Hence, the projects were tested for any significant difference with the other projects in the sample.

Table 3.2 presents a summary of the safety performance for all 86 projects, for only the complete projects, and for all self-performed and incomplete projects. The median RIR and LTCR of the “complete” and “self performed and incomplete projects” were evaluated using the Mann-Whitney test. It was found that there was not a statistically significant difference amongst the medians of all these two groups at the 95% confidence level for RIR (two sided p-value = 0.9999) and LTCR (two sided p-value = 0.1574). Hence, the authors decided to retain all of the self-performed and incomplete projects in the study sample.

Table 3.2: Project Data Reporting Status and Safety Performance

Combinations	# of Projects	Mean	Std Dev	Median
OSHA recordable incident rates (RIR)				
All projects	86	5.85	6.70	4.98
Complete projects	63	5.42	4.44	5.0
Self performed and incomplete projects	23	7.00	10.77	4.94
Lost time case incident rates (LTCR)				
All projects	86	2.48	6.41	0.70
Complete projects	63	1.51	3.09	0.63
Self performed and incomplete projects	23	5.12	11.03	1.2

The statistical comparison of green and non-green projects included all 86 projects. Table 3.3 presents a summary of the RIRs and LTCRs for the 38 green and 48 non-green projects. One of the graphical tools that will be used in the presentation of the analysis is box plots. Box plots are a widely used statistical tool especially when comparing several samples side-by-side. The graph gives an uncluttered view of the center, spread, and skewness of the distribution, and indicates the presence of unusually small or large outlying values (Ramsey and Schafer 2002). The box represents the middle 50 percent of a group of measurements. The top and bottom of each box indicate the upper and lower quartiles (25 percent) of each sample. The center horizontal line in the box represents the median value for the measurements.

Table 3.3: Green versus Non-Green Safety Performance

	Type	# of Projects	Mean	Std Dev	Median	Mann-Whitney (2-tail p-value)
RIR	Green	38	6.12	5.36	6.86	0.1859
	Non-green	48	5.63	7.65	4.63	
LTCR	Green	38	2.45	4.24	0.7	0.7212
	Non-green	48	2.50	7.75	0.78	

Figure 3.11 shows box plots comparing the RIR of green and non-green projects. The green projects have a higher median RIR (6.86) than the non-green projects (4.625). In addition, the spread for the green projects is greater than the non-green projects. A Mann-Whitney test was performed to test the presence of any difference statistically. The statistical result revealed suggestive evidence that the green projects experienced a higher median RIR than the non-green projects (two sided p-value = 0.1859). Analyses similar to that performed for the RIR were performed for the LTCR metrics. It was found that the green and non-green projects had no difference in median LTCR's as shown in Figure 3.12. However, it was clearly evident as seen in Figure 3.11, that there were several green projects that have LTCR's greater than the non-green projects. The statistical test revealed that there was no statistically significant difference in the median LTCR's between the green and non-green projects (two sided p-value = 0.7212).

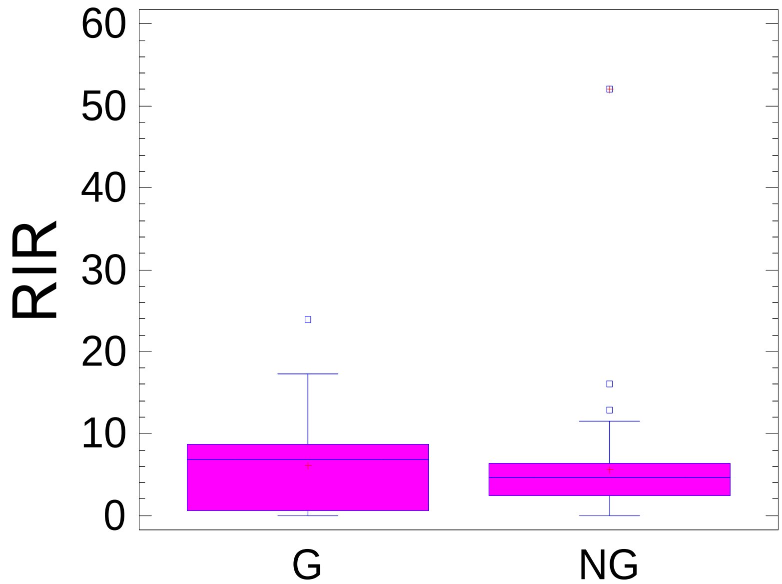

Figure 3.11: Box Plots for RIR of Green (G) and Non-green (NG) Projects

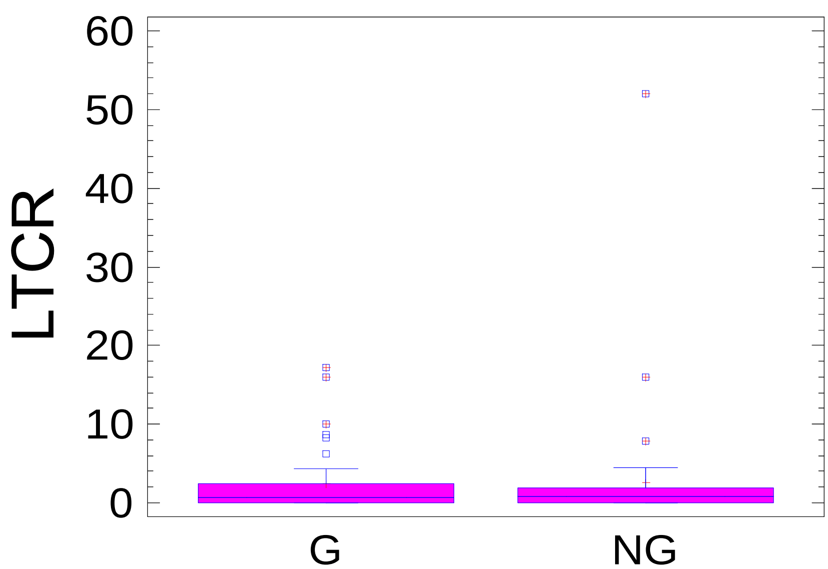

Figure 3.12: Box Plots for LTCR of Green (G) and Non-green (NG) Projects

The above analyses were based on the assumption that any differences in safety performance in the 86 sample projects were due to the project being “green” or “non-green”. However, there are several “confounding” variables that might affect the safety performance of a project. A confounding variable is related both to group membership and to the outcome. Its presence makes it difficult to establish the outcome as being a direct consequence of group membership (Ramsey and Schafer 2002). In this study, the group membership is green or non-green and some of the measurable confounding variables include: project type, facility type, project complexity as defined by the unit cost, project height, project location, and type of funding. Hence, the presence or absence of difference in sample medians may not just be attributed to a project being green or non-green.

In the present study it should be noted that the uni-variate analysis did not reveal any statistically significant difference between green and non-green projects (only inconclusive evidence for median RIR), and it is unlikely that a multi-variate analysis would show any trends in the sample. This is especially true since the study sample size is very small. However, the authors decided to test the individual variable’s affect on safety performance by assuming that all other variables have been controlled and do not have any affect on safety.

3.6.3.1 Contractor Type

All contractors are different. They vary in size, corporate culture, delivery methods, union status, and so forth. The safety culture within each contracting firm also differs. For instance, one contractor might choose to comply with the minimum local, state, and federal safety regulations, while others might implement many additional proactive safety efforts. This could also be one possible factor contributing to the difference in safety performance in the sample projects. Even though the EMR’s of all of the contractors who participated in the study were less than 1.0, a Kruskal-Wallis test was performed to test the presence of any difference in median RIR and LTCR among the seven contractors. One contractor, however only contributed two projects to the sample and has one of the projects with an incident rate of 52. Hence, this contractor was removed from the analysis.

It was found that there was a statistically significant difference between the six contractors based on the median RIR's (two sided p-value = 0.0148). In addition, there was suggestive but inconclusive evidence of a difference between the median LTCR's (two sided p-value = 0.1040). This result led to the question, "Could the suggestive difference in RIR between green and non-green projects from the earlier analysis have been attributed to the contactor type?" The presence of a difference in the median RIR's and LTCR's among the different contractors led the authors to compare the median RIR and LTCR for green and non-green projects constructed by the same contractor. The available data made such a comparison possible for contractors A, C, and G (see Tables 3.4, 3.5, and 3.6).

Contractor A provided 54% of the sample projects that included 17 green and 29 non-green projects. A Mann-Whitney test was performed revealing that there was significant difference in the median RIR (two sided p-value = 0.0101) between the green and non-green projects and no difference in median LTCR (two sided p-value = 0.9226). Since, "contactor A" contributed more than 50% of the projects to the study sample, the "suggestive" difference between the median RIR of green and non-green projects among the entire sample could have been confounded. For contractors C and G, there was no evidence of a difference between the median RIR's and LTCR's. However, it should be noted this conclusion is limited, since the contractors C and G, contributed very low numbers of projects to the study sample. This made it difficult for the authors to arrive at a meaningful conclusion.

Table 3.4: Safety Performance Comparison between Green and Non-green Projects for Contractor A

Contractor A	# of Projects	Mean	Std Dev	Median	Mann -Whitney (2-tail p-value)
OSHA recordable incident rates (RIR)					
LEED	17	7.93	5.01	7.57	0.0101
Non-LEED	29	5.46	2.43	5.09	
Lost time case incident rates (LTCR)					
LEED	17	1.89	3.73	1.19	0.9226
Non-LEED	29	1.07	1.03	1.02	

Table 3.5: Safety Performance Comparison between Green and Non-green Projects for Contractor C

Contractor C	# of Projects	Mean	Std Dev	Median	Mann -Whitney (2-tail p-value)
OSHA recordable incident rates (RIR)					
LEED	6	5.59	5.39	5.73	0.5824
Non-LEED	4	3.65	5.45	1.53	
Lost time case incident rates (LTCR)					
LEED	6	2.08	3.45	0.0	0.6940
Non-LEED	4	0.38	0.765	0.0	

Table 3.6: Safety Performance Comparison between Green and Non-green Projects for Contractor D

Contractor G	# of Projects	Mean	Std Dev	Median	Mann -Whitney (2-tail p-value)
OSHA recordable incident rates (RIR)					
LEED	5	4.97	4.74	6.18	0.9999
Non-LEED	5	6.44	6.03	4.4	
Lost time case incident rates (LTCR)					
LEED	5	4.97	4.74	6.18	0.9999
Non-LEED	5	6.44	6.033	4.4	

3.6.3.2 Project Ownership

Huang (2003) reported that private projects might be safer than public projects. Data from his study indicate that the total recordable injury rate (TRIR) of private projects was lower than public projects. This was attributed in part to public owners' use of primarily the traditional design-bid-build (DBB) project delivery method which awards construction contracts solely based on lowest bid. As a result it is not necessarily the safest contractor who gets the contract. In the DBB delivery method there is no coordination between the designer and the constructor since the constructor enters the system only after the design has been completed. In contrast, private owners have the opportunity to select contractors based on safety in addition to cost, quality, and schedule considerations. This encourages practices like constructability, design for construction worker safety, and so forth. Hence, it was essential to test the effect of ownership on safety performance.

It was found that there was not a statistically significant difference for the median LTCR (two sided p-value = 0.4115) between the private and public projects in the study sample (see Figure 3.7). There was suggestive evidence for a difference in the median RIR and as a result of the presence of a reasonable number of data points, a detailed analysis within these ownership types was performed. The absence of a difference in safety performance between the private and public projects could be due to the confounding variables such as the contractor type. As mentioned earlier, all of the contractors included in the study were safe contractors and had very good safety programs in place. This factor might have nullified the affect of ownership.

Table 3.7: Project Funding and Safety Performance

Funding	# of Projects	Mean	Std Dev	Median	Mann -Whitney (2-tail p-value)
OSHA recordable incident rates (RIR)					
Public	42	5.93	8.60	6.15	0.1831
Private	44	5.76	4.27	4.38	
Lost time case incident rates (LTCR)					
Public	42	2.62	8.30	0.63	0.4115
Private	44	2.34	3.95	1.07	

Of the 44 privately funded projects, 21 were green projects and 23 non-green projects, comprising an approximately equal distribution. The private green projects had a higher median RIR (7.06) than the non-green (4.96) projects. The difference was found to be statistically significant with a two sided p-value of 0.0505. For the LTCR, there was only inconclusive evidence of any difference in the median of the two samples within the private projects. Of the 42 publicly funded projects, 17 were green projects and 25 non-green projects. Statistical tests did not reveal any statistically significant difference in median RIR (two sided p-value = 0.2886) and LTCR (two sided p-value = 0.1355) among the green and non-green projects within the public projects.

<u>3.6.3.3 Project Size</u>

Project size is a good indicator of the amount of work performed on a job site. Size can be measured in terms of total constructed cost, the number of subcontractors on site, the number of workers on site, or the number of worker hours expended (Huang 2003). It could be hypothesized that a higher unit cost implies a more complex project which could affect project safety significantly. In previous sections, simple numerical analysis showed that green projects were more expensive compared to non-green projects. If this is in-fact true, then any presence/absence of a difference in median incident rates between green and non-green projects could be attributed to the unit cost and not the fact that the project is either green or non-green. Hence, the authors decided to test the hypothesis that: “there is no difference between green and non-green projects in terms of unit cost.”

A simple two sample t-test was performed between the green and non-green projects. The 38 green projects had a mean of 296.13 dollars/SF and a standard deviation of 159.04 dollars/SF, while the 48 non-green projects had a mean of 281.27 dollars/SF and a standard deviation of 231.41 dollars/SF. The t-test compared the means of the two samples and reported a p-value of 0.7257. Since the p-value for the t-test was greater than 0.05, no statistically significant difference was found between the mean unit cost of green and non-green projects at the 5% significance level. A box plot comparing the two group means is shown in Figure 3.13. The box plot revealed the presence of an outlier project with a unit cost of 1,429 dollars/SF. For the purpose of the analysis, this outlier was removed from the sample and the t-test was performed again. It was found that there was still an absence of significant difference between the means of the two samples (two sided p-value = 0.2618). Hence, it can be concluded for the study sample that the unit cost of green and non-green projects were the same and does not have had an affect on the safety performance. It should be noted that the purpose of the study was to compare and the safety performance of green and non-green projects. Hence, any conclusion on unit cost between green and non-green projects from this study cannot be generalized.

Having shown no difference in unit cost between green and non-green projects, the authors tested the presence of any difference in median RIR and LTCR with an increase in unit cost of the projects. A simple linear regression analysis would have been an ideal test for testing the presence of this relationship. However, the normality assumption required for the simple linear regression analysis was not met by the sample distribution.

Hence, non-parametric tests were conducted. The sample projects were grouped into five categories as shown in Table 3.8 and their mean, median, and standard deviation is reported. A statistical analysis was performed to test the presence of a difference between the medians of the five groups. It was found that there was not a statistically significant difference between the medians of the five groups at the 95% confidence level. Since the sample did not reveal any difference, any test within the green and non-green project sample was not warranted. In addition, the study did not have enough projects within each category to arrive at any meaningful conclusion.

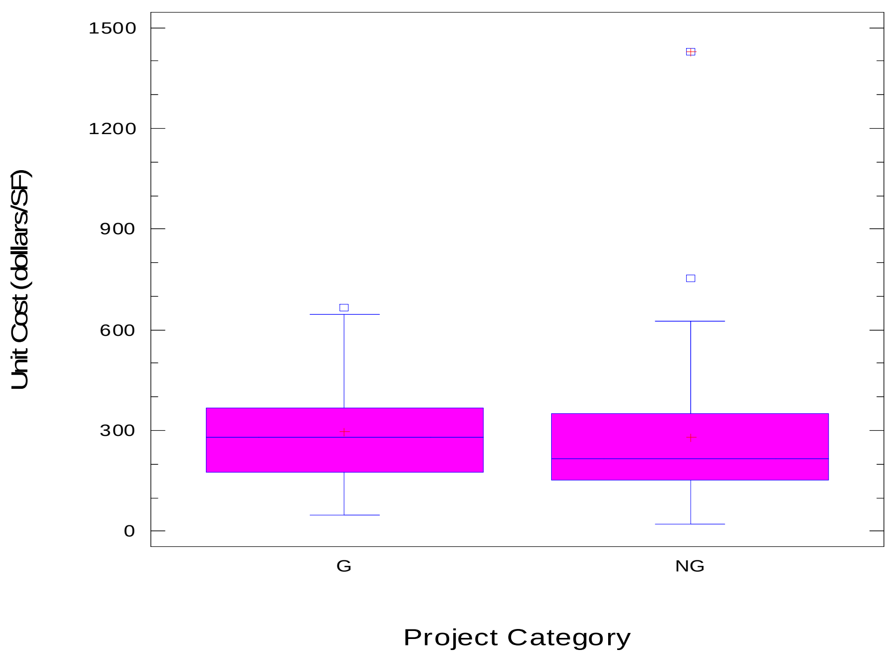

Figure 3.13: Box Plots for Unit Cost of Green and Non-green Projects

Table 3.8: Project Unit Cost and Safety Performance

Unit Cost ($/SF)	# of Projects	Mean	Std Dev	Median	Kruskal-Wallis (2-tail p-value)
OSHA recordable incident rate (RIR)					
0-100	5	3.19	3.40	3.87	0.5494
100-200	32	5.18	3.64	5.05	
200-300	18	6.77	11.54	4.54	
300-400	15	6.89	5.54	7.25	
>400	16	5.99	6.24	5.59	
Lost time case incident rate (LTCR)					
0-100	5	1.04	1.69	0.00	0.2695
100-200	32	2.71	3.75	1.33	
200-300	18	3.35	12.16	0.21	
300-400	15	2.13	4.43	0.00	
>400	16	1.82	3.88	0.85	

3.6.3.4 Project Height

Project height indicates how far the workers would have worked above ground level. Construction workers working on tall buildings face a great threat to their safety and health. For instance, a 50 story building might have more hazards (primarily fall) than a one or two story building. Earlier discussions suggested that green projects might be taller than the non-green projects in the study sample (see Figure 3.5). The 38 green projects had a mean height of 7.5 stories and a standard deviation of 5.9, while the 43 non-green projects (3 projects did not provide this information) had a mean of 5.1 stories and a standard deviation of 5.5.

It was desired to test whether the RIR and LTCR increased with an increase in height. A simple linear regression was not performed due to the absence of normality in the data. Hence, the authors grouped the project heights into four levels and tested for a difference in the median RIR and LTCR with the help of the Kruskal-Wallis test. It was found that there is not a statistically significant difference between the median RIR and LTCR of the four levels, at the 5% significance level (see Table 3.9). Since, the entire sample did not reveal any difference, any test for project heights within the green and non-green sample was not warranted. In addition, the study did not have enough projects within each category to arrive at any meaningful conclusion.

Table 3.9: Project Height and Safety Performance

# of Stories	# of Projects	Mean	Std Dev	Median	Kruskal-Wallis (2-tail p-value)
OSHA recordable incident rate (RIR)					
1-4	48	5.82	8.27	4.24	0.1159
5-10	15	4.24	4.09	2.06	
11-15	13	6.71	3.38	7.82	
>15	7	6.37	3.53	6.02	
Lost time case incident rate (LTCR)					
1-4	48	2.69	8.07	0.315	0.5546
5-10	15	1.94	3.32	0.41	
11-15	13	1.47	1.20	1.04	
>15	7	1.13	1.42	0.6	

3.6.3.5 Project Type

The study sample was categorized into three types of projects: new construction, major remodels, and mixed new and remodel. These three types of projects differ from each other in scope and complexity. In the case of renovation projects, workers have to work within the existing structure which might pose a greater hazard than construction of a new structure. Table 3.10 presents a summary of the safety performance for the 86 sample projects. A Kruskal-Wallis test revealed that there was no statistically significant difference between the median RIR's (two sided p-value = 0.2882) and LTCR's (two sided p-value = 0.1368) of the three project types at the 95% confidence level.

Table 3.10: Project Type and Safety Performance

Type of Project	# of Projects	Mean	Std Dev	Median	Kruskal-Wallis (2-tail p-value)
OSHA recordable incident rates (RIR)					
New construction	58	6.17	7.71	4.95	0.2882
Major Remodel	12	6.39	4.17	7.48	
Mixed	16	4.24	3.55	3.9	
Lost time case incident rates (LTCR)					
New construction	58	3.16	7.64	0.97	0.1368
Major Remodel	12	1.80	2.51	1.13	
Mixed	16	0.51	0.61	0.0	

3.6.3.6 Facility Type

The study sample was also categorized into five major facility types: education, office, public gathering, medical, and residential facilities. Each type of facility has its own impact on safety performance. For instance, healthcare construction projects are considered more complex to build than residential buildings due to the fact that healthcare facilities involve installation of major laboratory equipment and so forth. A summary of the safety performance of each of these facility types is presented in Table 3.11. A multiple sample comparison was performed to identify any difference between these five groups. It was found that there was no significant difference between the median RIR's and LTCR's of the five facility types. Since the sample did not reveal any difference, any test within the green and non-green samples was not warranted. In addition, the study did not have enough projects to arrive at any meaningful conclusion.

Table 3.11: Facility Type and Safety Performance

Facility Type	**# of Projects**	**Mean**	**Std Dev**	**Median**	**Kruskal-Wallis (2-tail p-value)**
OSHA recordable incident rates (RIR)					
Education	27	6.5	9.76	4.84	0.9635
Office	16	5.58	5.87	5.15	
Public Gathering	17	6.06	5.43	4.96	
Medical	14	4.77	3.71	4.34	
Residential	12	5.66	3.63	6.49	
Lost time case incident rates (LTCR)					
Education	27	3.10	9.95	.63	0.7155
Office	16	1.58	5.82	.3	
Public Gathering	17	1.72	3.78	.63	
Medical	14	2.35	2.23	1.145	
Residential	12	2.48	2.63	1.58	

3.6.3.7 Project Location

The study sample included projects from nine states and Canada. Since different states might have different environments, climates, unions, etc., it was necessary to test the difference in safety performance between projects completed in different states. The Kruskal-Wallis test for difference in median RIR's and LTCR's between the states revealed no statistically significant difference (two sided p-value > 0.05). Two states, Oregon and Washington, comprised 85% of the sample projects. These two states had enough projects to compare the green and non-green projects built in each state. Tables 3.12 and 3.13 presents a summary of safety performance of green and non-green projects in Oregon and Washington, respectively. A Mann-Whitney test did not reveal a statistically significant difference in safety performance between green and non-green projects built in Oregon and Washington.

Table 3.12: Safety Performance Comparison between Green and Non-Green Projects for Oregon

Category	# of Projects	Mean	Std Dev	Median	Mann –Whitney (2-tail p-value)
OSHA recordable incident rates (RIR)					
Green	24	6.21	5.53	6.49	0.2266
Non-Green	24	4.71	3.42	4.41	
Lost time case incident rates (LTCR)					
Green	24	2.29	3.98	0.87	0.8815
Non-Green	24	2.07	3.53	1.11	

Table 3.13: Safety Performance Comparison between Green and Non-Green Projects for Washington

Owner	# of Projects	Mean	Std Dev	Median	Mann -Whitney (2-tail p-value)
OSHA recordable incident rates (RIR)					
Green	9	7.09	5.44	8.19	0.5079
Non-Green	14	5.66	3.73	4.95	
Lost time case incident rates (LTCR)					
Green	9	3.81	5.71	1.4	0.3676
Non-Green	14	1.04	1.00	0.945	

3.6.3.8 LEED Certification and Safety Performance

The 38 green projects in the study sample had predominantly (90%) LEED-NC certified projects. Hence, it was not possible to compare safety performance among different categories of LEED certification. The sample projects consisted of three levels of certification certified, silver, and gold. In order to answer the question whether the safety performance changed with an increasing amount of green design and construction features, the median RIR and LTCR of these three certification levels were compared. Table 3.14 presents a summary of these three levels of certification.

Table 3.14: LEED Certification Levels and Project Safety Performance

Level of Certification	# of Projects	Mean	Std Dev	Median	Kruskal-Wallis (2-tail p-value)
OSHA recordable incident rates (RIR)					
Certified	5	5.11	3.73	6.12	0.2578
Silver	20	7.17	4.61	7.88	
Gold	12	5.31	6.95	3.03	
Lost time case incident rates (LTCR)					
Certified	5	3.52	4.42	1.41	0.8298
Silver	20	2.52	4.33	0.87	
Gold	12	2.10	4.46	0.64	

It was interesting to note that the silver level projects had a higher mean RIR than the other levels and the certified level had a higher mean LTCR. Table 3.14 did not reveal any trend in the data. The Kruskal-Wallis test revealed that there was not a statistically significant difference in the median RIR of the three levels of certification (two sided p-value = 0.2578).

In order to compare the number of LEED credits to safety performance, simple linear regression would have been an ideal test. However, the non-normal data would make this test invalid. Hence, a simple line graph (see Figure 3.14) was drawn to observe any trend associated with the number of credits and safety performance. The graph did not reveal any trend in a relationship between LEED credits and safety performance.

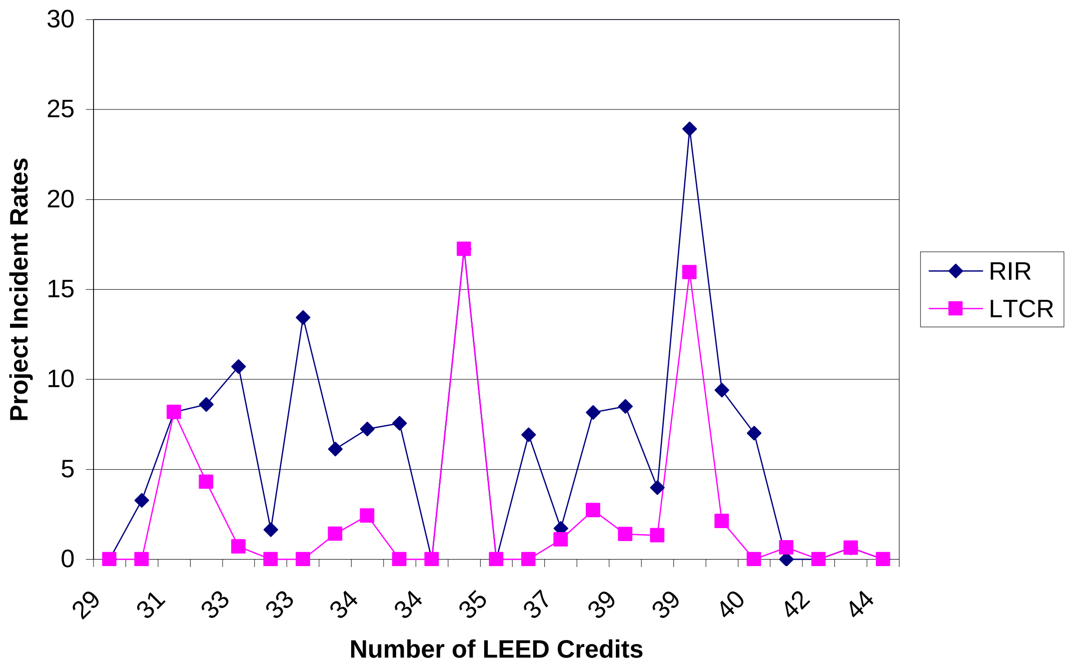

Figure 3.14: Comparison of LEED Credits and Safety Performance

3.6.4 Interview Data Analysis

A simple informal one-question interview was conducted with eight safety representatives from large construction companies who oversee green and non-green projects as part of their job. The safety representatives were asked, "whether there was any negative or a positive impact of green design and construction on worker safety and health. If so, what were the impacts?" Six of the respondents said that they did not see any difference in safety performance between green and non-green projects. The seventh safety professional noted that green projects tend to improve the "health" of construction workers due to the provision of less harmful construction materials as part of LEED. The last respondent noted that the extra efforts due to material handling "could" be a cause of concern for employee safety.

3.6.5 Study Limitations

Studies of green and non-green building projects in terms of safety have not been performed in the past. Three major limitations are present in this study which are listed below:

- One of the major limitations of the study is the data collection process. The projects in the study sample were not collected randomly. Since, the data was not randomly sampled, statistical inferences could not be made to the study population, in this case, all of the green and non-green projects built in U.S. and Canada. The sample selection was a two-stage selection process. First, a set of builders was selected to study. Second, a set of building projects were selected from these builders. The selection of the builders was based on the authors' knowledge of whether they build green projects and was not random. The projects provided were at the discretion of the builders and the researchers did not have any influence on this process. In summary, builder and project selection were not random and, therefore, inferences can be made only to the data set. Any generalization to the population would be speculative.
- A second limitation is associated with the study inferences. The OSHA recordable and lost time injury/illness rate data used for the study is observational data and cannot be used to make cause and effect statements. The strongest statement that can be made from the study is that there is an "association" between the OSHA recordable and lost time injury/illness rates and green design and construction.
- Another limitation is the small sample size. A larger sample size would have provided more confidence in the results. The major cause for this small sample size was the reluctance of contractors to provide safety and LEED information from their projects. Safety data was considered by some contractors to be part of the client-contractor confidentiality agreements. On the other hand, the LEED documentation which outlines the specific green design aspects of the projects was considered as a trade secret and some contractors declined to provide this information. This was one of the factors responsible for the lower response rate in the study.

3.7 Conclusions and Recommendations

The major objective of this study was to investigate the impacts of green building design and construction (as identified by LEED) on worker safety and health. A comprehensive statistical analysis of 86 projects (38 green and 48 non-green) was performed to test the presence of any difference in safety performance between green and non-green projects. Based on the above analyses it can be concluded that:

- There is suggestive, but inconclusive evidence of a statistically significant difference between the median RIR of green and non-green projects in the study sample. Green projects had a higher median RIR than the non-green projects.
- There is not a statistically significant difference between the median LTCR's for the green and non-green projects included in the current study.
- There was a statistically significant difference between the safety performances of the contractors who participated in the study. Contractor A's green and non-green projects have significant differences in median RIR's and suggestive difference in median LTCR's.
- Other factors, such as the project size, type, facility type, ownership, height, and location, did not have any impact on safety performance in the study sample projects.
- There was not a significant difference between the different levels of LEED certification and the median RIR and LTCR rates. It can be concluded that there was no negative or positive impact on safety performance when the amount of green design and construction features were increased in a project.

Based on this research, there appears to be little or no difference between the green and non-green projects in terms of construction safety and health. With both green and non-green buildings having the same safety performance, a question arises as to whether LEED buildings should be labeled as sustainable buildings. It should be concluded that LEED projects are sustainable environmentally but not sustainable in terms of worker safety and health.

3.8 Recommendations for Future Research

The project LEED information that was available for the current study was the: type and level of LEED certification, number of LEED points, and general descriptions of the green features on the project (from other sources like the project owner's website, case studies, USGBC, etc.). Therefore, it was not possible to make connections between each injury incident and specific green design and construction features. This analysis was also not proposed as part of this research study. Relating injury incidents to specific green design and construction features could be accomplished in a much larger study that involves a significant data gathering and project documentation review effort on multiple projects.

The researchers recommend the development of a rating system similar to LEED that will provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of those safety and health elements. The safety and health rating system could be kept as a stand-alone system or combined with LEED that leads to an environmental, health, and safety rating system for building projects.

3.9 References

DJSI (2006). "Dow Jones Sustainability Indexes", SAM Indexes GmbH, Zurich, Switzerland. <www.sustainability-indexes.com/default.html> (December 7, 2005).

Gilding, P., Humphries, R., and Hogarth, M. (2002). *Safe companies: A practical path for 'operationalizing' sustainability.* ECOS Corporation, Sydney, NSW, Australia.

Huang, J. (2003). *The Owners Role in Construction Safety.* Ph.D. Dissertation, 2003, University of Florida, Gainesville, FL.

Ramsey, F.L., and Schafer, D.W. *The Statistical Sleuth: A Course in Methods of Data Analysis (2nd edition).* Duxbury Thomson Learning, Pacific Grove, California

Schendler, A., & Udall, R. (2005). "LEED is broken . . . Let's fix it." *Construction Record,* 126, 910-924.

Statgraphicsplus 5.1, 2001. Statistical graphical corporation.

USGBC (2006). www.usgbc.org, United States Green Building Council, Washington, D.C.

Yudelson, Jerry (2004). "Perspective: Forecasting Market Demand for Green Buildings 2004-2007." *Environmental Design and Construction.*

Sustainable Construction Safety and Health Rating System

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4.0 SUSTAINABLE CONSTRUCTION SAFETY AND HEALTH RATING SYSTEM

4.1 Abstract

The objective of this study is to develop a sustainable construction safety and health (SCSH) rating system that will provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of those safety and health elements. A Delphi survey was conducted to develop the SCSH rating system which consisted of four surveys: an expert background survey, an open-ended survey, and two rounds of questionnaire surveys. The Delphi expert panel consisted of experienced safety and health professionals representing different sectors of the construction industry.

Data analysis between each Delphi round included calculating the mean, median, range, standard deviation, and the level of agreement for each element identified by the experts. A decision diagram that combined the study criteria “level of agreement” and “mean rating” was used to retain and/or drop elements from the rating system.

The study resulted in a total of 50 safety and health elements in the SCSH rating system. The rating system was organized into 13 major safety and health categories. Each category contains sustainable safety and health elements which carry credits based on their effectiveness in preventing construction worker injuries/illnesses. The premise of the rating system is that a higher number of total credits received by a project would indicate a lower potential for incidents that lead to construction worker injuries, illnesses and fatalities. The rating system can be used as a tool to help sustain the safety and health of construction workers by uniting and coordinating the safety and health efforts of the four important parties in a project: owner, designer, general contractor, and subcontractor. The rating system will help set in motion the sustainable safety and health drive in the construction industry.

4.2 Introduction

4.2.1 Problem Statement

Construction worker safety continues to be a major concern for the construction industry. It has historically employed about 5 percent of the country's workforce, yet has accounted for a disproportionate number of occupationally related fatal and non-fatal injuries (NSC 2006). Even though there has been a decline in the fatality and disabling injury rates in the past, it is still severe compared to other industries. The causes of injuries and illnesses in construction have long been recognized and their persistence continues to frustrate construction safety and health practitioners and researchers. Increased control of construction site hazards is needed to lower the level of risk and improve worker safety. Not only are the construction injuries a great concern for humanitarian reasons, but the high cost associated with injury/death calls for a more sustaining safety performance in the construction industry.

The stimulus for this research is the Leadership in Energy and Environmental Design (LEED) rating system. LEED projects are proposed by the owner at the start of the project development process (PDP) and implemented by the designer, constructor, and subcontractors. The LEED rating system does not include a formal construction worker safety and health component. LEED's negligible consideration of construction worker safety and health, and the fact that there is no significant difference in safety performance between the LEED and non-LEED projects, calls for the creation of a new concept called "sustainable construction safety and health." There has been minimal research applying the concept of sustainability to construction safety and health, leaving a large gap in knowledge in this research area. This study fills this gap by applying the concept of sustainability in construction worker safety and health with the development of the SCSH rating system. This rating system can be ultimately incorporated into the LEED rating system.

Over the past few decades, efforts have been made to improve worker safety and health in the construction industry. Construction safety has been the primary responsibility of the constructor (also referred to as the general or prime contractor). Construction companies have developed positive safety cultures and are committed to creating an "injury free work environment" in each of the projects they perform. However, no industry-wide recognition exists such as a Gold or Platinum safety certification for those projects, built by constructors who stand out in their commitment to reduce workplace fatalities and injuries. Such recognition will provide a motivation to constructors to sustain a high level of safety performance on all projects.

Past research has exposed the influence that owners, designers, and subcontractors have on construction worker safety and health. An owner can impact safety through the selection of safe contractors, inclusion of safety requirements in the contract, and active participation in safety during project execution (Hinze 2003). Designers dictate the configuration and components of a facility and thereby impact how the project will be constructed and the safety on the project (Hinze and Gambatese 1996). Subcontractors impact safety to a large extent since they perform the majority of the work on a project. Research has been conducted in the past to assess the role of the four critical players (owner, designer, constructor and subcontractors) individually in the PDP. Some projects involve the owner, designer, constructor, and subcontractors in addressing safety and health during the PDP. However, research aimed at identifying project safety performance if all four parties are involved and committed to worker safety is lacking. The research described in this manuscript tries to fill this gap with the help of the proposed SCSH rating system which consists of safety and health elements to be implemented by owners, designers, constructors, and subcontractors.

4.2.2 Proposed Solution

Construction worker safety and health plays a major role in achieving sustainable socio-economic development in the construction industry. The sustainable safety and health concept, which considers the social and economic well being of the construction workers, is a new approach to boosting the safety and health performance of construction workers. The sustainable safety and health concept aims to sustain the construction worker's safety and health:

- from start to finish of a single project;
- for each future project a worker is involved in; and
- during the worker's remaining life time after retirement.

For example, the work lives of many construction workers have been shortened by repeated physical hazards posed by exposure to lead, silica, asbestos, and many other chemical and environmental hazards to which the worker was exposed. The condition persists even after the exposure has been stopped when the worker quits the job or relocates to a different project. The construction worker's health can be sustained if he or she is properly protected from the exposure in the first place. Several safety and health elements, if properly implemented in a project development process, help sustain worker safety and health. The sustainable safety and health concept approaches the consideration and implementation of safety and health measures from a different perspective.

The sustainable safety and health concept can be implemented in the construction industry through the development of the SCSH rating system. The SCSH rating system will consist of safety and health elements to be implemented by owners, designers, contractors, and subcontractors to sustain worker safety and health from project-to-project. The rating system provides an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of safety and health elements. The rating system is aimed at certifying all project types in the construction industry.

4.2.3 Research Scope and Objective

The objective of this study is to assist the construction industry in incorporating construction worker safety and health into sustainability concepts and practice. The SCSH rating system is primarily aimed at building projects but could be used to test other project types. To fulfill the research objective, the following research questions were formulated:

- What are the important construction worker safety and health elements that should be part of the SCSH rating system?
- What is the effectiveness of each of these elements in preventing construction injuries/illnesses?
- What should be the structure of the SCSH rating system?
- How would credits be calculated for each element of the SCSH rating system?
- How feasible would it be to implement such a rating system in the construction industry?

The potential elements for the SCSH rating system were drawn from two sources: literature and experts. Construction safety and health research over the past several decades has helped to improve the safety and health performance of workers. The SCSH rating system is envisioned to provide a new perspective on the way industry practitioners view safety and health. Attaining injury free environments and sustaining the effort in the construction industry will require the effort of the project team. This rating system will fulfill the purpose of "building towards sustainable safety and health" by uniting the safety and health initiatives of all of the major parties on a project.

4.3 Literature Review

The parties who have significant control of and/or influence on construction worker safety and health are: the owner, general contractor, subcontractor, and designer. Just as each party influences and contributes to the completed project in its own way, each affects construction site safety differently. The SCSH rating system being proposed would include the efforts of all of these four parties. Past research has focused on each party and reveals their unique effects on construction site safety. These research studies were identified as a potential source from where critical elements for the SCSH rating system can be drawn. An in-depth review of literature was conducted through keyword searches of journal article databases and the World Wide Web to locate research papers, reports, and other documents relevant to the study. A wealth of literature on construction safety has accumulated over the past thirty-five years. Detailed review and analysis of all studies was not within the scope of this document. Only specific elements recommended from pertinent studies are extracted and reported in this section. The literature review aims to answer the following questions:

- What are major safety and health elements to be implemented by the owner, general contractor, subcontractor, and designer?
- Is there an existing rating system that evaluates projects based on safety?
- Is there any research that has investigated the combination of all four major players on construction worker safety and health?

Based on the results of the literature review, this section is divided into five different sub-sections that identify the roles of each of the major four parties and a fifth section that includes information on existing construction safety and health rating systems similar to the proposed SCSH rating system.

4.3.1 Owner Studies

There have been only a few studies that have examined the influence of owners on construction worker safety. One of the earliest findings on the impact of the owner's role on safety was reported by Levitt and Samelson (1993). They found that an owner's involvement in safety during construction can have a significant impact on improving the project safety performance. Some of the owner strategies to improve safety identified by Levitt and Samelson (1993) include:

- Stress safety as part of the contract during the pre-job walk-around.
- Require short-term permits, rather than ongoing permits, for hazardous activities.
- Conduct safety audits of the contractor during construction.
- Conduct periodic safety inspections.
- Require safety training of all project employees.
- Maintain statistics on the contractor's safety performance.
- Set goals for construction safety.
- Include general safety guidelines in the body of the contract.
- Set up a construction safety department to monitor contractor safety.

- Require immediate reporting of all worker accidents.
- Investigate the contractors' accidents.
- Always include safety on the agenda at owner-contractor meetings.
- Provide contractors with special safety guidelines they must follow.
- Require the contractor to assign safety coordination responsibility to someone onsite.
- Reimburse the contractor's safety costs in full.

In 1998, the American Society of Civil Engineers issued Policy Statement 350 which stated that improving construction site safety requires attention and commitment from all parties involved. The policy which has since been updated in 2001 states that safety should be addressed for each project on a project specific basis, and that owners should take an active role in project safety. According to the policy statement, the various ways that owners can actively address safety are the following:

- Assigning overall project safety responsibility and authority to a specific organization or individual (or specifically retaining that responsibility) that is qualified in construction safety principles, rules, and practice appropriate for the particular project;
- Including prior safety performance as a criterion for contractor selection;
- Designating an individual or organization to monitor safety performance during construction; and
- Designating in contract documents responsibility for the final approval of shop drawings and details.

Selection of contractors based on safety was found to be one of the major strategies project owners can follow to improve project safety performance. The different criteria to be included during the selection of contractors as summarized from three sources are the following (Hinze 1997, Huang 2003, and Hinze and Godfrey 2003):

- Injury incident rates (including lost workday injury rates, OSHA recordable injury rates, first aid injury rates, etc.)
- Job site safety inspections
- Behavior based worker observations
- Experience modification rates (EMR)
- Workers' compensation loss ratios
- Records of OSHA citations and fines
- Litigation related to injuries
- Performance records of key personnel
- Project safety plans
- Contractor qualification safety surveys
- Worker's perception surveys

In addition to selection of contractors, specification of safety requirements in contract documents was found to be an important strategy that has a positive impact on safety. Hinze (1997) suggested that owners should include the following safety requirements in contracts:

- Submittal of a project-specific safety plan
- Preparation of job hazard analyses
- Regular safety meetings with supervisory personnel
- A designated project safety coordinator
- Mandatory reporting of accidents, safety inspections, and safety meetings
- Inclusion of subcontractors in the safety program
- Compliance with the owner's safety guidelines
- Establishment of an effective worker orientation program

Gambatese (2000) also reported the positive impacts of owners on construction site safety. He stated that the owner's position on safety should be clearly communicated to the project team at the beginning of the project and to all team members joining the project as part of the construction phase. The position can be written in the project documents and contracts, and verbally communicated in project team meetings during design and construction. This study added some more elements to those reported in earlier studies. According to Gambatese (2000) the various ways owners can address safety include:

- Establish a clear position on safety
- Ensure that safety is addressed in project planning and design
- Consider safety performance when selecting a contractor
- Address safety in the construction contract
- Assign safety responsibility during construction
- Participate in project safety during construction

Similar to Hinze (1997), Gambatese (2000) also suggested to include the following requirements in construction contracts to promote safety:

- A requirement that the constructor abide by all applicable safety laws and regulations
- Delineation of the responsibility for safety on the jobsite
- Submission of a written constructor safety program before work begins
- A requirement for conducting a substance abuse program
- Submission of an emergency plan and accident reporting procedure

Gambatese (2000) also emphasized the importance of incorporating safety during the design and planning stages as influenced by the owner. The study reported a sample of best practices that an owner can implement during the design and pre-planning stages of a project. These include:

- Schedule different projects or construction phases that occur at the same location to be performed simultaneously.
- Provide a list and location of toxic substances and other hazardous materials that

are located on the site.

- Do not allow schedules that contain sustained overtime or night work.
- Impose a ceiling on the number of workers on site or in a particular area.
- Confirm that the constructor knows of the potential hazards of all construction materials and their proper storage and disposal.
- On renovation or retrofit projects, provide the constructor with original as-built drawings of the existing structure.
- Conduct a pre-construction meeting with the constructor (including all subcontractors) to discuss safety issues.
- Consider involving OSHA in planning safety measures prior to starting construction.

Huang (2003) investigated the impacts of owners on construction safety and concluded that owner involvement can significantly influence project safety performance. Huang suggests that the owner's concern and participation in safety should start from the very beginning of the project design and continue until the completion and even the operation and maintenance of the project. The study reveals that the owner can impact safety management and the safety commitment of the designer, general contractor, and subcontractors in various means. According to the study, owners can achieve better project safety performance by setting safety objectives, selecting safe contractors, addressing safety in contracts, and participating in safety management during construction. It should be noted that all of the studies examined in the literature agree that these four elements or strategies have the highest impact on reducing injury incidents. Another significance of this study is that, in contrast to other studies, Huang quantitatively demonstrated the effectiveness of these owner elements on safety. Huang provides further description of these main elements. When selecting the contractor, the owner should include the following selection criteria:

- Total Recordable Incident Rate (TRIR) on past projects,
- Qualifications of the contractor's safety staff,
- Qualifications of the contractor's project management team, and

- Assessment of the quality of the contractor's overall safety program.

Five contractual requirements that the owner should include to experience improved safety performance are (Huang 2003):

- Contractor must place at least one full-time safety representative on the project
- Contractor must submit the résumés of key safety personnel for the owner's review and approval
- Contractor must provide specified minimum safety training for the workers
- Contractor must submit a site-specific safety plan
- Contractor must submit a safety policy signed by its CEO

In terms of the owner's involvement in the safety practices, Huang found the following elements to be effective:

- Owners setting their expectations on safety from the very beginning of a project, especially the zero-injury objective.
- Owners imposing requirements on the safety programs developed by contractors and emphasizing specific items including: emergency plan (medical and hazardous materials), daily JSA (job safety analysis) conducted on the project site, and substance abuse program.
- Owners monitoring near miss rates and the safety inspection records on the projects along with other types of injury statistics (TRIR, lost-time injury rate, etc.).
- Owners maintaining accident statistics by contractor on their projects and including the contractor's injury statistics in their own accident records.
- Owners establishing a safety recognition program and contributing funds to the program.
- Owners actively participating in safety training and orientation and verifying the comprehension of the training (such as by testing).

- Owners assigning a full-time safety representative on site with various responsibilities including: enforcing safety rules; reviewing safety performance on site and submitting reports to the home office; monitoring pre-task analysis programs; participating in safety recognition programs; and participating in safety and/or tool box meetings.

Most of the safety elements reported by Huang are in agreement with the findings of previous research (Levitt and Samelson 1993, and Gambatese 2000). In addition, Huang reported that owners can take an active role in designing for safety through:

- Setting their expectations in the design phase that construction safety is one of their major concerns and is to be built into the project design;
- Addressing safety issues as early as the feasibility study and conceptual design phases and integrating safety into the objectives of the project;
- Actively participating and coordinating the efforts of the designer and the contractor through regular safety/constructability reviews of the project design; and
- If possible, awarding the contract to an engineering and construction company to help promote safety performance.

4.3.2 Constructor Studies

The OSH Act's mandate that employee safety is the responsibility of the employer places the burden of construction site safety foremost on constructors (prime or general contractors). Of all of the parties that play a role on a project, constructors commonly take the lead role, and often are the sole party, in addressing construction worker safety and health. Despite the emphasis within the Federal safety standards on the role of employers, most construction contract general conditions state that the project’s constructor has primary responsibility for safety on project sites (Toole 2002). Toole (2002a) studied the general opinion on construction site safety roles among the constructors, subcontractors, and designers involved in a project. The study revealed that there was not uniform agreement on the site safety responsibilities that should be assumed by each of these groups. Most of the respondents in the survey placed the primary responsibility for safety with the constructor. This is perhaps a reason why the majority of past safety research has focused on a constructor's organization and actions. Research on the constructor’s influence on safety has led to the identification of best practices for improving safety and health and the development of tools to assist constructors in eliminating jobsite hazards and ensuring safe work practices. Some of the important findings regarding a constructor’s role in safety are reported below.

Levitt and Parker (1976) studied the role of top management role of a construction firm in reducing construction injuries. Some of the findings of the study include:

- Companies whose top managers talked about safety when they visited jobsites had lower EMR’s than companies in which safety was not mentioned during these events.
- Companies with formal orientation programs had lower EMR’s compared with companies with no orientation programs.
- Incentives based on lost time accidents did not have any effect on safety.

It is commonly held among practitioners that top management commitment to safety is the most important factor responsible in improving safety performance. Findings from two earlier research studies conducted in the 1970s revealed that safety performance improved when companies had a low employee turnover rate (Hinze 1978, and Hinze and Pannullo 1978). This finding has been verified in recent studies (e.g., Gambatese and Hinze 2003). Hinze and Parker (1978) found that increased job-related pressure on superintendents led to increased injuries.

Several research studies have been conducted on what should be the essential elements to improve construction worker safety performance. According to OSHA, an effective occupational safety and health program should include the following four main elements (OSHA 2006):

- Management commitment and employee involvement,
- Worksite analysis,
- Hazard prevention and control, and
- Safety and health training.

In 1994, Meridian Research Group published a report citing various elements as essential to an effective construction safety program (Meridian Research 1994, as cited in Findley et al. 2004):

- Written, comprehensive safety and health program/plan
- Safety and health responsibility and accountability clearly established and implemented
- Employee involvement in the design and operation of the safety and health program
- Employees possess the overall fitness to perform the work
- Worksite analysis identifies safety, health and ergonomic hazards
- Safe work practices are established to effectively manage worksite hazards
- Frequent worksite inspections are performed
- Emergency response planning is performed in order to respond to rapidly changing hazards on construction worksites
- First aid and medical facilities are provided to address the unique requirements of each construction worksite
- Accidents are properly investigated, reported and analyzed
- Training and safety meetings are tailored to the hazards of a particular worksite
- Joint safety and health committees encourage employee involvement
- Contractor/subcontractor relationships for safety and health activities are well-defined

Liska et al. (1993) conducted an extensive research study that resulted in the identification of eight safety-related techniques (zero accident techniques) which, if implemented in a quality manner within a total safety program, will result in excellent project safety performance. These included:

- Safety Pre-Project/Pre-Task Planning
- Safety Training/Orientation
- Safety Incentives
- Alcohol and Substance Abuse Program
- Accident and Near Miss Investigation
- Record Keeping and Follow-up
- Safety Meetings
- Personal Protective Equipment

However, the study concluded that of the eight techniques, five had the greatest impact, in the order listed below, on attaining a zero or near zero accident project:

- Pre-Project/Pre-Task Planning
- Safety Orientation/Training
- Safety Incentives
- Alcohol and Substance Abuse Program, and
- Accident and Near Miss Investigation

Different strategies for achieving excellence in construction safety performance at the company and project level were reported by Jaselskis et al. (1996). For the purposes of the study, safety performance was defined in terms of recordable incident rate and EMR. Some of the important company-related safety improvement strategies/elements from the study include:

- Upper management support (as it relates to the amount of time spent with field safety representative)
- Time devoted to safety issues for the company safety coordinator

- Number of informal safety inspections made by the company safety coordinator
- Meetings between the field safety representatives and craft workers
- Length and detail of company safety program
- Safety training for new foremen and safety coordinators
- Specialty contractor safety management (as it relates to the number of meetings and participation in an alcohol and substance testing program)
- Company safety expenditures

Jaselskis et al. (1996) also reported the following strategies for safety excellence at a project level:

- Increased project manger experience level
- More supportive upper management attitude towards safety
- Reduced project team turnover
- Increased time devoted to safety for the project safety representative
- More formal meetings with supervisors and specialty contractors
- More informal meeting with supervisors
- Greater number of informal site safety inspections
- Reduced craft worker penalties
- Increased budget allocation safety awards

In their report to the Construction Industry Institute, Hinze et al. (2001) presented nine best practices to be followed by constructors to make zero accidents a reality. This study was conducted to examine changes made since the initial zero accidents research was published (Liska et al. 1993). The results of the study have been widely accepted and are followed in the construction industry by companies who are committed to improving their safety performances. The nine elements that resulted from this research include:

- Demonstrated management commitment
- Staffing for safety

- Safety planning
- Safety training and education
- Worker participation and involvement
- Recognition and rewards
- Subcontractor management
- Accident/incident reporting and investigations
- Drug and alcohol testing

4.3.3 Subcontractor Studies

Research about the influence of subcontractors on construction safety has been minimal, even though they perform most of the construction work. Two studies (Hinze and Figone 1988, and Hinze and Talley 1988) were funded by the Construction Industry Institute (CII) to consider the safety performance of subcontractors as influenced by the general contractor (GC) or the construction management (CM) firm. The studies described that several practices of constructors, to varying degrees, were noted as having an influence on the safety performances of subcontractors. One of the major findings of the studies was that project size impacted the type of influence that GCs and CMs have on subcontractors' safety performance.

The study findings indicate that subcontractor safety performances on medium-sized projects were adversely impacted by job pressures and coordination. The study revealed that subcontractor safety performances were better on smaller projects than larger projects. It was also reported that having fewer subcontractors on a project resulted in better safety performance. In addition, safer subcontractor performances were realized when the constructor had a policy of contracting with selected or known subcontractors. Further, subcontractor safety was influenced by the constructor's emphasis on safety, the concern about the workers, and compliance with safety regulations.

Similar to small or medium-sized projects, on large construction projects subcontractor safety was found to be influenced by the quality of the scheduling and coordination effort of the general contractor or CM, and the degree of emphasis placed on safety. The study revealed that safety performance among subcontractors was better when the GC or CM:

- Provided a full-time project safety representative
- Discussed safety at coordination meetings and pre-job meetings
- Monitored project safety performance
- Required full compliance with the safety regulations
- Had top management commitment/involvement in project safety

It can be concluded from these two studies that general contractors or construction managers have significant control over project safety performance compared to subcontractors.

Another study by Hinze and Gambatese (2003) identified factors that significantly influence safety performance of subcontractors. The study involved a variety of subcontractors, including a considerable number of roofing and mechanical contractors, as part of the study sample. The researchers found that the factors that positively affect safety performance of subcontractors include minimizing worker turnover, implementing employee drug testing, and training with the assistance of contractor associations. The study revealed that safety incentive programs were not necessarily associated with better safety performance. To some degree, safety inspections by the contractor seemed to improve safety performance among subcontractors.

In addition to the studies discussed above, researchers at Western Michigan University investigated three different types of subcontractors with a series of studies funded by the National Science Foundation:

- Mechanical contractors (Fredericks et al. 2002)
- Electrical contractors (Abudayyeh et al. 2003)
- Roofing contractors (Fredericks et al. 2005)

Fredericks et al. (2002) reported that eye injuries due to grinding and welding, and upper extremity cuts due to sheet metal work, are the most frequent mechanical contracting tasks/injury combination. According to Abudayyeh et al. (2003), hand/finger and shoulder injuries due to the use of power tools, back injuries due to lifting and pulling wires, and electric shocks, were primary ways in which electrical workers were injured. Fredericks et al. (2005) found hand and finger injuries due to cutting operations, and back injuries due to the manual handling of heavy and bulky materials, to be the most frequent roofing contracting task/injury combination among the roofing contractors.

These studies did not identify any particular elements to improve safety performance of the concerned trades. As presented above, the studies revealed the specific tasks in each of the specialty areas that were frequently involved with injuries, illnesses, and fatalities. All of the studies concentrated on subcontractors primarily from Michigan, and the results could not be generalized throughout the nation. Further, these studies did not recommend any safety and health elements that should be implemented by subcontractors to improve safety or any particular preventive strategies. Instead the studies concentrated on specific injuries and the tasks associated with the injury.

4.3.4 Designer Studies

Eliminating the hazard is widely recognized as a far more effective way to improve safety than reducing the hazard or providing personal protective equipment to workers (Gambatese et al. 2005). Designing to eliminate or avoid a hazard is given higher priority than simply controlling the hazard or protecting the workers from the hazard (Manuele 1997). The concept of designing for safety is recognized by safety professionals as the foremost method for eliminating hazards and reducing risk regardless of work industry (Gambatese et al. 2006). Similarly, the construction industry recognizes that opportunities to impact overall project cost, schedule, and quality diminish with each successive phase of a project (CII 1986). According to Szymberksi (1997), the ideal situation is for construction safety to be a prime consideration in the conceptual and preliminary design phases of the project development process as shown in the time-safety influence curve in Figure 4.1. This perspective brings into the safety picture the next major party involved in a construction project the designer or A/E. Toole (2002a) reported that the designers are in the best position to implement specific safety design recommendations, thereby preventing less safe conditions on the site.

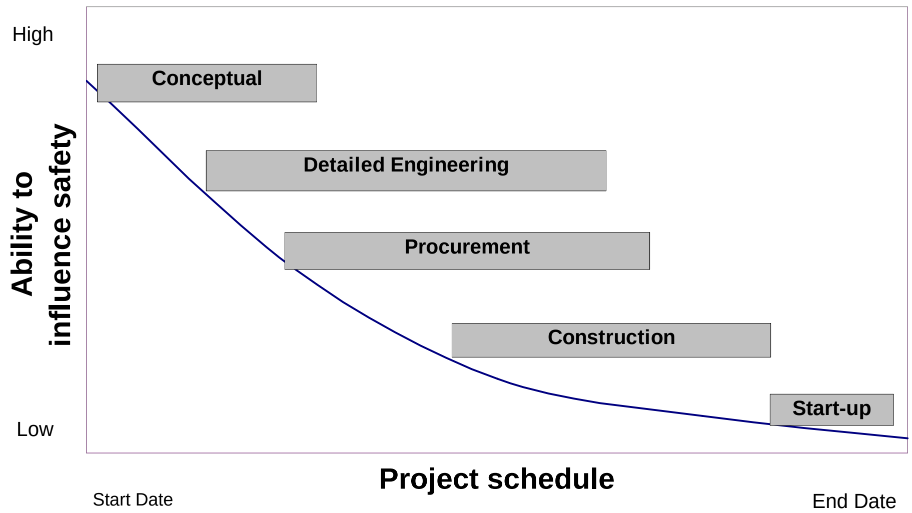


Figure 4.1: Time / Safety Influence Curve (Szymberksi 1997, adapted from Gambatese et al. 2005)

Historically, the design profession has not addressed construction site safety in its scope of work. Designers' lack of involvement can be attributed to their education and training, existing design tools and standards, their typical role on the project team, and their liability exposure. Designer education and training typically focuses on the safety of the "end user," such as the office worker, motorist, or equipment operator (Hinze and Gambatese 1996). Rarely do designers receive formal construction site safety education and training. Regardless of the aforementioned reasons why designers typically do not address construction worker safety, the construction industry has recently awakened to the need for designer involvement. It is becoming more evident that safety practices implemented solely by the constructor cannot eliminate all jobsite hazards. Constructors and safety professionals have realized that the design is an underlying facet of construction site safety (Hinze and Gambatese 1996).

Designing for safety is the consideration of construction site safety in the design of a construction project. This includes modifications to the permanent features of the construction project and to the preparation of plans and specifications for construction in such a way that construction site safety is considered. It also includes the utilization of design for safety suggestions and the communication of risks regarding the design in relation to the site and the work to be performed (Behm 2005, and Gambatese et al. 2005).

There has been plenty of evidence which shows that implementation of the “design for safety concept” improves safety and health performance of workers. The European Foundation for the Improvement of Living and Working Conditions reported an initial attempt at determining the extent to which the design and the design process are linked to construction accidents (Lorent 1987, as cited in European Foundation 1991). By reviewing construction fatalities, Lorent concluded that approximately 60% of fatal accidents in construction arise from decisions made upstream from the construction site. The researcher purports that these fatal accidents are due to shortcomings in design and organization of the work.

Hinze and Wiegand (1992) conducted an early research study on the design for construction safety concept. The researchers surveyed design firms and firms that conduct constructability reviews, and concluded that designers play a major role in reducing the incidence of construction injuries and fatalities. The researchers express that the evidence is clear that construction worker safety can be addressed during the design process.

Gibb et al. (2004) studied 100 construction accidents with the help of expert review, followed by validation of the experts’ opinion through the use of a research study steering group. The experts approached the review of each incident by asking the question, “What could designers have done to reduce the risk?” Based on the experts’ responses to this question, the researchers found that in almost half of the cases (47%), changes in the permanent design would have reduced the likelihood of the accidents (Gibb et al. 2004, as cited in Gambatese et al. 2006).

One of the most recent studies on this aspect of construction safety was conducted by Behm (2005) who sought to link the design for construction safety concept to construction fatalities through a review of fatality incidents in the U.S. As part of the study, Behm analyzed 224 construction accidents from the National Institute for Occupational Safety and Health's (NIOSH) Fatality Assessment Control and Evaluation (FACE) program databases. Each case was reviewed to determine whether the design could be linked to the incident. A link was deemed to exist if any one of the following criteria were met (Behm 2005):

- The permanent features of the construction project were a causal factor in the incident. Linkage to the design for construction safety concept was affirmed if the structure failed during construction because it was not designed to withstand construction activities or if the features of the permanent structure prohibited the constructor from implementing a temporary safety device.
- One of the previously developed design suggestions (Gambatese 1996) could have been implemented to reduce the safety hazard. Linkage to the design for construction safety concept was affirmed if one or more of these design suggestions would have reduced the risk posed to the constructor or provided a greater opportunity for the constructor to reduce risk by facilitating the utilization of temporary safety measures.
- The design or the design process could have been modified to prevent the incident. This portion of the research developed new design suggestions, adding to the existing body of knowledge in #2 above.

Of the 224 fatality cases reviewed, the design was linked to the incident in approximately 42% of the cases. In addition, 43 existing design suggestions were identified that could have been implemented to reduce the hazards associated with the fatalities, and 30 new design suggestions were developed. The research provided additional insights about the relationship between those incidents that could be related to the design and various project factors, such as the nature of the project (new construction, renovation, upgrade, etc.), project type (residential, commercial building, etc.), design element, Standard Industrial Classification (SIC) code, and designer discipline (architecture, civil, mechanical, etc.) (Behm 2005, as cited in Gambatese et al. 2006).

One recommendation presented by Behm was the employment of an expert panel composed of construction industry professionals to validate the research findings and determine the feasibility of implementing each linked design suggestion. Gambatese et al. (2006) utilized this approach in a subsequent study as a follow-up effort to Behm's initial research. The objectives of the research were to: (1) assess the connection between the design of a facility and construction worker safety; and (2) validate the findings of previous studies that showed a link between construction fatalities and the design for construction safety concept. The study involved an expert panel composed of 18 industry professionals and academics who reviewed a sample of ten fatality cases to judge whether the design was a factor in the incident. Each panel member reviewed five of the ten cases. The study revealed further evidence of the influence that the design can have on construction safety and the need for design professionals to play a role in the effort to improve construction safety and health.

Research has also found that construction worker health could be improved by the implementation of the design for safety concept. In a study of an intervention to prevent musculoskeletal injuries to construction workers, antecedents in design, planning, scheduling, and material specifications were identified as probable contributors to working conditions that pose risks of such injuries during the actual construction process (Hecker el al. 2001). This study indicates that addressing safety in design can also prevent health hazards in the construction industry.

Hinze and Gambatese (1996) addressed the issue of the role of designers in construction safety in a study involving the identification of design suggestions, or "best practices," which could be implemented during project planning and design in order to minimize or eliminate safety hazards in the construction phase. This effort was followed by the development of a design tool to assist designers in identifying and mitigating safety hazards. The research effort identified and developed over 400 design suggestions and led to the development of the “Design for Construction Safety Toolbox” computer program.

A new concept that incorporates the design for safety strategy was introduced by Hinze (2000), who recommended a concept called “designing for the entire life cycle of a building.” Hinze contended that to effectively address construction safety issues, the designer must consciously assess the implications on safety during each phase of a project’s lifecycle, including construction.

Other studies have stressed the importance of the concept life cycle safety. One study (Weinstein et al. 2005, and Hecker et al. 2005) analyzed the impacts of a large-scale safety-in-design initiative during the design and construction of a semiconductor manufacturing facility. The name given to this process was Life Cycle Safety (LCS) due to the fact that the team aimed to extend the concept of safety-in-design to reflect safety concerns in all phases of the facility’s lifecycle including programming, detailed design, construction, operations and maintenance, retrofit, and decommissioning. In this way, the LCS process sought to address health and safety issues for multiple stakeholders including construction workers, tool (equipment) installers, maintenance workers, and operators of the fabrication facility. LCS was envisioned to be a comprehensive review process to include the owner of the project, the design firm, general contractor, and numerous trade contractors involved in the construction and operation of the facility. Based on an evaluation of the LCS review process, the researchers identified 26 potential design changes, and considered whether the accepted design changes ultimately impacted construction site safety on the project. The researchers found that the design changes documented on the project certainly appeared to have had a positive impact on the reduction of hazardous exposures.

Another avenue for implementation of the design for safety concept is the constructability review process. Constructability can be defined as the use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives. Application of constructability concepts and principles during the project lifecycle can make the delivery of a facility easier, safer, and cheaper. Research on implementing the design for construction safety concept has been evaluated as part of the constructability review process (Gambatese 2000a). If safety is included as part of the constructability review process, design professionals can utilize the timely input of the constructor's knowledge regarding safety. The involvement of construction foremen during this process can lead to improved design and safer projects. Coble and Haupt (2000) described how construction foremen can make significant contributions to the design for safety effort, provided that designers recognize and harness their skills, site experience, and knowledge base. Therefore, safety can be included during the early stages of the project through a detailed constructability review process.

Supplementing the design for safety concept is the inclusion of warning symbols in construction drawings (ENR 2004). This innovative approach has been followed by a Florida-based design-build company. The firm includes eight different warning symbols in its project plans to flag potential hazards such as electrocution, asphyxiation, or falls. The firm has preconfigured the symbols into CAD programs and explains their meaning in a legend on the design drawings and contract documents. The company also trains designers in an extensive modified 10-hour OSHA safety program (ENR 2004).

4.3.5 Safety and Health Rating Systems

There appears to be no research that has created a system to rate projects based on safety and health efforts of all of the four major parties. The study by Huang (2003) created a scorecard (Table 4.1) that can be used to diagnose the level of the owner's involvement in construction safety management. Based on validation from real time projects, the study revealed that the scorecard was an accurate predictor of the level of involvement of the owner in project safety. The premise of the scorecard is that a higher score means a strong involvement and a low score reflects little involvement of the owner in the project.

Ng et al. (2004) created a framework for evaluating the safety performance of construction contractors at organizational and project levels. As part of the study, the researchers examined a scorecard system introduced by the Hong Kong government to evaluate safety performance of contractors. The scorecard consisted of six key aspects (Works Bureau, as cited in Ng et al. 2004):

- Provision and maintenance of plant
- Provision and maintenance of the working environment
- Provision of information, instruction and training
- Provision and implementation of safety systems at work
- Employment of safety officers/supervisors
- Site accident records

A weighting was allocated to each factor to reflect its importance. An assessor is required to assign a rating to each factor. However, one major weakness of the rating system as noted by Ng et al. is that it takes into account the contractor's safety performance at a project level without considering organization-related safety performance factors. The system does not include a solid foundation as to how the weightings are established.

Ng et al. (2004) created two types of evaluation systems to assess contractors. They identified a range of safety performance evaluation factors based on literature. Thirteen factors were organization-related and 18 were project-related. In order to establish the importance of each of the factors, the researchers conducted a questionnaire survey among clients or owners, contractors, and consultants. The respondents were asked to rate each of the factors on a scale of 1 to 5 with 1 indicating very low impact and 5 indicating very high impact. Based on the responses the researchers calculated a mean rating score and mean ranking for all of the elements. In terms of organization level factors, the top two elements identified by the respondents were "management commitment" and "training and education." This result supports studies discussed in previous sections of this report. At the project level, "provision of safe working environment" was found to be the most important factor in improving safety performance. The researchers calculated a factor called "performance index" value based on the relative importance of the factors to be given to all sub-factors under different performance scenarios (poor, satisfactory, good, very good). An evaluation form was created for both the organizational and project levels with which an assessor can simply record the actual safety performance of a contractor based on four rating categories of poor, satisfactory, good, very good, and total score can be computed by summing all of the sub-factor scores. A sample for one major element and its sub-factors is shown in Table 4.2. Similar tabulations for the entire major and sub factors were presented in the study.

The study by Ng et al. (2004), reports a project level evaluation system that can be an "after the fact" rating system to assess contractor performance on a project. The study limited the respondents to certain elements pre-selected by the researchers and did not give the respondents an opportunity to add more elements that might be important in assessing a project. Further, the study does not specify the qualifications of the respondents. Since, the basis of the evaluation system rests on the rating provided by the respondents, it is essential that the quality (quality can be defined in terms of the respondent's construction and safety work experience, education, and so forth) of the respondents be high to accept this rating system. Another limitation of this study is that it only addresses the contractor efforts on a project and does not include the designer, owner, and subcontractors who also play major roles in construction safety.

Table 4.1: Owner's Influence on Construction Safety Scorecard (after Huang 2003)

Project Context, Contractor Selection, Contractual Safety Requirements and Owner Involvement in Project Safety	Answer	
(1) Does the project work one shift?	☐Yes	☒No
(2) Does the project work five days a week or less?	☐Yes	☒No
Selection of contractor		
(3) Is the TRIR requirement for the contractor selection less than 2.0?	☐Yes	☒No
(4) Are the qualifications of the project team reviewed?	☐Yes	☒No
(5) Are the qualifications of the safety staff reviewed?	☐Yes	☒No
(6) Does the evaluation of each contractor's safety performance make a difference in awarding the contract?	☐Yes	☒No
Contractual safety requirements		
(7) Does the project use a design-build contract?	☐Yes	☒No
(8) Does the contract require the contractor to place at least one full-time safety representative on the project site?	☒Yes	☐No
(9) Does the contract require the contractor to submit all safety personnel résumés for the owner's approval?	☐Yes	☒No
(10) Does the contract require the contractor to prepare a site-specific safety plan?	☒Yes	☐No
(11) Does the contract require the contractor to submit a safety policy signed by its CEO?	☒Yes	☐No
(12) Does the contract require the contractor to provide a minimum specified amount of training to the construction workers?	☒Yes	☐No
Contractor Safety Program Requirements		
Which of the following are required to be included in the contractor's safety program?	☐Yes	☐No
(13) Contractor must prepare a plan for site emergencies	☒Yes	☐No
(14) Contractor must conduct pre-task safety planning on the project site	☒Yes	☐No
(15) Contractor must implement a substance abuse testing program	☒Yes	☐No
Owner's involvement in project safety management		
(16) Does the owner's safety representative investigate near misses?	☒Yes	☐No
(17) Are injury statistics on the projects maintained separately on each contractor?	☐Yes	☒No
(18) Are all project injuries included in the owner's overall measure of safety performance?	☐Yes	☒No
(19) The owner actively participates (gives presentations) during worker safety orientation?	☐Yes	☒No
(20) Comprehension of safety training is evaluated through testing?	☒Yes	☐No
Which of the following activities does the owner's site safety representative perform?		
(21) Enforcing safety rules and regulations	☒Yes	☐No
(22) Monitoring of the implementation of pre-task planning	☒Yes	☐No
(23) Participating in safety recognition programs	☒Yes	☐No
(24) Participating in safety and/or tool box meetings	☐Yes	☒No
(25) Does the owner set zero injuries as its safety expectation before the commencement of site work?	☐Yes	☒No
Total Count of Yes Responses	**12**	
Multiply the Yes Count by 4 (x4)	48%	

What the score means:
88% or better is strong owner involvement and 52% or less indicates weak owner involvement

Table 4.2: Safety Performance Assessment Form for Project Level (after Ng et al. 2004)

Factors	**Poor (x1)**	**Satisfactory (x2)**	**Good (x3)**	**Very Good (x4)**	**Score**
Project mgmt. commitment					
Definition of safety responsibility to all site personnel	2.71	5.43	8.14	10.85	
Safety committee Development	2.51	5.03	7.54	10.05	
				Sub-total	

4.3.6 Literature Review Summary

A wealth of literature exists in the area of construction safety and health that has accumulated over the past 35 years. Studies that identified the roles and influence of the four major parties (owner, constructors, subcontractors, and designers) were reviewed. All of the major elements reported in the literature to improve safety performance in a project were extracted and recorded.

Elements that should be implemented by owners to improve safety, and could potentially be part of the SCSH rating system are:

- Owner safety commitment
- Selection of contractors based on safety (TRIR, qualifications of safety and project management staff, quality of contractor safety program)
- Safety requirements in contracts (safety representative, resume of safety personnel, site specific safety plan, CEO safety commitment letter, and minimum training)
- Owner involvement in safety activities during pre-planning, design, and construction phases

There is a wealth of research focused on a constructor's organization and actions to improve safety performance. Research on the constructor's influence on safety has led to the identification of best practices for improving safety and health and the development of tools to assist constructors in eliminating jobsite hazards and ensuring safe work practices. Based on the review of the several studies discussed above, there is consensus among the researchers that the major elements that will help achieve better safety performance mostly revolve around the nine zero accident techniques reported by Hinze et al. (2001):

- Demonstrated management commitment
- Staffing for safety

- Safety planning
- Safety training and education
- Worker participation and involvement
- Recognition and rewards
- Subcontractor management
- Accident/incident reporting and investigations
- Drug and alcohol testing

It should be noted that one of the research studies suggested that incentives do not necessarily lead to improved safety performance. However, safety recognition was reported to be one of the nine zero accident techniques. The Hinze study (2001) provided substantial evidence from validation of real time projects and hence the incentive element was included in the list. This element has been a topic of debate among safety professionals. Many safety professionals claim that incentives only lead to underreporting and do not actually improve safety. Some add that crews may get rewarded based on just luck that they did not have any injuries, even after working in unsafe conditions. However this element was left in the final list and will be presented to the expert panel during the Delphi process.

Research on a subcontractor's role in construction safety has been minimal. Some of the significant subcontractor elements that could be part of a SCSH rating system include:

- Task coordination by analyzing project schedule
- Have fewer contractors on the project
- Hiring known subcontractors by the GCs
- GC or CM provided a full-time project safety representative
- GC discussed safety at coordination meetings and pre-job meetings
- GC monitored project safety performance
- GC required full compliance with the safety regulations from subs
- Top management commitment/involvement in project safety

- Minimizing worker turnover
- Implementing employee drug testing
- Training with the assistance of contractor associations
- Absence of incentive program

Literature was reviewed to extract the sustainable safety and health elements that should be implemented by designers to improve safety. Some of the significant designer elements that could be part of a SCSH rating system include:

- Safety during conceptual planning stages of project
- Safety in design concept
- Safety during constructability reviews
- Life cycle safety review
- Safety training for designers
- Inclusion of hazard symbols in project plans
- Involvement of foremen (GC) in constructability review/design process
- Use of the Design for Construction Safety Toolbox

The safety and health elements to be implemented by three (owners, general contractors and subcontractors) of the four major parties were neatly summarized by Huang (2003). The authors of this manuscript adapted Table 4.3 from Huang (text modified), and appended the designer's role in the table for comparison. Examining the table reveals that the best practices of the owner, constructor, and subcontractors were similar in nature. In contrast, most of the techniques were not applicable to the designers. This summary of safety and health elements will be used as a comparison during the first round analysis of the Delphi survey.

Table 4.3: Summary of Safety and Health Elements from Different Studies to be Implemented by Owners, Designers, General Contractors and Subcontractors (adapted from Huang 2003)

	Owner Studies	**Contractor Studies**	**Subcontractor Studies**	**Designer Studies**
Management Commitment	▪ Establish a clear position on safety ▪ Owner participates in safety activities	▪ Company president reviews safety reports ▪ Home office inspects safety frequently ▪ All recordable accident investigation – Top mgmt. involvement	▪ Home office manager comes to visit the job frequently	▪ Willingness to incorporate safety in design
Staffing for safety	▪ Owner assigns full-time safety rep. on site ▪ Safety rep. assumes various responsibilities	▪ Employment of full-time safety rep. ▪ Safety rep. reports to main office staff	▪ A designated person for safety on the project.	▪ N/A
Safety planning	▪ Owner requires certain items to be included in the safety program (inc. JSA) ▪ Safety rep. monitors safety planning program	▪ Require site-specific safety program ▪ Hold pre-task meetings ▪ TSA conducted in each phase	▪ GC reviews safety program of sub	▪ Incorporation of safety in design ▪ Constructability safety review ▪ Hazard identification in construction plans ▪ Life Cycle Safety
Safety training	▪ Involvement in training ▪ Owner has means to verify comprehension of training	▪ Formal safety training plan in print ▪ Safety training is a line Item in the budget	▪ Subcontractors are required to hold safety meetings	▪ Require to undergo OSHA 10 hr training

Table 4.3: Summary of Safety and Health Elements from Different Studies to be Implemented by Owners, Designers, General Contractors and Subcontractors (adapted from Huang 2003) (Continued)

	Owner Studies	Contractor Studies	Subcontractor Studies	Designer Studies
	▪ Owner rep. Involvement Formal worker safety observation program ▪ Management and supervisory person receive behavior overview training ▪ Safety perception surveys implemented	▪ Every worker receives safety orientation ▪ Formal safety training is conducted ▪ Intense safety training conducted monthly for workers and project management ▪ Tool box meetings held daily	▪ Separate safety meetings for supervisors	
Worker involvement	▪ Conduct safety observation program with participation of workers;	▪ Formal worker safety observation program ▪ Management and supervisory person receive behavior overview training ▪ Safety perception surveys implemented	▪ Subs participate in project meetings with owner ▪ Low turnover rate	▪ Involve foremen and workers in construability review
Safety incentive and recognition	▪ Owner funds safety recognition program ▪ Owner safety rep. participates in safety recognition program ▪ Safety dinners held on the project	▪ Safety award given to workers frequently ▪ Safety incentive based on zero-injury objective ▪ Family members attend safety dinner ▪ Field supervisors evaluated on safety	▪ No solid data support	▪ Huge incentive by owner to designer

Table 4.3: Summary of Safety and Health Elements from Different Studies to be Implemented by Owners, Designers, General Contractors and Subcontractors (adapted from Huang 2003) (continued)

	Owner Studies	**Contractor Studies**	**Subcontractor Studies**	**Designer Studies**
Subcontractor management	▪ Subcontractors are required to follow same safety regulations as contractor	▪ Sub is required to submit site-specific safety plan ▪ All sub workers attend formal safety training ▪ Sub holds safety meetings daily ▪ Sanction subs for non-compliance with safety stds.	▪ Subcontractor submits safety report to GC ▪ GC inspects sub safety	▪ N/A
Accident Report and investigation	▪ Incident stats. maintained by contractor ▪ Include safety stats. of contractor in owner's review ▪ Safety rep. reviews accident reports	▪ More near misses recorded on the project ▪ Top management investigates every accident	▪ GC investigates accidents of subs	▪ N/A
Drug test	▪ Substance abuse testing required in safety program	▪ Implement substance abuse test	▪ No solid data support	▪ N/A

There appears to be no research that has created a rating system to rate a project based on safety and health efforts of all of the four major parties on a project. The literature search was also targeted to identify prior research that has studied the impacts of all of these four major parties together. No research was found that has studied their combined effort on a project. This was evident from the recommendation from Huang (2003):

> Since separate studies have been conducted on the safety roles played by owners, contractors, subcontractors and designers, future research should be conducted on the impact on project safety when all parties are considered to be members of a project team. Prospective and experimental methods can be implemented in the research, and the most effective practices of each party with the presence of the other parties can be evaluated. The interactive impact on project safety performances of the different parties should be evaluated. Thus, an overall rating system can be developed with consideration of both the separate influence of each party and their interactive impacts. This would provide information by which to develop a holistic approach to project safety.

From the literature review, it is apparent that there is a need to conduct a research study that combines the efforts of all of the four major parties involved in a project. Hence, this study aims to create a rating system that will incorporate all significant elements to be implemented by the major parties in a project and also help rate projects based on safety and health.

4.4 Research Methodology

The Delphi technique was chosen as the research methodology to facilitate the development of the SCSH rating system. The Delphi technique facilitates drawing information and judgments from geographically dispersed experts in the construction field on the elements to be included in the SCSH rating system. This section presents the results of a detailed literature review on the Delphi technique. Based on the results of the literature review, a detailed plan of action was drafted for the study. Also, included in this section is the description on the Delphi technique and its application to the study. This section also includes discussions of: (1) how the Delphi experts were selected; (2) how the Delphi survey questionnaires were designed and implemented; and (3) how the data was analyzed.

4.4.1 Delphi Technique

4.4.1.1 Background

The Delphi technique was developed by a team of researchers in the 1950s at the RAND Corporation while involved in a U.S. military project (Dalkey and Helmer 1963). The Delphi technique is in essence a series of sequential questionnaires or rounds, interspersed by controlled feedback, that seek to gain the most reliable consensus of opinion of a group of experts (Linstone and Turoff 1975). Delphi's initial application was in the area of technological forecasting and corporate planning (Helmer 1983), but later has found widespread application in a number of fields. According to Gupta and Clarke (1996), between the period 1975 to 1994 Delphi methods have been used in a large number of domains including: academia, administration, agriculture, automotive, banking, criminal, justice, economics, education, environmental studies, finance, health care, housing, insurance, management, real estate, sales strategic planning, tourism, transportation, and utilities.

The Delphi technique is useful for situations where individual judgments are to be captured and combined in order to address a lack of agreement or incomplete state of knowledge (Delbecq et al. 1975). As such, the technique is particularly valued for its ability to structure and organize group communication. According to Rowe and Wright (1999), the structure of the Delphi technique is intended to allow access to the positive attributes of interacting groups (knowledge from a variety of sources, creative synthesis, etc.), while pre-empting their negative aspects (attributable to social, personal, and political conflicts, etc.). From a practical perspective, the method allows input from a larger number of participants than could feasibly be included in a group or committee meeting, and from members who are geographically dispersed. The ultimate goal of the Delphi technique is not to elicit a single answer or to arrive at a consensus, but to obtain as many high quality responses and opinions as possible on a given issue from a panel of experts to enhance decision-making (Gupta and Clarke 1996).

4.4.1.2 Key Elements of Delphi

The Delphi technique consists of three key features, namely: anonymity, iteration and controlled feedback, and the statistical aggregation of group response.

- *Anonymity* – Anonymity is achieved through the use of questionnaires. This encourages the experts to provide their opinion without any external influence.
- *Iteration and controlled feedback* – Delphi consists of several iterations of questionnaires. The controlled feedback of information over a number of rounds occurs through which experts are informed about the opinion of other experts. The iteration process also provides the experts an opportunity to change their views if necessary.
- *Statistical aggregation of group response* – Group opinion is documented accurately and defined as an appropriate aggregate of individual positions on the issue through simple statistical measures such as mean or median.

4.4.1.3 Delphi Process

The Delphi technique typically consists of several rounds of questionnaires sent to a panel of pre-selected experts. The rounds of questionnaires are structured to answer a specific research question. According to Jairath and Weinstein (1994), pilot testing of the initial questionnaire is optional but notes that it may help to identify ambiguities and improve the feasibility of administration of the Delphi technique.

The first round questionnaire can take several forms, but usually consists of an unstructured, open-ended question. This gives the experts relatively free scope to identify, and elaborate on, those issues they see as important. Open-ended questions are recognized as beneficial for increasing the richness of the data collected (Powell 2003). The issues identified by the experts are then consolidated into a single set by the monitor team, who produce a structured questionnaire from which the views, opinions, and judgments of the Delphi panelists may be elicited in a quantitative manner on subsequent rounds (Rowe and Wright 1999). After each round, responses are analyzed and statistically summarized (usually using medians plus upper and lower quartiles), which are then presented to the panelists for further consideration. Hence, from the third round onwards (if there are more than three rounds), panelists are given the opportunity to alter prior estimates on the basis of the provided feedback (Rowe and Wright 1999). A simplified summary of the Delphi technique, provided by Fowles (1978), includes ten steps:

1. Formation of a team to undertake and monitor a Delphi on a given subject
2. Selection of one or more panels to participate in the exercise. Customarily, the panelists are experts in the area to be investigated
3. Development of the first round Delphi questionnaire
4. Testing the questionnaire for proper wording (e.g., ambiguities, vagueness)
5. Transmission of the first questionnaires to the panelists
6. Analysis of the first round responses
7. Preparation of the second round questionnaires (and possible testing)
8. Transmission of the second round questionnaires to the panelists
9. Analysis of the second round responses (Steps 7 to 9 are reiterated as long as desired or necessary to achieve stability in the results.)
10. Preparation of a report by the analysis team to present the conclusions of the exercise

4.4.1.4 Strengths and weaknesses of Delphi

In spite of its presence for over 50 years, Delphi has several strengths and weakness. The primary advantage of the Delphi technique is that (Dalkey 1972):

> "When faced with an issue where the best information obtainable is the judgment of knowledgeable individuals and where the most knowledgeable group reports a wide diversity of answers, the old rule that two heads are better than one, or more practically, several heads are better than one, turns out to be well founded."

Other major advantages of the Delphi technique include:

- Achievement of consensus in a given area of uncertainty or lack of empirical evidence (Murphy et al. 1998).
- Allows the experts to be anonymous, which leads to more creative outcomes and adds richness to data (Okoli and Pawlowski 2004).
- Issues inherent in face-to-face groups such as individual dominance, conflict of interest, and group pressures are virtually eliminated (Murphy et al. 1998).
- From strictly a practical viewpoint, the Delphi technique is a relatively inexpensive method to organize and administer (Rowe and Wright 1999)
- Use of modern technologies such as on-line surveys and e-mails significantly reduces the time required to conduct the Delphi.

The Delphi technique as a research methodology has received criticisms over the past three decades which include:

- The Delphi technique is unscientific (Sackman 1974).
- Simmonds (1977) argues that one of the key weaknesses in using the Delphi technique is that certain questions do not get asked as they do not seem important when the study begins. However, once the study is underway new questions cannot be added, which in turn can weaken the study considerably.
- The quality if the research outcomes are limited by the caliber of the participants (Martino 1978).
- While two or more rounds are likely to result in some convergence of individual judgments, it is unclear whether this actually increases the accuracy of the group's decision making (Murphy et al. 1998).
- Participant commitment may falter if the process takes too long or they have other commitments. The panelists are likely to suffer fatigue from completing more than two rounds of questionnaires leading to a low response rate (Adler and Ziglio 1996). This issue leads to higher chances of a participant dropping out as the Delphi progresses into the second and any subsequent rounds.
- In terms of application of this technique, the results can be limited by sloppy execution, crudely designed questionnaires, poor choice of experts, unreliable

result analysis, limited value of feedback and consensus, and instability of responses among consecutive rounds (Gupta and Clarke 1996).

- Lang (1998) discussed the problem of bias in Delphi studies that can occur from poorly worded or leading questions or selective interpretation of the results. Lang suggests that this problem can be overcome by using a facilitation team or unbiased facilitator who has no stake in the results of the study.
- In contrast to some literature listing "time" as an advantage of Delphi, the researchers find this claim otherwise. A typical three round Delphi can take at least four months to complete. It should be noted that it also depends on the experts' response time.

4.4.2 Delphi Technique Selection

Delbecq et al. (1975) noted that before deciding whether or not the Delphi technique should be used, it is very important to consider thoroughly the context within which the method is to be applied. Adler and Ziglio (1996) suggest answering the following questions before selecting or ruling out Delphi:

- What kind of group communication process is desirable in order to explore the problem at hand?
- Who are the people with expertise on the problem and where are they located?
- What are the alternative techniques available and what results can reasonably be expected from their application?

Various criteria to use to determine whether the Delphi Technique should be selected as a research methodology are provided in the literature. The Delphi technique is appropriate when:

- Disagreement may exist among the experts to the extent that a referred communication process is desired (Towne 1967, as cited in Veltri 1985).
- The opinion of a group is more desirable than the opinion of a single expert (Pill 1971 as cited in Veltri 1985).

- It is desired that the psychological aspects of face-to-face confrontation to be minimized (Pill 1971, as cited in Veltri 1985).
- Questions to be answered by intuitive judgment supersede questions to be answered by concrete measurement (Pill 1971, as cited in Veltri 1985).
- The problem does not lend itself to precise analytical techniques, but can benefit from subjective judgments on a collective basis (Linstone and Turoff 1975).
- The individuals needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise (Linstone and Turoff 1975).
- More individuals are needed than can effectively interact in a face-to-face exchange (Linstone and Turoff 1975).
- Time and cost make frequent group meetings infeasible (Linstone and Turoff 1975).
- The efficiency of face-to-face meetings can be increased by a supplemental group communication process (Linstone and Turoff 1975).
- Disagreements among individuals are so severe or politically unpalatable that the communication process must be refereed and/or anonymity assured (Linstone and Turoff 1975).
- The heterogeneity of the participants must be preserved to assure validity of the results, i.e., avoidance of domination by quantity or by strength of personality ("bandwagon effect") (Linstone and Turoff 1975).
- Combining views to improve decision making is desired (Bass 1983).
- Immediate confirmation of the results is not possible (Veltri 1985).
- The research is contributing to an incomplete state of knowledge (Delbecq et al. 1975).
- There is a lack of empirical evidence (Murphy et al. 1998).

In addition to its appropriateness criteria, the Delphi technique is inappropriate when:

- The opinion of the real expert is diluted by the consensus of the group (Pill 1971, as cited in Veltri 1985)

- Results are immediately verifiable by some other means (Pill 1971, as cited in Veltri 1985)
- There is insufficient structure in the questionnaire implying that not enough information is available to the Delphi participants (Towne 1967).
- Consensus may be gained by means other than intuitive judgment (Veltri 1985)
- It is used for any purpose other than that of combining opinions of a selected group (Pill 1971, as cited in Veltri 1985)

4.4.2.1 Why Delphi for the research?

The Delphi technique is well suited to the current research study which involves the development of a SCSH rating system. Selection of safety and health elements that are to be part of the rating system calls for value judgment from experts in the construction safety and health field. The purpose is to extract new safety and health ideas from the experts in addition to the published literature. There has been no quantified research on the impact of safety and health elements relative to other elements. In simple words, research has not identified the importance of each element. This lack of factual knowledge in the literature led to the choice of the Delphi technique as the appropriate method to develop the SCSH rating system.

4.4.3 Expert Panel Selection

The success of a Delphi clearly rests on the combined expertise of the participants who make up the expert panel (Powell 2003). There are two key aspects to panel composition: panel size and expert qualification.

4.4.3.1 Panel size

No concrete guidance was found in the literature regarding the size of the expert panel. This was evident from Reid (1998), who reported that panel size varied in previous Delphi research from 10 to 1685. Turoff (1970) recommends that a Delphi sample size should be from 10-50 participants, whereas Adler and Ziglio (1996) suggest that with a homogonous group of experts, reasonable results can be obtained with small panels of 10 – 15 experts. Differences in the appropriate sample size are mainly based on the validity of the results. Murphy et al. (1998) believe that as the number of judges increases, the reliability of a composite judgment increases. But, Murphy et al. also note that, there is very little actual empirical evidence of the effect of the number of participants on the reliability or validity of consensus processes. However, authors of previous literature do agree on the fact that the number of participants will vary according to the scope of the problem and resources (money and time) available (Delbecq et al. 1975, Fink et al. 1991, Hasson et al. 2000, and Van Zolingen and klaassen 2003).

Another important criticism on the panel size is that the expert panel is not representative of the overall population. Powell (2003) clarified this issue by reporting that Delphi does not call for the expert panel to be a representative sample for statistical purposes. Representativeness is assessed on the qualities of the expert panel rather than its size.

Based on the above discussions, the authors decided to form a panel of 10 to 15 experts for the present study. The authors felt that this size was sufficient with a composition of highly qualified expert panel. The authors felt that one highly qualified expert from each of the different avenues of construction would be sufficient.

4.4.3.2 Panel member qualification and selection

Several studies in the literature discuss the qualities of a participant whose inclusion will result in a successful study. If the Delphi is to be successful in achieving the objectives, it is important that expert panel members are willing and able to make a valid contribution (Powell 2003). According to Delbecq et al. (1975):

> "It is unrealistic to expect effective participation unless respondents: (1) feel personally involved in the problem of concern to the decision makers, (2) have pertinent information to share, (3) are motivated to include the Delphi task in their schedule of competing tasks, and (4) feel that the aggregation of judgments of a respondent panel will include information which they too value and to which they would not otherwise have access."

In another study, (Tersine 1976, as cited in Veltri 1985), the researchers identify four basic criteria that should be considered in choosing participants. The participants must:

(1) possess a high degree of objectivity and rationality; (2) have a good performance record in their particular areas; (3) have the time available to participate to the conclusion of the programs; and (4) be willing to give the amount of time and effort to do a thorough job of participation.

The above two studies list generic criteria for who would make a good participant. The studies do not provide clear criteria for expert qualifications. What really defines an expert? There are differences amongst the authors in the literature on using the term "expert" and how to adequately identify a professional as an expert. A study by Rogers and Lopez (2002) listed five explicit expert criteria for defining an expert. In order to qualify as an expert, persons must meet 2 of the 5 criteria. The criteria are (all related to the area of research):

- Authorship
- Conference participant
- Member or chair of committee
- Employed in practice or supervisor with five years experience
- Employed as faculty member with specific interest in area

In another study by Veltri (1985), the expert panel was selected based on one or more of the following criteria:

- Demonstration of knowledge which members of recognized professions and society at large judge as being of expert quality.
- Exhibition of expertise by willingly submitting for critical examination, various publications related to the discipline involved.
- Participation in professionally related forums, conference and workshops with colleagues interested in advancing the related profession.

Based on the information drawn from the literature, a list of eight criteria was produced (Table 4.4) to help the authors define an "expert" for the present study. The expertise of the panel members in the development of the SCSH rating system is based on their professional accomplishments in several avenues within the field of construction worker safety and health. It was decided that persons who met three of the eight criteria would be included in the panel. As discussed earlier there were no specific guidelines in the literature which suggest how many criteria a participant should meet to qualify as an expert. Studies by Rogers and Lopez (2002) set 2 out of 5 criteria (40%), and Veltri (1985) set 1 out of 3 (33%). Hence, the present study criterion of 3 out of 8 seemed appropriate.

To identify potential participants, the authors created a list of 20 potential experts in the safety and health profession within a wide range of occupations closely related to the construction industry. The experts were affiliated with an owner, GC, subcontractor, insurance company, regulatory agency, and academia. All of the potential experts were contacted through the telephone and e-mail to solicit their participation on the Delphi panel. The potential experts were instructed about the research, its objective, the Delphi process, and the time commitment required for the study. Fifteen out of the 20 potential experts contacted responded positively to be part of the Delphi panel. The authors felt that a panel size of 15 was suitable for the study based on the literature and the quality of experts identified for the study. The characteristics of the experts and the extent to which they meet the stated criteria are presented in the Results section of this manuscript.

Table 4.4: Safety and Health Expert Panel Criteria

No	Criteria	Description
1	Authorship	Primary or secondary author of papers (at least three) published in the area of safety and health in the last five years in peer reviewed journals and/or articles.
2	Conference presentation	Primary or secondary presenter in conferences (at least three) in the area of safety and health in the last five years (ASCE or ASSE).
3	Book author or editor	Author of books or chapters, or editor of conference proceedings, in safety and health related field.
4	Safety committee	Part of a safety and health related organization, and serves on the safety committee of such an organization. A member of the ASCE safety committee, and a member of the construction specialty of ASSE are a few examples.
5	Faculty	Currently employed as a faculty member with in the safety and health specialty area.
6	Education	Holds at least a Bachelor’s degree in safety and health, construction, or related field.
7	License requirements	Professional Engineer (PE), Licensed Architect, Certified Industrial Hygienist (CIH), Certified Safety Professional (CSP), Construction Health and Safety Technician (CHST), or Associated Risk Manager (ARM).
8	Experience	Worked in construction safety practice and/or closely related position (superintendent/project manager) with a minimum of five years of experience and direct responsibility for worker safety and health.

4.4.4 Delphi Survey Design and Implementation

As discussed early in this manuscript the Delphi technique can include several rounds of questionnaires. One of the major disadvantages of having too many rounds is that the panelists are likely to suffer fatigue (Adler and Ziglio 1996). This might lead to a poor response rate. Adler and Ziglio (1996) suggest that two rounds of questionnaires are sufficiently effective in allowing an exchange of comments and reaching a broad consensus of opinion. The authors, based on the requirements of the current study, decided to conduct three rounds of survey in addition to the expert background survey to examine their expertise. The development of the rating system consisted of three important aspects that included: (1) identifying the elements needed to be part of the rating system; (2) allocating appropriate credits for the elements identified; and (3) developing a feasible structure for implementation of the rating system. It was decided to identify all of the possible elements in the first round, gaining consensus on their ratings in all three rounds, and finalizing the structure of the rating system in the third round. This led to selection of three rounds for the study instead of two as recommended in the literature.

4.4.4.1 Background survey

In order to gather information on the professional accomplishments of the participants, an on-line background survey was created. Based on their responses, the researchers intended to identify whether the participants were experts in the safety and health profession. The survey was posted on the Internet and the links were sent through e-mail. The e-mail cover letter and the background information questionnaire are presented in Appendices B.1 and B.2.

4.4.4.2 Delphi Round I

The first round questionnaire was sent to the fifteen experts who agreed to be part of the Delphi panel. The questionnaire consisted of the following two simple open-ended questions:

1. What are the various construction worker safety and health elements/initiatives implemented on projects? Include all elements/initiatives that any member of the project team might implement (owner, designer, general contractor, subcontractor, etc.).
2. Please rate each element/initiative you listed based on their effectiveness in preventing construction worker injuries/illnesses. Use a Likert-type scale of 1 to 5 as follows: “minimal impact/least effective” (1), “below average” (2), “moderate” (3), “above average” (4), or “large impact/most effective” (5).

The questionnaire was not pilot tested since it consisted of only the above two questions and the researchers felt that the expert panel could sufficiently understand and respond to the questions. The respondents were asked to answer the questions based on their personal knowledge and experience. The survey was sent out to participants via electronic mail. The panelists were asked to return their response by e-mail or fax. The surveys were sent out on December 2, 2005, and all were returned by the experts by January 25 2006. The questionnaire, cover letter, and accompanying documents used during the first round are presented in Appendices B.3 to B.5.

4.4.4.3 Delphi Round II

The expert panel contributed 329 safety and health elements during the first round of survey. The responses were reviewed to identify the unique elements provided by all of the experts. This process resulted in a list of 74 unique safety and health elements. In addition, the researchers added six elements to this list from the literature, increasing the total to 80 safety and health elements. These 80 elements were sorted into 14 safety and health categories:

- contract safety requirements,
- project team selection,
- project safety representatives and qualifications,
- project team safety commitment,
- safety planning,
- safety training and education,
- safety resources and tools,
- drug and alcohol program,
- accident investigation (AI) and reporting,
- incentive/disincentive programs,
- worker involvement,
- safety inspection and corrective action,
- accountability and safety performance measurement, and
- industrial hygiene health practices.

The experts also recorded a rating from 1 to 5 to represent the importance of each of the elements they identified. Mean ratings for each of the 74 elements were calculated and were presented to the experts in the second round. The purpose of the second round survey was to gain expert consensus on the 80 elements and the ratings. The survey was sent out again to the participants via electronic mail. The survey was sent out on February 8, 2006 with a deadline on February 27, 2006. The questionnaire and accompanying documents used during the second round are presented in Appendices B.6 and B.7.

4.4.4.4 Delphi Round III

The purpose of this final round survey was to: (1) confirm consensus on the elements and ratings, and (2) gain expert input on the structure for the rating system and method for implementation. The final questionnaire (see Appendix B.9) used in the third round had a list of 52 safety and health elements. Starting with the 80 elements in Round II, elements were retained in this questionnaire based on a decision diagram discussed later in this chapter. These 52 elements were once again placed into categories similar to round 2. The category "incentive/disincentive programs" was removed at the end of the second round. The reason for dropping the category is discussed in the Results section of this chapter.

Experts were asked to reconsider these remaining elements and rate them according to the Likert-scale used in round 2. In addition, a separate questionnaire was prepared to gain expert opinion on the structure and method for implementation for the rating system (See Appendix B.10). The survey was sent out to participants via electronic mail on March 22, 2006 with a response deadline of April 10, 2006.

4.4.5 Data Analysis

Analysis that takes place in a Delphi study has two purposes. First, analysis should provide feedback between rounds for respondents and, second, the analysis should be able to identify whether consensus has been reached. Literature was reviewed for possible methods of analysis to decide whether consensus has been reached among the experts. Rowe and Wright (1999) list different statistical measures used to analyze the data which include: median, mean, mode, percentage for each event; ranks; upper and lower quartile range; regression weights (or) induced (if then) rules; and statistical average of points for each factor. Qualitative material was also examined in previous research and in a number of studies “reasons” were analyzed and given to respondents as feedback. Greatorex and Dexter (2000) concluded that the mean, a measure of central tendency, can be understood to represent group opinion. They suggest that standard deviation (SD) can then be understood as a representation of the amount of disagreement within the panel. If the SD is low, the panel is in agreement, and the converse is also true. If the SD is high, the panel is in disagreement. Murphy et al. (1998) argue that the medians and the inter-quartile range are more robust than mean and SD.

One of the major aims of using Delphi is to achieve consensus among the experts. However, there are no agreed-upon criteria to declare consensus. Rowe and Wright (1999), note that empirically, consensus has to be determined by measuring the variance in responses of Delphi panelist over rounds, with a reduction in variance being taken to indicate that greater consensus has been achieved. This by itself, however is not universally accepted in literature on Delphi.

Responses to the Delphi Round I questionnaire were analyzed to shortlist all of the essential construction safety and health elements. Based on the ratings given to these elements, mean, median, range, and the number of times an expert mentioned this element were computed for each of the unique elements. Expert responses to Delphi Round II and III questionnaires were analyzed using mean, median, range, and the level of agreement received by each element. A decision diagram was created for the purpose of retaining and/or eliminating elements from the rating system. Responses to questions, seeking expert opinion on the rating system structure and method of implementation, were qualitatively analyzed.

4.5 Results and Discussion

As stated previously the major objective of this study was to develop a sustainable construction safety and health rating system that will provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of safety and health elements. To fulfill this objective, research questions developed and considered in the analysis were:

- What is the important construction worker safety and health elements/initiatives implemented on projects and which of these elements should be part of the SCSH rating system?
- What should be the ratings for each of these elements to reflect their effectiveness in preventing construction injuries/illnesses?
- What should be the structure of the SCSH rating system?
- How should credits be calculated for each of the elements of the SCSH rating system?
- How feasible is it to implement such a rating system in the construction industry?

4.5.1 Characteristics of Panelists

Success of a Delphi study is based in part on the quality of the experts. This section reports the findings of the professional accomplishments of the experts who were part of this study. The 15 panelists had varied backgrounds representing a wide variety of professions in the construction industry. Of the 15 participants: five (33%) are academics in the health and safety and/or construction disciplines; two (13%) work for general contractors; two (13%) work for an owner firm, one (6%) works for a subcontractor; one (6%) works for a safety and health regulatory agency; one (6%) is a design/build professional; one (6%) works as a loss control consultant in an insurance company; one (6%) works as a safety and health consultant; and one (6%) is a safety and health professional who represents a workers' union.

The panel was comprised of a diverse group of individuals associated with the construction industry. Eleven (73%) of the 15 initial participants fully completed the study: twelve participated in the first round, and 11 participated in the second and third rounds. The professional accomplishments of the twelve experts were gathered with the help of an online questionnaire survey. The background questionnaire was posted on the Internet and the links were sent through e-mail. The recorded responses were also collected through e-mail. The intent of the background questionnaire was to verify whether the participants fulfilled the study criteria to be labeled as an “expert”. The results are shown in Table 4.5.

Table 4.5: Summary of Delphi Expert Panel Professional Accomplishments

ID	Location	Group	Expert Criteria								
			EHS Exp	Const Exp	Degree(s)	Certification(s)	Paper(s)	Presentation(s)	Book (s)	Organization (s)	Criteria met
1	NC	Academia	15	0	PhD, PH	CSP	4	5	0	ASSE	7
2	OR	Academia	26	13	MS, PH		7	8	2	ACGIH, AIHA, APHA	7
3	PA	Academia	4	20	PhD, CE	PE	5	10	4	ASCE	8
4	OR	Subcontractor	15	33	BS, MS	CSP, ARM		3	0	ASSE	4
5	OR	General Contractor	19	14	BS, EHS	CSP	1	25	1	ASSE	5
6	OR	Owner	13	13	BS, EHS	CSP, ARM	0	3	0	ASSE	5
7	FL	Designer/Builder	6	42	B.Arch	Licensed Arch (34)	3	2	3	AIA, DBIA	6
8	WA	OSHA	31	0	BS	PE	0	5	0	OSHA	5
9	DC	Worker Association	25	25	MS PH	CIH	3	50	2	AIHA, ACGIH	7
10	OR	Insurance	14	40		CHST, ARM	0	6		ASSE	4
11	AZ	Consultant	50	33	BS	PE, CSP	3	3	2	HIFI, ASSE	7
12	OR	Owner	18	12	BA	CSP	1	5	0	ASSE	5
	6 states	9 groups	236	245			27	125	14		5.8
Minimum Requirements			5	5	Bachelors	1	3	3	1	1	3
Mean			19.7	20.4			2.5	10.4	1.3		5.8
Median			16.5	17			3	5	1		5.5
Minimum			4	0			0	2	0		4
Maximum			50	42			7	50	4		8

It was found that the panel members are geographically spread across the United States, representing 6 different states and the District of Columbia, with the majority in Oregon. Of the twelve experts, six (50%) were from Oregon, and one each (8%) from Arizona, the District of Columbia, Florida, North Carolina, Pennsylvania, and Washington. The spread is pictorially exhibited in Figure 4.2. The safety and health experience of the panelists ranged from four to 50 years (mean = 19.7 years; median = 16.5 years). In addition to their safety and health experience, the panelists were asked how much construction experience they possessed. The construction experience of the panelists ranged from zero to 42 years (mean = 20.4 years; median = 17 years). Except for two members who had no experience in construction, all others had more than 10 years of experience in the construction industry. Together the twelve panelists had a combined 236 and 245 years of experience in the safety and health profession and construction industries, respectively.

The panelists possessed a variety of academic degrees and industrial certifications. Eleven of the panelists have at least a Bachelor’s degree in safety or other related field; two also have an additional Master’s degree, and two have a Doctorate degree. All but one panelist had some kind of highly recognized certifications; some had more than one certification. There were six certified safety professionals (CSP), three professional engineers (PE), a certified industrial hygienist, a construction health and safety technician, a licensed architect (33 states), and two associated risk managers.

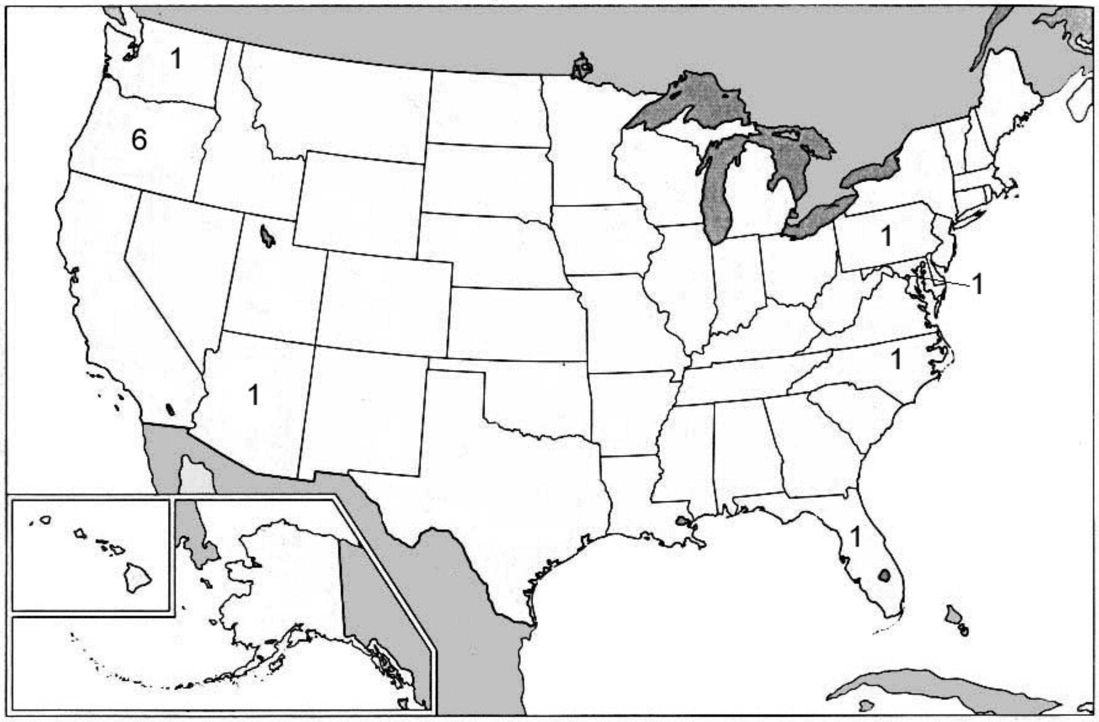


Figure 4.2: Location of the Delphi Experts Who Participated in the Study (n = 12)

The number of papers published by the panelists in peer-reviewed or trade journals ranged from zero to 7 papers in the last three years with a mean of 2.5 papers per panelist. In addition, the panelists were asked how many presentations they have given in the past three years in the field of safety and health. The responses ranged from 2 to 50 presentations with a mean of 10.4 presentations. The professional memberships of the panelists included several safety and health or related associations: American Society of Safety Engineers (ASSE), American Society of Civil Engineers (ASCE), American Institute of Architects (AIA), American Industrial Hygiene Association, American Conference of Industrial Hygienists (ACGIH), Design Build Institute of America (DBIA), and Greater Portland Construction Partnership.

As discussed previously, in order to be labeled as an expert, the participants have to meet three of the eight criteria developed for the study. It was found that all 12 participants fulfilled more than three criteria, with an average of six criteria fulfilled per expert. This indicates that the panelists can be considered as experts in the field of safety and health, and justifies their inclusion in and contribution to the current study.

4.5.2 Expert Bias

A limitation associated with collecting data based on expert opinion is potential for bias. Eight different biases were identified in the literature along with the possible ways for countering the biases. These biases are discussed below.

1. Psychological Bias: Traditional expert opinion methods such as group meetings, brainstorming sessions, etc. can generate a strong psychological bias or barrier among the experts attributable to social, personal, and political conflicts. Experts may feel reluctant to share their opinion, or feel shy about changing their previous opinion. This kind of bias is eliminated by the Delphi technique which maintains complete anonymity amongst the expert panel members throughout the process. Experts can share or change their opinion without any pressure from external sources during any round of the Delphi process.

2. Professional/occupational bias: The expert panel selected as a result of the process discussed previously consists of building designers, academics, and safety and health professionals representing general contractors, subcontractors, regulatory agencies, and insurance loss control experts. This wide range of representation might lead to bias in the SCSH rating development process. For example, a strong proponent of the design for safety concept would provide more elements on this particular subject and also rate these elements higher than his/her peers. Similar situations with an OSHA expert, a general contractor safety expert, and so forth, might create bias towards their particular occupations.

The Delphi process's analysis phase and the iteration process helps to counter this type of bias. According to Rowe and Wright (1999), "the means by which information is passed between panelists so that individual judgment may be improved and debiasing may occur." Statistical tools, like a box-whisker plot, can reveal if there are unusual responses and can give the researchers an idea of the bias in the form of outliers. As discussed previously, mean has been a widely accepted statistical measure to identify the center of the data, especially when involving a small rating range of 1 to 5 as in the present study.

3. Uneven distribution of experts: A panel with many experts in one field and just one from each of the other fields can result in a significant inclination towards one particular concept in the SCSH rating system. This type of bias was countered by selecting a reasonably equal number of experts from each category.

4. Location Bias: Bias might also arise as a result of the location the experts' practice. Some experts might work on the East coast and some in the West. They may be located in different states or different countries where the construction culture and safety and health regulations differ. As an example, California has an ergonomics regulation, but other states do not. An expert from California may not include ergonomics-related elements, since it is required by law. This kind of location bias can be countered with the help of the mean and standard deviation tools explained in the previous section of this report. It should be noted that the researchers did not include international experts.

5. Study Bias: According to Rowe and Wright (1999), the moderator (authors) might include study bias if they only:

- Select respondents who are easily available;
- Select respondents whose reputations are known to the researcher;
- Select respondents who meet a minimal number of criteria of familiarity with the field of the research problem; and
- Select respondents on the basis of self-ratings of their expertise.

This bias can be countered by random selection of experts from a database of professional associations such as the American Society of Safety Engineers. However, it should be noted that all experts are busy people who have many commitments in their work. If an expert does not know the researchers personally, the chances of an expert participating in the study are slim. This is the personal experience of the authors. So, even though this is considered a bias, in order to obtain a high level of participation and response in the Delphi, or to even conduct the Delphi, the authors had to select experts whom the authors know and who will definitely respond to the survey. Self ratings were not used for this study and hence are not applicable.

6. *Delphi Familiarity Bias:* An additional problem noted by van Zolingen and Klaassen (2003 as cited in Hanafin 2004), suggests that participants willing to take part in the Delphi method may be more favorable to the method. This, in turn, may mean that the participants are more inclined to agree with other panel members than those having a less adaptable attitude. It is however highly difficult to find an expert who is not familiar with Delphi. It is the authors' opinion as well that familiarity with the Delphi process can be an advantage since the expert's time spent on understanding the method is minimized and therefore participation increased. In the current study, while a description of the Delphi technique procedure was sent with the questionnaire for their guidance, no question was asked whether the experts had familiarity with the Delphi process.

7. *Knowledge Bias:* Some experts might not be familiar with some concepts addressed by their peers. Design for construction safety is a good example. Some panelists may be knowledgeable about designing for safety while others may not. However, all of the panelists must still respond to this element. If their knowledge is minimal, their rating might not be accurate and may eventually skew the results. Countering this bias is difficult. It is impossible to ask every expert whether they are familiar with all of the elements. It is assumed, however, that as experts, they are familiar with most, if not all, of the elements. There was no guidance in the literature on how to counter this bias.

8. Time Bias and Round Bias: The authors feel that the timing between the questionnaires might create some bias. For example, if the gap between two rounds of Delphi is just 2 or 3 weeks, the experts might get frustrated and be forced to fill in the questionnaire in a hurry. This situation might result in responses that are not the true "opinion" of the expert. In addition, the number of rounds of a Delphi study will also introduce this "hurry" factor. Too many rounds might introduce fatigue among experts, resulting in a decline in the quality of their response. Fatigue might also force the expert to drop out of the Delphi process, resulting in a poor response rate.

This type of bias was countered by planning the Delphi process early and thoroughly, which gave the experts sufficient time between each round. A minimum three week time interval was given to the experts to return the surveys. With respect to the number of rounds, Adler and Ziglio (1996) suggest that two rounds of questionnaires are sufficiently effective in allowing an exchange of comments and reaching a broad consensus of opinion. Based on the requirements of the current study the researchers, decided to conduct three rounds of survey in addition to the expert background survey.
The researchers felt that the least number of rounds that should be employed to gather the information needed for the development of the SCSH rating system was three. Two rounds will not be sufficient to conduct this study as recommended in the literature.

It is the researchers' opinion that Delphi is a tool that can be used to generate all possible ideas from safety and health experts from all avenues of the construction industry. The quality of information obtained from this method is invaluable, and helps to incorporate all of the essential elements of safety and health associated with the construction industry into the SCSH rating system. Hence, in spite of these potential biases, Delphi was selected as the research methodology for the development of the SCSH rating system.

4.5.3 Delphi Round I Results

4.5.3.1 General Elements Analysis

The first round questionnaire was structured as an open-ended question to give the experts relatively free reign to identify and elaborate on those safety and health elements they see as important and rate the elements based on their effectiveness in preventing construction worker injuries/illnesses. For convenience, the 15 experts were arranged alphabetically and each was given a study code from E1 to E15. Twelve (80%) experts completed the first round questionnaire. Of the three who did not respond, two were from academia and one from a general contracting firm. Two experts, one from academia and one from the general contracting firm, reported they were very busy with other commitments and were not able to participate in the study. The other expert from academia did not respond to the survey. The findings from the round one survey are presented in this section, based on the response from 12 experts.

A total of 329 safety and health elements were recorded during the first round survey. Table 4.6 shows the number of elements each expert suggested and their percentage contribution to the total number of elements. Experts E2, E14, and E15 did not respond to the first round survey. In order to maintain consistency in responses, only those who responded to the first round were allowed to participate in the remaining two rounds. The mean number of elements suggested by the experts to be part of the rating system was 27. The majority of the experts (83%) provided twenty or more elements, with four experts suggesting more than 40 safety and health elements. One expert recommended only four elements.

Table 4.6: Expert Response in terms of Number of Elements

Expert ID	Number of Elements	Percent of Total
E1	18	5.5
E2*	0	0.0
E3	41	12.5
E4	21	6.4
E5	20	6.1
E6	42	12.8
E7	27	8.2
E8	4	1.2
E9	23	7.0
E10	22	6.7
E11	44	13.4
E12	45	13.7
E13	22	6.7
E14*	0	0.0
E15*	0	0.0
Total	329	100.0

* Did not submit a response

The responses were examined to identify the unique elements. An MS Excel spreadsheet was created with fourteen columns. A serial number column, an element column, and 12 columns for the twelve expert responses named according to their study code. The responses were examined manually, and repetitive elements were grouped by placing the element in the “element column” and entering the corresponding rating (1 to 5) given to the element by different experts in the “rating” columns. For instance, an element that was suggested by all twelve experts would have 12 ratings and an element that was suggested by only one expert would have only one rating under the particular expert rating column. This process resulted in a list of 74 unique safety and health elements.

The first round data analysis involved three common types of summary statistics that include: number of experts who suggested each safety and health element (N or frequency), mean rating received for the safety and health element (mean), and median rating received for the safety and health element (median).

The number of experts who suggested each of the 74 safety and health elements were initially calculated. This was done to identify the common and familiar safety and health elements suggested by the experts to be part of the SCSH rating system. It was surprising to find that not a single element was suggested by all twelve experts. The two most common elements identified were “safety orientation for all workers” and “detailed accident/near miss investigation,” suggested by ten (83%) experts. It is interesting to note that both of these elements are part of the nine zero accident techniques reported by Hinze at al. (2001). Of the 74 elements derived from round one, 19 were suggested by five (42%) or more experts, as presented in Table 4.7. It should be noted that 32 (43%) elements were suggested by only one of the twelve experts, suggesting diversity in the experts’ thinking.

Table 4.7: High Frequency Safety and Health Elements Suggested by Experts in Round One

Safety and Health Elements	N*
Project safety orientation for all workers (should include health issues, noise, blood borne pathogens, asbestos, silica, lead, and asbestos awareness)	10
Detailed accident/near miss investigation	10
GC selection based on safety experience (EMR, incident rates, claims rate, prevention programs, personal interviews, OSHA citations)	9
GC and subcontractor project and senior management involvement in safety (project mission statement, safety addressed in all preconstruction conferences, participation in job walks and other safety activities on site at least monthly)	9
GC site specific safety plan reviewed and approved by owner/agent (should include emergency response plan mock tested, crisis management plan, site security, lockout/tag out, return to work program)	9
Subcontractor site specific safety plan reviewed and approved by owner/general contractor	9
Project safety incentive program	9
Safety inspections (supervisors, foremen, GC safety rep, sub safety rep, owner safety rep at least weekly)	9
Safety planning requirements in construction contracts (includes, but not limited to, safety commitment signature, drug/alcohol testing, safety professional, training, incident/near miss recording, stretching program, safety plan)	8
Safety in design stage (e.g. fall protection, perimeter guard railing, safe access of end users maintenance personnel, prefab assemblies)	8
Project Pre-task Planning	8
Toolbox Meetings	7
Continuous safety training (in addition to orientation, task specific training, injury free workshops to all personnel)	7
Safety training for all field supervisors (OSHA 30 hr)	7
Stretch and flex program for all workers	7
GC pre-bid, pre-award, and pre-construction meetings with subcontractors to discuss safety	6
Drug and alcohol testing program (pre-employment, random checking, and post accident)	6
GC full time Safety Representative on site	5
Project level worker safety committee and safety leadership teams	5

*N – Number of experts who suggested the safety and health element

In addition to the frequency of expert suggestions, the mean and median ratings were calculated for the 74 elements. While the frequency helped to identify the essential elements to be part of the rating system, the mean and median ratings were helpful in identifying the impact of these elements in improving the safety and health performance of a project. It was found that 54% of the elements (40) received a mean rating of 4 or more. Two elements, “safety in conceptual planning” and “clear project safety responsibility and accountability”, received a mean rating of 5 from the experts. The list of elements that received the top 10 mean ratings is presented in Table 4.8. As discussed earlier in this section, not all of the elements had a rating; only a few elements were suggested by more than one expert. As shown in Table 4.8, two elements, “pre-task planning” and “owner participation in safety”, were suggested by many experts and received a high mean rating. It was interesting to note that three experts suggested OSHA consultations as a way to improve safety and health and have also rated it very high. One expert recommended having all of the workers undergo OSHA-10 hour training as part of their education and training process.

Table 4.8: Safety and Health Elements that Received High Mean Rating from the Experts

Safety and Health Elements	Mean*	Median*	N*
Safety in project conceptual planning	5	5	1
Clear project safety responsibility and accountability	5	5	1
Project Pre-task Planning and documentation	4.8	5	8
Competent personnel for all high hazard tasks	4.5	4.5	2
Owner participation in safety related activities	4.5	4.3	6
Project Job Hazard Analysis (JHA) and documentation	4.5	4.5	4
Schedule look ahead to avoid trade stacking	4.5	4.5	2
OSHA 10 hour training for all workers	4.5	4.5	2
Employees empowered with stop authority for safety concerns and correct them before injury happens	4.5	4.5	2
Project agreements with OSHA (OSHA consultations)	4.3	4.0	3

*N – Number of experts who suggested the safety and health element
Mean – Mean rating received for the safety and health element
Median – Median rating received for the safety and health element

Elements with a frequency (N) of ≥ 5 and mean rating ≥ 4 were examined to identify safety and health elements that were highly “recommended” and also have a high impact on safety and health. It was found that only seven elements qualified under this condition (see Table 4.9). Accident investigation, general contractor and subcontractor management commitment, and safety inspections were among the top 3 elements that satisfied these conditions. Once again, it should be stressed here that these three elements were among the nine zero accident techniques reported by Hinze at al. (2001). These results reveal an agreement between the experts and the literature, and further validate the importance of these elements in preventing construction injuries/illness. Continuous training for project personnel and mandatory OSHA-30 hour training to all field supervisors also satisfied this condition. This result indicates the importance of training to improve safety and health performance.

Table 4.9: Safety and Health Elements with High Frequency and High Mean Rating

Safety and Health Element	Frequency (N > 5)	Mean Rating ≥ 4
Detailed accident/near miss investigation	10	4
GC and subcontractor project and senior management involvement in safety (project mission statement, safety addressed in all preconstruction conferences, participation in job walks and other safety activities on site at least monthly)	9	4.1
Safety inspections (supervisors, foremen, GC safety rep, sub safety rep, owner safety rep at least weekly)	9	4.3
Project Pre-task Planning	8	4.8
Continuous safety training (in addition to orientation, task specific training, injury free workshops to all personnel)	7	4.3
Safety training for all field supervisors (OSHA 30 hour training)	7	4
GC pre-bid, pre-award, and pre-construction meetings with subcontractors to discuss safety	6	4

Most of the safety and health elements identified during the literature review were featured in the list of 74 elements. In addition to the 74 elements suggested by the experts, six elements were added to the list from the literature and the authors' personal research and industry experience, increasing the total to 80 safety and health elements. The six additional elements include: designer provides checklist of possible hazards information to general contractor, zero injury project goal initiated by owner and signed by GC and subs, owner rep involvement in training, Automated External Defibrillator (AED) equipment on site, Material Safety Data Sheet (MSDS) library, and hazard communication program.

4.5.3.2 Analysis by Category

As part of the first round analysis, the possible structure for the envisioned SCSH rating system was evaluated. The foremost concern was how to structure elements in the rating system that would involve all major parties in a project instead of separating responsibilities. Three different alternatives as possible structures for the rating system were considered. The categories/structure that were considered during this process include:

- Categorizing under the four major players: Owners, Designers, General Contractors, and Subcontractors.
- Categorizing under the four major phases: Pre-construction, Procurement, During Construction, and Post-Construction.
- Categorizing under major safety and health initiatives such as education and training, and safety in contracts.

The primary concern with the first alternative was that it would eliminate the collective efforts of all of the players. Each party would work individually and it was feared that it would trigger adversarial relationships. Some of the processes associated with the elements identified during round one are “on-going” during a project and cannot be completed during one phase of construction. For instance, owner support for safety is an on-going process and cannot be restricted to one of the four phases; it flows through all four phases listed in the second alternative. The last categorization on the other hand does not allot responsibilities to separate people and encourages collective efforts of the four major parties during all phases of a project. Hence, the researchers chose a structure based on safety and health processes for the SCSH rating system.

The 80 elements identified from round one, were sorted into 14 safety and health categories: contract safety requirements, project team selection, project safety representatives and qualifications, project team safety commitment, safety planning, safety training and education, safety resources and tools, drug and alcohol program, accident investigation (AI) and reporting, incentive / disincentive programs, worker involvement, safety inspection, accountability and safety performance measurement, and industrial hygiene health practices. Table 4.10 shows the fourteen categories and the number of elements under each category. It was found that the “project safety planning” category had the most number of elements (17) suggested by the experts followed by “training and education” (10) and “contract requirements” (8). The complete rating system at the end of round one is presented in Appendix B.7, which was used as a round 2 response form.

Table 4.10: SCSH Rating System’s Fourteen Categories and its Number of Safety and Health Elements (Round One)

Category	N	Percent of Total
Contract safety requirements	8	10.0
Project team selection	3	3.8
Project safety representatives and qualifications	5	6.3
Project team safety commitment	4	5.0
Safety planning	17	21.3
Safety training and education	10	12.5
Safety resources and tools	7	8.8
Drug and alcohol program	1	1.3
Accident investigation (AI) and reporting	4	5.0
Incentive / disincentive programs	3	3.8
Worker involvement	6	7.5
Safety inspection	2	2.5
Accountability and safety performance measurement	4	5.0
Industrial hygiene health practices	6	7.5
Total	80	100%

4.5.4 Delphi Round II Results

4.5.4.1 General Elements Analysis

The 80 elements identified from round one were sorted into 14 safety and health categories and presented to the 12 experts. Experts were asked whether these elements were to be retained in the rating system, and whether they agreed with the mean rating obtained for each element in round 1. If they did not agree with the rating, they were asked to provide a new rating for the elements based on their effectiveness in preventing construction worker injuries/illnesses. Eleven (73%) experts completed the second round questionnaire. One expert with study code E13 did not respond to the second round survey. The findings from the round two surveys are presented in this section, based on the response from 11 experts. The mean, median, and range (difference between the highest and the lowest score received) were calculated for each element.

Mean ratings

The overall mean and median ratings for the 80 elements were found to be 3.6. Of the 80 elements, none received a mean rating less than 2.0, which indicates that, according to the experts, all of the elements have at least moderate impact in preventing construction injuries/illnesses. The mean ratings ranged from 4.9 (for the element "clear project safety responsibility and accountability") to the lowest mean rating of 2.3 (received by the element "project safety incentive program"). Twenty-six elements received a rating of 4.0 or higher, with 65 elements having a rating of 3.0 or higher. The distribution of mean ratings for the 80 elements is presented in Table 4.11. It was interesting to find that the incentive program element received a very low rating since ten experts had suggested this element be part of the rating system in round 1. This result adds to already contradictory views on an incentive program's effectiveness in improving safety performance among the industry practitioners. The mean ratings given to the 74 elements received in round 1 (6 were added in round 2) were compared between round 1 and round 2. It was found that 27 (36.5%) elements saw an increase in their mean rating, 42 (56.8%) received a lower rating, and the rating of five (6.7%) elements remained unchanged.

Table 4.11: Mean Rating in Safety and Health Elements from Round Two among All Elements

Mean Rating	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	Total (cumulative)
No. of elements	0	15	39	26	80
Percent of Total	0%	18.75%	48.75%	32.5%	100%

Level of agreement

The level of agreement between the panelists was examined in two ways: one based on the mean rating received by the elements, and the other in terms of the elements to be retained in the rating system. Oertel (2001) used the range to calculate the difference between the highest and the lowest rating received by an element. This was found to be a useful tool to analyze the level of agreement between the ratings received by an element. The Oertel (2001) study was used as a guideline for the Delphi analysis and structure of this research. The range was calculated for the 80 elements and the distribution is shown in Table 4.12. The range of 29 elements was very high (>2.0), showing a low level of agreement among the experts. Agreement tended to be higher for the elements that had a higher mean rating, as illustrated by the fact that the percentage of items with a range of 2.0 or less increased from 63.75% to 96.15% when only the top 26 elements (mean rating $\geq$ 4.0) were considered as shown in Table 4.13.

Table 4.12: Range in Safety and Health Elements from Round Two among All Elements

Range	0	0.1-1.0	1.1-2.0	2.1-3.0	3.1-.4.0	Total
No. of elements	1	26	24	25	4	80
Percent of Total	1.25%	32.5%	30%	31.25%	5%	100%

Table 4.13: Range in Safety and Health Elements from Round Two among Top 26 Elements (mean rating ≥4.0)

Range	0	0.1-1.0	1.1-2.0	2.1-3.0	3.1-.4.0	Total
No. of elements	1	14	10	1	0	26
Percent of Total	3.85%	53.8%	38.5%	3.85%	0%	100%

The level of agreement on retaining the elements was determined based on the percentage of participants recording “yes” to whether the element should be retained. The level of agreement was examined among all 80 elements. The agreement ranged from 100% to 18%. Fifteen safety and health elements received a 100% retainage consensus. A low of 18% was received by two elements. When the top 26 elements (mean rating ≥ 4.0) were examined, the trend considerably changed, ranging from 100% to a low of 64%.

Literature was reviewed to select criteria to decide whether consensus was achieved among experts to retain or drop elements from successive rounds. It was found that the consensus criteria varied from study to study. According to Scheibe et al. (1975), as cited in Tanner and Stone (1998), consensus is reached when 60% of the responders are in agreement. In another study by Williams and Webb (1994), consensus was defined as 100% agreement for items to be accepted. However, Williams and Webb note that others had set the level of agreement as low as 55% (Payne et al. 1976). Based on literature found, in Delphi studies consensus is generally assumed to have been reached when between 60% and 80% of participants agree with a particular view point (Lindman 1994, as cited in Oertel 2001). Oertel (2001) used three criteria for items to be maintained for the subsequent round: (1) items that have a mean of 4.0 or higher, (2) items that have a mode of either 4.0 or 5.0, and (3) items that have an agreement level of 60% or higher.

For the purposes of this study, the researchers used three criteria to retain elements for the subsequent round and/or the final rating system. These three criteria were incorporated into a decision diagram to make the process simpler. Elements that did not meet these criteria were dropped from the rating system. The decision diagram used for the study is presented in Figure 4.3. The criteria were as follows:

- Elements with a level of agreement of 60% or more and a mean rating ≥ 4.0 were “retained and required”.
- Elements with a level of agreement of 60% or more and a mean rating ≤ 4.0 were “retained and rated”.

- Elements with a level of agreement of less than 60% and a mean rating $\geq$ 4.0 were "retained and rated".
- Elements with a level of agreement of less than 60% and a mean rating $\leq$ 4.0 were "omitted" from subsequent rounds.

The end result "retained and required" represents those elements that satisfy the criteria "level of agreement 60% or more and mean rating $\geq$ 4.0." These elements are very critical in achieving minimum safety performance. The experts consider these elements as "mandatory" on any project to attain a sustainable safety and health performance. Hence, these elements would be a prerequisite for any project to get rated through the SCSH rating system. For instance, say an element "drug and alcohol testing," received a level of agreement of "100%" and a mean rating of 4.5. According to the decision diagram, for a project to get certified under the SCSH rating system, the project must incorporate drug and alcohol testing for all of its employees. The end result "retain and rated," however, means that the elements which satisfy this criterion would be an "elective" element and projects may or may not choose to fulfill these credits to get certified. If the project team wants to pursue higher levels of certification, they need to include the elective credits.

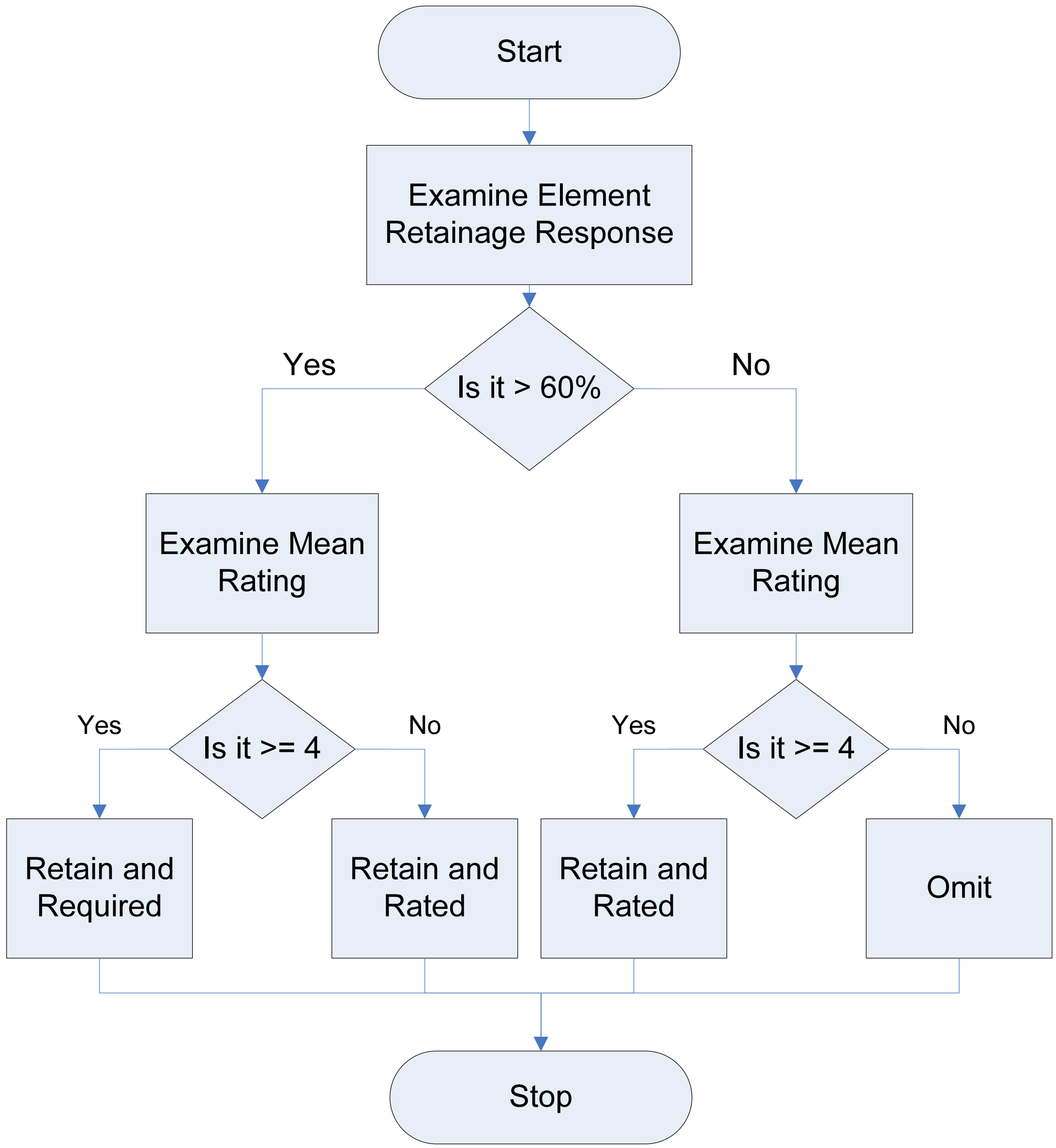


Figure 4.3: Decision Diagram Used to Retain Safety and Health Elements with High Level of Consensus and Importance

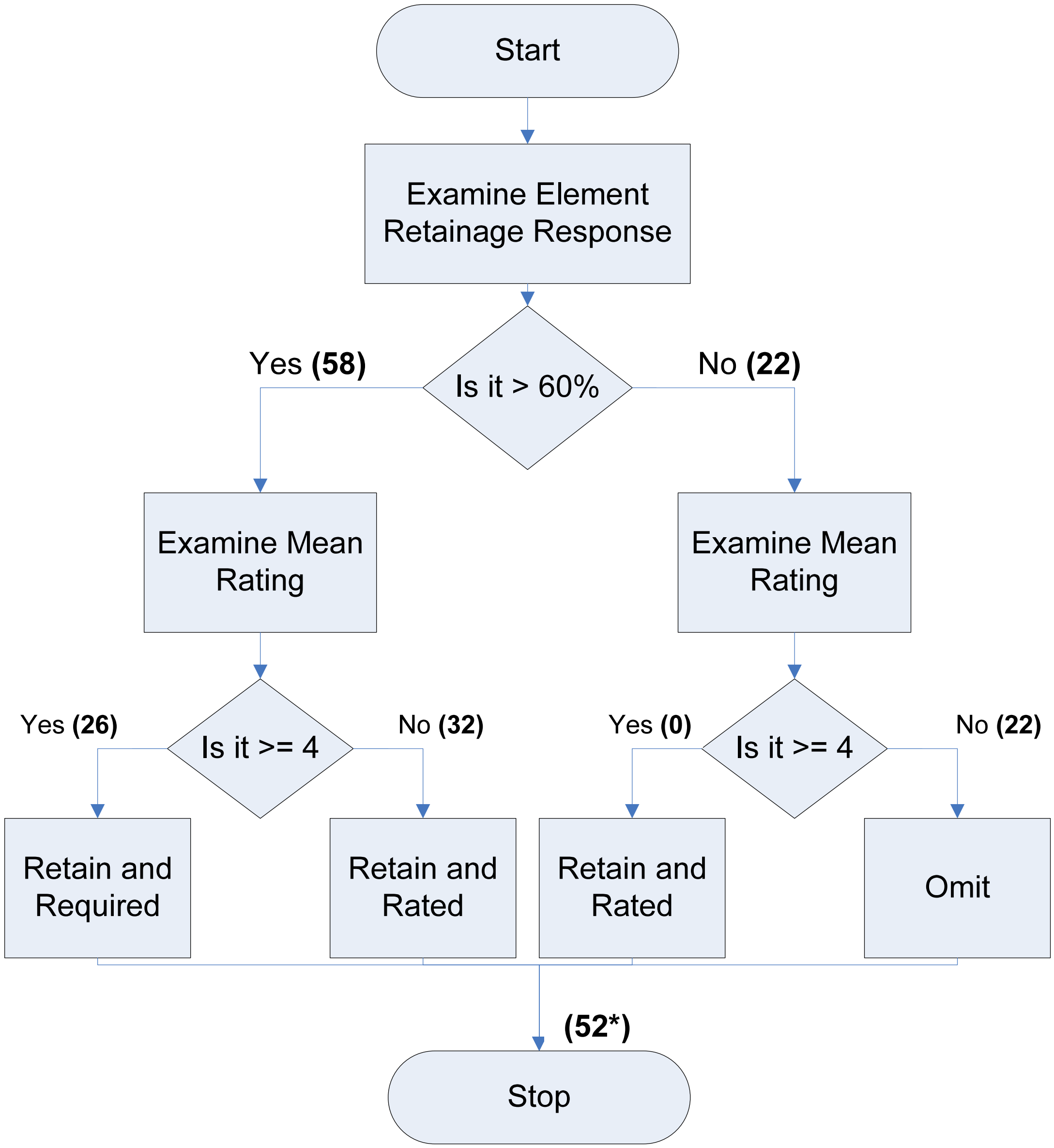
Based on the round two results, 58 elements received a level of agreement of 60% or more. Of these 58 elements, 26 elements received a mean rating of 4.0 or more. These 26 elements were labeled "retain and required." The remaining 32 elements received a mean rating of 4.0 or lower and were "retain and rated."

Twenty-two elements did not achieve the required consensus of 60% or more. Examining these 22 elements, it was found that in addition to the low level of agreement, these elements received ratings lower than 4.0. None of the 22 elements received a rating of 4.0 or more. This process left the researchers with 58 elements of which the experts suggested to regroup six elements within already existing elements. For example, “safety in bid documents” was initially a separate element and experts suggested that it be grouped within the “safety in contracts” element. Ultimately there were 52 elements at the end of round 2 to be included in the final round questionnaire. The results of this process are summarized through the decision diagram in Figure 4.4.

To validate the criteria set for the level of agreement at 60% or more, two tests were performed. The distribution of the mean rating among the top 58 elements (level of agreement of 60% or more) was examined and is presented in Table 4.14. The table shows that there was greater agreement among the top elements both in terms of “rating” and “level of agreement.” A simple two sample t-test was conducted on the mean ratings between elements with greater and lesser than 60% level of agreement. It was found that there was a significant difference (p=0) between the two samples. In addition, the mean rating of elements with level of agreement >60% (58 elements) was 3.85, compared to the mean rating for the <60% sample (22 elements) of 2.93. Based on these two tests, the criterion “60%” is further justified. Hence, all of the 22 elements with level of agreement <60% and mean rating <4.0 were dropped from the rating system/final round questionnaire.

Table 4.14: Mean rating in Safety and Health Elements from Round two among Top 58 Elements (Level of Agreement of 60% or more)

Mean Rating	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	Total (cumulative)
No. of elements	0	2	30	26	58
Percent of Total	0%	3.5%	51.7%	44.8%	100%



* Six Elements were regrouped, leaving 52 elements

Figure 4.4: Decision Diagram Used To Retain Safety and Health Elements with High Level of Consensus and Importance (Round Two)

4.5.4.2 Analysis by Category

The 52 elements from round 2 were sorted into 13 safety and health categories. The category "incentive/disincentive programs" was removed at the end of the second round as all of the individual elements from within this category were removed at the end of round 2. Table 4.15 shows the thirteen categories and the number of elements under each category at the end of the second round. It was found that the "project safety planning" category was still the category with the most 13 (25.0%) number of elements suggested followed by “training and education” (8) and “industrial hygiene practices” (5). The complete rating system at the end of round two is presented in the Appendix B.8, which was used as a round 3 response form.

Table 4.15: SCSH Rating System’s Fourteen Categories and its Number of Safety and Health Elements (round two)

Category	N	Percent of Total	Mean
Contract safety requirements	3	5.8	3.6
Project team selection	3	5.8	4.4
Project safety representatives and qualifications	4	7.7	4.0
Project team safety commitment	2	3.8	4.3
Safety planning	13	25.0	4.2
Safety training and education	8	15.4	3.8
Safety resources and tools	2	3.8	3.4
Drug and alcohol program	1	1.9	3.5
Accident investigation (AI) and reporting	3	5.8	3.7
Worker involvement	2	3.8	4.2
Safety inspection	2	3.8	3.7
Accountability and safety performance measurement	4	7.7	4.0
Industrial hygiene health practices	5	9.6	3.6
Total	52	100.0	

Some of the experts described the reasons for dropping or downgrading the elements in the rating system. For example, one expert explained that most of the elements presented in the second round were “good”, but not “required.” Another expert stated,

> “I removed an element if, by itself, would have no impact on safety. Also, I removed an element if it was clearly required by law and widely complied with.”

Each of the 13 categories is explained in detail in the following pages.

Contract safety requirements

The number of elements in the “contractual safety requirements” category dropped from 8 to 3. The elements “safety procedures in bid documents” and “GC pre-bid, pre-award, and pre-construction meetings with subcontractors to discuss safety” were grouped with the general safety in contracts element. The experts felt these were subsets of the main "safety in contracts" element. The remaining three elements that were dropped from this category included: contractual authority to designers to stop hazardous work, overtime limitation policy/holiday no work guideline, and designer provides checklist of possible hazards information to GC. In some cases, experts pointed out their reason for dropping certain elements from the rating system.

Sixty-four percent of the experts recommended dropping the element "contractual authority to designers to stop hazardous work." Even among the experts who suggested retaining this element, the mean rating was very low at 2.6. One expert noted that designers are not usually in the best position to observe, understand, and mitigate such hazards. Another expert pointed out that designers generally lack familiarity with health and safety concerns related to contractor processes and equipment, and thus lack the ability to identify many hazardous situations in construction. The expert added that, before being given stop-work authority, designers would need to be trained and assigned responsibility for identifying hazards and stopping work if it is appropriate. In addition, experts pointed out that designers are not a constant presence on-site and do not direct work activities. This view found support from an expert who noted,

> "Contractual authority to designers to stop hazardous work- Not sure designers have the knowledge for this, nor that they would ever exercise it."

In the case of dropping the element "designer provides checklist of possible hazards information to GC", 45% of the experts recommended to retain the element, but the majority suggested the removal of this element. One of the experts noted that:

> "My feeling on this is that designers should be aware of constructability issues enough to incorporate optimal safety into specifications, but it is not their role to highlight possible construction hazards. Most hazardous situations in our environment are created by the selection of who performs the work (knowledge, behavior, supervision) and how it is scheduled (sequencing, manpower, trade stacking, time pressures)--Not design issues."

Project team selection

There was 100% agreement among the experts that the project team (designers, general contactor, and subcontractors) should be selected based on their past safety experience. The experts believed that this process has a significant impact on the safety performance of a project as evident from the 4.2 mean rating for these three elements.

Project safety representatives and qualifications

The element "Certification of safety professionals onsite (CHST, CSP)" was grouped with the other elements in this category, which meant that all of the safety professionals on the site should be certified or licensed. Some experts were not sure of this requirement since they felt that it was not feasible to require all of the subs' safety representatives to be certified.

Project team safety commitment

Two elements from this category, namely "zero injury project goal" and "voluntary participation with local OSHA office", received an approval rating of 36% and 45%, respectively, from the experts. Hence, these elements were dropped from the rating system. One expert believed that "zero injury project goals" only works if there is real meaning behind it and it's usually too easy to be just rhetoric.

Safety planning

This category contained the most number of elements in both rounds. The experts recommended dropping three elements and regrouping one element in this category during the second round. The element "targeted injury reduction plan" was grouped with the general contractor safety plan element. One expert explained that targeted injury reduction plans (falls, electrocution, struck-bys, caught in betweens) may leave other important things like MSDS's out. The expert recommended periodically focusing on these specific issues but preferred to keep this open in the rating system. The elements that were dropped included: use of OSHA specific trade variance would require project manager approval, use of OSHA consultations, and use of fiberglass ladders on all sites. At the end of round 1, there were three OSHA related elements in the rating system.

However, there was common agreement among the experts to remove all of these items in round 2. There was no specific reason suggested by the experts for this trend.

One expert rated all planning and design stage activities highly. This expert suggested only four elements in round 1, which were all related to the design for safety concept. This result perhaps shows the importance of designing for construction safety as discussed in the literature (Gambatese et al. 2005, and Behm 2005). According to this expert,

> "Emphasis should be primarily to include safety at the time of design/planning to remove the hazards *before* the workers arrive at the work site. Behavior-based safety tends to blame the worker for many hazards that management entities should have eliminated in the design and planning stages of the project."

Safety Training and Education

Following safety planning, the category that received the most attention was "training and education." At the end of round 1 there were ten elements in this category which were reduced to eight during round 2. Two elements, namely "owner representative involved in safety training" and "recruitment of well-trained skilled workers (10 year background check for medical conditions and criminal records that might pose hazard)" were dropped from the rating system. These two elements received an 18% agreement; that is 82% of the experts suggested to drop these elements from the rating system. As discussed previously, these elements were ranked 79th and 80th among all 80 elements.

Expressing concerns regarding the element "recruitment of skilled workers", one expert pointed out that:

> "While these efforts may help qualify the work force on the project, they would be extremely cumbersome to manage and also very unfavorable by unions. In my opinion, there is little to gain here for the effort. The reality also is that there will always be some less-qualified workers, workers with criminal pasts, and workers with health problems on your project—You can't weed them all out, so deal with them appropriately: Hit them with skilled supervision."

The experts also feared that this element could be a source for violating the Americans with Disabilities Act (ADA) and worker’s privacy. On involving the owner representative in training, one expert raised the concern of liability issues. The expert noted that due to liability concerns, owner representative involvement with training contracted workers is not likely to be supported by many owners. The expert suggested that selected involvement (that shows support of contractor safety efforts) is more doable and beneficial.

Safety Resources and Tools

This section of the rating system was reduced from seven elements in the first round to two elements in round 2. Most of the elements received a level of agreement of 55%, with a mean rating lower than 3.0. One of the experts stated that most of these elements “seem too trivial for this list.” Some of the elements such as, digital camera to take pictures of hazards, and safety newsletter, were considered to have “no” or very little impact on worker safety. In contrast to this comment, it was puzzling to note that the element “communication devices for isolated work areas” required a level of agreement of 73% and thus retained in the rating system. The element “material safety data sheet” (MSDS) was recommended to be removed from the rating system since it is required by law.

Drug and Alcohol Program

There was 100% agreement among the experts to include this element in the rating system. Even though, this element received full consensus on retainage, the mean rating for this element was 3.0. This lower rating indicates that the experts believed this element has only moderate impact on worker safety.

Accident Investigation

This category had four elements at the end of round one. Experts suggested dropping the element “indirect cost sheets for every incident on project.” The element received a 55% level of agreement coupled with a low mean rating of 2.9 among the experts who suggested retaining this element. Construction companies commonly employ this type of work sheet to educate employees/management on the amount of expense incurred with accidents. Awareness of the related costs creates increased support from management and workers for safety. Another element that received some concerns from the experts was "Superintendent meets CEO/senior management after every accident." Experts recommended that it be more specific as to which superintendent, which management perrsonnel, and what types of accidents. One expert mentioned that:

> "Every accident needs to be defined here. I don't think senior management of any organization will actually follow through in a meaningful way with every incident occurring on site. If "every accident" were to be further defined as "every OSHA recordable injury and/or significant incident of liability concern", I think this would be a practical and effective effort."

It was also felt by the experts that in large companies doing millions of dollars worth of work, it would be impossible to implement this element. Another expert expressed a different concern on this element in that this action is reactive. The expert added that CEO engagement in safety needs to be regular and positive, not just punitive. However this element still received a level of agreement of 64% and was retained in the rating system.

Incentive/Disincentive Programs

One of the surprises of this round was the removal of this category from the rating system. In round 1, ten experts suggested to include this element in the rating system. The experts completely reversed their stance in round 2. The element "project incentive program" received a 55% level of agreement with a mean rating of 2.3. Excerpts from one expert's comments include:

> "I suggested removal of Incentive programs because these are generally not used in an appropriate manner. Rewarding lagging indicators usually drives injury and incident reporting underground. Yet management believes it is successful until a major incident occurs."

Worker Involvement

This category was reduced from six to two elements during round 2. The elements that were retained in the rating system included: Project level worker safety committee and safety leadership teams, and Employees empowered with stop authority for safety concerns and correct them before injury happens. One of the elements removed was "Safety observation (workers look out for each other - Behavior Based Safety)."An expert pointed out that there was insufficient evidence that this works in construction and a potential for distrust among workers outweighs potential benefits.

Safety Inspection

This category had two elements at the end of round 2. Experts agreed on the fact that safety inspections are critical for project safety and should be conducted not only by the safety professional, but should also include: supervisors, foremen, GC safety representative, sub safety representative, owner safety representative, corporate safety professional, and company management at least weekly. "Safety violations reported and discussed between project team (owner, GC, sub) and corrective action taken" was the second element of this category which had an approval rating of 73% among the experts.

Project Safety Accountability and Safety Performance Measurement

This category had four elements that include: Clear project safety authority, responsibility, and accountability; Safety metrics to evaluate safety at project level (leading indicators, lagging indicators, update meetings on safety, safety culture perception surveys); Supervisors evaluated based on safety performance; and Safety performance included in end of project contractor evaluation. All of the four elements received an approval rating of more than the required 60% criteria. The experts reinforced the importance of clear accountability and responsibility by rating that element high at 4.9, the highest received of all 52 elements.

Industrial Hygiene Practices

This section of the rating system concentrated on the health aspects of projects. It had six elements of which one element "Hazard communication program" was recommended to be regrouped with the project safety plan. The experts also mentioned this element is required by law and did not have to be a stand-alone element. The element which received the lowest mean rating (2.8) was "Stretch and flex program for all workers."

One expert suggested that there was no evidence for its effectiveness in injury prevention and worker health.

4.5.5 Delphi Round III Results

4.5.5.1 General Elements Analysis

As stated previously the purpose of this final round survey was to: (1) confirm consensus on the elements and ratings, and (2) gain expert input on the structure for the rating system and method for implementation. The 52 elements from round 2 (placed into 13 different categories) were presented to the experts to confirm consensus on the elements and ratings. The experts were asked to reconsider these remaining elements and rate them on the Likert-scale similar to round 2. The experts were given the mean rating of each element and the level of agreement reached during the second round. The mean, median, range, and the level of agreement were calculated similar to round 2.

Mean Rating

It was found that, of the 52 elements, none of the elements received a mean rating of less than 3.0, which was an improvement compared to round 2 where there were several elements with mean ratings less than 2.0. This is an indication of the fact that all of the elements retained at the end of round 2 do have a significant impact on improving safety. The mean ratings of the elements ranged from 4.8 (received by the element "clear project safety responsibility and accountability") to the lowest mean rating of 3.0 (received by the element "stretch and flex program for all workers"). Twenty five elements received a rating of 4.0 or higher. The distribution of mean ratings for the 52 elements is presented in Table 4.16.

Table 4.16: Mean Rating of Safety and Health Elements from Round Three among All Elements

Mean Rating	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	Total (cumulative)
No. of elements	0	0	27	25	52
Percent of Total	0%	0%	51.9%	48.1%	100%

The range was calculated for all of the 52 elements and summarized in Table 4.17. Comparing elements within a range of 2.0, agreement remained unchanged at 96.15% for all of the elements between round 2 and round 3. However, similar to the second round, agreement tended to be higher among the elements that had a higher mean rating, as illustrated by the fact that the percentage of items with a range of 2.0 or less increased from 96.15% to 100%, when only the top 25 elements were considered as shown in Table 4.18.

Table 4.17: Range in Safety and Health Elements from Round Three among All Elements

Range	0	0.1-1.0	1.1-2.0	2.1-3.0	3.1-.4.0	Total
No. of elements	2	34	14	2	0	52
Percent of Total	3.85%	65.4%	26.9%	3.85%	0%	100%

Table 4.18: Range in Safety and Health Elements from Round Three among Top 25 Elements

Range	0	0.1-1.0	1.1-2.0	2.1-3.0	3.1-.4.0	Total
No. of elements	1	17	7	0	0	25
Percent of Total	4%	68%	28%	0%	0%	100%

The changes in the mean ratings received by the 52 elements between round 2 and round 3 were compared to the changes between round 1 and round 3. Between round 2 and round 3, the mean ratings of 11 elements increased, 38 received a lower rating, and three elements remained unchanged. From round 1 to round 3, 19 elements experienced an increase in their mean rating, 32 received a lower rating, and one element’s mean rating remained unchanged. This shows that the experts changed their opinion between rounds, especially lowering their ratings from previous rounds. Even though the experts varied their ratings between rounds, the magnitudes of the changes were not significant. Oertel (2001) used the average standard deviation as a measure for testing the convergence between rounds. In the present study, the average standard deviation changed from 0.60 in round 2 to 0.34 in the third round. This change is a strong indication of convergence of expert opinion between the two rounds.

Level of agreement

The next analysis focused on the level of agreement for the elements in round 3. It was found that 30 out of the 52 elements had a level of agreement of more than 90%. The amount of change between round 2 and round 3 for the 52 elements was also examined. It was found that two elements, "Communication devices for isolated work areas" and "Superintendent meet CEO/senior management after every lost time or recordable accident", shifted below the 60% level of agreement to 55% consensus.

To test convergence among the experts in terms of level of agreement, the median consensus ratings for the 52 elements from both rounds 2 and 3 were calculated. The median approval rating among the 52 elements was 91% in the third round compared to 82% in the second round. This is an indication of a convergence of opinion between the two rounds. Twenty-nine (56%) elements received the same or an increased level of consensus as compared to round 2, with only 23 elements (44%) experiencing a slight decline in the level of consensus but still within the 60% criteria (except for two elements). The change in the level of agreement percentages between round 2 and round 3 is presented in Table 4.19. An increase in the level of agreement of 80% or more from 67.3% to 80.7% could also be considered as additional evidence of convergence of opinion.

Table 4.19: Comparison of Level of Agreement Percentages for the 52 Elements between Two Round 2 and Round 3

Round	100% Agreement	90%-99% Agreement	80%-89% Agreement	Total (cumulative)
Round 2	13	10	12	35 (67.3%)
Round 3	13	17	12	42(80.7%)

In order to retain or drop elements from the final SCSH rating system, the decision diagram was used as shown in Figure 4.5. Based on the round three results, 50 elements received a level of agreement 60% or more. Of these 50 elements, 25 (50%) received a mean rating of 4.0 or more. These 25 elements were labeled as "retain and required." The remaining 25 elements received a mean rating of 4.0 or lower and were "retained and rated." Two elements did not achieve the required consensus of 60% or more. When examining these two elements, it was found that in addition to the low level of agreement, these elements received ratings lower than 4.0. These two elements were therefore dropped from the final SCSH rating system.This process resulted in a SCSH rating system with 50 elements. The structure and other details of the rating system will be discussed in the following section.

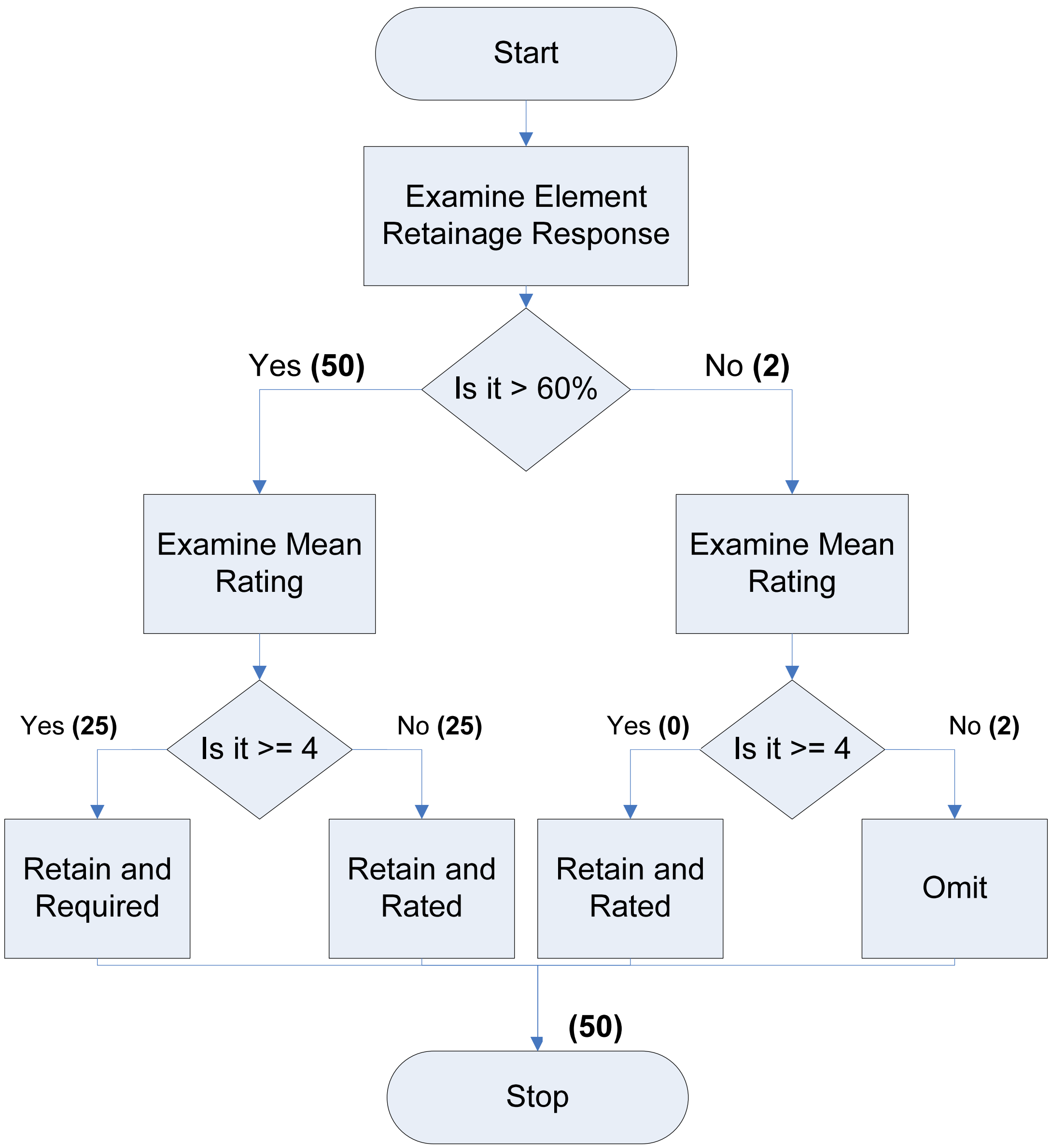


Figure 4.5: Decision Diagram Used To Retain Safety and Health Elements with High Level of Consensus and Importance (Round Three)

4.5.5.2 Analysis by Category

Only two elements, “Communication devices for isolated work areas” and “Superintendent meet CEO/senior management after every lost time or recordable accident”, shifted below the 60% level of agreement to 55% consensus. None of the other categories or elements experienced any change during this round. Hence, a detailed discussion on all categories is not warranted. Some of the general “comments” provided by the experts on the improvement of certain elements are presented below:

- *Safety Representatives (owner, GC and Sub):* The experts pointed out that these elements are project size dependent. They noted that the elements deserve to be in the rating system and their ratings are in the right range, but the elements are probably unreasonable for projects below a certain size. Also, the experts felt that it may not always be practical to expect subcontractors to have “certified” safety representatives working on-site. One expert recommended substituting the word “qualified” to add more scalability as to what is appropriate for knowledge, skills, and abilities related to the type of work performed.
- *Competent person for all high hazard tasks:* One of the experts had a very good suggestion regarding the element about competent person:

> “I routinely see work that requires an OSHA-defined “competent person” (scaffolding, excavation, fall protection, confined space, etc.), yet on-site contractors often fail to identify who this person is to the GC, and even their own workers. I believe it is commonly assumed that a foreman is automatically competent person as needed, and it may even change site-to-site for them. When this happens, the full responsibilities outlined under code are not fulfilled, especially since contractor management often fails to clearly communicate the responsibilities and expectations to the competent person(s). I have been in numerous incident reviews where the competent person becomes lined out like this AFTER a loss. It would be good to see the criteria expanded to include the responsibility to clearly identify any and all competent persons and their responsibilities, including conducting and documenting required inspections (one of the biggest oversights in my opinion).”

- *Toolbox meetings:* Experts felt that these meetings do not require the involvement of the owner or the general contractor.

- *Traffic control plan:* Traffic control planning should include provisions for TCS (Traffic Control Supervisor) duties, trained flaggers, and availability of ample traffic control devices.
- *Housekeeping plan:* In project planning for housekeeping, special attention should be paid to budgeting funds and bidding based on responsible individual(s) and contractors.
- *Safety inspections:* It would be helpful for this element to include "documentation" along with the inspections, including inspections of competent persons.
- *Stretch and flex:* An expert commented that he had left the element in the rating system, but the lack of evidence of effectiveness of these programs bothers him and so he lowered its rating.
- *Rating system implementation:* The researchers were advised to consider how the credits are audited in the rating system. Considerations such as how the credits are audited, when, and how often should be addressed. For example, elements such as traffic plan, housekeeping plan, and PPE plan are great risk reduction activities. However, to remain consistent throughout a project, they would have to be audited frequently, perhaps weekly. Secondly, who audits this and how is it consistent from project-to-project should be another area to consider. The expert felt that the onus should be on the owner or GC perhaps to document that this is happening. Would they be objective in their documentation? For example, in the case of the element "engineering controls", does this mean the project needs to utilize engineering controls or just consider them? These are some things that the experts recommend the researchers to consider during the final rating system development.

4.5.6 SCSH Rating system Structure and Methodology

The final round of the Delphi also obtained the experts' opinion on three different issues:

- What is the expert's opinion of the proposed rating system structure?
- How feasible would it be to incorporate such a rating system on a project?

- What is their opinion of the proposed assessment methodologies (see Appendix B.10) and how feasible would it be to incorporate each method in practice?

A total of eleven surveys were sent in round 3 and only eight experts (73%) returned responses to these questions. Provided below are summaries of the responses to each question. The actual responses to the questions from each person surveyed are provided in the Appendix B.11.

4.5.6.1 Question #1: What is your opinion of the proposed rating system structure?

This question solicited the expert's opinion on the concept and structure of the rating system that was categorized based on safety and health processes. A summary of the responses received is presented through different categories in this section.

Rating system concept

All of the respondents stated that the concept of having a rating system for construction safety was a good initiative and will hold promise as a foundation for introducing elementary-to-intermediate level safety performance on construction projects. The experts, however, warned that simply structuring a project using the 50 elements and assuming that it would *guarantee* safety would be unwise. According to one of the experts, without a clear move to safety as an organizational value, the rating system can at best yield very good results, but rarely "sustainable" or world-class results. The experts also feared that the rating system might make the safety management process too mechanical and might miss important qualitative evaluation. The major limitation of the rating system concept as pointed out by one expert, was that a project could get a good score but fail on one item or even one time on one item and result in a terrible safety record on the project. In other words, a project that gets a platinum score could have a bad safety record.

Basic structure (Category)

The rating system structure was acknowledged to be simple and straight forward, similar to U.S. Green Building Council's LEED rating system which has penetrated the construction industry. The experts felt that the rating system's structure was well-organized to predict a project's safety potential in an efficient manner. The experts also discussed which of the four major project parties (owners, designers, general contractors, and subcontractors) should be given more consideration in the rating system. One expert felt that GC management commitment to a zero-injury culture was the major factor in safe projects. The expert added that with all other elements the same, a GC with a passion for the safety culture will have a far safer work site than one that gives only "lip service" to safety. If the rating system was to be integrated with the LEED rating system, the rating system should be focused on the owner and the designer (but to a lesser extent) since these two typically drive "green" projects with the constructor(s) implementing the rating system. The rating system's scoring process was questioned by one of the experts. The expert mentioned that some of the items are rated in pre-planning, some during design, and some during the construction process. The overall safety outcome of the project is pretty well determined prior to the ability to evaluate some of the items on the list. If the project is evaluated after completion, the rating system will not have any effect on the safety outcome.

Safety and Health Elements

The number of elements in the rating system was discussed by one of the experts who noted that the number of elements should vary depending on whether the rating system will be integrated into the LEED rating system or as a stand-alone rating system. For the former case, the expert feels that 52 elements is far too many, and recommends five to eight, perhaps with one or two mandatory, as this thought process is similar to the USGBC credit system. If this is a stand-alone rating system, the 52 elements were felt to be optimal. One expert addressed the specificity of the elements. According to his opinion, the elements are a little light on specific safety issues except for the last section that specifies certain health areas (noise, respiratory, and musculoskeletal). However, the expert did not recommend changing the elements as any good safety program is going to address falls, electrical hazards, trenching, and the other major safety concerns in construction. The expert did suggest thinking about audience acceptance of the rating system.

The rating system was acknowledged to incorporate a good range of safety and health practices and that it will reward organizations for integration of safety into other project activities. One expert commented that the range of elements is wide and deep so it will likely show variation even within particular construction sectors. The expert suggested testing the rating system against reality both in seeing how far from the ideal the typical project is and in assessing how closely the rating system includes the real elements that relate to safety performance.

Rating system scoring levels (silver, gold, etc.)

The rating system's criterion to rate projects on different levels was questioned by one of the experts. The expert argues that there should be no scalable recognition (i.e. platinum, gold, etc.) for safety. According to the expert, either a project should meet the intent of the rating system much like the International Standards Organization (ISO) certification rather than LEED certification. If it is established as a scalable recognition, the expert wanted to see the bar set very high even for meeting the minimum level.

4.5.6.2 Question #2: How feasible would it be to incorporate such a rating system on a project?

This question solicited the expert's comments on the feasibility of incorporating this rating system in a project. Few experts suggested that the success of the rating system will depend on closely following LEED or other certification rating systems in existence. Experts did add that the rating system will diffuse slower compared to the LEED rating system. The credit allocation/calculation for the different elements was the major issue raised during the response. One expert pointed out that the development of the credit allocation will need careful attention since it involves some subjective evaluation (difficult to measure). The expert recommended showing examples that will help clarify to the rating system users the expected deliverables (documentation) to owners, designers, GCs, and subs for eligible credit. One expert identified a potential problem with consistency if scores from different auditors involved in rating different projects are compared. The expert suggested having only a few auditors to yield better results.

The experts felt that the availability of the rating system can potentially help in a number of ways. One expert suggested different ways to promote the rating system. The expert mentioned that it will be most effective and feasible if owners push it for their projects. It will resonate most with owners who have already thought about many of these issues and acted on some. In addition, groups like the American Society of Safety Engineers (ASSE) and OSHA agencies can point to it as another inventory of elements by which a company can benchmark itself, and one that some serious thought has gone into. The parallel to the LEED criteria will make it recognizable to both the construction and design communities. This was recommended as the smartest strategy for promotion, and the stronger the link the more feasible it will be to get a larger segment of the industry to pay attention to it.

4.5.6.3 Question #3: What is your opinion of the proposed methodologies and how feasible would it be to incorporate each method in practice?

In order to calculate the credits for each of the elements identified by the experts, three methodologies were proposed, namely method 1A, 1B, and 2, as shown in Appendix B.11. Experts were asked to share their opinion on the three different methodologies and identify the merits and demerits of each.

One expert summarized the effectiveness of the three methods as,

#1A – too simplistic

#1B – most feasible if a criterion for each sub item is objectively stated

#2 – too subjective

The experts pointed out that all of the methodologies looked like a good way to assess the relative maturity of a project at inception, and were a good leading indicator for what might be expected throughout the project. However, one expert stated that the rating system needs an underlying philosophy and organizational support; otherwise the rating system is simply a set of rules and scores without context.

Method 1A

Method 1A was cited as too simplistic and allows too much judgment on the auditor's part. Another expert stated that method 1A was the most feasible and least time-consuming in practice but quickly added it was the least satisfactory in terms of how meaningful the score would be. The expert recommended that there must be a means of assessing the elements beyond "exists" or "does not exist" in order for the rating system to have significant meaning. In the present rating system, virtually all of the elements could exist on paper without having much substance in reality. For example, the element engineering controls for health hazards could be put in a written safety plan as a goal, but in reality whenever such controls are considered they are dismissed as too costly. On the other hand the contractor could evaluate the feasibility of ventilation controls versus PPE for dust hazards and implement depending on cost, location, etc. The latter would reflect a good faith effort on engineering controls and should be rewarded with three out of four credits, while the former should get one out of four credits at the most. Under method 1A, both would probably get full credit. Hence, method 1A was not feasible for most of the elements.

Method 1B

Three experts suggested method 1B be used for the rating system's credit allocation calculations. This method is more specific in detail and will yield a more uniform and meaningful rating. The method provides an opportunity to incorporate various aspects into one criterion.

Method 2

Four experts suggested the use of methodology 2 for the rating system. The primary reason was that most of the activities in the rating system are rarely absolute, yet the rating system has the limitation of being subjective. One expert did acknowledge the fact that it may not be possible to totally get away from subjective evaluation, but the more objective the criteria for each element the better. One expert noted that the Likert scale evaluation was appropriate, but that the questions were much too vague. The expert described that people do not like vague questions unless specific questions would require work on their part to answer like in method 1B. One expert mentioned that he liked the language in method 2 which gives the assessor guidance in how to grade the element. The expert wanted to have this guidance provided for all of the elements. After evaluating the merits and demerits of the three methods, one expert suggested the use of both 1B and 2 depending on the nature of the element. Those that lend themselves to multiple sub-elements could legitimately be scored on the basis of 1B. Those for which it is harder to identify discrete sub-elements are better graded on a scale as in method 2.

The final recommendation came in the form of putting some up-front research into this question to see if you get significantly different scores using the method 1A versus the scale (method 2) or sub-elements (method 1B). If the results were not very different, the expert felt it provided an argument for using the simpler system (method 1A).

Summary

Based on the experts' opinions and authors' review, the credit calculation for the 50 elements was designed to include a combination of four types of calculation processes. There seems to be a consensus among the experts on the structure of the SCSH rating system based on the different safety and health categories. Hence, taking into consideration all of the expert review and authors' judgments and knowledge, the SCSH rating system was finalized and is presented in the next section.

4.6 Sustainable Construction Safety and Health Rating System

A Sustainable Construction Safety and Health rating system was developed with the help of a Delphi survey of twelve experts as discussed in the previous sections of this manuscript. The SCSH rating system consists of safety and health elements to be implemented by owners, designers, contractors, and subcontractors to sustain worker safety and health from project-to-project. The rating system will provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of those safety and health elements. The rating system is aimed at certifying all project types. The SCSH rating system is presented in Table 4.20 which shows the 50 safety and health elements and their corresponding credits. It should be noted that the mean ratings received during round 3 added up to a total of 198.2 credits. This high number is due to the fact that the ratings were on a scale of 1 to 5. For the purposes of implementation in practice, the authors decided to normalize the rating system to a total of 100 credits.

The SCSH rating system was organized into 13 safety and health categories. Each category contains sustainable safety and health elements which carry credits based on their effectiveness in preventing construction worker injuries/illnesses. In order to get certified, a project must fulfill all of the 25 required elements to some degree that add up to 54.5 credits. A project that incorporates more elements would receive more credits. The premise of the rating system is that a higher number of total credits received by a project would indicate a lower potential for incidents that lead to construction worker injuries, illnesses, and fatalities. The rating system has four levels of certification that include: certified, silver, gold, and platinum, to differentiate increasing efforts of safety by a project team. The credit range for different levels of certification is: Certified 54 - 60 credits; Silver 61 - 75 credits; Gold 76-90 credits, and Platinum 91 - 100.0 credits. The credit range was chosen arbitrarily and did not involve any scientific methodologies.

A detailed SCSH rating system guide was prepared to assist industry practitioners to use the rating system. The guide contains one page for each of the elements. Each element page consists of three sections: Purpose, Requirements, and Submittals. The intent of the element is described briefly under the Purpose section. The Requirements section provides information on the necessary activities to be fulfilled as part of the element. The Submittal section lists the documentation required to receive the credit. The calculation tables that are part of each element are simple and self explanatory. Samples of the four different methods used to calculate the credits for the safety and health elements are presented in Tables 4.21 through 4.24. The SCSH rating system guide is presented in Appendix B.12.

Table 4.20: Sustainable Construction Safety and Health (SCSH) Rating System
(R = Required, E = Elective)

Project Team Selection			6.6 Possible Credits
R	Element 1.1	Constructor Selection	2.3
R	Element 1.2	Subcontractor Selection	2.3
E	Element 1.3	Designer Selection	2.0
Safety and Health in Contracts			5.5 Possible Credits
R	Element 2.1	Safety and Health in Contracts	2.2
E	Element 2.2	Safety Hazard Symbols in Construction Drawings	1.6
E	Element 2.3	Specification of Less Hazardous Materials	1.7
Safety and Health Professionals			8.1 Possible Credits
R	Element 3.1	Competent Personnel for All High Hazard Tasks	2.4
E	Element 3.2	Owner Safety Representative	1.8
E	Element 3.3	Constructor Safety Representative	2.0
E	Element 3.4	Subcontractor Safety Representative	1.9
Safety Commitment			4.3 Possible Credits
R	Element 4.1	Management Commitment to Safety and Health	2.3
R	Element 4.2	Owner/Representative Commitment to Safety and Health	2.0
Safety Planning			27.8 Possible Credits
R	Element 5.1	Safety and Health During Conceptual Planning Phase	2.3
R	Element 5.2	Constructability Review	2.3
R	Element 5.3	Designing for Worker Safety and Health	2.2
R	Element 5.4	Life Cycle Safety Design Review (LCS)	2.0
R	Element 5.5	Safety Checklist for Designers	2.1
R	Element 5.6	Constructor Site Specific Safety Plan	2.0
R	Element 5.7	Subcontractor Site Specific Safety Plan	2.1
R	Element 5.8	Job Hazard Analysis	2.3
R	Element 5.9	Pre-task Planning	2.3
R	Element 5.10	Look Ahead Schedule	2.1
R	Element 5.11	On and Off site Traffic Plan	2.1
R	Element 5.12	Good housekeeping Plan	2.2
E	Element 5.13	Personnel Protection Equipment (PPE) Plan	1.8
Training and Education			15.3 Possible Credits
R	Element 6.1	Safety Training for Designers	2.0
R	Element 6.2	Safety Orientation for All Workers	2.0
E	Element 6.3	Safety Training for All Field Supervisors (OSHA 30 hour)	2.0
E	Element 6.4	OSHA 10-hour Training for All Workers	1.8
E	Element 6.5	Assessment of All Equipment Operators Skills and Training	1.8
E	Element 6.6	Toolbox Meetings	1.8

Table 4.20: Sustainable Construction Safety and Health (SCSH) Rating System, (Continued) (R = Required, E = Elective)

E	Element 6.7	Regular Safety Training for All Project Personnel	2.0
E	Element 6.8	Constructor Mentors Subs to Improve Safety Performance	1.9
Safety Resources			1.8 Possible Credits
E	Element 7.1	Task-based Hazard Exposure Database	1.8
Drug and Alcohol Program			1.8 Possible Credits
E	Element 8.1	Drug and Alcohol Testing Program	1.8
Accident Investigation and Reporting			3.7 Possible Credits
R	Element 9.1	Accident and Near Miss Investigation	2.0
E	Element 9.2	Accident and Near Miss Investigation with Pre-task/JHA	1.7
Employee Involvement			4.2 Possible Credits
R	Element 10.1	Employees Empowered with Stop Authority	2.3
E	Element 10.2	Employee Safety Committee and Leadership Team	1.9
Safety Inspection			3.8 Possible Credits
E	Element 11.1	Safety Inspections	2.0
E	Element 11.2	Safety Violations identified and corrected	1.8
Safety Accountability and Performance Measurement			8.0 Possible Credits
R	Element 12.1	Project Accountability and Responsibility	2.4
R	Element 12.2	Supervisors Evaluated Based on Safety Performance	2.2
E	Element 12.3	Safety Performance Evaluation using Safety Metrics	1.9
E	Element 12.4	Contractor Evaluation Based on Safety Performance	1.5
Industrial Hygiene Practices			9.1 Possible Credits
R	Element 13.1	Engineering Controls for Health Hazards	2.1
E	Element 13.2	Hearing Protection Program	1.6
E	Element 13.3	Respiratory Protection Program	1.9
E	Element 13.4	Stretch and Flex Program	1.5
E	Element 13.5	Ergonomic Task Analysis and Remediation	2.0
Project Total			100 Possible Credits

Certified 54 - 60 credits; **Silver** 61 - 75 credits; **Gold** 76-90 credits; **Platinum** 91 - 100.0 credits
All required elements to be fulfilled for all levels of certification

Table 4.21: Sustainable Construction Safety and Health (SCSH) Rating System Credit Allocation Methodology # 1

1.0 Project Team Selection

Element 1.1: Constructor Selection
Possible Credits: 2.3
Type: Required

Purpose

Employ a constructor with a good safety record.

Requirements

The owner should select a constructor based in part on past safety performance. Criteria used for selection should include the following: Experience Modification Rating (EMR); incident rates (OSHA recordable rate and lost time rate); claims rate; number of OSHA citations in the past 3 years; personal interview/personal knowledge of the constructor's safety performance; and review of the constructor's safety program.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner and the constructor.

Criteria used in constructor selection:		**Points (Yes = 1; No = 0)**
EMR	☐ Yes ☐ No	
Incident rates	☐ Yes ☐ No	
OSHA citations	☐ Yes ☐ No	
Personal interviews/knowledge	☐ Yes ☐ No	
Safety programs review	☐ Yes ☐ No	
Claims rate	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	6
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

Table 4.22: Sustainable Construction Safety and Health (SCSH) Rating System Credit Allocation Methodology # 2

2.0 Safety and Health in Contracts

Element 2.2: Safety and Health Hazard Identification in Drawings
Possible Credits: 1.6
Type: Required

Purpose

Include identification of construction hazards in the construction documents.

Requirements

The designers should identify potential safety and health hazards associated with the work by including hazard symbols or other features in the construction drawings.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, subcontractor, and designer.

Criteria	Rating
Were safety and health hazards identified in the construction drawings? If yes, how detailed was the process, rated on a scale from 1 to 5? If this criteria was not considered, "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

Table 4.23: Sustainable Construction Safety and Health (SCSH) Rating System Credit Allocation Methodology # 3

3.0 Safety and Health Professionals

Element 3.2: Owner Safety Representative
Possible Credits: 1.8
Type: Elective

Purpose

Owner ensures construction site safety efforts by appointing an owner safety representative.

Requirements

The owner should assign a full-time or part-time safety professional on-site depending on the project size.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner and constructor.

Criteria		Points (Yes = 1; No = 0)
Did the project have an owner safety professional?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

Table 4.24: Sustainable Construction Safety and Health (SCSH) Rating System Credit Allocation Methodology # 4

6.0 Training and Education

Element 6.2: Safety Orientation for All Workers
Possible Credits: 2.0
Type: Required

Purpose

Orient workers to the site and to working in a safe manner.

Requirements

All of the workers on the project should go through on-site safety orientation before starting work on the project. The orientation should be site specific.

Submittals

The calculation sheet provided below should be submitted with signatures from the constructor and subcontractors. Documentation showing that all the workers received safety orientation should also be submitted.

Criteria	Number
Total number of workers on the project	
Number of workers receiving safety orientation	

% of criteria fulfilled = Number of workers who received safety orientation /Number of workers =
Credit received = Possible credits * % of criteria fulfilled =

4.6 Conclusions and Recommendations

In this manuscript, the development of a sustainable construction safety and health rating system was described. The SCSH rating system was developed with the help of a Delphi survey among construction safety and health experts from industry and academia. The following conclusions can be drawn from the present study.

Based on the extensive literature review there exists a wealth of information on the individual roles of project owners, general contractors, designers, and subcontractors to improve project safety performance. Literature did not reveal any research that has investigated the impact on project safety when all of these parties are involved. The literature review did not reveal many studies on a rating system that could be used to rate projects based on worker safety and health activities. No findings from previous research on the application of sustainability concepts to construction worker safety and health were found. Hence, this research will provide new knowledge in this area through the development of the SCSH rating system.

A key aspect of the research is the application of the sustainability concept to construction worker safety and health. This concept, defined as sustainable construction safety and health, can be implemented in the industry with the help of the SCSH rating system.

One significant finding of the research is the elements included as part of the SCSH rating system and their relative importance expressed as ratings. The elements were extracted based on the literature review and Delphi survey of experts. Some of the findings from the rating system include:

- Based on the expert's validation, the concept of having a rating system to rate projects based on safety and health would improve safety and health performance. It would also provide a completely different perspective on the industry's efforts to improve safety.

- In order to have sustainable construction safety and health performance in the industry, a total of 50 elements should be implemented through the combined efforts of the project team.
- The rating system indicates that the most important elements (top 3) are: (1) clear project safety authority, responsibility, and accountability; (2) employee empowerment to STOP work authority; and (3) contractor selection based on safety. The least important elements (last 3) are: (1) task-based hazard database; (2) hearing conservation program; and (3) stretch and flex programs for all workers.
- It can be concluded from the study that project incentive programs are not considered integral to good safety performance as they lead to more underreporting and do not necessarily prevent injuries/illnesses.
- Rather than placing the responsibility for safety solely on of the constructor, this study found that all parties should be involved in project safety efforts to have sustainable safety results. It was found that “design for safety” is identified as an activity that can have a significant impact on safety performance. Design for safety was one of the highly rated elements, and in order to get a project certified under the rating system, project teams must consider safety during the conceptual and design stages of the project.
- Industry professionals have started to recognize the importance of ergonomic task analysis in preventing soft tissue injuries.
- When categorized into 13 different categories the “safety planning” category has the largest number of elements in it.

The findings of this study have a number of important applications in the industry. The sustainable safety and health rating system will incorporate the safety and health elements to be implemented to sustain worker safety and health from project-to-project. The rating system can be used as a tool to help sustain the safety and health of construction workers. Recognition for using the rating system will be an added incentive to the project team to improve the safety and health performance of the project. Since the rating system would require the joint efforts of all of the parties involved in a project, a team effort would be another benefit that will help set in motion the sustainable safety and health drive throughout the construction industry.

4.7 References

Abudayyeh, O., Fredericks, T.K., Palmquist, M., and Torres, H.N. (2003). "Analysis of Occupational Injuries and Fatalities in Electrical Contracting Industry." *Journal of Construction Engineering Management*, 129(2), 152-158.

Adler, M., and Ziglio, E. (1996). *Gazing into the Oracle: The Delphi Method and its Application to Social Policy and Public Health.* London: Jessica Kingsley Publishers.

Behm, M. (2005). "Linking Construction Fatalities to the Design for Construction Safety Concept." *Safety Science* 43 (2005) 589-611.

CII (1986). *Constructability: a primer*. Construction Industry Institute (CII), Austin, TX, Publication 3-1.

Coble, R. J., and Haupt, T. C. (2000). "Potential Contribution of Construction Foremen in Designing for Safety." Paper presented at the *Designing for Safety and Health Conference*, sponsored by C.I.B. Working Commission W99 and the European Construction Institute (ECI), London.

Dalkey, N. C. (1972). *The Delphi method: an experimental application of group opinion.* In N. C. Dalkey, D. L. Rourke, R. Lewis, & D. Snyder (Eds.) *Studies in the quality of life*. Lexington, MA: Lexington Books.

Dalkey, N.C., and Helmer, O. (1963). "An experimental application of the Delphi method to the use of experts." Management Science 9, pp 458-467.

Delbecq, A.L., Gustafson, D.H., Van de Ven, A.H. (1975). *Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes*, Scott, Foresman and Company, Glenview, IL.

Engineering News Record (ENR) (2004). "Design-Builder Builds Safety into Total Jobsite Approach." 252(26), 17.

European Foundation (1991). *From drawing board to building site*. European Foundation for the Improvement of Living and Working Conditions, Publication No. EF/88/17/FR. HMSO, London.

Everett, J.G., & Frank, P.B. (1996). "Costs of accidents and injuries to the construction industry". *Journal of Construction Engineering and Management*, 122(2), 158-164.

Findley, M., Smith, S.M., Kress, T., Petty, G., and Enoch, K. (2004). "Safety Program Elements in Construction." *Professional Safety, Journal of the American Society of Safety Engineers (ASSE)*, 49(2), 14-21.

Fowles, J., (1978). *Handbook of futures research*. Greenwood Press: Connecticut.

Fredericks, T.K., Abudayyeh, O., Choi, S.D., Wiersma, M., and Charles, M. (2005). "Occupational Injuries and Fatalities in the Roofing Contracting Industry." *Journal of Construction Engineering Management,* 131(11), 1233-1240.

Fredericks, T.K., Abudayyeh, O., Palmquist, M., and Torres, H.N. (2002). "Mechanical Contracting Safety Issues." *Journal of Construction Engineering Management,* 128 (2), 186-193

Gambatese, J. (2000). "Owner involvement in construction site safety." *Proceedings of Construction Congress VI,* ASCE, Orlando, Florida, 661-669.

Gambatese, J. (2000a). "Safety Constructability: Designer Involvement in Construction Site Safety." *Proceedings of Construction Congress VI,* ASCE, Orlando, Florida, 650-660.

Gambatese, J., Behm, M., and Hinze, J. (2005). "Viability of Designing for Construction Worker Safety". *Journal of Construction Engineering and Management*. 131(9), 1029-1036.

Gambatese, J.A., Behm, M., and Rajendran, S. (2006). "Additional Evidence of Design's Influence on Construction Fatalities." *CIB W99 International Conference Proceedings*, Global Unity for Safety & Health in Construction, Beijing, China, June 28-30, 2006.

Gibb, A., Haslam, R., Hide, S., and Gyi, D. (2004). "The role of design in accident causality." *Designing for safety and health in construction,* S. Hecker, J. Gambatese, and M. Weinstein, eds., UO Press, Eugene, Ore., 11–21.

Greatorex, J. and Dexter, T. (2000). "An accessible analytical approach for investigating what happens between the rounds of a Delphi study." *Journal of Advanced Nursing,* 32(4), 1016-1024.

Gupta, U.G., Clarke, R.E. (1996), "Theory and applications of the Delphi technique: a bibliography (1975-1994)." *Technological Forecasting & Social Change,* 53(2), 185-211.

Hasson, F., Keeney, S. and McKenna, H. (2000). "Research guidelines for the Delphi survey technique." *Journal of Advanced Nursing,* 32(4) 1008-1015.

Hecker, S., Gambatese, J., and Weinstein, M. (2005). "Designing for Worker Safety: Moving the Construction Safety Process Upstream." *Professional Safety*, Journal of the American Society of Safety Engineers (ASSE), 50(9), 32-44.

Hecker, S., Gibbons, B., and Barsotti, A. (2001). "Making Ergonomic changes in construction: Working training and task interventions." *Applied Ergonomics*, D. Alexander and R. Rabourn, eds., Taylor and Francis, London, 162-189.

Helmer, O. (1983). *Looking Forward - A guide to Future Research*. Beverly Hills/London/New Delhi.

Hinze, J and R. Godfrey. (2003). "An evaluation of safety performance measures for construction projects." Special Issue on Construction Health & Safety, *Journal of Construction Research*, 4(1).

Hinze, J. (2003). "*The Owners Role in Construction Safety.*" Construction Industry Institute Research Summary 190-1. The University of Texas at Austin.

Hinze, J. (1978). "Turnover, new workers, and safety." *Journal of construction division*, ASCE, 104(4), 409-417

Hinze, J. (1997). *Construction Safety*. Prentice Hall, Upper Saddle River, New Jersey.

Hinze, J. (2000). "Designing for the Life Cycle Safety of Facilities." Paper presented at the Designing for Safety and Health Conference, sponsored by C.I.B. Working Commission W99 and the European Construction Institute (ECI), London.

Hinze, J. and Gambatese, J. (1996). "*Addressing Construction Worker Safety in the Project Design.*" Construction Industry Institute Research Report 101-11. The University of Texas at Austin.

Hinze, J. and Gambatese, J. (1996). *Addressing Construction Worker Safety in the Project Design.* Construction Industry Institute Research Report 101-11. The University of Texas at Austin.

Hinze, J. and Pannullo, J. (1978). "Safety: function of job control." *Journal of construction division,* ASCE, 104(2), 241-249

Hinze, J. and Parker, H.W. (1978). "Safety Productivity and Job Pressures." *Journal of construction division,* ASCE, 104(1), 27-35

Hinze, J., and Figone, L. (1988). *'Subcontractor safety as influenced by general contractors on small and medium sized projects.* Source Document 38. The Construction Industry Institute, Austin, TX.

Hinze, J., and Gambatese, J.A. (2003). "Factors that Influence Safety Performances of Specialty Contractors." *Journal of Construction Engineering Management,* 129(2), 159-164

Hinze, J., and Talley, D. (1988). *"Subcontractor safety as influenced by general contractors on large projects."* Source Document 39. The Construction Industry Institute, Austin, TX.

Hinze, J., Mathis, J., Frey, P.D., Wilson, G., DeForge, P., Cobb, M., and Marconnet, G. (2001). "Making Zero Accidents a Reality," Annual Conference of the Construction Industry Institute, San Francisco, CA.

Hinze, J.W., and Wiegand, F. (1992). "Role of Designers in Construction Worker Safety." *Journal of Construction Engineering and Management*, ASCE, 118(4), 677-84.

Huang, J. (2003). *The Owners Role in Construction Safety*. Ph.D. Dissertation, 2003, University of Florida, Gainesville, FL.

Jairath, N. & Weinstein, J. (1994). "The Delphi Methodology (Part 1): A useful administrative approach." *Canadian Journal of Nursing Administration*, 7(3), 29-42.

Jairath, N. & Weinstein, J. (1994). "The Delphi Methodology (Part 2): Administrative applications." *Canadian Journal of Nursing Administration*, 7(4), 7-20.

Jaselskis, E.J., Anderson, S.D., and Russell, J.S. (1996). "Strategies for Achieving Excellence in Construction Safety Performance." *Journal of Construction Engineering and Management*, 122(1), 61-70.

Lang, T. (1998). "An overview of four futures methodologies." <http://www.soc.hamaii.edu/~future/j7/LANG.html> (January 29, 1999).

Levitt, R. E., and Samelson, N. M. (1993). *Construction Safety Management, 2nd edition*. John Wiley & Sons, New York.

Levitt, R.E., and Parker, H.W. (1976). "Reducing construction accidents – top management's role." *Journal of construction division*, ASCE, 102(3), 465-478.

Lindman, B.A. (1994). *Consensus of educational administrators on admission requirements, professional instruction, internship features, and evaluation of candidate competency for alternative routes into teaching licensure: A Delphi survey*. Doctoral dissertation, University of Minnesota, 1994.

Linstone, H., and Turoff, M. (1975). *The Delphi Method: Techniques and Applications.* Addison-Wesley, Reading, MA.

Liska, R.W., and Goodloe, D., and Sen, R. (1993). *Zero Accident Techniques: A Report to the Construction Industry Institute.* Source Document 86, Austin, TX: University of Texas, 1993.

Lorent, P. (1987). *Les conditions de travail dans l'industrie de la construction, productivité, conditions de travail, qualitié concertée et totale.* CNAC, Brussels.

Manuele, F.A. (1997). *On the practice of safety*. John Wiley and Sons, Inc., New York.

Meridian Research (1994). *Worker Protection Programs in Construction: Final Report.* Silvery Spring, MD: Meridian Research, 1994.

Murphy, M. K., Black, N. A., Lamping, D. L., McKee, C. M., Sanderson, C. F. B, Askham, J., & Marteau, T. (1998). "Consensus development methods, and their use in clinical guideline development." *Health Technology Assessment*, 2(3).

National Safety Council. (NSC) (2006). *Injury Facts.* 2005-2006 Edition. Itasca, IL

Ng, S.T., Cheng, K.P., and Skitmore, R.M. (2004). "A framework for evaluating the safety performance of construction contractors." *Building and Environment*, 40 (2005), 1347-1355.

Occupational Safety and Health Administration (OSHA) (2005). <http://www.osha.org> (October 9, 2005).

Oertel, B.J. (2001). *Identifying the Essential Characteristics of Curricular Learning Communities in Higher Education: A Delphi Study*. Doctoral dissertation, University of Minnesota.

Okoli, C. & Pawlowski, S. D. (2004). "The Delphi method as a research tool: an example, design considerations and applications." *Information & Management*, 42, 15-29.

Payne, R.L, Fineman, S., and Wall, T.D. (1976). *"Organizational climate and job satisfaction: A conceptual synthesis Organizational Behavior and Human Performance."* 16, 45-62.

Pill, J. (1971). "The Delphi Method: Substance, Context, a Critique and Annotated Bibliography." *Socio-Economic Planning Science*, Vol. 5, pp 55-71

Powell, C. (2003). "The Delphi technique: myths and realities." *Journal of Advanced Nursing*, 41(4), 376-382.

Reed, J. and Roskell, V. (1997). "Focus groups: issues of analysis and interpretation." *Journal of Advanced Nursing*, 26, 765-771.

Rogers, M.R., and Lopez, E.C. (2002). "Identifying critical cross-cultural school psychology competencies." *Journal of school psychology*, 40(2) 115-141.

Rowe, G., and Wright, G. (1999). "The Delphi technique as a forecasting tool: issues and analysis." *International Journal of Forecasting*, 15, 353-375.

Sackman, H. (1974). Delphi assessment: expert opinion, forecasting, and group process. Santa Monica, Calif.: Rand.

Scheibe, M., Skutsch, M., and Schofer, L. (1975). *Experiments in Delphi methodology*. In Linestone, H., and Turoff, M. (eds) The Delphi Method: Techniques and Application. Addison- Wesley, London

Simmonds, C. (1977). *The Nature of Futures Problems in Futures Research: New Directions*. Linstone, H., and Simmonds, C. (Eds) Addison-Wesley Publishing Company, London

Szymberski, R. (1997). Construction Project Safety Planning. *TAPPI Journal*, 80(11), 69-74.

Tanner, C. K., and Stone, C. D., (1998). "School Improvement Policy: Have Administrative Functions of Principals Changed in Schools Where Site-Based Management is practiced." *Education Policy Analysis Archives*, Vol 6 (6).

Tersine, R., and Riggs, W. (1976) "The Delphi technique: A. Long – range planning Tool." *Business horizons*, 19(2), 51-56.

Toole, T. (2002a). "Construction Site Safety Roles", *Journal of Construction Engineering and Management*, 128(3), 203-210.

Toole, T. M. (2002). "A Comparison of Site Safety Policies Of Construction Industry Trade Groups." *ASCE Practice Periodical in Structural Design and Construction*. 7(2), 90-95.

Towne, Douglas. C. (1967). *Influences Exerted upon Subject Responses by the Response Scale Structural Elements of Attitude Scales*. Doctoral dissertation, Cornell University.

Turoff, M. (1970). "The Design of a Policy Delphi." *Technological Forecasting and Social Change*, 2, 149-171.

Van Zolingen, S.J. and Klaassen, C.A. (2003). "Selection processes in a Delphi study about key qualifications in Senior Secondary Vocational Education." *Technological Forecasting and Social Change*, 70, 317-340.

Veltri, A.T. (1985). *Expected use of Management Principles for Safety Function Management.* Doctoral dissertation, West Virginia University.

Weinstein, M., Gambatese, J., and Hecker, S. "Can Design Improve Construction Safety: Assessing the Impact of a Collaborative Safety in Design Process". *Journal of Construction Engineering and Management*, 131(10), 1125-1134.

Williams, P., and Webb, C. (1994). "The Delphi technique: a methodological discussion." *Journal of Advanced Nursing*, 19, 180–186.

Works Bureau (2000). <http://www.etwb.gov.hk>

Validation of Sustainable Construction Safety and Health Rating System

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5.0 VALIDATION OF SUSTAINABLE CONSTRUCTION SAFETY AND HEALTH RATING SYSTEM

5.1 Abstract

This paper presents the results of a research study conducted to validate a sustainable construction safety and health (SCSH) rating system. The SCSH rating system consists of safety and health elements to be implemented by owners, designers, contractors, and subcontractors to sustain worker safety and health from project-to-project. The rating system will provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of those safety and health elements. For the purpose of this study “validation” was defined as accurately reflecting the safety performance of a project. A questionnaire survey was conducted to gather the information needed for the validation. The scope of the research included construction of all types of facilities.

The project data (25 projects) collected was analyzed to test the presence of any correlation between project safety performance and the total number of credits received by the project, based on the rating system. Based on the analysis it can be concluded that the SCSH rating system reflects the presence of a correlation between the SCSH credits and the TRIR. The negative correlation decreased significantly towards negative one when only projects that had expended more than 200,000 man-hours were considered. It was found that safety checklist for designers, life cycle safety design review, designer selection based on safety experience and knowledge, safety hazard identification in construction documents, designing for worker safety and health, and safety training for designers were the least implemented elements among the 25 projects. Some of the most commonly implemented elements include: top management commitment, site-specific safety plan, accident investigation, safety in contracts, and safety staffing.

5.2 Introduction

5.2.1 Background

Over the past few decades, efforts have been made to improve worker safety and health in the construction industry. Construction companies have developed positive safety cultures and are committed to creating an “injury-free work environment” on all of the projects they perform. However, no comprehensive tool exists to plan and evaluate construction safety and health performance. Similarly, no industry-wide recognition exists for those projects which stand out in their commitment to reduce workplace fatalities and injuries. Such recognition would provide a motivation to constructors to sustain safety and health performance on all projects. This need provided a stimulus for the researchers to develop an innovative construction worker safety and health planning tool, called the Sustainable Construction Safety and Health Rating System that will:

- provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of safety and health elements; and
- unify and coordinate the safety and health efforts of the four primary parties in a project: owner, designer, general contractor, and subcontractors.

Using the Delphi process and a panel of experts from across the U.S., a project rating system was created which is organized into 13 major safety and health categories that contain safety and health elements. Each element carries a number of credits based on the impact which the element has on eliminating jobsite hazards. A project that incorporates more elements, and does a superior job at incorporating the elements, would receive more credits. The rating system is aimed at certifying all project types, consists of a total of 100 credits. In order to get certified, a project must fulfill all of the 25 required elements to some degree that add up to 54.5 credits. A project that incorporates more elements would receive more credits. The premise of the rating system is that a higher number of total credits received by a project would indicate a lower potential for incidents that lead to construction worker injuries, illnesses, and fatalities. The rating system has four levels of certification to differentiate increasing efforts of safety by a project team: certified, silver, gold, and platinum. The credit range for different levels of certification is: Certified 54 - 60 credits; Silver 61 - 75 credits; Gold 76 - 90 credits; and Platinum 91 - 100 credits. The full version of the SCSH rating system is described in Manuscript three of this dissertation and presented in Appendix B.12.

5.2.2 Scope and objectives

The objective of this study is to validate the SCSH rating system by testing the presence of any correlation between the total SCSH credits and the safety performance of real time projects. For the purpose of the study, safety performance was defined in terms of the total OSHA recordable injury rate (TRIR). The study also aimed to identify the feasibility of implementation of some of the elements and recommend improvements to the SCSH rating system. The scope of the research included construction of all types of facilities.

5.2.3 Validation

For the current study, the rating system would be considered valid if the TRIR decreased as the total number of credits increased for the study sample projects. For example, a project with 90 credits would have a lower TRIR than a project with 20 credits. TRIR includes all OSHA recordable incidents, which are defined as those incidents that resulted from an exposure or event in the workplace and that required some type of medical treatment or first-aid. The total OSHA recordable incident rate is the number of recordable incidents per 100 workers per year (200,000 worker-hours). It is calculated for a project by multiplying the number of recordable injuries by 200,000 and then dividing by the number of work hours expended on the project.

5.3 Research Methodology

A quantitative research approach was adopted to validate the SCSH rating system. This involved the development and distribution of a questionnaire as the survey mechanism. The questionnaire was developed with the help of literature and the researchers' knowledge. Two of the primary research studies that were referred to during questionnaire development were by Hinze (2001) and Huang (2003). The study questionnaire consisted of three major sections, requesting information on project demographics, safety performance, and the safety efforts of the individual projects as required by the SCSH rating system.

The project demographics section aimed at gathering information such as the project type (new construction, major remodel or mixed), facility type (education, healthcare, etc.), project cost, size, type of ownership, location, etc. The second section solicited information on the safety performance of the project: total project work hours, number of OSHA recordable and lost time injuries/illnesses on the project, and the number of near misses (if recorded). The third section focused on safety efforts expended by the project team (owner, designer, constructor, and subcontractors) during the project development process. Questions were framed in such a fashion which helped the researchers calculate the total credits scored by the projects based on the SCSH rating system.

Questionnaires were sent to representatives of construction contracting firms and owners/developers located in the U.S. Twenty-five construction firms and five owner/developer firms were contacted as part of the study via personal interviews, email, written correspondence, and telephone calls. The construction firms included in the study consisted of medium- to large-sized companies which constructed all types of projects that include: general buildings, industrial, transportation, etc. Firms selected for the study consisted of two samples. One sample consisted of 10 firms with which the researchers have personal contact and which had expressed an interest in helping out with the research. The second sample consisted of 20 firms that were randomly selected from the Engineering News Record (ENR) Top 400 Contractors list (ENR 2006).

The survey respondents consisted of primarily the construction contracting firm's safety representatives but also included the firm's project managers. Owner representatives also participated as respondents. For some projects it was necessary to interview more than one individual involved in the project to gather the information required for the study. The respondents were asked to compile the survey information for as many projects as possible, limited to projects constructed in the past two years or which were near completion at that time. The respondents were asked to select the project(s) randomly instead of selecting only the projects with good safety performance to avoid bias. The completed questionnaires were returned via email, regular mail, and fax. The responses were followed up with emails or phone calls to clarify any unclear responses. The cover letter and the questionnaire used in the data collection process can be found in Appendix C.1 and C.2.

5.4 Results and Discussion

5.4.1 Survey Response

A total of 23 firms (23 out of 30) responded to the questionnaire survey and/or promised to return the completed survey. Of the firms that responded, twelve provided data from their projects, three questionnaires were not complete, five firm representatives were very busy and not able to fill in the questionnaire, and the other firms were not interested in providing the information due to confidentiality concerns. Several follow-up emails to the respondents were unsuccessful in increasing the response rate. The researchers expected a low response rate because of the lengthy questionnaire and the sensitivity of the requested information. This was evident from the comments from a respondent who noted, “I’d never share this data outside my company, regardless of the intent of the researchers.” Another respondent described that much of the information the researchers requested could be considered “attorney-client privilege” and therefore declined to participate.

The questionnaire requested information that the contracting firm may not be qualified to provide. For instance, out of the three incomplete questionnaires received, two were completed by a contracting firm. The representatives from this firm were not aware of owner and designer related SCSH elements. These projects had different owners and designers who did not respond to the survey when the researchers contacted them. In the case of the third incomplete questionnaire, it was the owner representative who filled in part of the questionnaire, but was not aware of some of the contractor related safety efforts. The survey response rate for the study is 40.0% (12 out of 30), which is reasonable considering the sensitivity of the data being collected.

5.4.2 Survey Results

5.4.2.1 Demographic Information

A total of 25 projects from twelve firms were received and utilized in this validation study. All of these projects were constructed (some in progress) in the last two years. The responding firms requested that the information provided be kept confidential, including their name and the individual project identities. Hence, this paper does not reveal any information about the responding firms or the project names. Instead they were coded with a letter from A to L. The responding firm included five firms whose annual volume of work was over 1 billion dollars. A breakdown of the owner/construction firm based on the number of projects contributed to the study sample is presented in Table 5.1.

Table 5.1: Categorization of Projects based on Responding Firms (n = 25)

Firm ID	No. of Projects	Percent of Study Sample Projects
A	2	8
B	5	20
C	6	24
D	4	16
E	1	4
F	1	4
G	1	4
H	1	4
I	1	4
J	1	4
K	1	4
L	1	4
Total	25	100%

The study sample included projects built in thirteen states geographically dispersed throughout the U.S. The name of the states/territories, followed by the number of study sample projects in parentheses are: Alaska (1), Arizona (1), California (3), District of Columbia (1), Florida (2), Indiana (1), Kentucky (1), Missouri (1), New York (1), Oregon (5), Utah (1), Virginia (1), and Washington (6). The 25 sample projects consisted of twenty-three “New Construction” and two “Mixed New and Remodel” projects. The sample projects consisted of eight facility types that included: high-rise residential and hotel buildings (8), health care facilities (5), industrial (4), higher education university buildings (3), transportation (2), office building (1), parking structure (1), and one animal shelter. This distribution of projects represents a good mix of construction projects. The four industrial projects included a food processing facility, two fabrication plants, and one major waste treatment facility. The two transportation projects included a skyway bridge and a light rail construction project.

Project size is a good indicator of the amount of work performed on a job site. Size can be measured in terms of total construction cost, the number of subcontractors on site, the number of workers on site, or the number of worker hours expended (Huang 2003). Hence, the researchers requested this information from the respondents to get a clear picture of the projects being validated. The cost of the 25 sample projects ranged from 4.9 million to 11.5 billion dollars (mean = $578.9M; median = $89.0M) and the size ranged from 22,000 to 1,200,000 square feet (SF) (mean = 366,000 SF; median = 307,000 SF). Unit cost was calculated for the sample projects by dividing the project cost by the project square footage to normalize the projects based on size. The unit cost of the projects included in this study ranged from 79.4 to 475.6 dollars per square foot (mean = $360/SF; median = $181/SF).

Responding to the question on the number of workers on the jobsite, the respondents did not present their response in a consistent manner. Some respondents provided the number of workers per day on the jobsite, while some provided the peak workers on-site. Others provided the total number of workers who were part of the entire project duration. This variation made it difficult to summarize this information effectively. However, it was helpful that, of the 25 projects, 21 provided the total number of workers for the entire project duration. The number of workers ranged from 45 to 2,544 workers (mean = 618 workers; median = 200 workers).

The survey also requested the number of subcontracts awarded as part of the project. The number of subcontracts awarded for the sample projects ranged from 2 to 100 (mean = 55.6 subcontracts; median = 50.5 subcontracts). The total number of worker hours expended for the sample projects ranged from 9,500 to 30,419,929 hours (mean = 1,678,429 work hours; median = 320,000 work hours). Hence, based on these four factors (total constructed cost, the number of subcontractors on site, the number of workers on site, and the number of worker hours expended), it can be concluded that the majority of the sample projects were large projects.

In terms of height, the sample projects in the study ranged from 1 to 65 stories (mean = 14.3 stories; median = 5 stories). Considering all of the 25 projects in the sample, the residential buildings were the tallest with a mean of 31.8 stories. All other buildings had a mean of 5.5 stories. Of the 25 projects, 14 projects were funded by the private sector and 11 by the public sector. It should be noted that for 15 of the 25 projects (60.0%), the construction work was in progress at the time of the study. Included in the 15 incomplete projects are nine projects which were at least 60% complete and six projects were less than 25% complete.

The study questionnaire requested the type of delivery method used by the project team. This information was essential due to the fact that the researchers envisioned that it might affect some of the SCSH rating system elements being implemented on a project. Table 5.2 presents the information on the type of delivery methods used by the study sample projects.

Table 5.2: Delivery Methods Used by the Sample Projects (N = 25)

Type of Delivery Method	# of Projects
Design-Bid-Build (DBB)	7
Design-Build (DB)	5
Construction Manager/General Contractor (CM/GC)	9
Others	4

5.4.2.2 Safety Information

The study questionnaire requested that the responding firms provide information about the total number of OSHA recordable injuries sustained and the number of near misses recorded on each of the projects being reported. The respondents were also asked to provide the total number of work hours that were worked on the projects. Based on these amounts, the TRIR was calculated. All of the 25 sample projects provided information on the number of OSHA recordable injuries and the total work hours expended during the projects. One project did not provide the information on total work hours, but that project did not have any OSHA recordables. Hence, the TRIR was assumed to be zero. Only eighteen projects recorded near misses as part of the safety records. For the 25 projects, the TRIR's ranged from 0 to 10.8 (mean = 4.2; median = 4.0), with 5 projects (20.0%) reporting zero injuries. The near miss rates ranged from 0 to 61.6 (mean = 10.7; median = 1.3), with 5 projects (20.0%) reporting zero near misses. Further discussion and analysis on safety information are provided in the Results section of this manuscript.

5.4.2.3 SCSH Information

Based on the information provided by the respondents, the total number of SCSH credits was calculated for all of the 25 sample projects. The SCSH rating system guide provided in Manuscript #3 and Appendix B.12, was used for this purpose. The total SCSH credits for the sample projects ranged from 28.2 to 91.5 credits (mean = 63.2 credits; median = 63.7 credits). As discussed previously, the SCSH rating system consists of four levels of certification: certified, silver, gold, and platinum. The credit range for each level is: Certified 54-60 credits; Silver 61-75 credits; Gold 76-90 credits; and Platinum 91-100 credits**.** All required elements have to be fulfilled for all levels of certification. However, it should be noted that the mandatory credit requirement criteria was not taken into account for the purpose of the analysis, but will be discussed later in this manuscript. The study sample consisted of five uncertified projects (20.0%), 5 Certified projects (20%), 10 Silver projects (60.0%), 4 Gold projects (16.0%), and one Platinum project (4%). Uncertified projects refer to projects that failed to score the minimum 54 credits. The SCSH credit distribution for the 25 sample projects is presented in Figure 5.1. The figure shows that the majority (80%) of the projects scored more than 54 credits based on the SCSH rating system. In other words, most of the projects included in the study have a reasonable safety commitment from the project team.

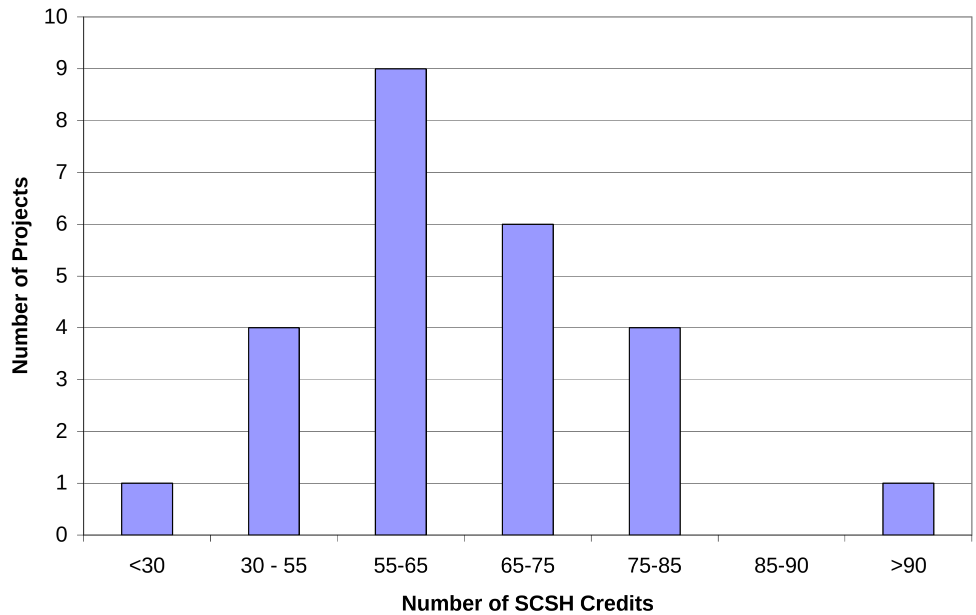

Figure 5.1: SCSH Credits Distribution for the 25 Sample Projects

5.4.3 Analysis

The primary objective of the analysis was to identify the presence/absence of any correlation between the total SCSH credits and the TRIR of a project. It was assumed that all “confounding” variables that might affect the safety performance of a project will be constant. Some of the measurable confounding variables include: project type, facility type, project complexity as defined by the unit cost, project height, project location, and type of funding. Hence, the presence or absence of correlation between SCSH credits and TRIR may not just be attributed to a project receiving higher or lower credits. MS Excel was used to compute simple statistics like mean and median, prepare graphs, and identify the degree of correlation between project credits and TRIR.

5.4.3.1 Validation

Table 5.3 presents a summary of all of the study sample projects along with their safety performance. The table also presents the near miss rate (NMR) calculated for the projects. The analysis gave the researchers four means to test the correlation that include: scatter plot, trendline, R-squared, and R-value. A scatter plot was developed between the

SCSH credits and the TRIR for the sample projects to examine any trends in the data set. MS Excel has a built-in function that helped the researchers plot a trend line (regression line) which is a graphical presentation of any trends in the data set. MS Excel also has a built-in function to display an R-squared value for the trendline. R-squared value is a number from 0 to 1 that reveals how closely the estimated values for the trendline correspond to the actual data. A trendline is most reliable when its R-squared value is at or near 1. It also helps to say how good one term is at predicting another. If R-squared is 1.0, then given the value of one term, the value of another term can be perfectly predicted. The R-squared value can be directly calculated using the syntax RSQ(y values, x values) in MS Excel. In this study the y-value is the TRIRs and the x-value is the SCSH credits.

The correlation between SCSH credits and TRIR was measured using a correlation coefficient called "R" value, which gives the measure of reliability of the linear relationship between the SCSH credits and the TRIR. The R-value can be calculated using the syntax CORREL(y values, x values) in MS Excel. It should be noted that Excel can return three types of correlation coefficient based on the data: positive correlation, negative correlation, and no correlation. Firstly, when large values of SCSH credits are associated with large values of the TRIR, there will be a positive correlation between SCSH credits and TRIR. This means that as the SCSH credits increase the TRIR values also increase, or the SCSH rating system elements do not help improve the safety performance of the projects.

Secondly, when the values of both SCSH credits and TRIR are not related then the R-value will be zero, indicating the absence of any correlation. In other words the SCSH rating system does not impact the safety performance of the projects.

When smaller values of SCSH credits are associated with large values of TRIR, or large values of SCSH credits are associated with small values of TRIR, then MS Excel will return a negative R. This indicates a negative correlation between SCSH credits and TRIR values. A negative correlation would indicate that the rating system is "valid", as the SCSH credits increases the TRIR decreases. In other words as the SCSH credits increase, the potential for incidents decreases on the projects.

The SCSH credits and TRIR values for all of the 25 projects were entered in an MS Excel spreadsheet. An XY scatter plot was developed between the SCSH credits and TRIR values. A trendline was added to the graph to examine any trends in the data set as shown in Figure 5.2. It was found that there was a weak correlation (R = -0.25) between the SCSH credits and the TRIR values. The R-squared value was very low, indicating that the SCSH credits do not predict the TRIR values for the projects. When examining the plot it was noticed that Project C with SCSH credits of 28.2 and a TRIR of zero was pulling the trendline towards a positive slope. This project could be considered an outlier since the project consisted of building a simple facility of only 20,000 SF compared to the mean for the data set of 366,000 SF. In addition, the project did not report the total man-hours worked. Hence, Project C was removed from the analysis.

Table 5.3: SCSH Credits and Project Safety Performance

Project ID	SCSH Credits	Total Recordable	Near Misses	Total man hours	TRIR	NMR
A	44.4	1	NA	50,000	4.0	NA
B	75.9	4	37	510,000	1.6	14.5
C	28.2	0	NA	NA	0.0	NA
D	56.8	6	40	130,000	9.2	61.5
E	69.6	0	0	65,000	0.0	0.0
F	79.5	6	200	740,000	1.6	54.1
G	75.1	3	NA	320,000	1.9	NA
H	84.0	0	2	180,000	0.0	2.2
I	63.7	4	2	149,217	5.4	2.7
J	49.9	21	0	463,748	9.1	0.0
K	67.5	1	0	150,000	1.3	0.0
L	65.6	32	34	702,131	9.1	9.7
M	68.0	21	NA	580,786	7.2	NA
N	68.2	17	6	704,660	4.8	1.7
O	61.6	44	NA	1,009,148	8.7	NA
P	61.6	24	NA	715,011	6.7	NA
Q	58.7	27	NA	737,316	7.3	NA
R	65.0	44	12	3,541,302	2.5	0.7
S	59.5	2	0	80,000	5.0	0.0
T	55.4	0	0	17,988	0.0	0.0
U	47.5	3	1	166,000	3.6	1.2
V	48.7	3	1	147,000	4.1	1.4
W	59.6	20	2	372,000	10.8	1.1
X	73.5	0	2	9,500	0.0	42.1
Y	91.5	180	50	30,419,929	1.2	0.3
Min	28.2	0	0	9,500	0.0	0.0
Max	91.5	180	200	30,419,929	10.8	61.5
Mean	63.2	18.5	21.6	1,748,364	4.2	10.7
Median	63.7	4	2	346,000	4.0	1.3

Note: Places where data was not available are indicated as NA.

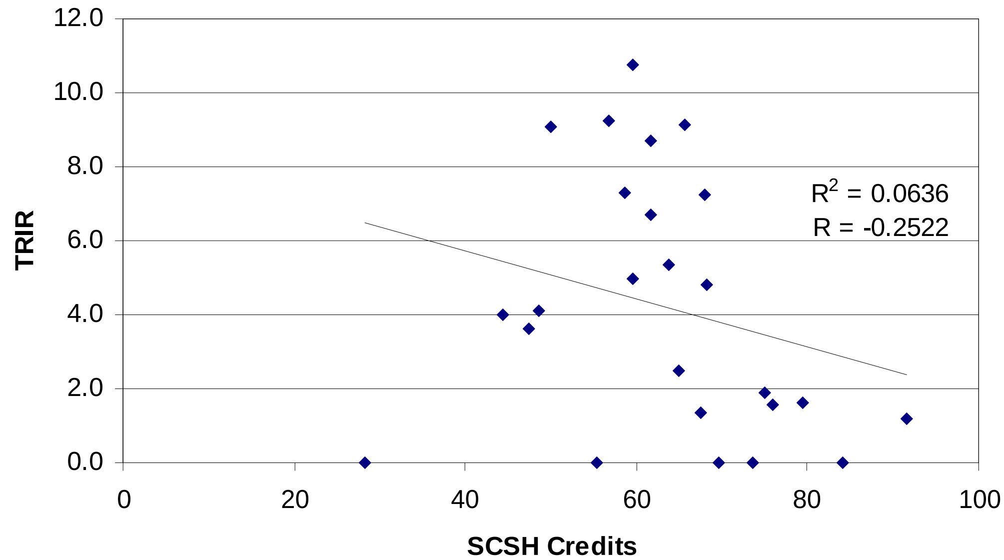

Figure 5.2: Correlation between TRIR and SCSH Credits (All sample projects, n = 25)

One of the confounding variables in the comparison of these projects could be the project size and amount of completion. The researchers decided to examine the correlation after removing smaller projects. For the purpose of the analysis, project size was defined in terms of the number of man hours worked. Some of the projects in the sample had just begun and only 9,500 hours had been worked. The researchers decided to analyze the trend between SCSH credits and TRIR for projects on which more than 100,000 man hours were worked and then for projects with more than 200,000 man hours. The 100,000 man hours was used to define project size in a previous research study (Huang 2003). Figures 5.3 and 5.4 present the results of this analysis.

Nineteen projects were part of the sample that had worked more than 100,000 man hours. It was found that the R-squared (0.37) and R-value (-0.61) improved significantly for these 19 projects. There were 13 projects that had worked more than 200,000 man hours. The R-squared (0.64) and R-value (-0.80) improved further for the 13 projects. Based on the correlation coefficient value (R) of -0.80, the result indicates that as the SCSH credits increase the TRIR value decreases.

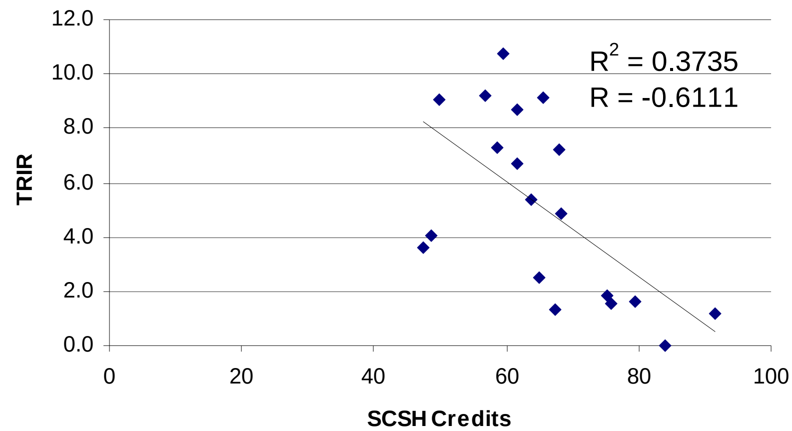

Figure 5.3: Correlation between TRIR and SCSH Credits (projects with work hours > 100,000, n = 19)

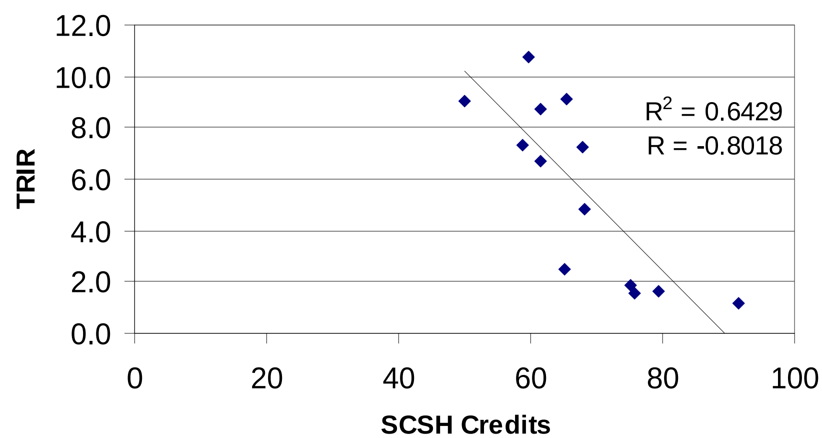

Figure 5.4: Correlation between TRIR and SCSH Credits (projects with work hours > 200,000, n = 13)

Similar analyses were performed based on other project characteristics like union status, delivery method, ownership, facility type, and builder type. The R-squared and R-value were calculated based on the syntaxes RSQ(Y, X) and CORREL (Y, X), respectively. Tables 5.4 and 5.5 show the R-squared and R-values for testing the relation between SCSH and TRIR based on the project delivery method and ownership, respectively. It was interesting to find that projects delivered through DBB had a slight positive correlation, while projects delivered using the DB method had a moderate negative correlation. For both private and public projects the correlation coefficient had a negative value. When project C was removed from the public projects, the R-value jumped to -0.61, indicating strong correlation between SCSH credits and TRIR among publicly-funded projects.

Table 5.4: Correlation between TRIR and SCSH Credits in terms of Project Delivery Method

Delivery Method	# of Projects	R	R^2	Mean TRIR
DBB	7	0.20	0.04	4.8
DB	7	-0.53	0.28	6.7
CM/GC	9	-0.12	0.04	2.6

Table 5.5: Correlation between TRIR and SCSH Credits in terms Project Funding

Funding	# of Projects	R	R^2	Mean TRIR
Private	14	-0.25	0.06	5.5
Public	11	-0.21	0.04	2.5

Figure 5.6 presents the R and R-squared values for union and open shops. It was found that the SCSH rating system worked well for union shops (R = -0.58) compared to open shops which had an R-value of -0.12. However, both had some correlations indicating that the rating system is indicative for both types of labor. In terms of the facility type, all types of facilities had a negative correlation between SCSH credits and TRIR (Table 5.7). It was found that the SCSH rating system would work perfectly for education (R = -0.99) and transportation facilities (R = -1.0) although the number of projects of these types in the sample was small. A similar trend was found for industrial (R = -0.74) and residential (R = - 0.79) facilities.

Table 5.6: Correlation between TRIR and SCSH Credits in terms of Union Status

Labor	# of Projects	R	R^2	Mean TRIR
Open shop	12	-0.12	0.02	2.4
Union shop	13	-0.58	0.34	5.9

Table 5.7: Correlation between TRIR and SCSH Credits in terms of Facility Type

Facility Type	# of Projects	R	R^2	Mean TRIR
Education	3	-0.99	0.98	4.7
Industrial	4	-0.74	0.55	2.6
Medical	5	-0.25	0.06	5.7
Residential	8	-0.80	0.63	4.5
Transportation	2	-1.0	1.0	5.8

The correlation analysis was performed for projects from individual builders (Table 5.8). Only three builders (B, C, and D) contributed an adequate number of projects to be included in this part of the analysis. It was found that all of the three builders had a negative correlation for SCSH credits and TRIR. Builder B had an R-value of -0.92 and an R-squared value of 0.85, the strongest correlation of the three builders.

Table 5.8: Correlation between TRIR and SCSH Credits in terms of Builder Type

Builder	# of Projects	R	R^2	Mean TRIR
B	5	-0.92	0.86	3.5
C	6	-0.33	0.11	7.3
D	4	-0.06	0.00	3.2

The last analysis included the examination of the relationship between the near miss rate and the SCSH credits. Nine projects did not report or record the near misses. Figure 5.5 shows the scatter plot and trendline along with the correlation statistics. It was found that the near miss rate had a positive correlation with the SCSH credits.

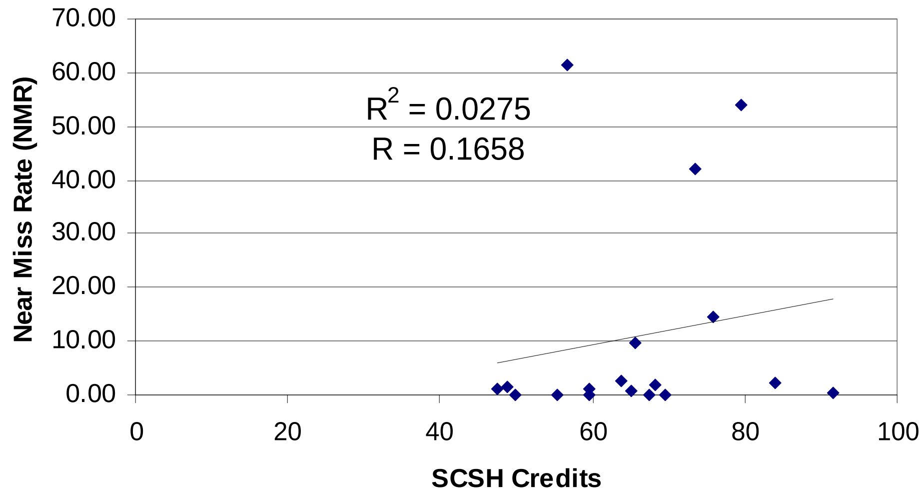

Figure 5.5: Correlation between NMR and SCSH Credits

5.4.3.2 Project characteristics and SCSH Credits

This section presents the results of the simple analysis that was performed to identify the relationship between project characteristics and the total SCSH credits received by the projects. Some of the questions examined include:

- Does the project delivery method and the type of project funding influence the number of SCSH credits received by the projects?
- Does the project size and complexity have any influence on the SCSH credits?
- Does the facility type have any influence on the SCSH credits?
- Does union status have any influence on the number of SCSH credits scored by the projects?

The statistics that were used to answer these questions included mean, median, and range of the SCSH credits received by the sample projects.

Some of the elements that are part of the SCSH system require the coordination between two or more primary parties: owners, designers, constructors, and subcontractors. In addition, the SCSH rating system requires the selection of the project team based on past safety performance and experience. Both of these factors are not typically possible in the traditional design-bid-build (DBB) project delivery method since the constructor enters the system only after the design has been completed and is commonly selected based on cost. In terms of type of project funding, public owners typically employ the DBB method. As discussed in previous chapters, private owners have the opportunity to employ any delivery method and also have the opportunity to select contractors based on safety in addition to cost, quality, and schedule considerations. This encourages practices like constructability, design for construction worker safety, and so forth, which are major elements in the SCSH rating system. This difference might lead to public projects and/or projects that employ the DBB delivery method receiving fewer credits. Hence, the researchers were interested in finding if there is any difference in SCSH credits based on the type of project delivery methods and ownership.

Table 5.9 presents a summary of the project delivery methods and their corresponding SCSH credits statistics. The study sample had an approximately equal number of the three commonly used delivery methods: Design-Bid-Build (DBB), Design-Build (DB), and Construction Manager/General Contractor (CM/GC). The mean and median SCSH credits for the DB projects were higher than the other two methods. The CM/GC method also had higher SCSH credits compared to the DBB delivery method. This may be a result of the coordination between the constructor and the designer during the design stages of the project in the DB and CM/GC method. This result indicates that fewer safety and health elements are implemented on DBB projects compared to the other delivery methods.

Table 5.9: Project Delivery Method and SCSH Credits

Delivery Method	# of Projects	Range	Mean	Median
Design-Bid-Build (DBB)	7	28.2 to 84.0	57	59.5
Design-Build (DB)	7	47.5 to 91.5	70.1	73.5
Construction Manager/ General Contractor (CM/GC)	9	56.8 to 75.1	63.9	61.6
Owner's Builder/Multiple Primes	1	69.6 to 69.6	69.6	69.6
Unknown	1	44.4 to 44.4	44.4	44.4

When examining the type of funding the projects received and their SCSH credits (Table 5.10), it was found that the public projects received more SCSH credits and had the only Platinum project. However, it should be noted that some of the high scoring public projects including the Platinum rated project did not employ the traditional DBB delivery method. The type of delivery method appears to have an influence on the number of SCSH credits received by a project.

Table 5.10: Project Funding and SCSH Credits

Funding	# of Projects	Range	Mean	Median
Public	11	28.2 to 91.5	65.4	65
Private	14	44.4 to 75.9	61.6	61.6

As discussed previously, project size and complexity are important indicators of the amount of safety efforts expended on a project. The various project characteristics that were used to measure project size and complexity and their corresponding project SCSH scores are presented in Table 5.11. Three factors, namely dollars per square foot, number of employees, and total worker hours worked, were also found to be indicators that the bigger and more complex the project, the higher the mean SCSH credits. In terms of the number of subcontracts awarded, it was found that the lower the number of subcontracts, the higher the SCSH credits. It was also found that the height of the projects did not have much affect on the number of SCSH credits scored by the projects. The mean SCSH credits of projects less than 10 stories and greater than 10 stories were almost the same.

The analysis indicates that project size does have some influence on the number of SCSH credits scored by a project.

Table 5.11: Various Measures of Project Size and Complexity and SCSH Credits

Measure	# of Projects	Range	Mean	Median
(a) Number of subcontracts				
Less than 50	9	44.4 to 84.0	66.1	67.5
50 or more	13	48.7 to 75.9	62.7	61.6
(b) Dollars per square foot (SF)				
Less than 150	3	55.4 to 63.7	58.6	56.8
150 to 300	10	28.2 to 79.5	62.7	66.6
300 or more	6	48.7 to 75.9	63.7	64.8
(c) Number of stories				
Less than 10	12	28.2 to 84.0	62.8	65.9
10 or more	9	44.4 to 73.5	61.3	61.6
(d) Number of employees				
Less than 100	5	44.4 to 73.5	56.3	55.4
100 to 500	9	47.5 to 84.0	66.0	67.5
500 or more	7	58.7 to 91.5	69.1	61.6
(e) Worker hours worked				
Less than 100,000	5	44.4 to 73.5	60.5	59.5
100,000 to 200,000	6	47.5 to 84.0	61.4	60.3
200,000 or more	13	49.9 to 91.5	67.7	65.6

In terms of the influence of the type of facility on the SCSH credits, there were not enough projects in each category to have a meaningful comparison. Table 5.12 presents the types of facilities and their SCSH credits. It was found that industrial facilities had a higher mean number of SCSH credits, followed by educational and high rise residential facilities. The top two projects of the study samples were both industrial projects. In addition examining the relationship between labor status and SCSH credits, it was found that there was not a significant difference in the credits scored between the union and open shop projects (Table 5.13).

Table 5.12: Facility type and SCSH Credits

Facility Type	# of Projects	Range	Mean	Median
Education	3	58.7 to 75.1	67.3	68.2
Residential	8	44.4 to 79.5	64.6	66.6
Transportation	2	49.9 to 65.0	57.5	57.5
Medical	5	48.7 to 75.9	63.2	61.6
Industrial	4	47.5 to 91.5	71.7	73.9
Parking	1	59.5 to 59.5	59.5	59.5
Animal shelter	1	28.2 to 28.2	28.2	28.2
Office	1	55.4 to 55.4	55.4	55.4

Table 5.13: Labor Type and SCSH Credits

Labor	# of Projects	Range	Mean	Median
Union shop	13	44.4 to 91.5	64.4	61.6
Open shop	12	28.2 to 79.5	61.9	65.6

5.4.3.3 SCSH Elements and Industry Practices

An effort was also made to identify the feasibility of the rating system elements and the construction industry's current safety and health practices by asking the following questions:

- What are the most commonly implemented SCSH elements in the construction industry?
- What are the least implemented SCSH elements in the construction industry?
- Are the criteria of mandating the required credits to obtain certification based on the SCSH rating system a feasible approach in the construction industry?

The questions were answered by performing a simple analysis of the information derived from the 25 study sample projects. A list of the SCSH rating system's 50 elements along with the number of projects that implemented those elements was created. This helped the researchers identify the most and least implemented safety and health elements among the sample projects. Tables 5.14 and 5.15 shows the least and most implemented elements. Any element that was implemented by only 25% or less of the projects was considered as one of the least implemented elements, and elements implemented by more than or equal to 75% of the projects could be termed as the most commonly implemented elements.

Elements that were not implemented by ≥ 60% of the study sample projects were examined. It was found that most of the elements that were not implemented, such as safety checklist for designers, life cycle safety design review, designer selection based on safety experience and knowledge, safety hazard identification in construction documents, designing for worker safety and health, and safety training for designers, were associated with the designing for safety concept. On the positive side, it was interesting to note that among the 25 sample projects:

- Five selected designers based on safety experience and knowledge,
- Five projects had identified safety hazards in construction/bid documents,
- Six projects had incorporated the concept of designing for construction worker safety and health, and
- Nine project's designers had some kind of training in either field safety or design for construction worker safety and health.

This finding supports the conclusions of Gambatese et al. (2005) that the design for safety concept is still at its infancy stage, but that the industry is gradually recognizing design for safety as a viable intervention to improve worker safety and health.

It was found that nine of the 50 elements were implemented by all of the sample projects. Elements that were implemented by ≥ 80% of the sample projects were examined. Twenty-four elements fell under this category. This list included five of the nine zero accident techniques reported by Hinze et al. (2001).

Table 5.14: List of Least Commonly Implemented SCSH Elements

Element Name	# of projects*	% of projects*
Safety Checklist for Designers	22	88
Life Cycle Safety Design Review (LCS)	21	84
Designer Selection	20	80
Safety hazard symbols in construction drawings	20	80
OSHA 10-hour Training for All Workers	19	76
Task based safety exposure database	18	72
Designing for Worker Safety and Health	18	72
Ergonomic Task Analysis and Remediation	17	68
Stretch and Flex Program	16	64
Safety Training for Designers	16	64
Subcontractor Safety Representative	14	56
Accident and Near Miss Invstg with pre-task/ JHA	13	52
Safety and Health During Conceptual Planning Phase	13	52
Specification of less hazardous construction materials	11	44
Hearing Protection Program	9	36
Employee Safety Committee and Leadership Team	8	32
Respiratory Protection Program	8	32
Constructability Review	8	32
Owner Safety Representative	7	28
Safety Performance Evaluation using safety metrics	7	28
On and Off site Traffic Plan	7	28
Engineering Controls for Health Hazards	7	28

*(Projects that DO NOT contain the elements)

All of the 25 projects had: a commitment from the construction firm's top management to improve safety performance of the project; a site specific safety plan, and a policy in place to investigate all accidents. It was interesting to note that 24 projects had a safety representative either part-time or full-time. In terms of subcontractor management, most contractors selected their subs based on safety (92%) and many required the subs to submit a site-specific safety plan (88%) before commencing work on the jobsite. In addition, project owners showed a commitment to safety by including safety requirements in the construction contracts (100%), signing a mission statement (96%), and evaluating the contractors based on past project safety performance (76%).

Table 5.15: List of Most Commonly Implemented SCSH Elements

Element Name	# of Projects*	% of Projects*
Personnel Protection Equipment (PPE) Plan	25	100
Safety Inspections	25	100
Safety Violations identified and corrected	25	100
Safety and Health in Contracts	25	100
Competent personnel for all high hazard tasks	25	100
Management Commitment	25	100
Constructor Site Specific Safety Plan	25	100
Accident and Near Miss Investigation	25	100
Employees Empowered with Stop Authority	25	100
GC full time Safety Representative	24	96
Safety Training for All Field Supervisors	24	96
Assessment of Equipment Operators Skills and Training	24	96
Toolbox Meetings	24	96
Owner/ Owner Representative Commitment	24	96
Look Ahead Schedule	24	96
Safety Orientation for All Workers	24	96
Subcontractor Selection	23	92
Project Accountability and Responsibility	23	92
Drug and alcohol testing program	22	88
Subcontractor Site Specific Safety Plan	22	88
Job Hazard Analysis	22	88
Good housekeeping Plan	21	84
Supervisors Evaluated Based on Safety Performance	21	84
General Contractor Selection	20	80
Constructor Mentors Subs to Improve Safety Performance	19	76
Contractor Evaluation Based on Safety Performance	19	76
Pre-task Planning	19	76
Regular Safety Training for All Project Personnel	19	76

*(Projects that implemented the elements)

In addition to examining the individual elements, the 13 SCSH rating system categories were analyzed (Table 5.16). It was found that 5 projects did not have any kind of industrial hygiene elements implemented. In addition 72% of the projects did not have a task-based hazard database as part of their project safety resource. This questions the feasibility of this element being part of the rating system.

Table 5.16: SCSH Rating System Category and its Implementation

Element Category	# of Projects*	% of Projects*
Project Team Selection	23	92
Safety and Health in Contracts	25	100
Safety and Health Professionals	25	100
Safety and Health Commitment	25	100
Safety and Health Planning	25	100
Training and Education	25	100
Safety Resources	7	28
Drug and Alcohol Program	22	88
Accident Investigation and Reporting	25	100
Employee Involvement	25	100
Inspection	25	100
Safety Accountability and Safety Performance Measurement	24	96
Industrial Hygiene and Health Practices	20	80

* Projects that contain the elements in the category

One of the questions that the researchers were interested in answering was whether to have the 25 mandatory safety and health elements required as part of the rating system. For this purpose, a list of all 25 projects by their ID and the number of "required" elements that were not implemented was developed. The list also included their SCSH credits, level of certification without considering the mandatory requirement, and the mean TRIR. The list is tabulated in Table 5.17. Only one of the 25 projects (project H) had fulfilled all of the 25 required elements. Thus, only project H would be eligible to be certified by the SCSH rating system. Eighteen projects (72%) had not fulfilled five or more required elements. In addition, project Y, which scored credits equivalent to being certified as Platinum cannot be certified because it did not satisfy only one required credit. Project Y had a TRIR of 1.2 with several million man hours worked, but according to the rating system it cannot be certified as a safety conscious project. This result leads one to question this mandatory requirement.

From another perspective, examining the most common non-compliant required elements showed that the most frequent (top 6) included:

- Safety Checklist for Designers (88%)
- Life Cycle Safety Design Review (84%)
- Designing for worker safety and health (72%)
- Safety Training for Designers (64%)
- Safety and health during conceptual planning (52%)
- Constructability review (32%)

These elements are viewed as being effective in improving worker safety performance, but the industry has not embraced them yet. This result adds to the complexity of the findings and brings up the question of whether the elements should be made electives? This issue should be studied further to arrive at a reasonable solution.

Table 5.17: Sample Projects and Number of Non-Compliant Required Elements

ID	# of Noncompliant Elements	# of Noncompliant Required Elements	SCSH Credits	Certification Without Requirement	Mean TRIR
A	21	12	44.4	Uncertified	4.0
B	9	3	75.9	Gold	1.6
C	31	14	28.2	Uncertified	0.0
D	15	6	56.8	Certified	9.2
E	14	6	69.6	Silver	0.0
F	8	6	79.5	Gold	1.6
G	11	6	75.1	Gold	1.9
H	2	0	84.0	Gold	0.0
I	17	5	63.7	Silver	5.4
J	18	8	49.9	Uncertified	9.1
K	14	5	67.5	Silver	1.3
L	14	5	65.6	Silver	9.1
M	10	4	68.0	Silver	7.2
N	12	2	68.2	Silver	4.8
O	16	6	61.6	Silver	8.7
P	16	6	61.6	Silver	6.7
Q	16	6	58.7	Certified	7.3
R	13	7	65.0	Silver	2.5
S	15	5	59.5	Certified	5.0
T	17	4	55.4	Certified	0.0
U	22	8	47.5	Uncertified	3.6
V	22	8	48.7	Uncertified	4.1
W	14	7	59.6	Certified	10.8
X	8	4	73.5	Silver	0.0
Y	1	1	91.5	Platinum	1.2

5.4.4 Study Limitations

Some of the major limitations that are present in this study are listed below:

1. The survey questionnaire consisted of questions that required the respondents to rate the extent of implementation of some of the elements on a scale of one to five. The response is dependent upon the judgment of the respondents. The response might not be accurate in some instances and may vary between the 25 survey respondents.

2. A second limitation is associated with the study inferences. The TRIR used for the study is observational data and cannot be used to make cause and effect statements. The strongest statement that can be made from the study is that there is an "association" between the TRIR and the SCSH credits.
3. Another limitation is the small sample size. This can be attributed to the sensitivity of the information being requested and the lengthy questionnaire used for the survey.
4. In some cases the general contracting firm responded to all of the questions in the survey. The reliability of the information gathered through this respondent depends completely on the knowledge of the GC of the designer, owner, and sub's safety and health efforts on the project.

5.5 Conclusions and Recommendations

The major objective of this study was to validate the SCSH rating system. A simple analysis was performed based on the information collected from 25 construction projects. Based on the analysis the following conclusions were made:

- The SCSH rating system is valid for the study sample due to the presence of the negative correlation between the SCSH credits and the TRIR for the current data set. The negative correlation decreased significantly towards negative one when only projects that had expended more than 200,000 man hours were considered.
- The SCSH rating system had a better correlation with TRIR for projects delivered through DB (greater R – value) than projects delivered through DBB.
- The SCSH credits for residential, transportation, education, industrial facility types had a good correlation with TRIR. The SCSH rating system works well for these facility types.
- The builder had an influence on the accuracy of the SCSH rating system. The correlation changed from one builder to another and did not work perfectly for all of the three major builders in the study.

The study also examined the information from the 25 projects to identify the feasibility of implementing some of the elements and the mandatory requirements of the rating system. The following conclusions were made:

- The mean SCSH credits for the DB projects were higher compared to other project delivery methods. The type of delivery method has an influence on the number of SCSH credits received by a project.
- Three factors, namely dollars per square foot, number of employees, and total worker hours worked, were in agreement with the fact that the bigger and more complex the project, the higher the mean SCSH credits.
- Industrial facilities scored the highest mean number of SCSH credits, followed by educational and high rise residential facilities.
- The elements associated with the designing for safety concept such as safety checklist for designers, life cycle safety design review, designer selection based on safety experience and knowledge, safety hazard identification in construction documents, designing for worker safety and health, and safety training for designers, were the least implemented elements among the 25 projects.
- Some of the most commonly implemented elements include: top management commitment, site-specific safety plan, accident investigation, safety in contracts, and safety staffing.
- Only one of the 25 projects had fulfilled all of the 25 required elements criteria.

Further research should be conducted to improve the rating system structure and its feasibility of implementation. Assessment of the credit calculation methodology currently consists of only a few subjective responses, and should be explored further. Some of the elements, for example “OSHA 10 hour certification for all workers”, were found to not be feasible for a project given the fact that some workers only work 2 or 3 hours on a project. Another such example would be having an owner safety representative for the project; small owners cannot afford to have a safety representative.

A major inhibitor for the institution of the SCSH system in the construction industry could be cost. Several questions might be raised by the construction community about the rating system:

- What will it cost to get a project rated by the SCSH system?
- Will there be a difference in cost for each level of rating (Silver, Gold and so forth)?

Implementation of the SCSH rating system will definitely incur a cost for the project team. There is no quantified data on this claim, but considering the range of elements that are part of the system, it will cost more than a non-rated project. Research is needed to document the cost of implementation of the SCSH rating system.

5.6 References

Gambatese, J., Behm, M., and Hinze, J. (2005). "Viability of Designing for Construction Worker Safety". *Journal of Construction Engineering and Management*. 131(9), 1029-1036.

Hinze, J., Mathis, J., Frey, P.D., Wilson, G., DeForge, P., Cobb, M., and Marconnet, G. (2001). "Making Zero Accidents a Reality," Annual Conference of the Construction Industry Institute, San Francisco, CA.

Huang, J. (2003). *The Owners Role in Construction Safety*. Ph.D. Dissertation, 2003, University of Florida, Gainesville, FL.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The overall goal of the research study is to help the construction industry sustain the safety and health of construction workers. A key aspect of the research is the application of the sustainability concept to construction worker safety and health. This concept, defined as sustainable construction safety and health, can be implemented in the industry with the help of the SCSH rating system. To meet the study goal, the research involved three main objectives.

The first objective was to determine the difference, if any, in safety and health performance of green and non-green building projects as identified by LEED. Two research activities were planned to fulfill this objective. The first activity was a pilot study on a LEED rated building project to serve as a preliminary investigation of the relationship between green design and construction and construction worker safety and health. Focus group interviews were used as the method of data collection. The pilot study provided a preliminary view of the impacts of green design and construction practices on construction worker safety and health. The following conclusions were drawn from the study:

- Current literature does not provide any evidence of the impact of green design and construction on the safety and health of construction workers.
- Some features of LEED buildings, such as the construction material recycling programs, appear to negatively impact the safety of construction workers, while others, such as the use of low VOC materials, help to eliminate construction site health hazards. It should be noted, however, that these hazards may occur as well on any project and not just on a LEED project.
- Project personnel felt that green building projects were a little safer than conventional building projects.

- One of the OSHA recordable injuries experienced on the project (foot punctured by nail) was related to a green feature of the project (material recycling).
- Some of the design features of the building made it unsafe for the construction workers, while others improved the conditions to perform work safely. As noted above, this type of injury may also occur during general housekeeping on any project and not just on a LEED project.

The pilot study revealed that there was an impact on construction worker safety and health on the project due to the fact that the building was designed as a green building and a LEED rating was desired. This finding suggested a need for a larger study of many projects to determine if the relationship between green design and construction features and construction worker safety and health exists throughout the construction industry or whether it is project-specific.

A comprehensive statistical analysis of 86 projects (38 green and 48 non-green) was performed to test the presence of any difference in safety performance between green and non-green projects. It was found that there was suggestive, but inconclusive evidence of a statistically significant difference between the median RIR of green and non-green projects in the study sample. Green projects had a higher median RIR than the non-green projects. There was not a statistically significant difference between the median LTCR for the green and non-green projects included in the current study. There was not a significant difference between the different levels of LEED certification and the median RIR and LTCR rates. It can be concluded that there was no negative or positive impact on safety performance when the amount of green design and construction features were increased in a project. However, with both green and non-green buildings having the same safety performance, a question arises as to whether LEED buildings should be labeled as sustainable buildings. LEED projects are sustainable environmentally, but not sustainable in terms of worker safety and health.

The development of a sustainable construction safety and health rating system similar to LEED will provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of those safety and health elements. The safety and health rating system could be kept as a stand-alone system or combined with LEED to create an environmental, health, and safety rating system for building projects.

The SCSH rating system was developed with the help of a Delphi survey among construction safety and health experts from industry and academia. It was found that in order to have sustainable construction safety and health performance in the industry, a total of 50 elements should be implemented through the combined efforts of the project team. The most important elements (top 3) are: (1) clear project safety authority, responsibility, and accountability; (2) employee empowerment to STOP work authority; and (3) contractor selection based on safety. The least important elements (last 3) are: (1) task-based hazard database; (2) hearing conservation program; and (3) stretch and flex programs for all workers. Project safety incentive programs are not considered integral to good safety performance as they lead to more underreporting and do not necessarily prevent injuries/illnesses.

Rather than placing the responsibility for safety solely on the constructor, all parties should be involved in project safety efforts to have sustainable safety results. Designing for safety is an activity that can have a significant impact on safety performance. Designing for safety was one of the highly rated elements, and in order to get a project certified under the rating system, project teams must consider safety during the conceptual and design stages of the project. Industry professionals have started to recognize the importance of ergonomic task analysis in preventing soft tissue injuries.

The final objective of the research study was to validate the SCSH rating system developed based on real-time projects. A simple analysis was performed using information collected from 25 construction projects. Based on the analysis, the following conclusions can be made:

- The SCSH rating system provides an accurate representation of safety performance due to the presence of the negative correlation between the SCSH credits and the TRIR. The negative correlation decreased significantly towards negative one when only projects that had expended more than 200,000 man hours were considered.
- The SCSH had a stronger negative correlation with TRIR for projects delivered through DB than for projects delivered through DBB. The SCSH rating system works better for DB projects than DBB projects.
- The SCSH credits for residential, transportation, education, and industrial facility types had a moderate negative correlation with TRIR. The SCSH rating system works well for these facility types. It should be noted that the sample size limits the application of this conclusion beyond the sample projects.
- Builder type had an influence on the SCSH rating system. The correlation changed from one builder to another and did not work perfectly for all of the three major builders in the study. However, the correlation coefficient was negative for all three.

The study also examined the information from the 25 projects to identify the feasibility of implementing some of the elements and the mandatory requirements of the rating system. The following conclusions can be made:

- The mean and median SCSH credits for the DB projects were higher compared to other project delivery methods. Therefore, the type of delivery method has an influence on the number of SCSH credits received by a project.
- Three factors, namely dollars per square foot, number of employees, and total worker hours worked, were used to illustrate that bigger and more complex projects have higher mean SCSH credits.
- Industrial facilities scored the highest mean number of SCSH credits, followed by educational and high-rise residential facilities.
- Elements such as safety checklist for designers, life cycle safety design review, designer selection based on safety experience and knowledge, safety hazard

identification in construction documents, designing for worker safety and health, and safety training for designers, which are associated with the designing for safety concept, were the least implemented elements among the 25 projects.

- Some of the most commonly implemented elements include: top management commitment, site-specific safety plan, accident investigation, safety in contracts, and safety staffing.
- Only one of the 25 sample projects had fulfilled all of the 25 required elements criteria.

The findings of this study have a number of important applications in the industry. The sustainable safety and health rating system consists of the important safety and health elements to be implemented to sustain worker safety and health from project-to-project. The rating system can be used as a tool to help sustain the safety and health of construction workers. Recognition for using the rating system will be an added incentive to the project team to improve the safety and health performance of the project. Since the rating system would require the joint efforts of all of the parties involved in a project, a team effort would be another benefit that will help set in motion the sustainable safety and health drive throughout the construction industry.

6.2 Recommendations

Recommendations for future research were identified based on the research study. The project LEED information that was available for the current study was the type and level of LEED certification, number of LEED points, and general descriptions of the green features on the project (from other sources like the project owner's website, case studies, USGBC, etc.). Therefore, it was not possible to make connections between each injury incident and specific green design and construction features. This analysis was also not proposed as part of this research study. Relating injury incidents to specific green design and construction features could be accomplished in a much larger study that involves a significant data gathering and project documentation review effort on multiple projects.

As discussed previously there is a significant amount of room for improvement for the SCSH rating system and most recommendations are geared towards this subject.

The 50 elements that are part of the SCSH rating system were derived based on the expert opinion during the Delphi survey. As discussed previously, the final elements and their corresponding credits allocated might be a result of the expert's personal experience and professional knowledge of the various elements' effectiveness in improving worker safety and health. It should be noted that the researchers do not completely agree with the experts on certain elements, their credit, and mandatory/elective requirement. In terms of content, some of the elements, for example "OSHA 10 hour certification for all workers", were found to not be feasible for a project given the fact that some workers only work 2 or 3 hours on a project. Another such example would be having an owner /constructor safety representative for the project. Small owners cannot afford to have a safety representative or some projects would not have the need for a full time safety representative. For instance, research has to be performed to identify criteria for projects in terms of cost or number of employees, to require safety representatives. From a mandatory credit perspective, elements "safety inspection" and "drug and alcohol testing program" ended up as elective elements. The researcher's personal opinion and past research indicates, that these elements are very important and should have been mandatory.

The research hypothesized that projects cannot be labeled sustainable if consideration is not given to the entire life cycle of a building. In order to have sustainable safety and health, the SCSH rating system should include elements that deal with safety of the facility maintenance personnel. Even though the current rating system has one element "life cycle safety review" that addresses this issue, more effort should be made in this avenue.

One of the major recommendations of this research study would be the development of a separate planning tool/rating system for designers similar to the SCSH rating system. During the SCSH rating system validation, it was found that the industry is still in its infancy stage when it comes to design for safety and health. Effort should be made to develop a detailed construction safety and health planning tool that would guide designers to consider worker safety and health during design. This would be a new effort since past research has focused on studying fatalities and answered the questions whether design for safety would have prevented those fatalities. But, there is lack of knowledge about whether implementing certain elements would improve worker safety and health. This gap can be filled by the development of designer safety and health rating system that will rate designers based on safety and health efforts expended by an individual or company-wide. This would be an incentive to the designers to incorporate safety in the design phase of a project.

The major inhibitor for the institution of the SCSH system in the construction industry could be cost. The construction community might raise several questions about the cost of implementation of the rating system. The implementation of the SCSH rating system will definitely add cost to a project. There is no quantified data on this claim, but considering the range of elements that are part of the system, it will cost more than a non-rated project. Research has to be conducted to document the cost of implementation of the SCSH rating system.

BIBLIOGRAPHY

Abudayyeh, O., Fredericks, T.K., Palmquist, M., and Torres, H.N. (2003). "Analysis of Occupational Injuries and Fatalities in Electrical Contracting Industry." *Journal of Construction Engineering Management*, 129(2), 152-158.

Adler, M., and Ziglio, E. (1996). *Gazing into the Oracle: The Delphi Method and its Application to Social Policy and Public Health.* Jessica Kingsley Publishers, London.

Behm, M. (2005). "Linking Construction Fatalities to the Design for Construction Safety Concept." *Safety Science*, 43 (2005), 589-611.

Construction Industry Institute (CII). (1986). Constructability*: A Primer*, Austin, Texas, Publication 3-1.

Coble, R. J., and Haupt, T. C. (2000). "Potential Contribution of Construction Foremen in Designing for Safety." Paper presented at the *Designing for Safety and Health Conference*, sponsored by C.I.B. Working Commission W99 and the European Construction Institute (ECI), London.

Dalkey, N.C., and Helmer, O. (1963). "An experimental application of the Delphi method to the use of experts." *Management Science* Vol. 9, 458-467.

Dalkey, N. C. (1972). The Delphi method: an experimental application of group opinion. In N. C. Dalkey, D. L. Rourke, R. Lewis, & D. Snyder (Eds.) *Studies in the quality of life*. Lexington, MA: Lexington Books.

Delbecq, A.L., Gustafson, D.H., Van de Ven, A.H. (1975). *Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes*. Scott, Foresman and Company, Glenview, Illinois.

DJSI (2006). "Dow Jones Sustainability Indexes, SAM Indexes." <www.sustainability-indexes.com/default.html> GmbH, Zurich, Switzerland, (March 2006).

Engineering News Record (ENR). (2004). "Design-Builder Builds Safety into Total Jobsite Approach." 252(26), 17.

Elkington, J. (1998). *Cannibals with Forks : The Triple Bottom Line of 21st Century Business*. New Society Publishers, Gabriola Island, BC, Canada.

European Foundation (1991). *From drawing board to building site*. European Foundation for the Improvement of Living and Working Conditions, Publication No. EF/88/17/FR. HMSO, London.

Everett, J.G., & Frank, P.B. (1996). "Costs of accidents and injuries to the construction industry". *Journal of Construction Engineering and Management,* 122(2), 158-164.

Findley, M., Smith, S.M., Kress, T., Petty, G., and Enoch, K. (2004). "Safety Program Elements in Construction." *Professional Safety, Journal of the American Society of Safety Engineers (ASSE)*, 49(2), 14-21.

Fowles, J., (1978). *Handbook of futures research*. Greenwood Press, Connecticut.

Fredericks, T.K., Abudayyeh, O., Palmquist, M., and Torres, H.N. (2002). "Mechanical Contracting Safety Issues." *Journal of Construction Engineering Management*, 128 (2), 186-193

Fredericks, T.K., Abudayyeh, O., Choi, S.D., Wiersma, M., and Charles, M. (2005). "Occupational Injuries and Fatalities in the Roofing Contracting Industry." *Journal of Construction Engineering Management,* 131(11), 1233-1240.

Gambatese, J. (2000). "Owner involvement in construction site safety." *Proceedings of Construction Congress VI*, ASCE, Orlando, Florida, 661-669.

Gambatese, J. (2000a). "Safety Constructability: Designer Involvement in Construction Site Safety." *Proceedings of Construction Congress VI*, ASCE, Orlando, Florida, 650-660.

Gambatese, J., Behm, M., and Hinze, J. (2005). "Viability of Designing for Construction Worker Safety". *Journal of Construction Engineering and Management*. 131(9), 1029-1036.

Gambatese, J.A., Rajendran, S., and Behm, M., (2006). "Building Towards Sustainable Construction Safety and Health." *ASSE Professional Development Conference & Exposition*, Seattle, WA, June 12-14, 2006.

Gambatese, J.A., Behm, M., and Rajendran, S. (2006). "Additional Evidence of Design's Influence on Construction Fatalities." *CIB W99 International Conference Proceedings*, Global Unity for Safety & Health in Construction, Beijing, China, June 28-30, 2006.

Gibb, A., Haslam, R., Hide, S., and Gyi, D. (2004). "The role of design in accident causality." *Designing for safety and health in construction,* S. Hecker, J. Gambatese, and M. Weinstein, eds., UO Press, Eugene, Ore., 11–21.

Gilding, P., Humphries, R., and Hogarth, M. (2002). *Safe Companies: A Practical Path for 'Operationalizing' Sustainability*. ECOS Corporation Publications, Sidney, New South Wales, Australia.

Greatorex, J. and Dexter, T. (2000). ”An accessible analytical approach for investigating what happens between the rounds of a Delphi study.” *Journal of Advanced Nursing,* 32(4), 1016-1024.

Gupta, U.G. and Clarke, R.E. (1996), “Theory and applications of the Delphi technique: a bibliography (1975-1994).” *Technological Forecasting & Social Change*, 53(2), 185-211.

Hasson, F., Keeney, S. and McKenna, H. (2000). “Research guidelines for the Delphi survey technique.” *Journal of Advanced Nursing,* 32(4) 1008-1015.

Hecker, S., Gibbons, B., and Barsotti, A. (2001). “Making Ergonomic changes in construction: Working training and task interventions.” *Applied Ergonomics*, D. Alexander and R. Rabourn, eds., Taylor and Francis, London, 162-189.

Hecker, S., Gambatese, J., and Weinstein, M. (2005). “Designing for Worker Safety: Moving the Construction Safety Process Upstream.” *Professional Safety, Journal of the American Society of Safety Engineers (ASSE),* 50(9), 32-44.

Helmer, O. (1983). *Looking Forward. A guide to Future Research*. Beverly Hills/London/New Delhi.

Hinze, J. (1978). “Turnover, new workers, and safety.” *Journal of construction division*, ASCE, 104(4), 409-417

Hinze, J. and Pannullo, J. (1978). “Safety: function of job control.” *Journal of construction division,* ASCE, 104(2), 241-249

Hinze, J. and Parker, H.W. (1978). “Safety Productivity and Job Pressures.” *Journal of construction division*, ASCE, 104(1), 27-35

Hinze, J., and Figone, L. (1988). *‘Subcontractor safety as influenced by general contractors on small and medium sized projects.* The Construction Industry Institute, Austin, Texas, Source Document 38.

Hinze, J., and Talley, D. (1988). *Subcontractor safety as influenced by general contractors on large projects.* The Construction Industry Institute, Austin, Texas, Source Document 39.

Hinze, J.W., and Wiegand, F. (1992). “Role of Designers in Construction Worker Safety.” *Journal of Construction Engineering and Management*, ASCE, 118(4), 677-84.

Hinze, J. and Gambatese, J. (1996). *“Addressing Construction Worker Safety in the Project Design.”* Construction Industry Institute, Austin, Texas, Research Report 101-11.

Hinze, J. (1997). *Construction Safety*. Prentice Hall, Upper Saddle River, New Jersey.

Hinze, J. (2000). "Designing for the Life Cycle Safety of Facilities." Paper presented at the Designing for Safety and Health Conference, sponsored by C.I.B. Working Commission W99 and the European Construction Institute (ECI), London.

Hinze, J., Mathis, J., Frey, P.D., Wilson, G., DeForge, P., Cobb, M., and Marconnet, G. (2001). "Making Zero Accidents a Reality," Annual Conference of the Construction Industry Institute, San Francisco, CA.

Hinze, J and R. Godfrey. (2003). "An evaluation of safety performance measures for construction projects." Special Issue on Construction Health & Safety, *Journal of Construction Research*, 4(1).

Hinze, J. (2003). "*The Owners Role in Construction Safety."* Construction Industry Institute, Austin, Texas, Research Summary 190-1.

Hinze, J., and Gambatese, J.A. (2003). "Factors that Influence Safety Performances of Specialty Contractors." *Journal of Construction Engineering Management*, 129(2), 159-164

Hill, Darryl C. (2003). *Construction Safety Management and Engineering*. American Society of Safety Engineers, Illinois.

Huang, J. (2003). *The Owners Role in Construction Safety*. Ph.D. Dissertation, 2003, University of Florida, Gainesville, Florida.

International Council for Research and Innovation in Building and Construction (CIB). (2002). "Construction Site Waste Management and Minimization." Report Prep. by Dennis S. Macozoma. Report No. BOU/C361.

IUCN/UNEP/WWF (1991) Caring for the Earth. A strategy for sustainable living. IUCN, UNEP and WWF, Gland, Switzerland, and Earthscan, London.

International Council for Local Environmental Initiatives (ICLEI) (1996). "Local Agenda 21 Planning Guide: An Introduction to Sustainable Development Planning." ICLEI, Toronto.

Jairath, N. & Weinstein, J. (1994). "The Delphi Methodology (Part 1): A useful administrative approach." *Canadian Journal of Nursing Administration*, 7(3), 29-42.

Jairath, N. & Weinstein, J. (1994). "The Delphi Methodology (Part 2): Administrative applications." *Canadian Journal of Nursing Administration*, 7(4), 7-20.

Jaselskis, E.J., Anderson, S.D., and Russell, J.S. (1996). "Strategies for Achieving Excellence in Construction Safety Performance." *Journal of Construction Engineering and Management*, 122(1), 61-70.

Lang, T. (1998). "An overview of four futures methodologies." <http://www.soc.hamaii.edu/~future/j7/LANG.html> (January 29, 1999).

Levitt, R.E., and Parker, H.W. (1976). "Reducing construction accidents – top management's role." *Journal of construction division*, ASCE, 102(3), 465-478.

Levitt, R. E., and Samelson, N. M. (1993). *Construction Safety Management, 2nd edition*. John Wiley & Sons, New York.

Lindman, B.A. (1994). *Consensus of educational administrators on admission requirements, professional instruction, internship features, and evaluation of candidate competency for alternative routes into teaching licensure: A Delphi survey*. Doctoral dissertation, University of Minnesota, Twin Cities.

Linstone, H., and Turoff, M. (1975). *"The Delphi Method: Techniques and Applications."* Addison-Wesley, Reading, MA.

Liska, R.W., and Goodloe, D., and Sen, R. (1993). *Zero Accident Techniques: A Report to the Construction Industry Institute.* Source Document 86, Austin, TX: University of Texas.

Lorent, P. (1987). *Les conditions de travail dans l'industrie de la construction, productivité, conditions de travail, qualitié concertée et totale.* CNAC, Brussels.

Manuele, F.A. (1997). *On the practice of safety*. John Wiley and Sons, Inc., New York.

Meridian Research (1994). *Worker Protection Programs in Construction: Final Report.* Meridian Research, Silvery Spring, MD.

Murphy, M. K., Black, N. A., Lamping, D. L., McKee, C. M., Sanderson, C. F. B, Askham, J., & Marteau, T. (1998). "Consensus development methods, and their use in clinical guideline development." *Health Technology Assessment*, 2(3), 1-88.

National Safety Council. (NSC) (2006). *Injury Facts.* 2005-2006 Edition. Itasca, IL

Ng, S.T., Cheng, K.P., and Skitmore, R.M. (2004). "A framework for evaluating the safety performance of construction contractors." *Building and Environment*, 40 (2005), 1347-1355.

Occupational Safety and Health Administration (OSHA) (2005). <http://www.osha.org> (October 9, 2005).

Oertel, B.J. (2001). *Identifying the Essential Characteristics of Curricular Learning Communities in Higher Education: A Delphi Study*. Doctoral dissertation, University of Minnesota, Twin Cities.

Okoli, C. & Pawlowski, S. D. (2004). “The Delphi method as a research tool: an example, design considerations and applications.” *Information & Management*, 42, 15-29.

Payne, R.L, Fineman, S., and Wall, T.D. (1976). *“Organizational climate and job satisfaction: A conceptual synthesis Organizational Behavior and Human Performance.”* 16, 45-62.

Pill, J. (1971). “The Delphi Method: Substance, Context, a Critique and Annotated Bibliography.” *Socio-Economic Planning Science*, Vol. 5, pp 55-71

Powell, C. (2003). “The Delphi technique: myths and realities.” *Journal of Advanced Nursing,* 41(4), 376-382.

Ramsey, F.L., and Schafer, D.W. “The Statistical Sleuth: A Course in Methods of Data Analysis (2nd edition).” Duxbury Thomson Learning, Pacific Grove, California.

Reed, J. and Roskell, V. (1997). “Focus groups: issues of analysis and interpretation.” *Journal of Advanced Nursing,* 26, 765-771.

Rogers, M.R., and Lopez, E.C. (2002). “Identifying critical cross-cultural school psychology competencies.” *Journal of school psychology,* 40(2) 115-141.

Rowe, G., and Wright, G. (1999). “The Delphi technique as a forecasting tool: issues and analysis.” *International Journal of Forecasting,* 15, 353-375.

Sackman, H. (1974). “Delphi assessment: expert opinion, forecasting, and group process.” Rand, Santa Monica, California.

Scheibe, M., Skutsch, M., and Schofer, L. (1975). *Experiments in Delphi methodology.* In Linestone, H., and Turoff, M. (eds) The Delphi Method: Techniques and Application. Addison- Wesley, London.

Schendler, A., & Udall, R. (2005). “LEED is broken . . . Let’s fix it.” *Construction Record, 126*, 910-924.

Simmonds, C. (1977). *The Nature of Futures Problems in Futures Research: New Directions.* Linstone, H., and Simmonds, C. (Eds) Addison-Wesley Publishing Company, London.

Statgraphicsplus 5.1, (2001). Statistical graphical corporation.

Szymberski, R. (1997). “Construction Project Safety Planning.” *TAPPI Journal*, 80(11), 69-74.

Tanner, C. K., and Stone, C. D., (1998). “School Improvement Policy: Have Administrative Functions of Principals Changed in Schools Where Site-Based Management is practiced.” *Education Policy Analysis Archives*, Vol 6 (6).

The Brundtland Report (1987). *World Commission on Environment and Development—Our Common Future*. Oxford University Press, New York.

Tersine, R., and Riggs, W. (1976) “The Delphi technique: A. Long – range planning Tool.” *Business horizons*, 19(2), 51-56.

Toole, T. (2002a). “Construction Site Safety Roles”, *Journal of Construction Engineering and Management*, 128(3), 203-210.

Toole, T. M. (2002). “A Comparison of Site Safety Policies Of Construction Industry Trade Groups.” *ASCE Practice Periodical in Structural Design and Construction*. 7(2), 90-95.

Towne, Douglas. C. (1967). *Influences Exerted upon Subject Responses by the Response Scale Structural Elements of Attitude Scales*. Doctoral dissertation, Cornell University.

Turoff, M. (1970). “The Design of a Policy Delphi.” *Technological Forecasting and Social Change*, 2, 149-171.

United States Green Building Council (USGBC) (2006). “Leadership in Energy and Environmental Design” <www.usgbc.org> Washington, D.C. (June 2006).

United States Green Building Council (USGBC) (2005a). “Green Building Fact Sheet: April 2005.” United States Green Building Council, Washington, D.C.

Van Zolingen, S.J. and Klaassen, C.A. (2003). “Selection processes in a Delphi study about key qualifications in Senior Secondary Vocational Education.” *Technological Forecasting and Social Change*, 70, 317-340.

Veltri, A.T. (1985). *Expected use of Management Principles for Safety Function Management.* Doctoral dissertation, West Virginia University.

Weinstein, M., Gambatese, J., and Hecker, S. “Can Design Improve Construction Safety: Assessing the Impact of a Collaborative Safety in Design Process”. *Journal of Construction Engineering and Management*, 131(10), 1125-1134.

Williams, P., and Webb, C. (1994). “The Delphi technique: a methodological discussion.” *Journal of Advanced Nursing*, 19, 180–186.

Works Bureau (2000). <http://www.etwb.gov.hk>

APPENDICES

Appendix A.1: Impacts of Green Building Design and Construction on Construction Worker Safety and Health Cover Letter

Dear Sir or Madam,

I am a graduate student working with Dr.Gambatese at Oregon State University on my research related to construction safety and sustainability. The research involves the development of a sustainable construction safety and health model that will provide an opportunity to rate projects based on the extent of safety and health elements implemented. One of the objectives of the research is to predict the difference in safety and health performance between sustainable and non-sustainable building projects as identified by the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system. The scope of the research is limited to building projects.

We are aware that your firm constructs a variety of sustainable (LEED) and non-sustainable projects, and ask your assistance with the study. We are interested in collected data on project demographics and injuries/illnesses from these two types of projects that your company has built in the last 5 years. In addition, we are interested in your comments on the impacts that sustainable building design and construction strategies have on construction worker safety and health. Your input will help create a means for ensuring sustainable safety and health in the construction industry.

The data request for information is attached with this letter. All of the data provided will be kept anonymous and confidential, and will not be used for anything unrelated to this study.

Thank you for your help with this study. Please contact me (rajendrs@engr.orst.edu, 541-231-9126) or Dr. Gambatese (john.gambatese@oregonstate.edu, 541-737-8913) if you have any questions.
Sincerely,

Sathy Rajendran
PhD Student
Oregon State University

Appendix A.2: Impacts of Green Building Design and Construction on Construction Worker Safety and Health Survey

No	Description	Project # 1
	Demographic Data	
1	Project Type (e.g., School, Hospital, etc.)	
2	Project Size (in square feet)	
3	Total cost of project	
4	Project Scope (new construction, renovation, or both)	
5	Height of Project (in terms of stories)	
6	Percent project complete (e.g., 100%, 75%, etc.)	
7	Location (city, state)	
8	Year project completed/in-progress	
9	Type of ownership	
	Safety Data	
10	Total number of worker hours worked on the project (if project is in-progress, total hours worked to date)	
11	If subcontractor work hours not tracked by you, please mention and report the self performed work hours	
12	Total number of OSHA recordable injuries (if project in-progress, injuries to date)	
13	If injuries of subcontractor employees not tracked by you, please report the number of recordable injuries of your employees	
14	Total number of lost time, transfer, or restriction injuries (if project is in-progress, total hours worked to date)	
15	If injuries of subcontractor employees not tracked by you, please report the number of lost time injuries of your employees	
16	Number of near misses (if tracked)	
	LEED Data	
17	Is the project LEED certified/registered? (Y/N)	
18	What type LEED certification is seeked for? (NC, EB,CS etc)	
19	If LEED certification or registered, what is the Level (Certified, Silver, Gold, or Platinum)	
20	Number of LEED points obtained for the project	
21	Is LEED documentation available? (Y/N)	

Appendix B.1: Delphi Experts Background Survey Cover Letter

Dear _____________,

Thank you very much for your first round response to the "Development of Sustainable Safety and Health Rating system – Delphi Survey". This email is to inform you that we have successfully completed our first round of the Delphi survey with responses from 11 of the 14 experts. I will be starting to analyze the first round response and prepare the second round questionnaire within a few weeks. I will send out the second round questionnaire to you in February.

One of the major requirements of studies involving the Delphi method is to report the expertise of the panel members. For this purpose I have put together an on-line questionnaire which seeks your background and expertise in the area of safety and construction. I would appreciate you taking the time to fill out the survey at the following link:http://web.engr.oregonstate.edu/~rajendrs/A/Delphi.htm

The survey contains 11 questions and is designed to be completed in 3 to 5 minutes. Should you have any questions or comments about the questionnaire please contact me.

Thanks again for responding to the first round and making it a success.

Sincerely,

Sathy Rajendran

Appendix B.2: Delphi Expert Panelist Background On-Line Questionnaire

Please take a few minutes to answer the following questions about your professional expertise in safety and health. The questionnaire contains 11 questions and is designed to be completed in a few minutes. When you have completed the questionnaire, return it by clicking on the "Submit" button at the end of the survey. Thank you for your help with the questionnaire.

Name______________________________
Please enter your firm's name ______________________________
What is your job title? ______________________________
How many years of experience do you have as a safety professional (includes health, loss control, ergonomist, etc.)? ______
How many years of experience do you have in the construction industry? ______
Do you hold any associate or professional degree in safety, construction, or any other related field? ☐Yes ☐No
If yes, what degree(s)? ______________________________
Do you have a certification in safety or related field (e.g. CSP, CHST, ARM, CIH, PE, etc.)? ☐Yes ☐No
If yes, what certification(s)? ______________________________
Have you published any articles or papers in safety or construction publications in the last five years (Professional Safety, Journal of Construction Engineering and Management, etc.)? ☐Yes ☐No
If yes, how many? ______
Have you given a presentation at any safety or construction conferences in the last five years (ASCE, ASSE conference, chapter meetings, etc.)? ☐Yes ☐No
If yes, how many? ______
Have you written any books or book chapters on safety or construction topics?
☐Yes ☐No If yes, how many? ______
Are you a member of any safety or closely related organizations (e.g., ASSE, ASCE, etc.)?☐Yes ☐No
If yes, what are they and your position (president, member, etc.)?

Thank you for your responses. We greatly appreciate your time and effort in completing this questionnaire, and look forward to sending you the second round Delphi survey.

Sincerely,
Sathy Rajendran

Appendix B.3: Delphi Survey First Round Cover Letter

Thank you for agreeing to be part of my PhD research study. You are part of the twenty safety and health experts participating in this Delphi panel from around the country. The research involves the development of a sustainable construction safety and health rating system that will provide an opportunity to rate projects based on the extent of safety and health elements implemented. This rating system will be similar to U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system. The scope of the research is limited to building projects. The completion of this research will be part of my dissertation requirement for a doctorate degree at Oregon State University.

Your input will help identify the important safety and health elements that will be part of the rating system. The Delphi technique will be used to obtain consensus among the industry experts on the essential construction safety and health elements that should be part of the rating system.

This is the first of three rounds of surveys to be conducted as part of the Delphi process. This first part consists of two open-ended questions:

1. What are the various construction worker safety and health elements/initiatives implemented on projects? Include **all** elements/initiatives that any member of the project team might implement (owner, designer, general contractor, subcontractor, etc.).
2. Please rate each element/initiative you listed based on their effectiveness in preventing construction worker injuries/illnesses. Use a scale of 1 to 5 as follows:

1 = Minimal impact/Least effective	2 = Below average
3 = Moderate	4 = Above average
5 = Large impact/Most effective	

Please respond to these questions based on your knowledge and experience. Please use the attached form to record and submit your response. Use as many copies of the form as needed. The following information is also attached to this e-mail to provide more information about the research study and Delphi process:

- Study Objective
- Envisioned Rating system Structure Description
- Delphi Technique

When finished with the survey, please return your response to me by e-mail (rajendrs@engr.orst.edu) or by fax (541-737-3300). Thank you for your help with this study. Please contact me if you have any questions.

Sincerely,
Sathy Rajendran

Appendix B.4: Delphi Survey Research Process Information to Experts

Study Objective

The objective of this research study is to develop a "Sustainable Safety and Health Rating system" that will provide an opportunity to rate building construction projects based on the extent of safety and health elements implemented. The sustainable safety and health concept aims to sustain the construction worker's safety and health:

- from start to finish of a single project;
- for each future project a worker is involved in; and
- during the worker's remaining life time after retirement,

without any injuries or illnesses as a result of the construction work.

Envisioned Rating system Structure

Many parties are involved in the construction process: the owner, contractors, subcontractors, suppliers, designers, sureties, financial agencies, attorneys, accountants, engineers, consultants, and others. The parties who have major control and/or influence on safety and health are: the constructor, owner, and designer. Just as each party influences and adds to the completed project in its own way, each affects construction site safety differently. The sustainable safety and health rating system being developed will have three major safety categories, one for the owner, the designer, and the constructor. Past research and literature have focused on each party and reveal their unique effects on construction site safety. The basis of the rating system is to combine the safety and health initiatives of these three parties. Under each of these categories there would be a number of sustainable safety and health initiatives, which will carry credits based on the frequency and severity of the safety and health issue it addresses. The credits under the three categories will add up to a total credit. A project that incorporates more initiatives would receive more credits. The premise of the rating system is that a higher number of total points received by a project would indicate a lower potential for incidents. The technique to be used for this rating system development is called a Delphi Technique. Upon development of the rating system, it will be validated using real time construction projects.

Delphi Technique

The Delphi technique is in essence a series of sequential questionnaires or rounds, interspersed by controlled feedback, that seek to gain the most reliable consensus of opinion of a group of experts. The Delphi technique will help draw information and judgments from geographically dispersed experts in the construction field that include: building designers, contractors, safety professionals, regulatory agencies, insurance loss control experts, and academe, on the elements of the sustainable safety and health rating system.

The study will consist of three rounds of surveys. We estimate that each round will consume no longer than 15-20 minutes of each panel member's time. We expect to receive the response within 4 weeks in order to complete the study within the time frame.

Appendix B.4: Delphi Survey Research Process Information to Experts (Continued)

A reminder will be sent at the end of the second week. A description of the different steps involved in the Delphi process is provided below.

- Formation of team to undertake and monitor Delphi Technique (Dr. Gambatese and Sathy Rajendran)
- Selection of panel of experts
- Development of first round open-ended question
- Transmission of questionnaires to expert panel
- Analysis of first round response
- Preparation of second round questionnaire
- Transmission of second round questionnaire to panel
- Analysis of second round response
- Preparation of third round questionnaire
- Transmission of third round questionnaire to panel
- Finalization of rating system

Appendix B.5: Delphi Survey Round One Questionnaire (with example)

No.	Construction Safety and Health Element/Initiative	Injury/illness prevention effectiveness rating				
		1	2	3	4	5
1	Constructor prequalification based on safety					X
2	Designing fall protection systems into the permanent structure				X	
3	Specifying less hazardous materials				X	
4	Subcontractor project-specific safety plan					X
5	Mandatory stretch and flex program			X		

Comments (Optional):

Appendix B.6: Delphi Survey Second Round Cover Letter

Thank you for your first round response to my research study involving the development of a sustainable construction safety and health rating system. Your continued participation is critical. Twelve safety and health experts contributed 329 safety and health elements during the first round of the survey. The data was reviewed to identify the unique elements recorded by the experts. This process resulted in a list of 74 unique safety and health elements. In addition, the researchers added elements to this list from the literature, increasing the total to 80 safety and health elements.

The attached MS Word document contains the list of 80 elements and instructions for the second round responses. The purpose of this second round survey is to gain your (experts) consensus on the elements and ratings. Please review the elements presented in the attached MS Word document and suggest:

1. Should the element be retained in the rating system? If yes, enter “Y”; if not, enter “N”.
2. If you answered “Yes” to Question #1, do you agree with the mean rating given to this particular safety and health element? If yes, enter “Y”. If not, please rate the element based on its effectiveness in preventing construction worker injuries/illnesses. Use a scale of 1 to 5 as follows:

1 = Minimal impact/Least effective	2 = Below average
3 = Moderate	4 = Above average
5 = Large impact/Most effective	

Please respond to these questions based on your knowledge and experience. Your responses can be entered directly in the MS Word document. When finished with the survey, please return your response to me by e-mail (rajendrs@engr.orst.edu) or by fax (541-737-3300).

Thank you again for your willingness to participate in this study. Please return the completed form by 5:00 pm (PST) on Feb. 27. Please contact me if you have any questions.

Sincerely,
Sathy Rajendran

Appendix B.7: Delphi Survey Round Two Questionnaire (example)

Construction Safety and Health Element/Initiative	**Round 1 Responses**				**Round 2 Questions**	
	N	**Mean**	**Median**	**Range**	**Retain? (Y/N)**	**Agree? (Yes, or new rating)**
Safety and Health Element #1	1	4.0	4.0	4 to 4	N	N/A
Safety and Health Element #2	1	4.0	4.0	4 to 4	Y	Y
Safety and Health Element #3	3	3.0	3.0	2 to 4	Y	4.0
Safety and Health Element #4	8	3.9	4.0	2 to 5	Y	2.0
Safety and Health Element #5					Y	5

N – Number of experts who suggested the safety and health element
Mean – Mean rating received for the safety and health element
Median – Median rating received for the safety and health element
Range – The range of ratings received for the safety and health element
Retain? – Should this element be retained in the rating system? (Yes or No)
Agree? – Do you agree with the mean rating for this element (Yes or, enter your new rating based on a scale of 1 to 5.

Rating Scale: 1 = Minimal impact/Least effective; 2 = Below average; 3 = Moderate; 4 = Above average; 5 = Large impact/Most effective

Appendix B.7: Delphi Survey Round Two Questionnaire (Continued)

Construction Safety and Health Element/Initiative	Round 1 Responses				Round 2 Questions	
	N	Mean	Median	Range	Retain? (Y/N)	Agree? (Yes, or new rating)
Project Contract Safety Requirements						
Safety procedures/requirements specified in bid documents	1	4.0	4.0	4 to 4		
Safety hazard symbols in construction drawings	1	4.0	4.0	4 to 4		
Specification of less hazardous construction materials	3	3.0	3.0	2 to 4		
Safety planning requirements in construction contracts (includes, but not limited to, safety commitment signature, drug/alcohol testing, safety professional, training, incident/near miss recording, stretching program, safety plan)	8	3.9	4.0	2 to 5		
Contractual authority to designers to stop hazardous work	1	3.0	3.0	3 to 3		
Overtime limitation policy/holiday no work guideline in contracts	1	3.0	3.0	3 to 3		
GC pre-bid, pre-award, and pre-construction meetings with subcontractors to discuss safety	6	4.0	4.0	3 to 5		
Designer provides checklist of possible hazards information to GC						
Project Team Selection						
Designer selection based on safety experience (prior project experience and willingness to incorporate safety in design)	4	3.8	4.0	3 to 4		
GC selection based on safety experience (EMR, incident rates, claims rate, prevention programs, personal interviews, OSHA citations)	9	3.9	4.0	2 to 5		
Subcontractor selection based on safety experience (EMR, incident rates, claims rate, prevention programs, personal interviews, OSHA citations)	3	4.0	4.0	3 to 5		
Project Safety Representatives and Qualifications						
Owner full time Safety Representative on site	1	4.0	4.0	4 to 4		
GC full time Safety Representative on site (familiarity with job and work stop	6	3.8	4.0	3 to 5		

authority)						
Subcontractor Safety Representative on site	2	4.0	4.0	3 to 5		
Competent personnel for all high hazard tasks	2	4.5	4.5	4 to 5		
Certification of safety professionals onsite (CHST, CSP)	2	3.5	3.5	3 to 4		
Project Team Safety Commitment						
GC and subcontractor project and senior management involvement in safety (project mission statement, safety addressed in all preconstruction conferences, participation in job walks and other safety activities on site at least monthly)	9	4.1	4.0	2 to 5		
Voluntary partnership with OSHA local office	1	3.0	3.0	3 to 3		
Owner/ Owner's Rep participation in safety related activities	6	4.3		3 to 5		
ZERO injury project goal (posters on fence, orientation room and hard hat) initiated by owner and signed by GC and subs						
Project Safety Planning						
Safety in project conceptual planning	1	5.0	5.0	5 to 5		
Life cycle safety design review	1	4.0	4.0	4 to 4		
Constructability review (GC involvement)	4	4.3	4.0	4 to 5		
Safety in design stage (e.g. fall protection, perimeter guardrailing, safe access of end users maintenance personnel, prefab assemblies)	7	3.7	4.0	2 to 5		
Safety checklist for designers	1	4.0	4.0	4 to 4		
GC site specific safety plan reviewed and approved by owner/agent (should include emergency response plan mock tested, crisis management plan, site security, lockout/tag out, return to work program)	9	3.4	3.3	2 to 4.7		
Subcontractor site specific safety plan (all subs, reviewed and approved by GC/owner)	9	3.6	4.0	2 to 5		
Project Job Hazard Analysis (JHA) and documentation	4	4.5	4.5	4 to 5		
Project Pre-task Planning and documentation	8	4.8	5.0	4 to 5		

Targeted injury reduction plans (falls, electrocution, struckbys, caught in betweens)	1	4.0	4.0	4 to 4		
Project agreements with OSHA (OSHA consultations)	3	4.3	4.0	4 to 5		
Schedule look aheads to avoid trade stacking (minimize crowding and hazards from other trades)	2	4.5	4.5	4 to 5		
Good traffic plans, organized lay down area, and free material flow	4	4.3	4.0	4 to 5		
Good housekeeping with explicit assignment to an individual	4	4.3	4.0	4 to 5		
Proper PPE and PPE information readily available on site	4	3.3	3.0	3 to 4		
Use of fiberglass ladder on all jobsites	1	4.0	4.0	4 to 4		
Use of OSHA-specific trade variance would require PM approval	1	4.0	4.0	4 to 4		
Project Safety Training and Education						
Project Safety orientation for all workers (site specific with presence of direct supervisor) with proper documentation (should include health issues, noise, blood borne pathogens, asbestos, silica, lead, and asbestos awareness…which have high latency period)	12	3.9	4.0	3 to 5		
Toolbox talks (owner and GC involvement)	7	3.6	3.0	2 to 5		
Continuous safety training (in addition to orientation, task specific training, injury free workshops to all personnel)	7	4.3	4.0	3 to 5		
Safety training for designers	1	4.0	4.0	4 to 4		
Safety training for all field supervisors (OSHA 30 hour training)	7	4.0	4.0	3 to 5		
OSHA 10 hour training for all workers	2	4.5	4.5	4 to 5		
GC mentors subs to increase safety performance (lectures, resources, tools provision)	2	3.5	3.5	3 to 4		
Assessment of all equipment operators (cranes, excavators…) skills and training	1	3.0	3.0	3 to 3		
Recruitment of well-trained skilled workers (10 year background check for medical conditions, criminal records that might pose hazard)	2	3.0	3.0	2 to 4		
Owner rep involvement in training						
Project Safety Resources and Tools						
Good onsite safety library, internet/intranet access, task based hazard info database, bilingual)	2	3.5	3.5	3 to 4		

Task based safety exposure database available to all project personnel	1	4.0	4.0	4 to 4		
Project safety newsletter	1	3.0	3.0	3 to 3		
Communication devices for isolated work areas	1	3.0	3.0	3 to 3		
Digital camera to take pictures of hazards	1	2.0	2.0	2 to 2		
At least one AED equipment on site (all supervisors trained to used AED)						
Material Safety Data Sheet (MSDS) Library						
Project Drug & Alcohol (D/A) Program						
Drug and alcohol testing program (pre-employment, random checking, and post accident)	6	3.3	3.2	2 to 5		
Project Accident Investigation (AI) and Reporting						
Detailed accident/near miss investigation, documentation, and corrective action recommendation to prevent repeats	10	4.0	4.0	3 to 4		
Accident/near miss investigation required, and pretask and/or JSA reviewed	1	3.0	3.0	3 to 3		
Superintendent meets CEO/senior management after every accident	1	4.0	4.0	4 to 4		
Indirect cost sheets for every incident on project	1	3.0	3.0	3 to 3		
Project Incentive/Dis-incentive Programs						
Project safety incentive programs (based on injury statistics, safety suggestions, follow safety rules) operated at owner, GC and sub level	10	3.1	2.8	1 to 5		
Project safety violation/dis-incentive programs (based on injury statistics, safety suggestions, follow safety rules) operated at owner, GC and sub level	4	4.3	4.0	4 to 5		
Safety violations reported and discussed between project team (owner, GC, sub) and corrective action taken	1	3.5	3.5	3.5 to 3.5		
Project Safety Worker Involvement						
Project level worker safety committee and safety leadership teams	6	3.7	4.0	2 to 5		
Employees empowered with stop authority for safety concerns and correct them before injury happens	2	4.5	4.5	4 to 5		
Union representation of workers	1	4.0	4.0	4 to 4		

Safety observation (workers look out for each other - Behavior Based Safety)	2	3.0	3.0	2 to 4		
Craft feedback lunches	1	4.0	4.0	4 to 4		
Worker suggestions box and follow up	1	3.0	3.0	3 to 3		
Project Safety Inspection and Corrective action						
Safety inspections (supervisors, foremen, GC safety rep, sub safety rep, owner safety rep at least weekly) of hazards, violations, PPE.	9	4.3	4.0	3 to 5		
Corporate safety professionals inspection at jobsites (GCs and Subs)	1	4.0	4.0	4 to 4		
Project Safety Accountability and Safety Performance Measurement						
Clear project safety authority, responsibility, and accountability	1	5.0	5.0	5 to 5		
Safety metrics to evaluate safety at project level (leading indicators, lagging indicators, update meetings on safety, safety culture perception surveys)	4	4.0	4.0	4 to 4		
Supervisors evaluated based on safety performance	4	3.8	4.5	1 to 5		
Safety performance in end of project contractor evaluation (injury stats)	1	2.0	2.0	2 to 2		
Project Level Industrial Hygiene and Health Practices						
Hearing conservation program (hearing protection over OSHA level)	1	3.0	3.0	3 to 3		
Respiratory protection program (monitoring for chemical and physical hazards)	1	4.0	4.0	4 to 4		
Engineering controls for health hazards	1	4.0	4.0	5 to 4		
Stretch and flex program for all workers	7	3.1	3.0	2 to 4		
Ergonomic task analysis and remediation	1	4.0	4.0	4 to 4		
Hazard communication program						

Comments (optional): Please provide the reason why, you removed an element from the list (if any) and any other comments on the safety and health elements.

Appendix B.8: Delphi Survey Third Round Cover Letter

Thank you for your second round response to my research study involving the development of a sustainable construction safety and health rating system. Your continued participation is appreciated. Eleven safety and health experts participated during the second round of the survey. Data was reviewed to identify the elements that should be retained in the final rating system. This process resulted in a list of 52 unique safety and health elements.

The purpose of this final round survey is to: (1) confirm consensus on the elements and ratings, and (2) gain your input on the structure for the rating system and method for implementation.

1. Please review the elements presented in the attached MS Word document (Round 3 Response form)
   and answer the following two questions:

   3. Should the element be retained in the rating system? If yes, enter "Y"; if not, enter "N".
   4. If you answered "Yes" to Question # a, do you agree with the mean rating given to this particular safety and health element? If yes, enter "Y". If not, please rate the element based on its effectiveness in preventing construction worker injuries/illnesses. Use a scale of 1 to 5 as follows:

1 = Minimal impact/Least effective	2 = Below average
3 = Moderate	4 = Above average
5 = Large impact/Most effective	

2. Please review the attached MS Word document (Rating system structure and method) and provide suggestions on the rating system structure and methodology to allocate credits to each element.

Please respond to these questions based on your knowledge and experience. Your responses can be entered directly in the MS Word documents. When finished with the survey, please return your response to me by e-mail (rajendrs@engr.orst.edu) or by fax (541-737-3300).

Thank you again for your participation in this study. Your participation so far has successfully led to the development of this rating system. Please return the completed form by 5:00 pm (PST) on April 10. Please contact me if you have any questions.

Sincerely,
Sathy Rajendran

Appendix B.9: Delphi Survey Round Three Questionnaire

No	Construction Safety and Health Element/Initiative	Round 2 Response		Round 3 Questions	
		Mean Rating	Yes, Retain element (%)	Retain? (Y/N)	Agree? (Yes, or new rating)
I	**Project Team Selection**				
1	Designer selection based on safety experience (prior project experience and willingness to incorporate safety in design)	3.9	100		
2	GC selection based on safety experience (EMR, incident rates, claims rate, prevention programs, personal interviews, OSHA citations)	4.5	100		
3	Subcontractor selection based on safety experience (EMR, incident rates, claims rate, prevention programs, personal interviews, OSHA citations)	4.3	100		
II	**Project Contract Safety Requirements**				
4	Safety planning requirements in construction contracts (includes, but not limited to, safety commitment signature, drug/alcohol testing, safety professional, training, incident/near miss recording, stretching program, safety plan, GC meeting with Subs to discuss safety)	4.2	100		
5	Safety hazard symbols in construction drawings	3.3	73		
6	Specification of less hazardous construction materials	3.3	82		
III	**Project Safety Representatives and Qualifications**				
7	Owner full time or part time certified Safety Representative on site	3.5	64		
8	GC full time certified Safety Representative on site	3.8	100		
9	Subcontractor full or part time certified Safety Representative on site	3.8	73		
10	Competent personnel for all high hazard tasks	4.6	82		
IV	**Project Team Safety Commitment**				
11	GC and subcontractor project and senior management involvement in safety (project mission statement, safety addressed in all preconstruction conferences, participation in job walks and other safety activities on site at least monthly)	4.5	100		
12	Owner/ Owner's Rep participation in safety related activities	4.1	82		
V	**Project Safety Planning**				

13	Safety in project conceptual planning	4.3	100		
14	Constructability review with GC involvement	4.4	91		
15	Safety in design stage (e.g. fall protection, perimeter guardrailing, safe access of end users maintenance personnel, prefab assemblies)	4.1	100		
16	Life cycle safety design review	3.6	64		
17	Safety checklist for designers	3.8	82		
18	GC site specific safety plan reviewed and approved by owner/agent (should include emergency response plan mock tested, crisis management plan, site security, lockout/tag out, return to work program, targeted injury reduction)	3.8	100		
19	Subcontractor site specific safety plan (all subs, reviewed and approved by GC/owner)	4.1	100		
20	Project Job Hazard Analysis (JHA) and documentation	4.6	91		
21	Project Pre-task Planning and documentation	4.6	100		
22	Schedule look aheads to avoid trade stacking (minimize crowding and hazards from other trades)	4.3	82		
23	Good traffic plans, organized lay down area, and free material flow	4	91		
24	Good housekeeping with explicit assignment to an individual	4.3	91		
25	Proper PPE and PPE information readily available on site	3.3	73		
VI	**Project Safety Training and Education**				
26	Safety training for designers (provide design for safety tools and resources)	4	73		
27	Safety training for all field supervisors (OSHA 30 hour training)	3.8	91		
28	Project Safety orientation for all workers (site specific with presence of direct supervisor) with proper documentation (should include health issues, noise, blood borne pathogens, asbestos, silica, lead, and asbestos awareness…which have high latency period	4	100		
29	OSHA 10 hour training for all workers	3.6	82		
30	Assessment of all equipment operators (cranes, excavators…) skills and training	3.4	73		
31	Toolbox talks (owner and GC involvement)	3.5	82		
32	Continuous safety training (in addition to orientation, task specific training, injury free workshops to all personnel)	3.9	91		
33	GC mentors subs to increase safety performance (lectures, resources, tools provision)	3.6	73		

VII	**Project Safety Resources and Tools**				
34	Task based safety exposure database available to all project personnel	3.5	64		
35	Communication devices for isolated work areas	3.1	73		
VIII	**Project Drug & Alcohol (D/A) Program**				
36	Drug and alcohol testing program (pre-employment, random checking, and post accident)	3.1	100		
IX	**Accident Investigation and Reporting**				
37	Detailed accident/near miss investigation	3.9	91		
38	Accident/near miss investigation require, review with pretask and/or JSA	3.4	82		
39	Superintendent meets CEO/senior management after every "lost time" or "recordable" accident	4.1	64		
X	**Employee Involvement**				
40	Project level worker safety committee and safety leadership teams	3.6	91		
41	Employees empowered with stop authority for safety concerns and correct them	4.6	91		
XI	**Safety Inspection**				
42	Safety inspections (supervisors, foremen, Corp safety reps, GC safety rep, sub safety rep, owner safety rep at least weekly) of hazards, violations, PPE.	3.8	82		
43	Safety violations reported and discussed between project team (owner, GC, sub) and corrective action taken	3.6	73		
XII	**Safety Accountability and Performance Measurement**				
44	Clear project safety authority, responsibility, and accountability	4.9	82		
45	Safety metrics to evaluate safety at project level (leading indicators, lagging indicators, update meetings on safety, safety culture perception surveys)	3.6	82		
46	Supervisors evaluated based on safety performance	4.2	91		
47	Safety performance in end of project contractor evaluation (injury stats)	2.7	64		
XIII	**Industrial Hygiene Practices**				
48	Hearing conservation program	3	64		
49	Respiratory protection program	3.7	73		
50	Engineering controls for health hazards	4.3	64		
51	Stretch and flex program for all workers	2.8	64		
52	Ergonomic task analysis and remediation	3.9	73		

Appendix B.10: Delphi Survey Rating System Structure and Methodology Questionnaire

Introduction
The sustainable safety and health rating system that is being developed will incorporate safety and health elements to be implemented by owners, designers, general contractors, and subcontractors to sustain worker safety and health from project-to-project. The rating system will provide an opportunity to rate projects based on the extent of implementation of those elements identified that promote worker safety and health.

Purpose
The purpose of this part of the study is to gain the expert's opinion on the:

1. Structure of the rating system, and
2. Methodology to grant credits to the projects.

1. Rating system Structure
Projects will receive credits for each of the 52 elements implemented. The credits from each of the elements implemented will add up to a total project credit. A project that incorporates more elements would receive more credits. There will be different levels of recognition, such as certified, silver, gold, and platinum, based on the number of total project credits earned. The premise of the rating system is the higher the number of total credits received by a project, the lower potential for accidents.

Expert Suggestions and Comments: What is your opinion of the proposed rating system structure? How feasible would it be to incorporate such a rating system on a project? Any other comments are appreciated

2. Methodology
The total number of credits for the 52 elements will add up to 100. Some elements will be mandatory while other elements are electives. The following methods for allocating the credits are being considered. Please review the methods and provide your suggestions.

Credit Allocation Method # 1A
Example: Element # 2: General contractor selection based on safety Possible Credits (4.5)

Criteria	Yes = 1; No = 0	Points
Was the general contractor selection criterion include safety performance?	☒ Yes ☐ No	1
Total points received		1
Total points possible		1
Percent of criteria fulfilled		1/1 = 100%
Credit received for this element = Possible credits * % fulfilled = 4.5 * 1.0		**4.5 credits**

Appendix B.10: Expert Opinion on Structure and Methodology Survey (Continued)

Credit Allocation Method # 1B

Example: Element # 2: General contractor selection based on safety-Possible Credits 4.5

Criteria used in GC selection:	Yes = 1; No = 0	Points
EMR	☒ Yes ☐ No	1
Incident rates	☒ Yes ☐ No	1
OSHA citations	☒ Yes ☐ No	1
Personal interviews	☐ Yes ☒ No	0
Safety programs review	☒ Yes ☐ No	1
Claims rate	☐ Yes ☒ No	0
Total points received		4
Total points possible		6
Percent of criteria fulfilled		4/6 = 66%
Credit received for this element = Possible credits * % fulfilled = 4.5 * 0.66		**3.0 credits**

Credit Allocation Method # 2

Example: Element # 13: Safety considered in design of the facility-Possible Credits 4.1

Criteria	Rating
Was safety of workers considered during the design stage? If yes, how detailed was the process, rated on a scale from 1 to 5? If safety was not considered in design "0" points will be awarded. (1 = Very low consideration, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐0 ☐1 ☐2 ☒3 ☐4 ☐ 5
Total points received	3
Total points possible	5
Percent of criteria fulfilled	3/5 = 66%
Credit received for this element = Possible credits * % fulfilled = 4.1 * 0.66	**2.7 credits**

Expert Suggestions and Comments:

1. What is your opinion of the proposed methodologies?
2. How feasible would it be to incorporate each method in practice?
   Any other comments are appreciated.

Appendix B.11: SCSH Rating System Structure and Methodology Responses

Eight responses were received from round 3 "rating system structure and methodology survey." The following are the responses recorded from the surveys for each of the questions asked.

Question #1: What is your opinion of the proposed rating system structure?

- The rating system holds promise as a foundation for introducing elementary-to-intermediate level safety performance on construction projects. However, to assume that simply structure a project using the 52 elements would *guarantee* safety would be unwise. Building good safety performance over time requires a series of steps that follow traditional organizational development rating systems. Improvement begins with enforcing compliance with a set of policies and procedures; or, in the case of this study, the rating system structure. However, as compliance becomes habit, the organization at every level must begin to accept the associated behaviors as desirable – individuals in the organization must make the choice to utilize the rating system structure. The only way this happens in a sustainable fashion is if the organization explicitly professes the results of adherence to the rating system to be a value of the organization. Value is an expression of culture, so the most effective leaders will stimulate the culture of the organization. Without a clear move to Safety as an Organizational Value, the rating system can at best yield Very Good results, but rarely sustainable, world-class results.
- The proposed rating system structure makes a lot of sense and could predict a project's safety potential. However, I think one element above all others will dictate overall performance and probably should be weighted more heavily. GC management commitment to a 0-injury culture. With all other elements the same, a GC owner with a passion for the safety culture will have a far safer work site than one that gives only lip service to safety.
- The main issue I see with the rating system is that some of the items are rated in pre-planning, some during design and some during the construction process. The overall safety outcome of the project is pretty well determined prior to the ability to evaluate some of the items on the list. If the project is evaluated after completion, the rating system will not have any effect on the safety outcome. Another issue is that you could do 51 of the items right and get a good score, but fail on one item or even one time on one item and have a terrible safety record on the project. In other words, a project that gets a platinum score could have a bad safety record. An ideal system would provide ongoing safety input to the team during the whole process so that it could effect needed changes rather than measuring before or after the fact. The whole point is not the measurement system itself, but the safety results that it could bring.
- I believe this it is a feasible rating system structure. As a possible counter-proposal to this rating system structure, part of me thinks that there should be no scalable recognition (i.e. platinum, gold, etc.); either you are meeting the intent of the rating system program or you're not, much more like ISO certification rather than LEEDs

certification. If it is established as a scalable recognition, I would like to see the bar set very high even for meeting the minimum level.

- Well, it depends on if this rating system is a stand-alone rating system or if it is to be integrated with the existing USGBC rating system. If it is focusing on USGBC integration then I would stress that a credit type rating system should be focused on the owner and the designer (but to a lesser extent) since they typically drive “green” projects as we know them today; the constructor(s) implement the criterion. Also, 52 elements is far too many; I’d recommend 5 to 8, perhaps with one or two mandatory, as this thought process is similar to the USGBC credit system. If this is a stand-alone rating system then I think 52 elements is fine.
- The rating system structure seems straight forward and similar to LEED rating, which has really taken off. So I think this structure is feasible but expect your rating system will diffuse much slower than LEED did.
- I like the basic rating system. It incorporates a good range of safety and health practices and structures and rewards organizations for integration of safety into other project activities. The range of elements is wide and deep so it will likely show variation even within particular construction sectors. It will be important to test the rating system against reality both in seeing how far from the ideal the typical project is and in assessing how closely you’ve hit the real elements that relate to safety performance. I notice in looking over the final elements that it’s a little light on specific safety issues. Interestingly, the last section specifies certain health areas- noise, respiratory, musculoskeletal- but the only specific references like this on the safety side are in the safety in design element (15). I’m not sure it’s necessary to change this as any good safety program is going to address falls, electrical hazards, trenching, and the other major safety concerns in construction. But it’s something to think about in terms of audience acceptance of the rating system.
- I’m not sure how it would work in practice. Is this a self-assessment? I think that it could miss important qualitative evaluation and become too mechanical.

<u>Question #2: How feasible would it be to incorporate such a rating system on a project?</u>

- I see a potential problem with consistency if you compare scores from different raters. This rating system will yield better results with the fewest number of different people involved in rating the projects.
- I believe its success would depend on closely following LEEDs or other certification rating systems in existence. Development of the credit allocation will need careful attention since it involves some subjective evaluation. I would also like to see examples provided to help clarify expected deliverables (documentation) to owners, designers, GCs and subs for eligible credit.
- Many items may be difficult to measure. I recommend quantitative aspects for items such as EMR (i.e., credit counts for EMR if X% of constructor(s) selected for the project have an EMR below 1.
- As to feasibility, I think the answer, like many others in construction safety, lies in who drives it. The availability of the rating system can potentially help in a number of ways. It will be most effective and feasible if owners push it for their projects. It

will resonate most with owners who have already thought about many of these issues and acted on some. That is one place to promote it. I think it can be useful to groups like ASSE and OSHA agencies who can point to at as another inventory of elements by which a company can benchmark itself, and one that some serious thought has gone into. The parallel to the LEEDS criteria will make it recognizable to both the construction and design communities. That seems like the smartest strategy for promotion and the stronger that link the more feasible it will be to get a larger segment of the industry to pay attention to it.

- It could be used, but like the comment above, who would be doing the rating?

Question #3: What is your opinion of the proposed methodologies?

- This methodology looks to me to be a good way to assess the relative maturity of a project at inception, and a good leading indicator for what might be expected throughout the project. However, it needs an underlying philosophy and organizational development rating system, otherwise it is simply a set of rules and scores without context.
- I like it and am interested to see how it works in practice. I like the Credit Allocation Method of #1B better than # 1A. The more specific detail contained in the criteria, the more uniform and meaningful the rating. I suggest you add wording to some of the criteria to give credit for familiarity with subjects. For example, if an owner is familiar with a GC and uses them regularly, the owner would not have to review the S&H plan nor interview them. I suggest wording such as "Personal Interviews/Personal Knowledge" and "Safety Program Reviews/Personal Knowledge of Plan."Non-uniformity between different raters may be a problem.
- Method 2 is superior—the activities included in the survey are rarely absolute.
- I like this methodology, and I think it is very feasible. As in previous comment above, I would like to see examples provided for obtaining optimal credit for each criteria. It will also be important to develop the rating evaluation with comment from prominent, progressive EHS professionals. It may not be possible to totally get away from subjective evaluation, but the more objective the criteria for each element, the better.
- I like 1B as proposed above. In keeping a credit system limited this is a great way to incorporate various aspects into one criterion. For example, I would suggest in #2 above, that the credit include both design and conceptual planning and include various elements from the rating system (#1, 2, 3, 4, 11, 12, 14, 16, 17, 22 among other) as sub-elements as you do in 1B above. Question – In auditing a project's score, will there be specific parameters for 1B? For example on EMR, will a pre-determined percentage of contractors and subs need to have an EMR less than a certain number? (i.e., credit is given if 75% of all constructor companies selected have an EMR less than 1 – same with other items). 1A is too simplistic and allows too much judgment on the auditor's part. If it includes one criterion (as I the example in 1A) is it a yes? Ranking as in #2 above, appears too subjective in the score. What is the difference between a 2 and 3 for example? If using this method, you'd need to assign criteria to scores or something to make the process or

objective. I think this method is too subjective for this process. I recommend making the scoring as objective and as clear as possible.

- I think a Likert scale is appropriate but the questions are much too vague. People don’t like vague questions unless specific ones would require work on their part to answer.
- Method 1A is the most feasible and least time-consuming in practice but the least satisfactory in terms of how meaningful the score would be. There must be a means of assessing the elements beyond “exists” or “does not exist” in order for the rating system to have significant meaning. In looking over the elements I see that virtually all of them could exist on paper without having much substance in reality. For example, #50 Engineering controls for health hazards could be put in a written safety plan as a goal, but in reality whenever such controls are considered they are dismissed as too costly. On the other hand the contractor could evaluate the feasibility of ventilation controls vs PPE for dust hazards and implement sometimes but not others based on cost, location, etc. The latter would reflect a good faith effort on engineering controls and should be rewarded with 3 out of 4 credits, while the former should get 1 out of 4 at the most. Under 1A both would probably get full credit._I could see a rating system that employed both 1B and 2 depending on the nature of the element. Those that lend themselves to multiple sub-elements could legitimately be scored on that basis. Those for which it is harder to identify discrete sub-elements are better graded on a scale as in method 2. Some survey researchers prefer a 1-4 scale rather than 1-5 because they feel it forces choices by the respondent (or assessor in this case). I’m not sure whether that applies in this case. I like the language in 2 that gives the assessor guidance in how to grade the element. I assume this would be provided for all elements._If I had to choose between 1B and 2 I would probably select 2 because it is more widely applicable through all the elements. _The more detailed evaluation required in the methods I prefer might be a deterrent to wider application of the rating system. It would be worth putting some up-front research into this question to see if you get significantly different scores using the yes/no method vs the scale or sub-elements. If the results were not very different then you’d have an argument for using the simpler system (1A).
- I think that #1 B works best for me and would allow more specific criteria for the specific element.

Question #4: How feasible would it be to incorporate each method in practice?

- Again, who would be doing the evaluation, and at what stage of the project. To be done early, where there’s a chance to change, some of the elements could not be evaluated yet
- #1A – too simplistic; #2 – too subjective
  #1B – most feasible if criteria for each sub item is objectively stated
- Method 2 is superior—the activities included in the survey are rarely absolute.
- I think this would be feasible to apply in practice. It would definitely identify the poorer candidates and the higher risk projects.
- The methodologies would be easy to implement as a leading indicator. Equivalent process exists on Intel projects. I reiterate, however, that the equivalent process is just an element of Intel’s organizational value of safety.

Appendix B.12: Sustainable Construction Safety and Health (SCSH) Rating System

The Sustainable Construction Safety and Health (SCSH) rating system consists of safety and health elements to be implemented by owners, designers, constructors, and subcontractors to sustain worker safety and health from project-to-project. The rating system provides an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of those safety and health elements. This rating system is aimed at certifying all project types.

The SCSH rating system is organized into 13 major safety and health categories. Each category contains sustainable safety and health elements, which carry credits based on their effectiveness in preventing construction worker injuries/illnesses. The credits under these categories add up to a total of 100 credits. In order to get certified a project must fulfill all of the 25 required elements to some degree that add up to 54.5 credits. A project that incorporates more elements would receive more credits. The premise of the rating system is a higher number of total credits received by a project would indicate a lower potential for incidents that lead to construction worker injuries, illnesses and fatalities.

Each element page consists of three sections: Purpose, Requirements, and Submittals. The intent of the element is described briefly under the Purpose section. The Requirements section provides information on what the necessary activities to be fulfilled as part of this element. The Submittal section lists the documentation required to receive the credit. The calculation tables that are part of each element are simple and self explanatory.

Sustainable Construction Safety and Health (SCSH) Checklist

(R = Required, E = Elective)

Project Team Selection			6.6 Possible Credits
R	Element 1.1	Constructor Selection	2.3
R	Element 1.2	Subcontractor Selection	2.3
E	Element 1.3	Designer Selection	2.0
Safety and Health in Contracts			5.5 Possible Credits
R	Element 2.1	Safety and Health Requirements in Contracts	2.2
E	Element 2.2	Safety and Health Hazard Identification in Drawings	1.6
E	Element 2.3	Specification of Less Hazardous Materials	1.7
Safety and Health Professionals			8.1 Possible Credits
R	Element 3.1	Competent Personnel for All High Hazard Tasks	2.4
E	Element 3.2	Owner Safety Representative	1.8
E	Element 3.3	Constructor Safety Representative	2.0
E	Element 3.4	Subcontractor Safety Representative	1.9
Safety and Health Commitment			4.3 Possible Credits
R	Element 4.1	Management Commitment to Safety and Health	2.3
R	Element 4.2	Owner/Representative Commitment to Safety and Health	2.0
Safety and Health Planning			27.8 Possible Credits
R	Element 5.1	Safety and Health During Conceptual Planning Phase	2.3
R	Element 5.2	Constructability Review	2.3
R	Element 5.3	Designing for Worker Safety and Health	2.2
R	Element 5.4	Life Cycle Safety Design Review (LCS)	2.0
R	Element 5.5	Safety Checklist for Designers	2.1
R	Element 5.6	Constructor Site Specific Safety Plan	2.0
R	Element 5.7	Subcontractor Site Specific Safety Plan	2.1
R	Element 5.8	Job Hazard Analysis	2.3
R	Element 5.9	Pre-task Planning	2.3
R	Element 5.10	Look Ahead Schedule	2.1
R	Element 5.11	On and Off site Traffic Plan	2.1
R	Element 5.12	Good housekeeping Plan	2.2
E	Element 5.13	Personnel Protection Equipment (PPE) Plan	1.8
Training and Education			15.3 Possible Credits
R	Element 6.1	Safety Training for Designers	2.0
R	Element 6.2	Safety Orientation for All Workers	2.0
E	Element 6.3	Safety Training for All Field Supervisors	2.0
E	Element 6.4	OSHA 10-hour Training for All Workers	1.8
E	Element 6.5	Equipment Operators Skills and Training Assessment	1.8
E	Element 6.6	Toolbox Meetings	1.8
E	Element 6.7	Regular Safety Training for All Project Personnel	2.0

E	Element 6.8	Constructor Mentors Subs to Improve Safety Performance	1.9
Safety Resources			1.8 Possible Credits
E	Element 7.1	Task-based Hazard Exposure Database	1.8
Drug and Alcohol Program			1.8 Possible Credits
E	Element 8.1	Drug and Alcohol Testing Program	1.8
Accident Investigation and Reporting			3.7 Possible Credits
R	Element 9.1	Accident and Near Miss Investigation	2.0
E	Element 9.2	Accident and Near Miss Investigation with pre-task/JHA	1.7
Employee Involvement			4.2 Possible Credits
R	Element 10.1	Employees Empowered with Stop Authority	2.3
E	Element 10.2	Employee Safety Committee and Leadership Team	1.9
Safety Inspection			3.8 Possible Credits
E	Element 11.1	Safety Inspections	2.0
E	Element 11.2	Safety Violations identified and corrected	1.8
Safety Accountability and Performance Measurement			8.0 Possible Credits
R	Element 12.1	Project Accountability and Responsibility	2.4
R	Element 12.2	Supervisors Evaluated Based on Safety Performance	2.2
E	Element 12.3	Safety Performance Evaluation using safety metrics	1.9
E	Element 12.4	Contractor Evaluation Based on Safety Performance	1.5
Industrial Hygiene Practices			9.1 Possible Credits
R	Element 13.1	Engineering Controls for Health Hazards	2.1
E	Element 13.2	Hearing Protection Program	1.6
E	Element 13.3	Respiratory Protection Program	1.9
E	Element 13.4	Stretch and Flex Program	1.5
E	Element 13.5	Ergonomic Task Analysis and Remediation	2.0
Project Total			100 Possible Credits

Certified 54-60 credits; **Silver** 60-75 credits; **Gold** 76-90 credits; **Platinum** 91-100 credits
All required elements to be fulfilled for all levels of certification

1.0 Project Team Selection

Element 1.1: Constructor Selection
Possible Credits: 2.3
Type: Required

Purpose

Employ a constructor with a good safety record.

Requirements

The owner should select a constructor based in part on past safety performance. Criteria used for selection should include the following: Experience Modification Rating (EMR); incident rates (OSHA recordable rate and lost time rate); claims rate; number of OSHA citations in the past 3 years; personal interview/personal knowledge of the constructor's safety performance; and review of the constructor's safety program.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner and the constructor.

Criteria used in constructor selection:		**Points (Yes = 1; No = 0)**
EMR	☐ Yes ☐ No	
Incident rates	☐ Yes ☐ No	
OSHA citations	☐ Yes ☐ No	
Personal interviews/knowledge	☐ Yes ☐ No	
Safety programs review	☐ Yes ☐ No	
Claims rate	☐ Yes ☐ No	

Total points received =	
Total points possible =	6
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

1.0 Project Team Selection

Element 1.2: Subcontractor Selection
Possible Credits: 2.3
Type: Required

Purpose

Employ subcontractors with good safety records.

Requirements

The constructor should select subcontractors based in part on past safety performance that include: Experience Modification Rating (EMR); incident rates; claims rates; number of OSHA citations in the past 3 years; personal interview/personal knowledge of the contractor's safety performance; and review of the subcontractor's safety program.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and all of subcontractors who where part of the project.

Criteria used in subcontractor selection:		**Points (Yes = 1; No = 0)**
EMR	☐ Yes ☐ No	
Incident rates	☐ Yes ☐ No	
OSHA citations	☐ Yes ☐ No	
Personal interviews/knowledge	☐ Yes ☐ No	
Safety programs review	☐ Yes ☐ No	
Claims rate	☐ Yes ☐ No	

Total points received =	
Total points possible =	6
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

1.0 Project Team Selection

Element 1.3: Designer Selection
Possible Credits: 2.0
Type: Required

Purpose

Employ designers with construction safety knowledge and experience.

Requirements

The owner should select a designer based on past experience, knowledge, and willingness to incorporate worker safety and health in the project design. Selection should include: checking past records on designer experience, knowledge of safety and health in design concepts, and personal interviews/knowledge.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner and the designer.

Criteria used in designer selection:		**Points (Yes = 1; No = 0)**
Past safety experience	☐ Yes ☐ No	
Knowledge of construction safety and health	☐ Yes ☐ No	
Willingness to design for safety	☐ Yes ☐ No	
Personal interviews/knowledge	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	4
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

2.0 Safety and Health in Contracts

Element 2.1: Safety and Health Requirements in Contracts
Possible Credits: 2.2
Type: Required

Purpose

Inclusion of safety and health requirements in construction contracts

Requirements

The owner should incorporate safety and health requirements in the contract with the constructor. The owner should also require the constructor to include the same requirements in subcontracts. The requirements should include: full time safety professional for constructor and at least part time for subcontractors, mandatory drug and alcohol testing program, mandatory safety orientations and site specific training to all workers on site, investigation of all near misses, site specific safety plan, management commitment through mission statement, pre-bid, pre-award, pre-construction meetings of constructor with subcontractors to discuss safety and health.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, designer, constructor, and subcontractors.

Criteria used in contracts terms:		**Points (Yes = 1; No = 0)**
Safety representative	☐ Yes ☐ No	
Drug and alcohol program	☐ Yes ☐ No	
Orientation and site specific training for all workers	☐ Yes ☐ No	
Near miss investigations	☐ Yes ☐ No	
Site specific safety plan	☐ Yes ☐ No	
Top management commitment	☐ Yes ☐ No	
Pre-bid, award, construction safety meetings	☐ Yes ☐ No	

Total points received =	
Total points possible =	7
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

2.0 Safety and Health in Contracts

Element 2.2: Safety and Health Hazard Identification in Drawings
Possible Credits: 1.6
Type: Required

Purpose

Include identification of construction hazards in the construction documents.

Requirements

The designers should identify potential safety and health hazards associated with the work by including hazard symbols or other features in the construction drawings.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, subcontractor, and designer.

Criteria	Rating
Were safety and health hazards identified in the construction drawings? If yes, how detailed was the process, rated on a scale from 1 to 5? If this criteria was not considered, "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

2.0 Safety and Health in Contracts

Element 2.3: Specification of Less Hazardous Materials
Possible Credits: 1.7
Type: Required

Purpose

Specify less hazardous construction materials to eliminate health hazards.

Requirements

To satisfy this credit, the designers should specify less hazardous materials.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, subcontractor, and designer. A list of all of the alternative materials specified should be submitted along with this calculation sheet.

Criteria	Rating
Was specification of less hazardous materials considered/ specified? If yes, how detailed was the process, rated on a scale from 1 to 5? If criterion was not considered, "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

3.0 Safety and Health Professionals

Element 3.1: Competent Personnel for All High Hazard Tasks
Possible Credits: 2.4
Type: Required

Purpose

Assign competent person for all high hazard tasks.

Requirements

The constructor and subcontractors should assign a competent person who is capable of identifying existing and predictable hazards in the work environment, which are hazardous or dangerous, and has the authority to stop work or take corrective actions to eliminate the conditions. A list of all major activities in the project should be created and whether or not a competent person would be required at the start of the project. In addition to the OSHA-required competent person mandate, the competent personnel should be required for various other activities.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors. A list of all of the activities and the corresponding competent person assigned to that particular task with name and a signature.

Criteria		**Points (Yes = 1; No = 0)**
Were competent personnel assigned for all high hazard tasks?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

3.0 Safety and Health Professionals

Element 3.2: Owner Safety Representative
Possible Credits: 1.8
Type: Elective

Purpose

Owner ensures construction site safety efforts by appointing an owner safety representative.

Requirements

The owner should assign a full-time or part-time safety professional on-site depending on the project size.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner and constructor.

Criteria	Points (Yes = 1; No = 0)
Did the project have an owner safety professional?	☐ Yes ☐ No
Total points received =	
Total points possible =	1
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

3.0 Safety and Health Professionals

Element 3.3: Constructor Safety Representative
Possible Credits: 2.0
Type: Elective

Purpose

Ensure safety efforts by appointing a full time safety professional for the project.

Requirements

The constructor should assign a safety representative for the project.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner and constructor.

Criteria		Points (Yes = 1; No = 0)
Did the project have a full time safety professional representing the constructor?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

3.0 Safety and Health Professionals

Element 3.4: Subcontractor Safety Representative
Possible Credits: 1.9
Type: Elective

Purpose

Ensure safety efforts by appointing a safety professional for the project.

Requirements

Subcontractors should assign a safety professional on-site depending on the project size.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors.

Criteria		Points (Yes = 1; No = 0)
Did the project have a subcontractor safety professional (full-time/part-time)?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

4.0 Safety and Health Commitment

Element 4.1 Management Commitment to Safety and Health
Possible Credits: 2.0
Type: Required

Purpose

Ensure strong safety commitment from constructor and subcontractor management.

Requirements

In order to receive full credits, management from all of the parties involved should: sign a project safety mission statement, address safety in all project conferences, visit job sites at least once a month, participate in accident investigation (lost time injuries), and review company safety plans.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractor. Attachments should be submitted with the calculation sheet that includes: all mission statements, minutes of conferences, job visit logs, and evidence of safety plan review.

Criteria		**Points (Yes = 1; No = 0)**
Safety mission statement signed	☐ Yes ☐ No	
Safety addressed in meetings	☐ Yes ☐ No	
Job site visits (monthly)	☐ Yes ☐ No	
Participation in accident investigation	☐ Yes ☐ No	
Review of project safety plan	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	5
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

4.0 Safety and Health Commitment

Element 4.2: Owner Commitment to Safety and Health
Possible Credits: 2.3
Type: Required

Purpose

Ensure strong safety commitment from the owner and owner's representative.

Requirements

The owner or owner's representative should participate in various safety activities on site that include: sign a project safety mission statement, accident investigation, participation in safety meetings, and tool box talks, job site visits, review the constructors project plan, and allocate budget for safety.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors. A list of all safety related activities participated in by the owner and owner's representative should be attached.

Criteria		**Points (Yes = 1; No = 0)**
Safety mission statement signed	☐ Yes ☐ No	
Participation in meetings	☐ Yes ☐ No	
Job site visits (monthly)	☐ Yes ☐ No	
Participation in accident investigation	☐ Yes ☐ No	
Review of project safety plan	☐ Yes ☐ No	
Safety Budget	☐ Yes ☐ No	

Total points received =	
Total points possible =	6
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled **=**	

5.0 Safety and Health Planning

Element 5.1: Safety and Health During Conceptual Planning Phase
Possible Credits: 2.3
Type: Required

Purpose

Address worker safety during the conceptual planning stages of the project.

Requirements

Construction worker safety and health should be considered during the project conceptual planning phase.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, subcontractor, and designer. A list of all considerations should be submitted along with this calculation sheet.

Criteria	Rating
Was safety of workers considered during the conceptual planning stage? If yes, how detailed was the process, rated on a scale from 1 to 5? If safety was not considered, "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

5.0 Safety and Health Planning

Element 5.2: Constructability Review
Possible Credits: 2.3
Type: Required

Purpose

Improve safety and health performance of the project by considering the "buildability" or "constructability" of the design.

Requirements

A detailed constructability review should be conducted with the involvement of the constructor.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, subcontractor, and designer. A list of all considerations and improvements should be submitted along with this calculation sheet.

Criteria	Rating
Was a detailed constructability review conducted? If yes, how detailed was the process, rated on a scale from 1 to 5? If not conducted, "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

5.0 Safety and Health Planning

Element 5.3: Designing for Worker Safety and Health
Possible Credits: 2.3
Type: Required

Purpose

Address safety during the design stage.

Requirements

Construction worker safety and health should be considered during the project design phase.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, subcontractor, and designer. A list of all considerations should be submitted along with this calculation sheet.

Criteria	Rating
Was safety of workers considered during the design stage? If yes, how detailed was the process, rated on a scale from 1 to 5? If safety was not considered in design, "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

5.0 Safety and Health Planning

Element 5.4: Life Cycle Safety Design Review
Possible Credits: 2.0
Type: Required

Purpose

Minimize safety hazards by conducting life cycle safety design review.

Requirements

Construction worker safety and health considered during the entire life cycle of the project from conceptual planning to operations and maintenance.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, subcontractor, and designer. A list of all considerations should be submitted along with this calculation sheet.

Criteria	Rating
Was safety of workers considered from a life cycle safety design perspective? If yes, how detailed was the process, rated on a scale from 1 to 5? If life cycle safety was not considered in design, "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

5.0 Safety and Health Planning

Element 5.5: Safety Checklist for Designers
Possible Credits: 2.1
Type: Required

Purpose

Provide a checklist of safety considerations to be considered during design.

Requirements

Designer should be provided with a checklist of all hazards for consideration during the design process.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner and designer. The checklist should be submitted along with this calculation sheet.

Criteria		**Points (Yes = 1; No = 0)**
Was the designer provided with a safety checklist?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

5.0 Safety and Health Planning

Element 5.6: Constructor Site Specific Safety Plan
Possible Credits: 2.0
Type: Required

Purpose

Prepare a site-specific safety plan.

Requirements

The constructor should prepare a site specific safety plan that includes atleast the following: emergency response plan mock tested, crisis management plan, site security, lockout/tag out, return to work program, and targeted injury reduction plan. This plan should be reviewed and approved by the project owner.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and all of subcontractors who are part of the project.

Criteria		**Points (Yes = 1; No = 0)**
Did the project have a constructor site-specific safety plan?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

5.0 Safety and Health Planning

Element 5.7: Subcontractor Site Specific Safety Plan
Possible Credits: 2.1
Type: Required

Purpose

Prepare a subcontractor site-specific safety plan.

Requirements

All subcontractors should prepare a site specific safety plan that includes at least the following: emergency response plan mock tested, crisis management plan, site security, lockout/tag out, return to work program, and targeted injury reduction plan. This plan should be reviewed and approved by the project owner and the constructor.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and all of subcontractors who are part of the project.

Criteria		**Points (Yes = 1; No = 0)**
Did the project have a subcontractor site-specific safety plan reviewed and approved by the constructor?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

5.0 Safety and Health Planning

Element 5.8: Job Hazard Analysis
Possible Credits: 2.3
Type: Required

Purpose

Envision potential hazards by Conducting Job Hazard Analyses (JHA).

Requirements

Detailed Job Hazard Analyses should be prepared for all tasks that are part of the project.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and all of subcontractors who are part of the project. All of the Job Hazard Analyses prepared, as part of the project should be attached with the calculation sheet.

Criteria		**Points (Yes = 1; No = 0)**
Were Job Hazard Analyses performed for all of the tasks on the project?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled **=**	

5.0 Safety and Health Planning

Element 5.9: Pre-task Planning
Possible Credits: 2.3
Type: Required

Purpose

Envision potential hazards and review each activity by conducting a pre-task plan.

Requirements

A detailed pre-task plan should be prepared for all of the tasks as part of the project.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and all of subcontractors who are part of the project. All of the pre-task plans prepared, as part of the project should be attached with the calculation sheet.

Criteria		**Points (Yes = 1; No = 0)**
Were pre-task plans prepared for all jobs on the project?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

5.0 Safety and Health Planning

Element 5.10: Look-Ahead Schedule
Possible Credits: 2.1
Type: Required

Purpose

The purpose of this credit is to improve the safety and health performance of the project by preparing look-ahead schedules to avoid trade stacking.

Requirements

Look-ahead schedules should be prepared and reviewed to avoid trade stacking.

Submittals

The calculation sheet provided below should be submitted with signatures from the constructor and subcontractors.

Criteria		**Points (Yes = 1; No = 0)**
Were look-ahead schedule prepared on the project to avoid trade stacking?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

5.0 Safety and Health Planning

Element 5.11: On and Off-site Traffic Plan
Possible Credits: 2.1
Type: Required

Purpose

Control traffic on and off site and material flow within the site.

Requirements

Prepare a detailed traffic control and lay down area plan.

Submittals

The calculation sheet provided below should be submitted with signatures from the constructor and subcontractors. The traffic control plan and lay down area plan should be submitted with the calculation sheet.

Criteria		**Points (Yes = 1; No = 0)**
Was a traffic control and lay down area plan prepared?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

5.0 Safety and Health Planning

Element 5.12: Good Housekeeping Plan
Possible Credits: 2.2
Type: Required

Purpose

Maintain a clean project to prevent injuries.

Requirements

Prepare and implement a detailed housekeeping plan with assigned responsibility.

Submittals

The calculation sheet provided below should be submitted with signatures from the constructor and subcontractors. The housekeeping plan with a signature from the assigned person should also be submitted with the calculation sheet.

Criteria		**Points (Yes = 1; No = 0)**
Was a detailed housekeeping plan with assigned responsibility prepared and implemented?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

5.0 Safety and Health Planning

Element 5.13: Personnel Protective Equipment (PPE) Plan
Possible Credits: 1.8
Type: Elective

Purpose

Protect workers from hazards by providing Personal Protective Equipment.

Requirements

Require all workers to wear proper Personal Protective Equipment and provide all necessary information to the workers on all PPE used on the project.

Submittals

The calculation sheet provided below should be submitted with signatures from the constructor and subcontractors.

Criteria		**Points (Yes = 1; No = 0)**
Were all workers required to wear PPE?	☐ Yes ☐ No	
Was information on all PPE available to the workers?	☐ Yes ☐ No	
Total points received =		
Total points possible =		2
% of criteria fulfilled = Points received/Points possible =		
Credit received = Possible credits * % of criteria fulfilled =		

6.0 Training and Education

Element 6.1: Safety Training for Designers
Possible Credits: 2.0
Type: Required

Purpose

Train designers about construction worker safety to eliminate hazards at the source.

Requirements

The project designers should undergo training to incorporate construction safety and health during the initial stages of the project.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner and the designer. Documentation identifying the training should be attached.

Criteria	**Points (Yes = 1; No = 0)**
Did the designers receive safety training? ☐ Yes ☐ No	
Total points received =	
Total points possible =	1
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

6.0 Training and Education

Element 6.2:	Safety Orientation for All Workers
Possible Credits:	2.0
Type:	Required

Purpose

Orient workers to the site and to working in a safe manner.

Requirements

All of the workers on the project should go through on-site safety orientation before starting work on the project. The orientation should be site specific.

Submittals

The calculation sheet provided below should be submitted with signatures from the constructor and subcontractors. Documentation showing that all the workers received safety orientation should also be submitted.

Criteria	Number
Total number of workers on the project	
Number of workers receiving safety orientation	

% of criteria fulfilled = Number of workers who received safety orientation /Number of workers =

Credit received = Possible credits * % of criteria fulfilled **=**

6.0 Training and Education

Element 6.3: Safety Training for All Field Supervisors
Possible Credits: 2.0
Type: Elective

Purpose

Educate and train field supervisors on how to ensure and improve project safety performance.

Requirements

All of the field supervisors should be educated and trained in proper safety and health procedures that include OSHA 30-hour training certification.

Submittals

The calculation sheet provided below should be submitted with signatures from the constructor and subcontractors. Documentation showing that all of the supervisors received OSHA 30 hour training should be submitted.

Criteria	Number
Total number of field supervisors on the project	
Number of field supervisors receiving OSHA 30 hr certification	

% criteria fulfilled = Number of supervisors with certification/ Number of supervisors =

Credit received = Possible credits * % of criteria fulfilled =

6.0 Training and Education

Element 6.4: OSHA 10-hour Training for All Workers
Possible Credits: 1.8
Type: Elective

Purpose

Educate and train the construction workers regarding the construction hazards, safety procedures, and regulatory requirements.

Requirements

All of the construction workers on the project should be educated and trained through OSHA 10-hour certification.

Submittals

The calculation sheet provided below should be submitted with signatures from the constructor and subcontractors. Documentation showing that all of the workers received OSHA 10 hour certification should also be submitted.

Criteria	Number
Total number of workers on the project	
Number of workers receiving OSHA 10 hr certification	

% of criteria fulfilled = Number of workers with certification/ Number of workers =
Credit received = Possible credits * % of criteria fulfilled =

6.0 Training and Education

Element 6.5: Assessment of all Equipment Operators Skills and Training
Possible Credits: 1.8
Type: Elective

Purpose

Ensure proper safety credentials of construction equipment operators.

Requirements

All of the construction equipment operators should be assessed on their skills and training before being allowed to perform work on-site.

Submittals

The calculation sheet provided below should be submitted with signatures from the constructor and subcontractors. Documentation showing that all of the operators had proper training and skills should also be submitted.

Criteria		**Points (Yes = 1; No = 0)**
Were the construction equipment operators' skills and training verified before operating equipment on site?	☐ Yes ☐ No	
Total points received =		
Total points possible =		1
% of criteria fulfilled = Points received/Points possible =		
Credit received = Possible credits * % of criteria fulfilled =		

6.0 Training and Education

Element 6.6: Toolbox Meetings
Possible Credits: 1.8
Type: Elective

Purpose

Assure that all workers are aware of the safe work practices and procedures for their assigned work.

Requirements

Foremen should conduct toolbox talks at the crew level during the project.

Submittals

The calculation sheet provided below should be submitted with signatures from the constructor and subcontractors. Toolbox meeting records should be submitted.

Criteria		**Points (Yes = 1; No = 0)**
Are toolbox (safety) meetings held regularly on the jobsite at the crew level?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

6.0 Training and Education

Element 6.7: Regular Safety Training to All Project Personnel
Possible Credits: 2.0
Type: Elective

Purpose

Educate and train project personnel on safety.

Requirements

All project personnel should be given regular safety training during the project as seen pertinent.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors.

Criteria		Points (Yes = 1; No = 0)
Was regular safety training given to all project personnel?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

6.0 Training and Education

Element 6.8: Constructor Mentors Subs on Safety and Health
Possible Credits: 1.9
Type: Elective

Purpose

The constructor mentors subcontractors on worker safety and health to help improve their awareness of worker safety and health.

Requirements

Constructor should seize every opportunity to help subcontractors and teach them about worker safety and health.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractor. Documentation on any mentoring event should be submitted.

Criteria	Rating
Were subs mentored by the constructor? If yes, how frequent was the process, rated on a scale from 1 to 5? If no, "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

7.0 Safety and Health Resources

Element 7.1: Task-based Hazard Exposure Database
Possible Credits: 1.8
Type: Elective

Purpose

Educate project personnel on the hazards associated with all major construction tasks.

Requirements

A detailed task based hazard exposure database should be created and maintained during the project. It should be readily available to all project personnel.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor and subcontractors. A copy of the database should also be submitted with the calculation sheet.

Criteria		**Points (Yes = 1; No = 0)**
Was a detailed task based hazard exposure database prepared and implemented?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

8.0 Drug and Alcohol Program

Element 8.1: Drug and Alcohol testing Program
Possible Credits: 1.8
Type: Elective

Purpose

Prevent workers under the influence of drugs and alcohol from working to prevent injuries while on the jobsite.

Requirements

All employees must be tested for drugs and alcohol: prior to employment, post incident (all incidents), and randomly. Any employee who tested positive should not be allowed to carry out work on the site.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors.

Criteria		**Points (Yes = 1; No = 0)**
Pre-employment screening	☐ Yes ☐ No	
Random testing during course of employment	☐ Yes ☐ No	
Post incident testing	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	3
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled **=**	

9.0 Accident Investigation and Reporting

Element 9.1: Accident and Near Miss Investigation
Possible Credits: 2.0
Type: Required

Purpose

To conduct thorough accident and near miss investigation.

Requirements

All accidents and near misses should be recorded and investigated, and corrective action should be taken to prevent similar accidents in the future.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor and subcontractors. Documentation of all accident and near miss investigations should be submitted.

Criteria	Number
Total number of accidents and near misses on the project	
Number of accidents and near misses investigated	

% of criteria fulfilled = Number of accidents and near misses/
Number of investigations conducted =
Credit received = Possible credits * % of criteria fulfilled =

9.0 Accident Investigations and Reporting

Element 9.2: Accident and Near Miss Investigation with Pre-task Planning/JHA
Possible Credits: 2.0
Type: Elective

Purpose

Use of Pre-task planning /JHA with accident and near miss investigation.

Requirements

All accidents and near misses should be recorded and investigated, and corrective action should be taken to prevent similar future accidents. Pre-task planning/JHA of the activity associated with the accident should be used during the investigation. The findings should be communicated through pre-task plans/JHA of similar activities.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors. Documentation of all accident and near miss investigations should be submitted.

Criteria	Number
Total number of accidents and near misses on the project	
Number of pre-task plans and JHAs prepared during accidents and near misses investigated	

% of criteria fulfilled = Number of accidents and near misses/ Number of pre-task plans and JHAs prepared and used =

Credit received = Possible credits * % of criteria fulfilled =

10.0 Worker Involvement

Element 10.1: Employees Empowered with Stop Authority
Possible Credits: 2.3
Type: Required

Purpose

Empower employees to stop hazardous work.

Requirements

The workers should be given the authority to stop work in case of any hazardous work or condition on the job site.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors.

Criteria		Points (Yes = 1; No = 0)
Are the workers empowered to stop hazardous work?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

10.0 Worker Involvement

Element 10.2: Employee Safety Committee and Leadership Team
Possible Credits: 1.9
Type: Elective

Purpose

Inform and educate project personnel about the jobsite hazards and abatement methods.

Requirements

Safety committees should be formed whose goal is to oversee project safety efforts and to ensure compliance with project safety plans and other applicable government regulations. The overall goal should be implemented through worker safety committees (small group with workers and a leader) and leadership teams (all project group leaders, safety professional, and superintendent). The committees should meet at least once every week and plan proactively to eliminate injuries.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors. Documentation of all of these meetings should be submitted along with the calculation sheet.

Criteria	Number
Total number of weeks in the project multiplied by four	
Number of worker committee and leadership committee meetings held	
% of criteria fulfilled = Number of Committee Meetings / (Number of weeks *4) =	
Credit received = Possible credits * % of criteria fulfilled =	

11.0 Inspection

Element 11.1: Safety Inspection
Possible Credits: 2.0
Type: Elective

Purpose

Identify and eliminate potential construction safety and health hazards during the work.

Requirements

The superintendent, constructor safety professional, subcontractor safety professional, owner safety professional, management personnel, and foremen should conduct safety inspections on a regular basis. All potential hazards identified must be investigated and corrective action must be taken immediately. These actions should be documented.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor and subcontractors. All inspection logs should be submitted along with the calculation sheet.

Criteria		**Points (Yes = 1; No = 0)**
Superintendent inspections	☐ Yes ☐ No	
GC safety Rep inspections	☐ Yes ☐ No	
Sub safety Rep inspections	☐ Yes ☐ No	
Owner safety Rep inspections	☐ Yes ☐ No	
Foremen inspections	☐ Yes ☐ No	
Management personnel inspections	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	6
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

11.0 Inspection

Element 11.2: Safety Violation Identification and Correction
Possible Credits: 1.8
Type: Elective

Purpose

Identify and correct all safety violations identified during safety inspections.

Requirements

All OSHA and company safety violations should be identified, investigated, and corrective action must be taken immediately. These actions should be documented.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors. All documentation on the safety violations identified and corrected.

Criteria	Number
Total number of safety violations identified during project	
Number of safety violations corrected	

% of criteria fulfilled = Violations corrected/ Number of violations =
Credit received = Possible credits * % of criteria fulfilled =

12.0 Accountability and Performance Measurement

Element 12.1: Project Accountability and Responsibility
Possible Credits: 2.4
Type: Required

Purpose

Establish collective safety accountability and responsibility among management and project personnel.

Requirements

Create, circulate, and maintain a responsibility matrix that clearly defines the responsibility and accountability for project safety and health. The roles and responsibilities of all of the project personnel and management should be clearly established at the start of the project. The project safety supervisor/manager should be a technical resource to the project team and should not be the person held accountable in case of accidents.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, subcontractor, and designer. The job responsibility matrix created as part of the project should be attached with the calculation sheet.

Criteria		**Points (Yes = 1; No = 0)**
Was a job responsibility matrix establishing clear safety accountability and responsibility created as part of the project?	☐ Yes ☐ No	
Total points received =		
Total points possible =		1
% of criteria fulfilled = Points received/Points possible =		
Credit received = Possible credits * % of criteria fulfilled =		

12.0 Accountability and Performance Measurement

Element 12.2: Supervisor Evaluation based on Safety Performance
Possible Credits: 2.2
Type: Required

Purpose

Improve project safety performance by evaluating project supervisor personnel based on safety performance on the project.

Requirements

Develop a system that penalizes or rewards supervisors based on their project safety performance.

Submittals

The calculation sheet provided below should be submitted with signatures from the concerned management (constructor or subcontractor).

Criteria		Points (Yes = 1; No = 0)
Were project supervisors evaluated based on safety performance on the project?	☐ Yes ☐ No	
Total points received =		
Total points possible =		1
% of criteria fulfilled = Points received/Points possible =		
Credit received = Possible credits * % of criteria fulfilled =		

12.0 Accountability and Performance Measurement

Element 12.3: Safety Performance Evaluation
Possible Credits: 1.9
Type: Elective

Purpose

Use performance metrics to evaluate and improve project safety performance.

Requirements

Project safety performance should be measured and improved with the help of the following metrics: weekly inspections (number of OSHA and company violations identified), all accidents including near misses investigated and documented, OSHA recordable and LTA rates, claims rate, and accident costs. The project team should show improvement in the above metrics as the project progresses.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors. All weekly/monthly metrics should be submitted. A graphical representation of the metrics over the project period should also be submitted.

Criteria used in performance measure:		**Points (Yes = 1; No = 0)**
OSHA and company violations	☐ Yes ☐ No	
OSHA recordable and LTA incident rates	☐ Yes ☐ No	
Near misses	☐ Yes ☐ No	
Accident costs	☐ Yes ☐ No	
Accident investigation	☐ Yes ☐ No	
Claims rate	☐ Yes ☐ No	

Total points received =	
Total points possible =	6
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

12.0 Accountability and Performance Measurement

Element 12.4: Contractor Evaluation Based on Safety Performance
Possible Credits: 1.5
Type: Elective

Purpose

Evaluate contractors based on safety performance on the project.

Requirements

The owner should include a safety performance specification in the contracts that the contractors (general and subcontractor) have to comply with. Failure to comply will lead to penalty in the final payment or more compliance can lead to profit sharing. The owner can use all of the six criteria specified in "Element 12.3" to evaluate the contractor. The evaluation benchmark selected is up to the owner.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors. The owner's initial safety target along with whether or not the contractors complied should be submitted with proper records.

Criteria		**Points (Yes = 1; No = 0)**
Did the owner evaluate the contractors based on safety performance?	☐ Yes ☐ No	
	Total points received =	
	Total points possible =	1
	% of criteria fulfilled = Points received/Points possible =	
	Credit received = Possible credits * % of criteria fulfilled =	

13.0 Industrial Hygiene Practices

Element 13.1: Engineering Controls for Health Hazards
Possible Credits: 2.1
Type: Required

Purpose

Prevent and control worker health hazards at the source with the help of engineering controls.

Requirements

To the extent feasible, the work environment and the job itself should be designed to eliminate hazards or reduce exposure to hazards. Engineering control should be the first option in dealing with any hazards. The following principles as recommended by OSHA should be followed:

- If feasible, design the facility, equipment, or process to remove the hazard or substitute something that is not hazardous.
- If removal is not feasible, enclose the hazard to prevent exposure in normal operations.
- Where complete enclosure is not feasible, establish barriers or local ventilation to reduce exposure to the hazard in normal operations.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, subcontractor, and designer. A list of all engineering control considerations on the project should be submitted along with this calculation sheet.

Criteria	Rating
Was engineering control considered for all health hazards? If yes, how detailed was the process, rated on a scale from 1 to 5? If this criterion was not considered, “0” points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

13.0 Industrial Hygiene Practices

Element 13.2: Hearing Protection Program
Possible Credits: 1.6
Type: Elective

Purpose

Protect employees from potentially harmful effects of exposure to extreme noise through the introduction of engineering controls, implementation of administrative controls, or through the use of personal protective equipment (PPE).

Requirements

Create and implement a hearing protection program as part of the project safety plan. Hearing protection must be made available to all workers exposed at or above the action level. All workers who are subjected to a noise level of 85 dBA or above are to be included in a Hearing Conservation Program.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors.

Criteria	Rating
Was a hearing protection plan created and implemented as part of the project safety plan? If yes, how effective was the process, rated on a scale from 1 to 5? If this criterion was not considered "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

13.0 Industrial Hygiene Practices

Element 13.3: Respiratory Protection Program
Possible Credits: 1.9
Type: Elective

Purpose

Ensure that all employees have adequate respiratory protection in the workplaces to reduce the exposure to airborne contaminates through the introduction of engineering controls, implementation of administrative controls, or through the use of personal protective equipment (PPE).

Requirements

Create and implement a respiratory protection program as part of the project safety plan.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors.

Criteria	Rating
Was a respiratory protection plan created and implemented as part of the project safety plan? If yes, how effective was the process, rated on a scale from 1 to 5? If this criterion was not considered, "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled **=**	

13.0 Industrial Hygiene Practices

Element 13.4: Stretch and Flex Program
Possible Credits: 1.5
Type: Elective

Purpose

Reduce the risk and severity of back and musculoskeletal disorder (MSD) type injuries.

Requirements

All workers perform stretching exercises at the start of the work shift each day.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, and subcontractors.

Criteria	Rating
Were workers required to perform stretching exercises at the start of the work shift each day? If yes, how effective was the process, rated on a scale from 1 to 5? If this criterion was not considered, "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	0
	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

13.0 Industrial Hygiene Practices

Element 13.5: Ergonomic Task Analysis and Remediation
Possible Credits: 2.0
Type: Elective

Purpose

Improve workplace ergonomics to prevent cumulative trauma disorders (CTDs) and strains/sprains among construction workers.

Requirements

Create and implement a detailed ergonomic task analysis plan for the project as part of the project safety plan. All of the ergonomic risk factors, such as awkward postures, contact stress, vibration, static loading, repetition, and force, should be identified and remediated. Remediation should be aimed at fitting the job (tools, tasks, and environment) to the employee, instead of forcing the worker to fit the job.

Submittals

The calculation sheet provided below should be submitted with signatures from the owner, constructor, subcontractor, and designer. The ergonomic task analysis plan implemented on the project should be submitted along with this calculation sheet.

Criteria	Rating
Was ergonomic task analysis performed as part of the project safety process? If yes, how detailed was the process, rated on a scale from 1 to 5? If this criterion was not considered "0" points will be awarded. (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high)	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Total points received =	
Total points possible =	5
% of criteria fulfilled = Points received/Points possible =	
Credit received = Possible credits * % of criteria fulfilled =	

Appendix C.1: Sustainable Construction Safety and Health Rating System Validation

Dear Sir/Madam,

I am a PhD candidate working with Dr. John Gambatese at Oregon State University on my research related to construction worker safety. The research involves the development of a sustainable construction safety and health (SCSH) rating system that will provide an opportunity to rate projects based on the importance given to safety and health and the degree of implementation of those safety and health elements. Based on inputs from a 12 member expert panel, a comprehensive sustainable construction safety and health rating system has been successfully developed.

As part of the research we need to test the validity of rating system based on real time projects before formal usage by the industry. Hence, we are interested in collecting data from individual construction projects to test the validity of the rating system. A questionnaire survey has been developed for this purpose. We are aware that your organization constructs a variety of projects and would like to include and rate your projects as part of the study. Please fill in the attached questionnaire for any project built by your firm that have been completed in the past 2 years or are near completion at this time. Please select the project (s) randomly instead of selecting only the projects with good safety performance, to avoid bias. The scope of the rating system is aimed at certifying all project types in the construction industry.

All of the data provided will be kept anonymous and confidential, and will not be used for anything unrelated to this study. Your responses can be entered directly in the attached MS Word document. When finished with the survey, please return your response to me by e-mail (rajendrs@engr.orst.edu) or by fax (541-737-3300).

Thank you for your help with this study. Please contact me or Dr. Gambatese (john.gambatese@oregonstate.edu, 541-737-8913) if you have any questions. It would be great if we could receive the data from you by August 30, 2006.

Sincerely,
Sathy Rajendran
PhD Candidate
Oregon State University

Appendix C.2: Sustainable Construction Safety and Health Rating System Validation Questionnaire

The following questions are aimed at identifying the importance given to safety and health and the degree of implementation of safety and health elements in a particular project. The safety and health efforts of the four primary parties in a project (owner, designer, general contractor, and subcontractors) are included in this survey. Information requested in this questionnaire is specifically focused on one current or recently completed project. For most questions, there is only one answer to check, however in some cases a short typed response is requested.

Title of Person Interviewed/Surveyed: ___________________________________
Project Name: ____
Owner: ____
General Contractor: ____
Architect: ____

PROJECT INFORMATION

Did the project have a zero injury goal? ☐ Yes ☐ No
What is the type of project, i.e., education, healthcare? __________
What is the scope of the project, i.e., renovation, new construction? __________
What is the total estimated cost of construction of the project? $__________ million
What type of contracting arrangement was used on this project? ________________
How many subcontracts have been awarded on this project? ____________________
Is the owner public or private? ________________
Is this primarily a union shop or merit (open) shop project? ________________
What is the total square footage of the project? ________________
What is the height of the project in terms of stories? ________________
How many workers are/were on the project? ________________
What is the current percent of completion for the project? ________________
What is the total duration for the project? _________________________
Is this project undertaken under an owner controlled insurance program (OCIP) or Contractor Controlled Insurance Program (CCIP)? _____________________

SAFETY PERFORMANCE

How many worker-hours have been expended on this project? ________________ hrs
How many injuries have been recorded on this project?
________________ OSHA recordable
________________ Lost workday
How many near misses have been experienced on this project? ________________

PROJECT TEAM SELECTION

Constructor selection:
During the owner's selection of the constructor, was safety performance a factor in the prequalification process? ☐ Yes ☐ No
If yes, what measures were used to compare the safety performance of different contractors? (Please check all that apply and specify any specific criteria on these metrics)

- ☐ Experience Modification Rating (EMR) of the contractor, should be less than ___
- ☐ OSHA recordable injury rate of the contractor, should be less than _____
- ☐ Number of OSHA citations, should be less than _____ in the past ____ years
- ☐ Personal interview/knowledge of the contractor's safety performance

- ☐ Review of the overall safety program of the contractor
- ☐ Claims rate of the contractor, should be less than ______
- ☐ Qualifications of the safety staff
- ☐ Others (please specify): ____________________________________

<u>Subcontractor selection:</u>
During the selection of subcontractors, was construction safety a factor in the prequalification process? ☐ Yes ☐ No
If yes, what measures were used to compare the safety performance of different subcontractors? (Please check all that apply and specify any specific criteria on these metrics)

- ☐ Experience Modification Rating (EMR) of the contractor, should be less than ____
- ☐ OSHA recordable injury rate of the contractor, should be less than _____
- ☐ Number of OSHA citations, should be less than _____ in the past three years
- ☐ Personal interview/knowledge of the contractor's safety performance
- ☐ Review of the overall safety program of the contractor
- ☐ Claims rate of the contractor, should be less than ______
- ☐ Qualifications of the safety staff
- ☐ Others (please specify): _______________________________

<u>Designer Selection</u>
During the owner's selection of the designer, was safety performance a factor in the selection process? ☐ Yes ☐ No
If yes, what measures were used to compare different designers? (Please check all that apply and specify any specific criteria on these metrics)

- ☐ Past safety experience of designer
- ☐ Safety knowledge of the designer
- ☐ Willingness to incorporate safety during conceptual and design stages
- ☐ Personal interview/knowledge of the designer's past safety performance
- ☐ Others (please specify): _______________________________

<u>SAFETY REQUIREMENTS IN CONTRACTS</u>
<u>Safety requirements</u>
What safety requirements were specifically included in the construction contract?

- ☐ Contractor must place at least one full-time safety representative on the project.
- ☐ Contractor must implement a drug-testing program.
- ☐ Contractor must provide safety orientation to all employees on-site.
- ☐ Contractor must record, investigate, and report near misses to the owner.
- ☐ Contractor must submit a safety policy signed by its CEO.
- ☐ Contractor must conduct pre-bid, award, and construction meetings with subs.
- ☐ Contractor must comply with the local, state, and federal safety regulations.
- ☐ Contractor must submit the résumés of key safety personnel for owner approval.
- ☐ Contractor must submit a site specific safety plan for the owner's approval.
- ☐ Contractor must report all lost time injuries to the owner.
- ☐ Contractor must report all OSHA recordable injuries to the owner.
- ☐ Contractor must include personnel from the owner in coordination meetings.
- ☐ Contractor must implement a permit system when performing hazardous activities.
- ☐ Other (please specify): ____

<u>Construction hazard recognition</u>
Were safety and health hazards identified in the construction drawings? ☐ Yes ☐ No

If yes, how detailed was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Specification of less harmful materials
Was specification of less hazardous materials considered/specified? ☐ Yes ☐ No
If yes, how detailed was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

SAFETY PERSONNEL
Competent Person
Was a competent person assigned to all high hazard tasks? ☐ Yes ☐ No
Was this requirement on top of OSHA standards? ☐ Yes ☐ No
If yes, what tasks, other than those required by OSHA, had competent personnel?

Owner Safety Representative
Did the owner assign an owner safety representative to this project? ☐ Yes ☐ No
Was the representative full time or part time? ☐ full time ☐ part time
Did this person have any responsibility on other projects? ☐ Yes ☐ No
What are the representative's qualifications?
Education _________________
Certification _______________
Work experience_____________

Constructor Safety Representative
Did the constructor assign a safety representative for this project? ☐ Yes ☐ No
Was the representative full time or part time? ☐ full time ☐ part time
Did this person have any responsibility on other projects? ☐ Yes ☐ No
What are representative's qualifications?
Education _________________
Certification _______________
Work experience_____________
Were there minimum qualifications for the safety staff? ☐ Yes ☐ No
If yes, what were the qualifications _____________________

Subcontractor Safety Representative
Did subcontractors assign full-time/part-time safety representative for the project? ☐ Yes ☐ No
If yes, what percent of subcontractors safety representatives assigned to the project were: Full-time ____% Part-time _____%

SAFETY AND HEALTH COMMITMENT
Management Commitment to Safety and Health
Was there specific mission statement for this project from constructors and subs? ☐ Yes ☐ No
If yes, was safety mentioned in it? ☐ Yes ☐ No
Was safety addressed in all top management meetings? ☐ Yes ☐ No
Did top management participate in job site walks? ☐ Yes ☐ No
Did top management participate in accident investigations? ☐ Yes ☐ No
Did top management review the project safety plan? ☐ Yes ☐ No
Describe any other management activities related to worker safety and health _________

Owner Commitment to Safety and Health
Is there a specific mission statement for this project from the owner? ☐ Yes ☐ No

If yes, is safety mentioned in it? ☐ Yes ☐ No
Did owner personnel participate in site safety meetings? ☐ Yes ☐ No
Did owner personnel participate in job site walks? ☐ Yes ☐ No
Did owner personnel participate in accident investigations? ☐ Yes ☐ No
Did owner personnel participate in safety orientations? ☐ Yes ☐ No
Did owner personnel review the project safety plan? ☐ Yes ☐ No
Did the owner allocate any specific amount of funds to promote project safety? ☐ Yes ☐ No
Did the owner have a site project safety incentive program? ☐ Yes ☐ No
Did the owner require all employees to undergo orientation? ☐ Yes ☐ No
Did the owner consider itself accountable for injuries sustained by the employees of the construction contractor? ☐ Yes ☐ No
Describe other owner/owner personnel activities that indicate commitment to safety and health:

SAFETY AND HEALTH PLANNING

Conceptual planning phase
Was safety of workers considered during the project conceptual planning stage? ☐ Yes ☐ No
If yes, how detailed was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Constructability Review
Was a detailed constructability review conducted? ☐ Yes ☐ No
Was safety a part of the constructability review? ☐ Yes ☐ No
If yes, how detailed was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Designing for construction worker safety and health
Was the designer familiar with the design for construction safety concept? ☐ Yes ☐ No
Was safety of construction workers considered during the design stage? ☐ Yes ☐ No
If yes, how detailed was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Life cycle safety design review
Was the designer familiar with the life cycle safety concept? ☐ Yes ☐ No
Was safety of workers considered from a life cycle safety design perspective? ☐ Yes ☐ No
If yes, how detailed was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Safety checklist for designers
Was the designer provided with a safety checklist? ☐ Yes ☐ No
Did the designer already have a safety hazard checklist from prior projects? ☐ Yes ☐ No
If yes, what were the contents of the checklist:
Did the designer use the checklist during the project design? ☐ Yes ☐ No

Constructor site specific safety plan
Did the project have a site specific safety plan? ☐ Yes ☐ No
What were the contents of it? ______ (Can we get a copy of the plan?)
If yes, how extensive is it, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Did the project owner review it? ☐ Yes ☐ No
Did the constructor's top management review it? ☐ Yes ☐ No

If yes, who reviewed the plan: ☐ CEO ☐ Safety Director ☐ Project Manager ☐ Others (specify): _______________

Subcontractor site specific safety plan
Did the project require all subcontractors to prepare a site specific safety plan? ☐ Yes ☐ No
What were the contents of it? _______ (Can we get a copy of the plan?)
If yes, how extensive is it rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Did the constructor review it? ☐ Yes ☐ No
Did the owner review it? ☐ Yes ☐ No

Job Hazard Analysis
Were job hazard analyses performed prior to each major phase of work? ☐ Yes ☐ No
If yes, how extensive is it rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Pre-task safety planning
Were pre-task plans prepared for work on the project? ☐ Yes ☐ No
If yes, how extensive is it rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Are workers required to be involved in pre-task safety planning prior to performing their work?
☐ Yes ☐ No
When is the pre-task planning is performed? ______________________________
Who has the primary responsibility for pre-task planning? ____________________
What documents or resources are most often used for pre-task planning? _________

Look ahead schedule
Were look ahead schedules created during the project to avoid trade stacking? ☐ Yes ☐ No
If yes, how extensive is it rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Who does this task: ☐ Superintendent ☐ Safety professional ☐ Project Manager ☐ Others
What type of schedule is used on this project?
☐ Bar chart ☐ Critical Path ☐ Milestones ☐ Others: ______________________

Traffic and Lay down area plan
Was traffic control/lay down area plan prepared as part of the project safety plan? ☐ Yes ☐ No
If yes, how extensive is it rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Good housekeeping with assigned responsibility
Was a detailed housekeeping plan prepared as part of the project safety plan? ☐ Yes ☐ No
If yes, how extensive is it rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
If yes, was a specific individual assigned responsibility for its implementation? ☐ Yes ☐ No

Personal Protective Equipment (PPE) and information
Were all workers required to wear PPE? ☐ Yes ☐ No
What PPE was required to be worn by the workers at all times?
☐ Hard hats ☐ safety shoes ☐ safety glasses ☐ Others (specify):_________
How does the company pay for the PPE? _________________________
☐ Project budget ☐ Special corporate budget ☐ Special job safety allocation

TRAINING AND EDUCATION

Safety Training for Designers

Did the designers receive safety training? ☐ Yes ☐ No

If yes, what type of training did the designers receive?

☐ Design for safety training ☐ General job site safety training

If no, are the designers already qualified in design for safety? ☐ Yes ☐ No

Safety orientation for all workers

Did every worker on the project participate in a safety orientation? ☐ Yes ☐ No

Did the workers get tested on the safety orientations? ☐ Yes ☐ No

Did project management personnel participate in safety orientations? ☐ Yes ☐ No

Did owner representatives participate in safety orientations? ☐ Yes ☐ No

What type of safety orientations did the new hires receive? ☐ None ☐ Formal ☐ Informal

Who conducted the orientations? _________________________

Safety training for all workers

Are the workers required to attain a minimum OSHA 10 hour certification? ☐ Yes ☐ No

If no, are there any other special requirements for the training of the employees?

Was there a formal safety training plan for the project? ☐ Yes ☐ No

Safety training for all field supervisors

Did all supervisory personnel receive safety training? ☐ Yes ☐ No

Did the foremen receive any type of safety training on this project? ☐ Yes ☐ No

Did the general foremen receive any type of safety training on this project? ☐ Yes ☐ No

Did the superintendent receive any type of safety training on this project? ☐ Yes ☐ No

Are the supervisory personnel required to attain a minimum OSHA 10hr certification?

☐ Yes ☐ No

Are the supervisory personnel required to attain a minimum OSHA 30hr certification?

☐ Yes ☐ No

If no, is there any other special requirement for the training of the supervisory personnel?

Equipment operator skills and training

Are construction equipment operator skills and training verified before they operate equipment on site? ☐ Yes ☐ No

If yes, please mention how it is done: ________________________________

Toolbox meetings

Were toolbox (Safety) meetings held on the jobsite at least weekly? ☐ Yes ☐ No

Were these held at the crew level or do several crews attend the same meeting?

Did subcontractors conduct their own safety meetings? ☐ Yes ☐ No

Continuous safety training for all project personnel

Was regular safety training given to the project personnel to maintain certifications, improve safety knowledge, and for specific hazards? ☐ Yes ☐ No

If yes, how many hours of training were offered to each person each month? ___ hrs

Constructors mentoring subs on safety and health

Were subs mentored by the constructors? ☐ Yes ☐ No

If yes, how frequent was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Give some examples of such activities:

<u>SAFETY AND HEALTH RESOURCES</u>
<u>Task-based hazard exposure database</u>
Was a detailed task-based hazard exposure database prepared and implemented? ☐ Yes ☐ No
If no, is there any similar kind of resource that help workers during JHA/Pre-task planning to know what are the common hazards associated with that particular task?____
Did the project have a safety newsletter? ☐ Yes ☐ No
If yes, how often were they circulated? ________________

<u>DRUG AND ALCOHOL PROGRAM</u>
Was there a substance abuse testing program on this project? ☐ Yes ☐ No
What types of testing were conducted? ☐ pre-employment ☐ random ☐ reasonable cause ☐ post-accident ☐ blanket testing ☐ follow up testing
On pre-employment screening tests, what percent have tested positive? ____%
On random tests,

What percent of the workforce is tested? ____%
How often are random tests conducted on average? ______
Typically, what percent of the random tests are positive? ____%

What was the project policy when a worker tests positive? ________________
Were staff and salaried personnel also tested in these random tests? ☐ Yes ☐ No

<u>ACCIDENT INVESTIGATION AND REPORTING</u>
<u>Accident and Near Miss Investigation</u>
What types of accidents were investigated? ☐ near miss ☐ OSHA recordable ☐ lost work day ☐ Others (specify): ____________
What percent of the accidents were investigated? ____%
Who conducted these accident investigations? ☐ foreman ☐ superintendent ☐ project manager ☐ safety representative ☐ Others________
How were the accidents investigated? ___________________
Is a JHA/pre-task plans used during the investigation? ☐ Yes ☐ No
Were the findings considered in future pre-task plans/JHA? ☐ Yes ☐ No
What happened after the investigation was done?________________
Where was the report sent? ☐ job file ☐ home office ☐ others (Specify):
How is a near miss defined? __________________________
How many near misses have been recorded on this project? _________________

<u>WORKER INVOLVEMENT</u>
<u>Worker authority</u>
Do the workers have the authority to stop hazardous work? ☐ Yes ☐ No
If yes, is there any document that describes this authority? ______________

<u>Safety committee</u>
Was there a formal safety committee on the project? ☐ Yes ☐ No
Was there a committee exclusively for workers that is led by a worker or foreman? ☐ Yes ☐ No
Was there a committee among the worker committee leaders? ☐ Yes ☐ No
How often did they meet? _______________
What percent of the meetings were held as scheduled during the project? ________%
How many workers were on the committee? _________________
What is the purpose of this committee? _________________

How were the workers selected to serve on the committee? _________________
How were the committee leaders selected? _________________
What was the formal authority of the committee? _________________
Any comments: _________________

SAFETY INSPECTION

Who did the safety audits? and	How often?
☐ Superintendent	
☐ GC safety Rep	
☐ Sub safety Rep	
☐ Owner safety Rep	
☐ Foremen	
☐ Management personnel	
☐ General foremen	
☐ Insurance loss consultant	

Were all the violations identified documented and corrected? ☐ Yes ☐ No
If yes, what is the latest time by which the violations should be corrected? _________
What percent of the violations identified were corrected? ___%

ACCOUNTABILITY AND PERFORMANCE MEASUREMENT
Was a job responsibility matrix establishing clear safety accountability and responsibility among the project team members created as part of the project? ☐ Yes ☐ No
Are the project supervisors evaluated based on safety performance on the project? ☐ Yes ☐ No
If yes, does this safety performance affect their career advancement/ bonus? ______
Did the project use performance metrics to evaluate and improve project safety performance?
☐ Yes ☐ No
If yes, what performance metrics were used?

- ☐ Number of OSHA violations identified during inspections
- ☐ Number of company violations identified during inspections
- ☐ Number of near misses
- ☐ Accident costs
- ☐ Timely investigation and report on accident investigations
- ☐ Claims rate
- ☐ OSHA recordable and lost time case rates
- ☐ Others (specify):____________________

Did the owner evaluate the constructor based on safety performance? ☐ Yes ☐ No
Is the fee received from the owner dictated in part on the safety performance of the project?
☐ Yes ☐ No
Contractually, what sanctions does the owner impose on a contractor for non-compliance with safety requirements? (Please check all that apply)

- ☐ A certain amount of money could be deducted from the payment earned by the contractor.
- ☐ Site work could be suspended until the contractor complies with safety requirements specified in the contract.

☐ The contract could be terminated.
☐ Other (please specify):________________________________

Did the constructor use the same sanctions with subcontractors? ☐ Yes ☐ No
If no, what sanctions does the constructor impose on the subs for non-compliance with safety requirements: ____

INDUSTRIAL HYGIENE PRACTICES

Were engineering controls considered for all health hazards? ☐ Yes ☐ No
If yes, how detailed was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Was a hearing protection plan created and implemented as part of the project safety plan?
☐ Yes ☐ No
If yes, how extensive was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Was a respiratory protection plan created and implemented as part of the project safety plan?
☐ Yes ☐ No
If yes, how extensive was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Were workers required to perform stretching exercises at the start of the work shift each day?
☐ Yes ☐ No
If yes, how extensive was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Were ergonomic task analyses performed as part of the project safety process?
☐ Yes ☐ No
If yes, how detailed was the process, rated on a scale from 1 to 5? (1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very high) ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Please explain process: _____________________________________

OTHERS

Have OSHA consulting services ever been used on this project? ☐ Yes ☐ No
Has OSHA helped in any way on this project? ☐ Yes ☐ No
Please explain: ____
Was this project constructed as a LEED rated project? ☐ Yes ☐ No
What level of certification is being sought/has been achieved?
☐ Certified ☐ Silver ☐ Gold ☐ Platinum
What is the number of points obtained/sought for: ________ points?
What is the type of rating being sought: ☐ NC ☐ CS ☐ EB ☐ CI ☐ Others (specify): ___
Do you think this had any impact on safety and health? ☐ Yes ☐ No
If yes, what are the impacts: