THE OWNER'S ROLE IN CONSTRUCTION SAFETY

By

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This dissertation is dedicated to my wife, Jie Bai; my parents, Xiaoyi Huang and Guizhen Zhang; my family and everyone engaged daily in the battle against the poor safety and health performance of the construction industry.

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The construction industry has long been regarded as one of the most dangerous industries. The construction industry has a history of poor safety performance. This is despite the fact that dramatic improvements have been made in the safety performance of the construction industry in the past decade. The improvements are due, in part, to the concerted efforts of owners, contractors, subcontractors, and designers. While past studies have investigated the safety roles of contractors, subcontractors, and designers, the owner's impact on construction safety has not been thoroughly studied.

The owners of projects are the primary consumers of construction services, the sources of project finances, and, in many cases, the end users of the facilities. They are often at the pivotal position of the projects. Traditionally, owners have not been directly involved in construction safety, often in order to avoid economic losses and legal entanglements resulting from injuries. With the increase of accident costs and legal cases

involving owners as the third-party defendants, owners have come to realize the importance of safety.

In this study, the owner's role in construction safety was investigated. The relationship between project safety performance and the owner's influence was examined, with particular focus on the project context, selection of safe contractors, contractual safety requirements, and the owner's proactive involvement in safety management. A questionnaire survey sent to owners with large construction budgets and interviews conducted on projects with large worker hour exposures were the primary means of data collection for the study. Statistical analysis shows that there is a strong relationship between project safety performance and owner involvement. Practices of owners significantly associated with project safety performances were identified. A model to demonstrate how owners can help improve safety was established. A scorecard that can be used to assess the owner's involvement in safety was developed and tested.

It was concluded that the owner's involvement can significantly influence project safety performance. Owners can achieve better project safety performances by setting safety objectives, selecting safe contractors, and participating in safety management during construction.

CHAPTER 1
INTRODUCTION

With peak levels of employment reaching eight million workers, the United States construction industry has the dubious distinction of perpetually being one of the industries with the worst injury and fatality records. The mining industry and the agriculture industry are the only industries that have worse records than the construction industry. While the actual incidence of construction worker injuries has declined over the past three decades, the number of injuries and fatalities is still at an unacceptable level (Hinze, 1997). According to the Census of Fatal Occupational Injuries (CFOI, 2003), an average of 1,115 workers were killed annually on construction sites from 1995 to 2000, which accounted for nearly 20% of all industrial fatalities in the United States. This number is a disproportionate distribution of construction worker fatalities since construction workers account for only 7% of the industrial workforce. While many strides have been made to reduce the incidence of injuries, there is considerable room for improvement. The industry is trying to find new ways to improve safety performance.

In the construction industry, most construction projects involve the participation of owners, designers, and contractors. The owners (also called facility clients, or project buyers) of projects are the primary consumers of construction services, the sources of project finances, and, in some cases, the end users of the facilities. Owners include both public and private entities. Some owners obtain the services of a construction firm to build a facility with virtually no interaction between the owner and the construction firm during the construction process. Other owners play varying roles during the construction

phase, with some being closely involved with the construction effort during every stage of project execution.

Generally, an owner of a project will require various objectives to be satisfied by the designer and contractor (Hinze, 2001). The owner defines the scope of a project to become a reality, which requires the services of several parties. First, the designer will develop the guidance document for building the project. The contractor will then follow by executing the construction of the project.

Typical objectives required by the owners include, but are not limited to the following: when a particular project should be finished; what quality requirements the project must satisfy; the owner's cost of the project; and possibly the safety standards that must be met during project construction. The roles of some of the parties are shown in the organizational chart for a general contract agreement in Figure 1-1. In all types of contract agreements, the owner is at the top position of the project organization. Essentially, the owner has the overall authority on the project.

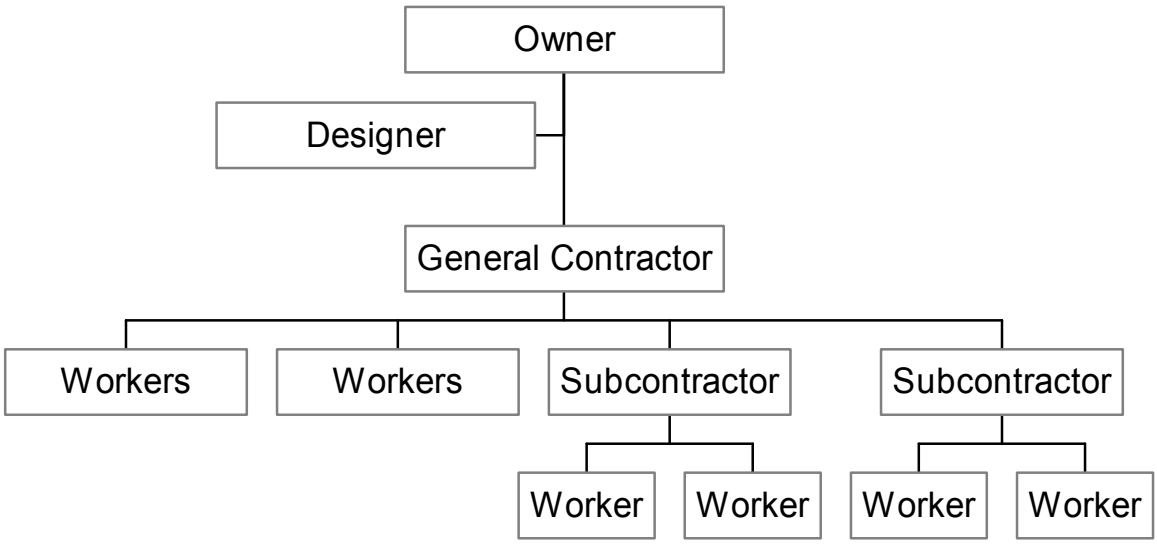


Figure 1-1. The organizational chart of a typical general contract agreement

Traditionally, safety responsibilities have rested solely on the shoulders of contractors. Owners and designers have held the view that they should not get involved in construction worker safety for fear of incurring increased liability exposure. However, in the past decades more and more parties to the construction process have come to realize that zero accidents is an attainable objective, but only through the concerted efforts of all parties involved in the construction process. Owners, A/E firms (also called designers), and contractors/subcontractors have different roles in preventing accidents to achieve an injury-free worksite (Hinze, 1997; Gambatese, 1996; Toole, 2002). The contractor is undoubtedly the pivotal party to control jobsite safety. Strategies and approaches taken by contractors to improve project safety have been thoroughly investigated in past research studies (Levitt and Samelson, 1993; Hinze, 1997; Hinze, 2002). Subcontractor safety influenced by the general contractor in various sizes of projects was investigated by Hinze and Figone (1988, for small and medium projects), and Hinze and Talley (1988, for large projects). Designers can reduce safety hazards in the working environment by considering worker safety issues in their design decisions. Hinze and Gambatese (1996) gathered various "best practices" for designers to address safety issues in their designs and developed a safety design tool to help designers eliminate hazards when making decisions. Today, more and more owners have come to realize that the costs of construction accidents are ultimately their own financial burden, and that they cannot with certainty shield themselves from the legal liabilities associated with worker injuries. As a result, many owners are taking more active roles in construction safety. This begins with the selection of safer construction firms and can also be observed in the safety provisions included in the construction contract. Owners

will continue to influence safety performance by the nature of their involvement during the construction process.

Despite all the research that has been conducted with the various parties to the construction process, little prior work has examined the specific role played by project owners in promoting safety performance. How owners regard their role in safety and how they attempt to exert their influence in the construction process have not been previously examined in detail. This study is focused on the investigation of the impact of owners on construction safety.

CHAPTER 2
LITERATURE REVIEW

Accident Facts

Accident data prepared by the Bureau of Labor Statistics (2003) show that the construction industry has performed much worse than the average of all industries (see Figure 2-1). Although the statistics have improved dramatically in the 1990's, accident rates in the construction industry are still 50% higher than that of all industries, lagging all industries by about 10 years. An alarming fact is that the number of fatalities in the construction industry has increased in the past decade (see Figure 2-2).

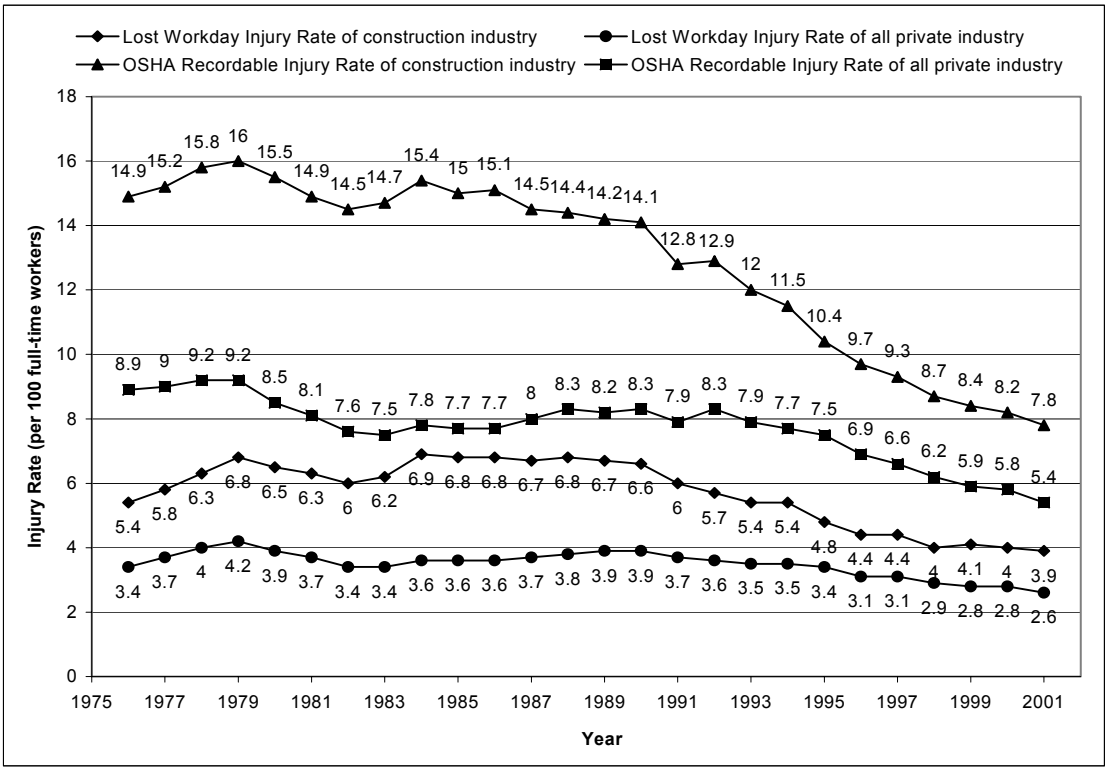


Figure 2-1. Injury rate of construction and all private industry

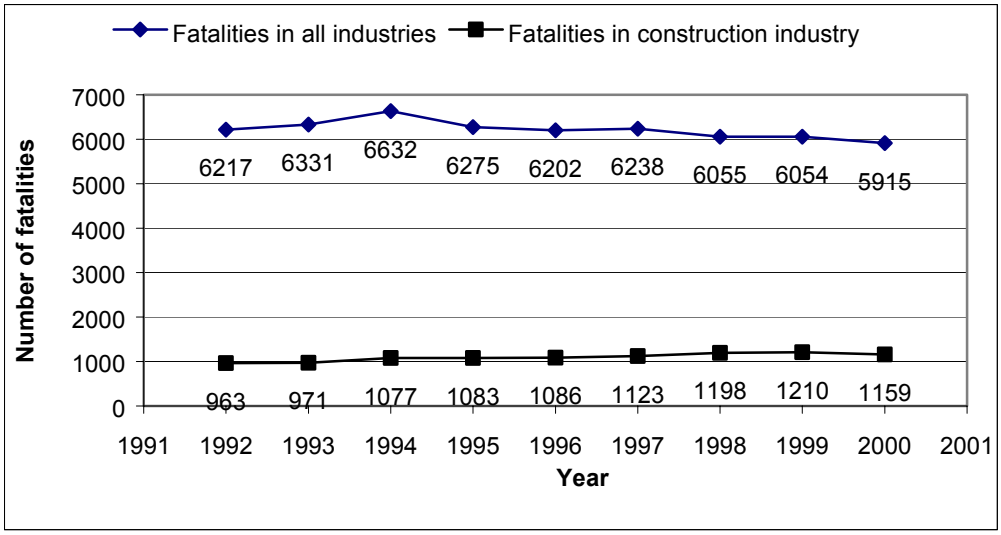


Figure 2-2. Fatalities in construction industry and all industries

Figure 2-3 shows the major types of construction accidents that have occurred in the past decade, based on the analysis of all serious injuries and fatalities investigated by OSHA. Falls, struck-bys, electric shocks, caught-in-or-betweens, and other are the major causes of injuries, although the relative proportion of each type has changed somewhat in recent years (see Figure 2-4).

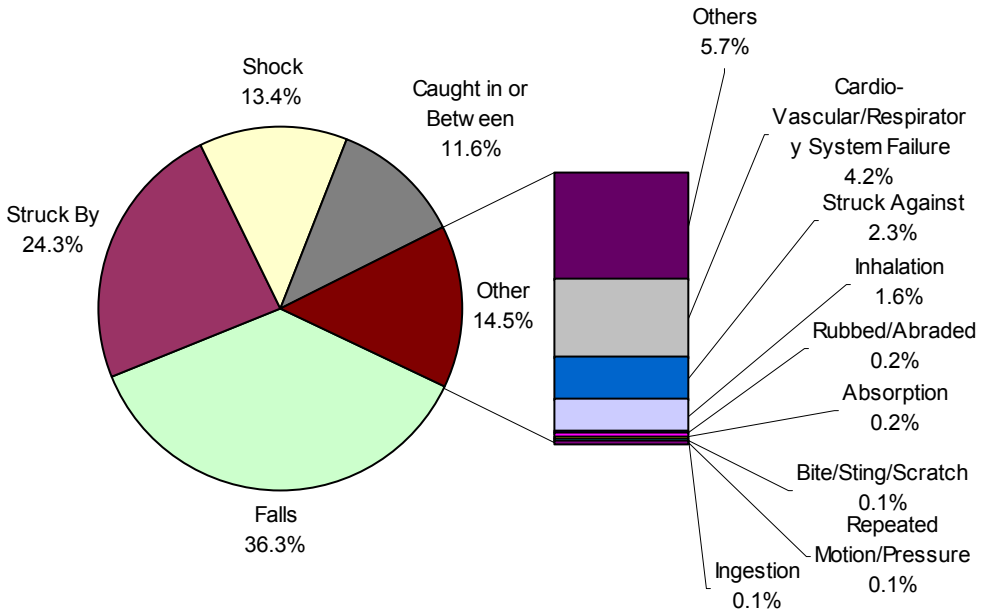


Figure 2-3. Causes of construction fall accidents investigated by OSHA (01/90-10/01)

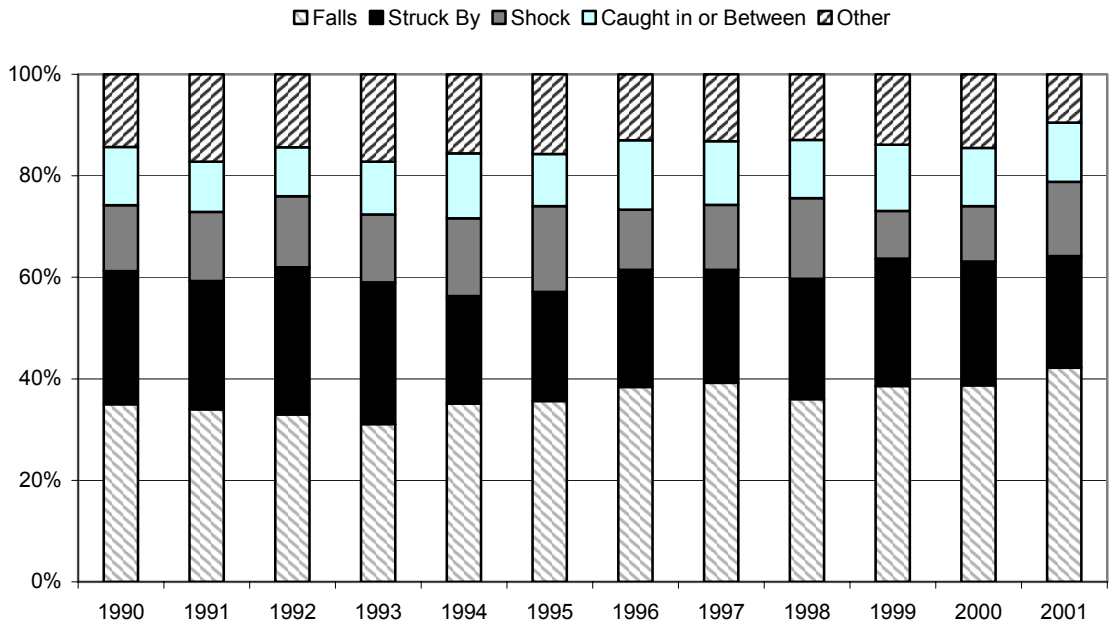


Figure 2-4. Breakdown of OSHA investigated accidents in construction (01/90-10/01)

Owners' More Active Involvement In Safety

With a higher proportion of injuries, the construction industry has long been regarded as a dangerous industry. With an average employment of approximately 7% of the industrial workforce, the construction industry has generally accounted for nearly 20% of all industrial worker fatalities (CFOI, 2003). The research conducted by Everett and Frank (1996) concluded that the total costs of construction accidents accounted for 7.9-15.0% of the total costs of new, non-residential projects. A more recent but unpublished research by Coble and Hinze (2000) showed that the average worker's compensation insurance costs could be conservatively estimated as constituting 3.5% of the total project cost.

Safety performance of the construction industry did improve during the 1990's (see Figure 2-1). As suggested by Hislop (1999), perhaps the most significant factor attributed to this improvement is the increased management commitment to safety. Management has been motivated to make a greater commitment to safety, based on its

increased awareness of the impact of the high costs of worker's compensation payments, the higher dollar value settlements in lawsuits, the increased amounts of OSHA fines for safety violations, and the adverse impacts of poor safety performance on the corporate image.

In order to reduce and eventually eliminate construction accidents, researchers have explored techniques to fulfill the "zero injury objective" through the concerted efforts of all parties involved. The involvement of owners has been regarded as an essential requirement for this objective. For example, in the research conducted by Liska et al. (1993), it was found that an important prerequisite attributed to excellent safety performance was the involvement of the owner not only in pre-project planning including financially supporting the contractor's safety program, but also in the day-to-day project safety activities. In the construction accident causation model developed by Suraji et al. (2001, see Figure 2-5), construction accidents are caused by different responses to certain constraints and the environment on construction projects. In the model, owner (client) responses are the actions (or inactions) of the owner in response to constraints during the development of a project brief (Duff, 2000). These include, for example, reducing the project budget, adding new project criteria, changing project objectives, and accelerating the design or construction efforts of the project. All these elements will play an essential role in accident occurrences.

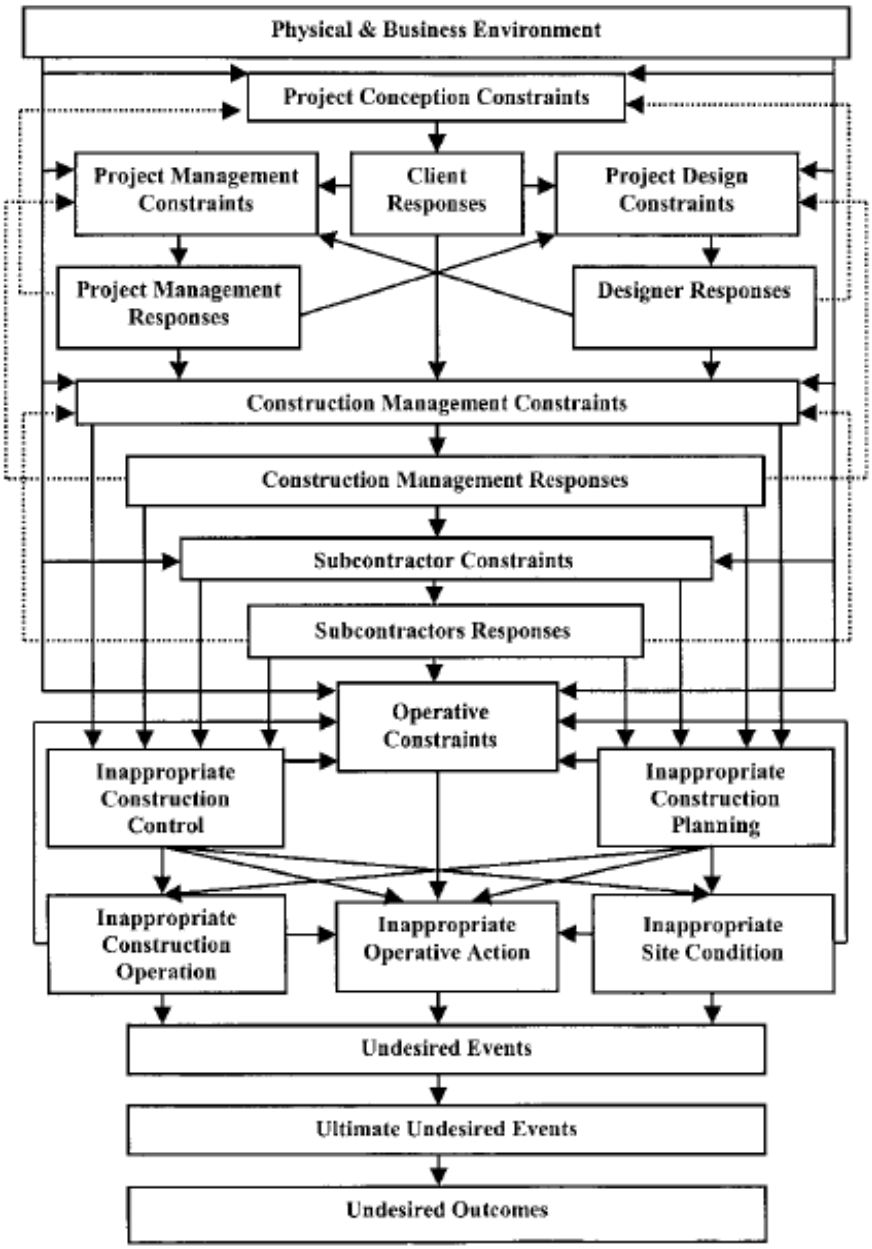


Figure 2-5. Construction Accident Causation Model: Constraints and Responses

In the past, there was a reluctance of owners to become involved in matters related to construction safety issues for the fear of added liability exposure (Sikes et al., 2000). However, since the 1980's more and more owners, especially owners with larger construction budgets, have voluntarily expanded their role in ensuring worker safety. A series of studies conducted at the University of Washington in the early 1990's

demonstrated that owners' concern for construction safety was increasing (Hinze, 1997).

The major reasons include the following:

- The rising costs of health care and workers' compensation are not being ignored by owners (see Table 2-1).

Table 2-1. Average cost of construction site injuries

Type of injury	Job Costs		Estimated Liability Costs	Total Cost to Employer
	Direct	Indirect		
Medical Only	$520	$440	$240	$1,200
Lost Work Day	$6,900	$1,600	$16,500	$25,000

(Hinze and Appelgate, 1991)

- Owners realize that the costs of injuries are ultimately reflected in the cost of construction (Gambatese, 2000b).

- Litigation involving third parties has escalated in the past three decades. For example, in the case of Phillips v. United Engineers & Constructors, Inc., and Plasteel Products Corp., 500 N.E. 2d 1265 (1986), owner was sued but was not held responsible for a worker's fall from catwalk during steel erection. In another case Rigatti v. Reddy, 723 A.2d 1283 (1999), the owner was similarly cleared of being responsible for a roofer's fall. In the case of Stark v. Rotterdam Square, 603 N.Y.S.2d 347 (1993), the owner of a mall was held liable for injuries suffered by a roofer when he fell through a hole cut into the roof.

Because of these types of lawsuits, many owners have come to realize that reducing the frequency and severity of construction injuries is the only sure way of reducing their potential liability for worker injuries (Levitt and Samelson, 1993).

Since the early 1980s, several efforts have been undertaken to formally require owners to participate in construction site safety. A major effort to expand safety legislation resulted after 28 workers died in the tragic collapse of the L'Ambiance Plaza Building in Bridgeport, Connecticut (Godfrey, 1988). This accident became the driving force behind U.S. Senate Bill 2581 to amend the Occupational Safety and Health Act to "require all construction projects to be supervised by . . . a professional engineer-architect designated by the owner and registered in the state where the construction is to be

performed" (ASCE, 1988). Opposition to this bill from a large segment of the construction industry ultimately resulted in its failure.

Although these legislation efforts failed in the U.S., the liability of owners in the United Kingdom was specified by the Construction (Design and Management) Regulations 1994 (CDM), in which the owner's main duties are contained in Regulations 6, 10, 11 and 12 (Holt, 2001). In CDM, a owner is defined as "any person for whom a project is carried out, whether carried out by another person or in-house." CDM imposed criminal liability onto the owner who ignores construction safety and where this results in an accident. Each project owner has a responsibility for safety on the project. In cases where there are multiple owners, the owners can appoint an agent or another owner to carry out the owner's duties, and then have to make a declaration to the enforcing authority (the Health and Safety Executive) that the transfer of duties has been made. Under CDM, the owner must do the following:

- Appoint a Planning Supervisor and a Principal Contractor for each project, being satisfied that these "duty holders" are competent and have the resources to perform their duties adequately.
- Not permit the construction work to start unless a health and safety plan, which complies with the safety regulations, is in place for that project.
- Provide the planning supervisor with information about the state or condition of the premises where the work is to be carried out. This is information which is relevant, and which the owner either has or could get after making reasonable inquiries.
- Verify that any designer or contractor that is appointed directly is competent for the task and has allocated sufficient resources to it.
- Make the health and safety file available for inspection by anyone who may need information to comply with legal requirements. The owner will sell or pass on the file to a future owner or a person acquiring the interest in the property of the structure to which it refers.

The trend is clear that owners are getting more concerned about construction safety, but many owners are confronted with the problem of how to effectively influence project safety. For example, a safety campaign supported by the owner was conducted during the construction of the Øresund Link between Denmark and Sweden. Primarily, the safety campaign consisted of a comprehensive information campaign aimed at promoting positive attitudes towards safety among the employees, and a specific campaign aimed at the behavioral aspects to increase the level of safety when performing routine work at the construction site (Spangerberg, 2002). In the end, the results of the campaign did not satisfy the owner's expectations of low injury rate, which led people to question what techniques by the owner can effectively improve construction safety.

Therefore, it would be essential to investigate the current techniques employed by owners to achieve good safety performances on construction sites, and if possible establish the effect the techniques on the resultant safety performance.

How Owners Take Their Role In Safety

Owners can actively impact construction safety by selecting safe contractors, addressing safety issues in design, and participating in safety management during construction (Hinze, 1997). To the extent possible, the owners, through their project representatives, should participate with the contractors in all project safety activities, including but not limited to new employee orientation, safety meetings, audits and accident investigations, training, incentive programs and other safety related programs (Gambatese, 2000b).

One of the earlier studies on the owner's role in construction safety by Levitt et al. (1981) reached the conclusion that construction owners who selected or prequalified contractors based on safety performance, and/or who got involved in construction safety

management, had fewer accidents on their projects. The owner's involvement in construction safety management not only reduces the number and severity of accidents but probably also reduces the owner's total liability exposure.

The American Society of Civil Engineers (ASCE) moved to the forefront in the trend to involve owners in safety following the issuance of ASCE's Policy Statement 350 on construction site safety in 1998. The statement outlines ASCE's belief that "improving construction site safety requires attention and commitment from all parties involved." The policy 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." Various ways owners can actively address safety were given in the policy, including 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 practices 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.
- Designating in the contract documents those parties responsible for the final approval of shop drawings and details.

Gambatese (2000b) summarized various ways in which owners can actively address safety, including the following:

- 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.

Establish And Communicate Attitudes Towards Safety

All owners have a legal and moral responsibility to insist on the safe performance of their construction contractors and to use reasonable care to prevent contractors from injuring others on the site. Owners should understand that their involvement in construction safety management not only reduces the number and severity of injuries, but is also likely to reduce the owners' total liability. In addition, the owner should realize that safe performance is generally related to lower costs, better quality work, improved productivity, adherence to schedule, reduced exposure to bad publicity, and minimal disruption of the work being performed. As Hinze (1997) stated, owners whose objectives are to avoid injuries are likely to have a proactive and more direct involvement in construction operations. Therefore, the first step of the owner's involvement in safety is commitment, especially management commitment, to create an injury-free project. Each owner in the survey conducted by Levitt and Samelson (1993) stated the belief that active involvement in construction safety, done properly, served to reduce rather than increase the firm's potential liability for construction accidents.

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 during the construction phase (Gambatese, 2000b). During project development, owners should convey their commitment to safety to the contractors through various means, including devising incentives for safety and by implementing sanctions for failing to support the owners' safety initiatives.

Consider Safety In Contractor Selection

Traditionally, selecting safe contractors was recognized by many owners as the most effective way to guarantee safety performance on their projects. Criteria for

selecting safe contractors have been extensively investigated in the past. Levitt and Samelson (1993) stated that screening contractors in terms of their expected safety performance is an easy and effective way for construction owners to enhance construction safety. Levitt and Samelson (1981) suggested that the criteria must be (1) predictive of safe project performance; (2) equally applicable to different construction firms; and (3) objective. Possible selection measures were EMRs, OSHA recordable injury rates, and management safety accountability. Findings from the research that are indicative of safety accountability include the following:

1. Who in the organization receives and reviews accident reports, and what is the frequency of distribution of these reports? (Frequent reports, detailed by operating units, and reviewed by the president of the firm would be an indication of high company accountability for safety.)

2. Frequency of safety meetings for field supervisors.

3. Compilation of accident records by foremen and superintendents and the frequency of reporting. (Contractors who categorize their accident statistics by superintendent and foremen, rather than by larger units, have a more detailed accountability system.)

4. Frequency of project safety inspections and the degree to which they involve project managers and field superintendents.

5. Use of an accident cost system allocating or assigning responsibility to individual foremen and superintendents, as well as project managers.

Certain safety criteria during the selection of contractors suggested by Hinze (1997), and Hinze and Godfrey (2003) include the following:

- Injury incident rates (including lost workday injury rates, OSHA recordable injury rates, first aid injury rates, and etc.)
- Job site safety inspections
- Behavior based worker observations
- Experience modification rates (EMR)
- Loss ratios of workers' compensation
- Records of OSHA citations and fines
- Litigation related to injuries
- Performance records of key personnel

- Project safety plans
- Contractor qualification safety surveys
- Worker's conception surveys

Contractual Safety Arrangements

Owners must also make sure that contractors recognize their contractual responsibility to perform safely (Levitt and Samelson, 1993). Contractually, most owners have the contractor indemnify them from any losses or liabilities resulting from injuries, but it is also essential to include specific and thorough safety requirements in the construction contract. The requirements might include the following(Gambatese, 2000b):

- The requirement that the contractor abide by all applicable safety laws and regulations;
- A delineation of the responsibility for safety on the jobsite;
- The submission of a written contractor safety program before work begins;
- A requirement for implementing a substance abuse program; and
- The submission of an emergency plan and accident reporting procedure.

Questionnaires sent to owners and contractors (Business Roundtable, 1982) were used by Stanford University to identify safety requirements owners placed on construction contractors and specific practices of owners to emphasize safety with contractors. The responses are arranged in decreasing order of use by the respondents. Require use of a system of permits for potentially hazardous activities.

1. Require the contractor to designate a responsible supervisor for safety coordination on the job site.
2. Provide the contractor with safety guidelines that must be followed.
3. Discuss safety at owner-contractor meetings.
4. Periodically discuss safety audits of the contractor operations.
5. Require immediate reporting of contractor accidents.

6. Stress safety as part of the contract during pre-bid walk-arounds.
7. Investigate contractor accidents.
8. Maintain statistics of contractor accidents.
9. Conduct periodic safety inspections.
10. Set goals for construction safety.
11. Consider safety in prequalifying contractors for bidding on projects.
12. Set up a construction safety department to monitor contractor safety.
13. Set safety guidelines in the body of the contract.
14. Be involved in orientation sessions alerting workers to safety hazards on the job.

An owner, to be actively involved in construction safety, might consider several contractual issues. Many of the issues relate to the safety obligations placed on the contractor. Hinze (1997) suggested that contract provisions may include the following requirements:

- Submittal of a project-specific safety plan
- Job hazard analysis
- 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

As the major binding document between the owner and contractor, the contractual arrangement (lump-sum or cost reimbursable) will also impact how safety will be addressed on the project. One reason that the contract type should be considered when addressing project safety is that the contract essentially determines how the owner will make payment to contractors to compensate them for their services on the project, and therefore, can impact the relationship between owner and contractor (Dagostino, 2002). As safety can be obtained only through the concerted efforts of different parties (owner,

contractor, and designer), the nature of their relationships can be expected to impact safety. For example, if the contractor has a close, long-term relationship with the owner, they will generally use cost reimbursable contracts (cost plus). Thus, safety investments will be reimbursed by the owner to support the contractor's efforts. This arrangement encourages the contractor to spend the necessary funds on safety.

Address Safety During Design And Constructability Review

Design decisions can dictate the structure, elements, materials and even the construction methods to be used on the project. For example, the selection of forming systems, cycle times, sequences, equipment, and design of temporary structures are significantly impacted by the design of the permanent construction. Therefore, designers are very influential, perhaps unknowingly, in impacting the way safety issues will be addressed during construction. Consideration of construction worker safety by designers (hereinafter also called A/E) can lead to a reduction in injuries and associated costs during the construction phase (Hinze and Wiegand, 1992; Gambatese, 1998; Gambatese 2000a). Toole (2002) stressed that the A/Es are in the best position to implement specific safety design recommendations, thereby preventing less safe conditions on the site. Also, A/Es may be best able to identify questionable structural situations such as temporary loadings on the permanent structure or temporary work platforms, provided they are explicitly requested to do so and possess all of the data necessary to perform the analysis. One reason why the Corps of Engineers has had particularly low injury rates on their construction projects is that it coordinates the design with erection procedures and coordinates their efforts on safety (MacCollum, 1995). Although the involvement of design professionals in construction site safety has been minimal to nonexistent on many projects, when they are involved their influence can be significant, and can help reduce

accident occurrence. This influence has favorable cost implications for the projects (Gambatese, 2000a. see Figure 2-6).

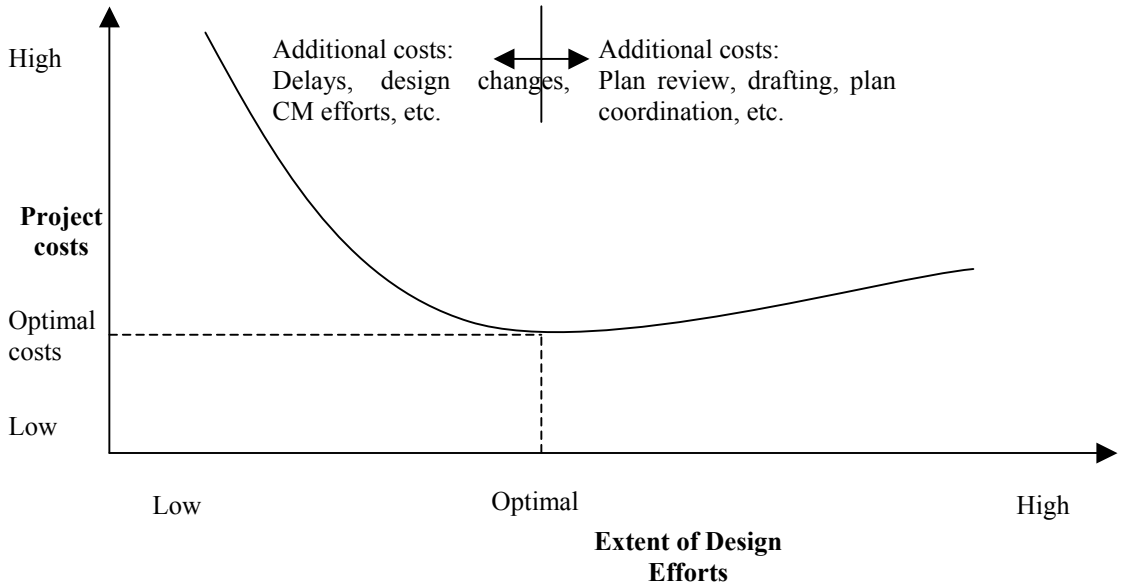


Figure 2-6. Relationship between Design Effort and Project Cost

In the past, design professionals typically would distance themselves from the responsibility for the safety of the construction workers. The reasons include their lack of safety education and training, the lack of safety design tools, their restricted role on the project team, and an attempt to limit their liability exposure (Gambatese, 1996). However, with the unacceptable injury and fatality rates, the construction industry has concluded, "The need for changes in attitude does not stop at educating erectors to work more safely. It has to go back to the architect and engineer who should not only ask themselves if it can be built, but can it be built safely." (Baggs, and Cunningham, 1988) In the UK, the Construction (Design and Management) Regulations 1994 place duties on designers and owners to make assessments of the impact of the proposed design on the life cycle safety of the facility, including the construction workers, maintenance personnel, and the facility occupants (Holt, 2001). Although a similar U.S. bill to expand

the designer and owner responsibilities on construction safety did not pass, the OSHA standards are certainly not foreign to designers, which is a potential source of designer liability. This occurs not solely by assuming the contractor's responsibilities for the means or methods of the construction process, but through the understanding of their duty as designers to help provide a safe workplace which is basic in their review of the contractor's work product (Coble and Blatter, 1999). In response to the needs of the industry, some architects started to work as construction managers on small projects and thus coordinated the construction and design efforts to reduce accidents and costs (McKee, 1994). MacCollum (1995) ranked the methods used for reducing safety risks according to their priority and effectiveness, including the following:

- Design to eliminate or minimize the hazards;
- Guard the hazards;
- Give warnings;
- Provide special procedures and training; and
- Provide personal protective equipment.

He further suggested that the design team should include at least one safety professional, and should develop and implement a hazard prevention plan for each project.

Owners can impact designers and contractors through their proactive participation in construction safety issues. In the construction accident causation model developed by Suraji et al. (2001, see Figure 2-5), designer responses to project design constraints (which may arise from the owner) can in turn place constraints on the construction process. This may result in a chain reaction effect on accident causation. For example, the constraints imposed by the owner may include the following:

- Accelerated design program
- Inadequate design budget
- Conflict of objectives or demands of other projects

Designer response is the action or inaction by designers to respond or react to the constraints existing during the project design stage. These include the following:

- Increased design complexity
- Sublet part of design process
- Reduction in design resources
- Reduction in quality of components
- Ignore legal liabilities

Therefore, owners can take an active role in design 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 integrate 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.

Participate In Safety During Construction

In the research conducted by Levitt and Samelson (1993), it was found that the owners with the safest construction projects tended to use many of the following strategies with their contractors:

- Stress safety as part of the contract during the pre-job walk-around. This gives contractors the opportunity to include all safety-related items in their bids and lets contractors know early that the owner is serious about safety.

- Require short-term permits, rather than ongoing permits, for hazardous activities. This means that contractors must check daily or more frequently to ensure that any planned hazardous activities are coordinated with other contractors and with the owner's own plant work force.

- Conduct safety audits of the contractor during construction. The owner's or construction manager's safety staff conducts these audits to ensure compliance with the owner's safety requirements and with all state and federal safety regulations. They are aimed at systems and procedures rather than at specific hazards.

- Conduct periodic safety inspections.

- Require safety training of all project employees.
- Maintain statistics on the contractor's safety performance.
- Set goals for construction safety. Project-wide safety goals should be set, along with specific goals for contractors who need special attention because of past poor performance or particularly hazardous work operations.
- 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. Immediate rather than periodic reporting gives the owner more time to intervene and ensure that the contractor has corrected any identified hazards before others can be injured by them. Such notification can also serve to initiate consultations with the contractor's senior management, if needed.
- Investigate the contractors' accidents. The owner's involvement in investigating the contractors' accidents gives the owner valuable insights about generic safety hazards on the project, as well as additional insights about the contractors' organization and capabilities in the area of safety.
- 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 on site.
- Reimburse the contractor's safety costs in full.

The following is a sample of best practices suggested by Gambatese (2000b) that an owner can implement:

- Adjust the scheduling of different activities or construction phases that would otherwise occur at the same location and 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 contractor knows of the potential hazards of all construction materials and their proper storage and disposal.

- On renovation or retrofit projects, provide the contractor with complete and updated as-built drawings of the existing structure.

- Conduct a pre-construction meeting with the contractor (including all subcontractors) to discuss safety issues.

- Consider involving OSHA in planning for project safety prior to starting construction.

Gambatese (2000b) also suggested that owners should:

- Establish a clear position on safety. 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. The actions of all members of the owner's organization during the course of the project must reflect and reinforce the established position.

- Ensure that safety is addressed in project planning and design. Thus, owners must provide the initial impetus, by requesting or even requiring, by contract terms, that designers consider construction site safety in their designs.

- Consider safety performance when selecting a contractor.

- Address safety in the construction contract. There are numerous clauses that could be included in a contract to promote safety.

- Assign safety responsibility during construction. The responsibility for overseeing safety on a construction project should be held by a competent organization or individual.

- Participate in project safety during construction. Perhaps the most effective way an owner can influence safety is through jobsite participation. Another common means by which owners can be involved in safety is by requiring the submittal of regular safety reports. Reports can be requested that provide information on the results of jobsite inspections, a listing of all injuries, safety meeting minutes, and investigations of major accidents.

Hinze (1997) summarized some unique owner practices as the following:

- Placing company representatives on every construction project
- Conducting safety meetings with the contractors
- Requiring the contractors to adhere to owner-developed safety practices

- Providing specialized safety training for the contractor personnel
- Requiring all workers to go through safety orientation
- Reviewing each contractor's safety program
- Conducting regular audits of contractor safety performance
- Implementing safety incentive programs on all construction projects

The participation of owners in safety during construction is an integral part of the efforts of many owners, but it is far from the sole participation of owners in safety. Safety involvement of owners often starts at the very beginning of the project, and lasts throughout the life cycle of the facility. Owner involvement in safety includes selecting safe contractors, addressing safety in design, including safety requirements in the construction contract, and being actively involved in project safety management.

Total Safety Culture And Behavior-Based Safety

When participating in construction safety management, proactive owners generally implement initiatives that promote safety. The concept of total safety culture and behavior-based safety management are among the latest safety management initiatives that will be introduced.

Originally, people believed that accidents were a result of pure chance, and could happen to anyone at any time, and some people were more likely to suffer an accident than others. This was referred to as the accident proneness model (Cooper, 1998). In the past, the prevailing influence of this approach meant that most accidents were blamed solely on employees rather than on the work processes, poor management practices or a combination of these. Recent studies have found no solid evidence to show that certain people were more likely to be involved in accidents, and thus concluded that accident proneness was essentially related the individual's propensity to take risks (Hinze, 1997).

The most famous accident causation model is the Domino model suggested by Heinrich (1959, see Figure 2-7). The model shows that an accident is the result of a

series of events related to the social environment and heredity, personal failings or mistakes, physical hazards and unsafe behavior. These events, if permitted to occur in continuity, result in an accident, which may result in injuries and damages. Any accident is prevented by breaking the chain (or removing a domino) of the series of events at any location. While it is generally understood that most accidents are preceded by a series of events, it is common practice to place most of the attention on the action that occurred immediately before the accident. A more proactive approach would be to focus on the "upstream" activities or events that set the series of events in motion.

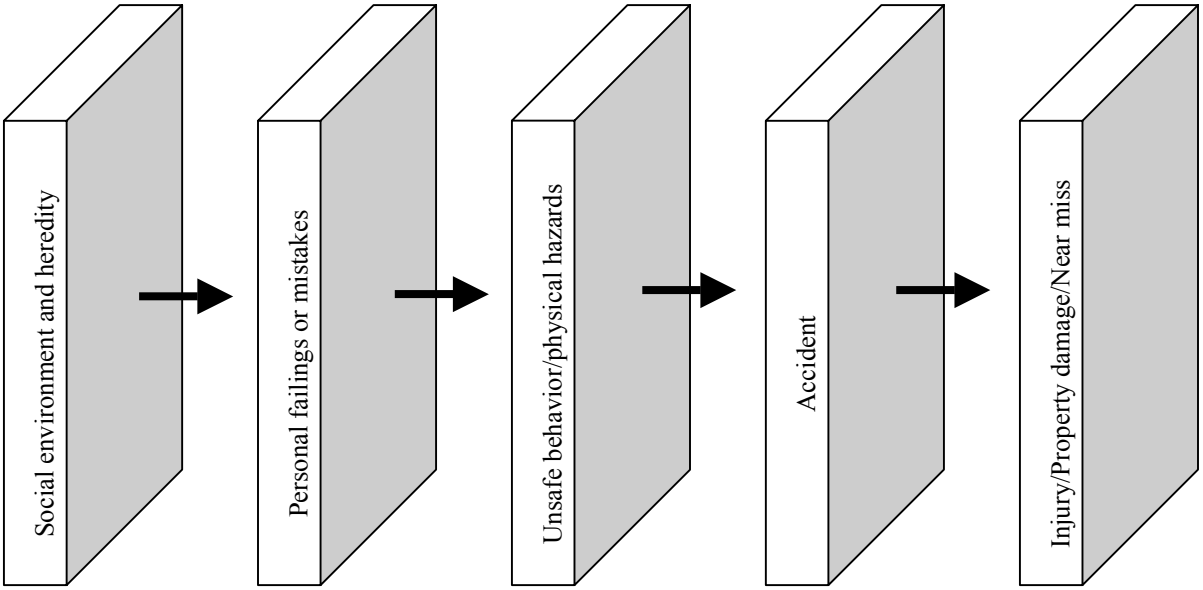


Figure 2-7. Domino accident causation model suggested by Heinrich (1959)

Many other theorists used Heinrich's domino theory as the starting point for their own work. For example, in 1971 Weaver modified the original theory to propose that the last three dominos in the sequence were caused by management omissions (Cooper, 1998). In essence, Weaver's model placed the immediate responsibility for accidents squarely on the shoulders of poor supervision and line management, instead of the injured workers.

Today, as the zero injuries objective is accepted and sought by many owners and contractors, total safety culture (TSC) and behavior-based safety (BBS) have become the popular approaches being implemented by many proactive firms. The basic logic of these approaches is to prevent construction accidents by continually addressing the very front-end of the accident chain – the culture and habits. Safety management is based on the scientific approach that is focused on the psychology and the behavior of workers. Geller (2001) summarized the essence of TSC as the following:

- Promotes a work environment based on employee involvement, ownership, teamwork, education, training, and leadership.
- Builds self-esteem, empowerment, pride, enthusiasm, optimism, and encourages innovation.
- Reinforces the need for employees to actively care about their fellow coworkers.
- Promotes the philosophy that safety is not a priority that can be reordered, but is a value associated with every priority.
- Recognizes group and individual achievement.

He further pointed out that total safety culture requires continual attention to three domains environmental factors (including equipment, tools, physical layout, procedures, standards, and temperature), personal factors (including people's attitudes, beliefs, and personalities), and behavior factors (including safe and at-risk work practices, as well as going beyond the call of duty to intervene on behalf of another person's safety). In a total safety culture:

- Everyone feels responsible for safety and does something about it on a daily basis;
- People go beyond the call of duty to identify unsafe conditions and at-risk behaviors, and they intervene to correct them;
- Safe work practices are supported intermittently with rewarding feedback from both peers and managers;

- People "actively care" continuously for the safety of themselves and others;
- Safety is not considered to be a priority, but it is a value. This change in philosophy is based on the premise that priorities can change but values cannot.

Weinstein (1997) proposed another approach toward total safety culture through incorporating Total Quality Management with safety. He suggested a Total Quality Safety Management System which is achievable through the implementation of Total Quality Management Principles, Process Safety Management Guidelines, ISO-9000 Quality Guidelines, and OSHA VPP (Voluntary Protection Program) guidelines. The core of this approach relies on the commitment to and leadership of safety, and the involvement of each individual and each work team in safety.

Cooper (1998) criticized the approach that most accidents were blamed solely on employees rather than the work processes, poor management practices or a combination of all three. He analyzed different theoretical models to explain the accident causation, and supported the argument that the main focus of accident prevention should be shifted away from the worker's unsafe acts and more onto the organization's overall management system, particularly in relation to the implementation of the organization's strategic decisions. Cooper concluded that safety culture should be *the product of multiple goal-directed interactions between people (psychological), jobs (behavioral) and the organization (situational)* (Cooper, 1998, page 17). Viewed from this perspective, an organization's prevailing safety culture is reflected in the dynamic inter-relationships between members' perceptions about, and attitudes towards, organizational safety goals; members' day-to-day goal-directed safety behavior; and the presence and quality of organizational safety systems to support goal-directed behavior.

In recent years, behavior theories are widely used in safety management. The behavior-based safety approach is being utilized more extensively on construction projects. The objective of behavior-based safety is to eliminate unsafe behaviors and encourage safe behaviors through effective management interventions, based on behavior and psychological theories. The core of the behavior-based safety approach is to track both safe and unsafe behaviors of workers. According to Sutherland et al. (2000), the basic premise of the behavior-based safety approach can be stated very simply: *Behavior is determined by its consequences*. That is, people tend to repeat those behaviors that produce 'positive' consequences, and not repeat those that result in either no positive or 'negative' consequences. Therefore, by giving workers with safe behaviors "nice" things or removing negative effects, safety behaviors can be positively reinforced. On the contrary, by giving workers with unsafe behaviors negative feedback or by taking away "nice" things, unsafe behaviors will be punished and eliminated. This is also known as negative reinforcement. Workers who work safely could be rewarded (positive reinforcement), while workers who are unsafe could be punished (negative reinforcement). Management must decide which of these are most appropriate.

Peterson (1988) summarized the most common ways the behavioral scientist has contributed to safety management. The major approaches include the following:

- Survey methodology. Managers concerned about characteristics of their organizations have often used employee attitude surveys to identify problem areas, to assess the effects of organizational change or policies on job satisfaction, and as an index of management performance.
- Selection and assessment of personnel. The contribution of the behavioral sciences, particularly psychology, to improved selection, placement, and assessment of personnel is a most common use.
- Programmed Instruction. This concept includes such sensible elements as behavioral definition of training goals, the analysis of learning tasks into

manageable units, and systematic applications of principles of reinforcement to the learning situation.

- Motivation theory. Intervening safety behavior through motivation techniques is the core of the theory. In the minds of some observers, the impact of the motivation theory and the application of the practices they advocate constitute the major contribution of the behavioral scientists to the construction industry.

- Participative management. Workers would be more fully committed if they had a voice in setting the goals and conditions of their work environment.

- Organizational development. Organizational development is a process of systematic, planned change in an organization. It incorporates a definite philosophy that organizational change should be in the direction of mutual trust, openness in communication, readiness to deal with feelings as legitimate data, and understanding intra- and inter- group relations.

Today, behavior-based safety approaches are widely used by many proactive owners and contractors on their construction projects. The common approaches include safety observations, worker participation (through job safety analysis, safety survey etc.), and safety recognition programs.

Summary

From the literature review, it is apparent that although various recommendations exist, there is still no solid evidence in the previous research to describe how owners can efficiently promote construction safety on their projects, and how to assess the relationship between safety performance and the owner's involvement in project safety. A detailed research study at the project level to evaluate the owner's impact on construction safety has not been conducted. This conclusion gave impetus for conducting this research. Certain aspects to be investigated include the owner's commitment to safety, the selection of contractors, contractual requirements, and the owner's participation in safety management during construction.

CHAPTER 3
RESEARCH MOTHODOLOGY

Since previous studies and perspectives expressed in the literature suggested that the owner's impact on construction safety can be demonstrated in various ways, this study will focus on the influence of these factors on the safety performance of construction projects. This chapter will describe the research methodology to disclose the relationship of the owners' actions on project safety performance.

Research Design

Research Components

The objective of the study: To compare the effectiveness of several different factors of the owner's involvement in construction safety on project safety performance. In order to identify the relationship between a specific factor and project safety performance, the median safety performances of projects on which owners implement specific safety approaches will be compared with the median safety performances of projects on which owners do not have such an approach.

Universe: All construction projects in North American with U.S. and Canadian owners

Experimental Unit: Any individual construction project

Population: Collection of safety performances of projects in the universe

U-Sample: Collection of construction projects included in the study

P-Sample: Collection of safety performances of projects in the study

Inclusion criteria:

The projects selected in the study should have at least 100,000 worker hours accumulated to provide viable information on safety performance;

1. The projects should be on-going or have been completed within the past two years;
2. The safety personnel of the projects must be willing to participate in the study.

Response Variable: Project safety performance is the response variable in the study. It is measured by the total OSHA recordable injury rate (TRIR) of the project, which is the number of OSHA recordable injuries occurring per 100 full-time workers annually (or injuries per 200,000 worker hours of exposure). TRIR can be easily calculated with the number of OSHA recordable injuries and total worker hours expended on a project.

Factors and levels: Each specific aspect of owner involvement in construction safety can be identified as a factor. Therefore, there are multiple factors included in this study. Based on the results of the literature review and previous study results, the factors of interest can be classified into four categories, as follows:

Project context: the characteristics of the projects, including the following:

- The size of the project as measured by the estimated worker hours expended on the project (quantitative factor);
- The construction effort on the project: whether a new project, renovation project, maintenance project, or shutdown/turnaround/outage project (qualitative factor);
- The type of the project: whether a manufacturing project, a petrochemical project, a civil work, a residential project, a utility project, or a commercial project (qualitative factor.);
- The labor relationship of the project: whether the labor on site is union, open shop or merit shop (qualitative factor);
- Type of owner for the project: whether public or private (qualitative factor);
- Basis for contract award, whether the contractor is selected through competitive bidding or not (qualitative factor);

- Type of contract arrangement used on the project: whether general contract, multiple primes, design-build, C.M. at risk, or C.M. agency contract (qualitative factor);
- Type of contract used on the project: whether lump sum contract or cost plus contract, similar to a time and materials (T&M) contract (qualitative factor);
- Firm providing the workers' compensation insurance on the project, whether the owner (OCIP), the project (PCIP), the general contractor (CCIP), or if each employer provides their own insurance coverage (qualitative factor);
- Number of work shifts per day: whether one, two, or three (quantitative factor);
- Number of workdays per week: whether four, five, six, or seven (quantitative factor);
- Number of workers at the peak level of employment on the project (quantitative factor);
- Total estimated monetary value of the project (quantitative factor);
- Percent of workers on site that do not speak English (quantitative factor);
- Number of subcontractors awarded on the project (quantitative factor);
- The prime contractor's commitment to safety, as evaluated by the owner's site personnel (quantitative factor);

Selection of contractor: the factors related to safety that owners consider when selecting contractor(s) to execute their projects, including:

- Whether or not the owner uses a preferred list when selecting a contractor (qualitative factor);
- Whether or not safety performance is a consideration in contractor selection (qualitative factor);
- Measurements used to evaluate safety performance of a contractor including TRIR, EMR, safety personnel qualifications, project team qualifications, quality of overall safety program, the OSHA log, and OSHA inspection history (qualitative factor);

Contractual safety arrangement: the safety requirements that are included in the contract between the owner and contractor. This category will include different safety

management techniques that contractually must be employed by the contractor. They are typically qualitative factors.

Owner's involvement during project execution: the practices of the owner during the project execution to improve safety, including:

- Responsibilities of owner's site safety representative (qualitative factor);
- Implementation of a safety observation program on the project (qualitative factor);
- Specific items that must be included in the contractor's safety program (qualitative factor);
- Means of addressing injury statistics on the project: whether by project, by contractor, or blended with owner's safety performance statistics (qualitative factor);
- Treatment of near misses: whether recorded and investigated, or recorded without further investigation (qualitative factor);
- Owner support of project safety, specifically whether extra funds are provided to promote safety (qualitative factor);
- Owner participation in an OSHA Voluntary Protection Program (VPP) (qualitative factor);
- Whether or not a nurse or EMT is provided for the construction site by the owner (qualitative factor);
- Extent of owner involvement in the safety training program (qualitative factor);
- Implementation of a safety recognition/reward program on the project, and the level of the owner’s involvement (qualitative factor);
- Distribution of a safety newsletter on the project (qualitative factor);
- Use of safety lunches to promote safety (qualitative factor);
- Incorporation of safety in the design of the project (qualitative factor);

Most of the factors are qualitative factors, and a few are quantitative factors. For each qualitative factor, the **parameters** of interest are:

ξ_Y = the true median TRIR of all projects where the owners employed the safety technique

ξ_N = the true median TRIR of all projects where the owners did not employ the safety technique

The statistics of interest are:

$\overline{M_Y}$ = The observed median TRIR of all projects where the owners employed the safety technique

$\overline{M_N}$ = The observed median TRIR of all projects where the owners did not employ the safety technique

Thus, the objective of this study could be achieved by **testing the hypothesis** (H_0: $\xi_Y = \xi_N$ vs. H_a: $\xi_Y < \xi_N$) for each qualitative factor. This is a one-tail test, since TRIR can be expected to be less when the owner implements a safety approach or when the project possesses a specific characteristic identified in the literature review. The hypothesis testing will be further discussed in chapter 5.

Method Design

This study is a retrospective observational study, in which both response variable and factor levels are observed from the samples selected. Personal interviews based on a questionnaire were used to collect most of the data necessary for the study on each project selected. This is one of the methods frequently used in studies on construction projects. Since construction projects generally cost millions of dollars, and they are often under the influence of many different factors, it is not practical to conduct a prospective experimental research study. The interview was therefore employed to obtain as much information as possible.

Because little prior research had been conducted on this topic, an initial study was necessary to get some idea of the most commonly employed techniques of owners to promote construction safety, and whether they might be related with safety performance. Also, a follow-up questionnaire survey with contractor safety personnel was conducted to help verify some of the findings and determine how contractors would like owners to get involved in project safety management.

As the study is an uncharted one, it is difficult to reasonably determine which factors might be extraneous factors and which might be major factors that influence project safety. Therefore, all the factors suggested in previous studies and the industry pilot study were included and analyzed. Statistical analysis and discussion will identify which factors make a difference on project safety performances. Finally, based on the analysis, a model was built to explain how owners can influence construction safety.

Sample Size Determination

Since the objective of this study was to compare ξ_Y to ξ_N, the type of inference is hypothesis testing. In order to determine the minimum acceptable sample size required for the study, the following steps to perform hypothesis testing were followed:

1. Determine the null hypothesis (H_o). The null hypothesis is H_o: $\xi_Y = \xi_N$.
2. Determine the alternative hypothesis (H_a). The alternative hypothesis is H_a: $\xi_Y < \xi_N$ (one-tail test). When the literature suggested that projects where owners implemented specified practices would have better safety performance, and the median TRIRs also supported the statement, a one-tail test was conducted, i.e. H_a: $\xi_Y < \xi_N$.
3. Determine a suitable significance level and power for the statistical test. The significance level is set as $\alpha = 10\%$, instead of 5%. Since this study intends to identify those potential influences owners can have on project safety, the significance level is set higher than usual. The power of the statistical test is set to be $1-\beta = 1-20\% = 80\%$ (β is set to be 20%). That is to say, the probability of a Type I error (the probability of erroneously rejecting H_o when it is actually true) is 10% and the

probability of Type II error (the probability of erroneously accepting H_o when it is actually false) is 20%, respectively.

4. Choose and compute the test statistic. The test statistics have been discussed.
5. Make correct conclusions. This will be discussed in Chapter 5.

According to a previous study (Hinze, 2002), it was estimated that the practical difference between TRIR of two projects that makes sense in the industry is B = 1.0. This is determined to be the clinical significant difference to determine the sample size of this study. Since it was assumed that most of the projects that would participate in the interview study would have better safety performances than the construction industry average (which is 7.8 for TRIR in 2001, BLS, 2003), the response variable is estimated to be between 0 and 6. Therefore, based on the Empirical Rule, the estimate of the standard deviation of TRIR is $\sigma = (6-0)/4 = 1.5$. Then the sample size determination can be calculated with the following indexes:

$DELTA = B/\sigma = 1/1.5 = 0.67$

$\alpha = 10\%$, $\beta = 20\%$

By referring to the tables listed in (Rosner, 1995), the sample size for each factor level (when owners do or do not implement a particular safety management approach) should be 28 projects. Therefore, the total sample size for this study is 28*2 = 56 projects.

Computation of the sample size needed to provide valid research findings was found to be 56. This means that a sample size of 56 would be expected to yield reliable results.

Sample Selection

Most of the projects in the project interview phase (the major phase of this study) were recommended by the Construction Industry Institute Project Team #190 (with the title "the role of owners in construction safety"), based on the inclusion criteria. The contact persons of the projects were then asked whether they could accept an interview. The person was then interviewed with the questionnaire after he or she agreed to accept the interview. Essentially, the project sampling was a voluntary sampling, since attitudes of owners towards safety varied significantly, and only those that would participate in the study and responded could be included in the sample. Note that all projects identified in the research was contacted to request their participation. These tended to be projects known to the CII project team members. However, whether or not the data could be regarded as representative would then depend on the variability of the data collected and the size of the projects. That is, if the variability of the response variable was similar to the large projects in the population (projects of the large owners), it could be regarded as representative of the population. If the sizes of the projects in the study summed up to a significant portion of the total size of projects in North American, the data could be reasonably regarded as representative. Also, in order to test whether the injury data (which might be sensitive to some owners and therefore biased) was true, the injury triangle by Heinrich (1959) was used to test the results.

Data Collection

Three studies were conducted to collect data for this research effort: the pilot study, the project interviews, and a follow-up survey. The pilot study consisted of a mailed survey sent to large owner firms that were known to have significant construction budgets. This research was followed by a study in which representatives of owners were

interviewed at participating construction sites. The interview data consisted of more detailed information than was obtained in the mailed survey study, and therefore constituted the major data collection phase. Most of the findings of this research are generated based on the data collected through the project interviews. The follow-up survey of contractors was a supplementary part of the study, with the purpose of comparing the findings of the project owner interviews with the opinions of construction firms.

Mailed Survey Study (Phase 1)

The first phase consisted of surveys to study the practices of owners and their resultant impact on construction safety at the company level. The purpose of the survey was to establish and refine the hypotheses to be tested in the subsequent interview study. Also, the survey was to help identify new factors to be tested. This included the acquisition of information on why safety is essential to owners, means used to ensure that safe contractors are employed on their projects, how safety is addressed in construction contracts, how contractors are expected to address safety during construction, the means used by owners to monitor contractors during construction, and the nature of the active role played by owners during project execution. The questionnaire was developed by relying on the literature review and the input from construction industry safety personnel. The survey questionnaire asked questions related to safety performances of the owner projects, safety coordination of the owner, owner safety management practices on projects, safety in design phases, and other safety related topics (see Appendix a). The U.S. owners surveyed were those making large annual expenditures for construction, as listed in the Top 425 owners provided by ENR (Engineering News Report, 2001). Their construction budgets in year 2000 ranged from 23.8 million to 3.8 billion dollars.

Project Interview (Phase 2):

The second phase of the study was designed to acquire more detailed information, which would not be feasible or realistic in a mailed survey. The purpose of this study was to test the hypotheses that had been developed. This study, with its focus at the project level, was conducted through in-depth interviews. In addition to obtaining information about the various practices of owners to ensure the safety of construction workers on their sites, information was also obtained on measures of safety performance. Based on the results obtained from the literature review and the mailed survey, a detailed interview questionnaire was designed. The questionnaire went through a series of iterative improvements as suggestions were offered by members of CII Project Team #190. The questionnaire mainly focused on four aspects of the owner's involvement in construction safety:

- Project description,
- Selection of safe contractors,
- Safety requirements in contracts, and
- Owner's involvement in safety during construction.

Factors such as project characteristics, contractual arrangements, contractor's commitment to safety, and so on were also addressed in an attempt to control external impacts on project safety performance.

The questionnaire was modified through approximately 15 iterations before it was used to conduct interviews. After three telephone interviews were conducted, a final version was devised. After the first three interviews, the interviewees were asked about the clarity and integrity of the questionnaire. This feedback was used to further modify the questionnaire before it was finalized and used in the remaining interviews. The final version of the questionnaire is included in Appendix b. Approximately 100 construction

projects were identified for inclusion in this research. The criteria to select projects included:

- Under construction or newly completed (within the past two years);
- Worker exposure of at least 100,000 hours (some exceptions were made, as explained later);
- Variety in the types of projects: public or private; petrochemical, utility, manufacturing, commercial or residential projects
- Whenever the owner had several smaller projects at the same location and implemented the same safety management policy, the multiple projects were regarded as a combined project.

Persons interviewed included site representatives of the owner, including construction managers, safety managers, and safety coordinators. The face-to-face project interviews generally took one and a half hours to two and a half hours to conduct. Whenever face-to-face interviews were economically infeasible, the interviewee was asked to fill out the questionnaire and return it to the researcher by Fax or email. For questionnaires returned this way, a follow-up telephone interview, lasting about half an hour, was conducted to clarify any questions. Most of the projects were introduced by members of the CII Project Team #190. Often either the owner or the contractor on the project, or both, were CII members; however, CII membership was not a criterion for inclusion in the study. Many owners of projects were not affiliated with the CII.

At the conclusion of this study, 81 projects had been interviewed. Among them 59 projects provided the TRIR data and satisfied all the criteria to be included in the data analysis. The final sample of 59 projects included 49 U.S. projects, seven projects in Canada, and three international projects with U.S. owners and U.S. contractors.

Follow-Up Survey To Contractors (Phase 3)

A survey of contractors was conducted after the project owner interviews were completed. This was not a major part of the data collection. This study was to obtain information from contractors, because contractors may hold different views towards the same questions regarding owners. Therefore, it was deemed reasonable to conduct a separate survey of contractors to identify possible bias of the data obtained from owners. Also, some questions asked how the contractors would like the owners to help promote project safety. The information could help communication and cooperation of the two parties on future projects. This survey was conducted with a short questionnaire developed on the basis of the analysis results obtained from the project interviews (see Appendix c). The participating contractors may or may not have been involved in the owners' projects in the primary study.

Data Analysis

The main objective of the project was to test whether the involvement of owners in safety management made a difference to the safety performances of projects. Project safety performance, defined as the OSHA recordable injury rate (also referred to as Total Recordable Injury Rate, TRIR), was the dependable variable in the analysis. The different safety management techniques implemented by the owners were regarded as the independent variables. Other information obtained relating to project properties and contractor's commitment to safety constituted extraneous factors and were not the major variables to be considered in the research. They were also regarded as the independent variables in the analysis.

Analysis of the data obtained from the mail-out questionnaire survey to owners (Phase 1) used non-parametric methods, univariate methods and the logistic regression

method based on the type of the response variables. The analysis attempted to recognize the involvement of owners that might help project safety.

Analysis of the data set obtained through the project interviews (Phase 2) was the major part of the data analysis. It can be divided into three stages. The first stage was focused on the descriptive statistics of the variables, that is, means, medians and standard deviation of the interval variables, and the proportions of nominal and ordinal variables were calculated. By this means, the frequency and popularity of different safety practices and techniques were identified. The second stage aimed at testing reasonable associations among the variables, especially the associations between safety performance and safety management approaches. Efforts in the third stage were conducted on the establishment of a model to define the relationship between project safety performance and various types of owner involvement. A scorecard was developed to evaluate the owner's involvement in construction safety management.

All the data, once obtained, were input into a document developed in the Statistical Package for Social Sciences (SPSS v10.0), according to the data structure of the questionnaire. In the first stage of data analysis, the software was used to describe the properties of the projects interviewed, including their location, size, safety performance, contractual arrangement, types and labor arrangement. Frequencies of different safety management techniques were also summarized to provide a holistic picture of the information of the projects interviewed. As one aspect of the analysis, data from projects in Canada were examined separately from the projects in the U.S to address any possible regional variations. It should be noted that no clear differences were found between the U.S. and Canadian projects.

In the second stage, multi-variable statistical analysis methods, especially non-parametric methods (which treat the response variable as an ordinal variable) were conducted to find the relationship between safety performance and the safety management techniques. Safety performances of projects with different safety management techniques were compared to identify those techniques that made a difference on safety performance. In this stage, the data were stratified to get a better idea of how some owners emphasized safety on large projects, and how owners would focus on safety on petrochemical projects. This was done because the pilot study showed that larger contractors and petrochemical projects appeared to have better safety performances. When considering the variety of the projects interviewed, the significance level was set at 0.10, to detect all the safety management techniques implemented by owners that could potentially impact safety performance.

In the third stage of the data analysis, answers to some open-ended questions, as well as some detailed cases, were considered to test how the owner's involvement could make a difference to project safety performance. Based on the analysis in the first and second stages, this stage was focused on establishing a model to describe the cause-effect relationship between the owner's involvement and project safety performances. Also, the most effective and important points for the future reference by owners were summarized into a scorecard to evaluate the owner's involvement in safety management.

Analysis of data collected in the survey of contractors (Phase 3) was mainly composed of descriptive statistical analysis. Those statistics were then referenced to support the findings in the interview questionnaire, and provide suggestions for owners to better cooperate with contractors in promoting construction safety.

CHAPTER 4
QUESTIONNAIRE SURVEYS FOR LARGE OWNERS

In this chapter, the analysis of the data obtained from the questionnaire survey is presented with different non-parametric statistical methods, including the Mann-Whitney U test, Wilcoxon test, Kruskal-Wallis test, and Friedman two-way ANOVA. These non-parametric tests were selected because of the low response rate. By using the non-parametric statistical methods, the medians (or distributions) of the response variable for different factor levels are compared.

The Data Set

The population surveyed was the ENR-list of the top (based on expenditures on construction) 425 owners in the U.S. The questionnaire was mailed out on February 21, 2002. Thirty-one responses were received by April 12, 2002, after which no additional replies were received. The response rate was about 7.3%, which was lower than the expected response rate of 10%. Possible reasons of the low response rate can be:

- The envelope of each survey was addressed to "Construction Contract Manager". Although this was the title suggested by some owner members of CII, the appropriate person to fill out the survey may have a different title in different companies. It is quite probable that the questionnaires were not received by the appropriate individuals.

- The questionnaire may have been too lengthy, requesting too much information. Some individuals may not be patient enough to complete the surveys and return them. This was considered during the design of the survey, and it was determined that people familiar with safety could complete the survey within 20 minutes. Most of the information sought required a multiple-choice response.

- Only companies that emphasize safety and had better safety performances may have decided to participate in the study. It is possible that safety is still not the top

priority in many owner companies. Some companies may be reluctant to reveal information about an unacceptable safety performance.

- As the consumer of construction products and services, most owner companies are expected to have their primary interests in the revenue generating sectors of their own businesses. It is suspected that many owners still regard construction safety as resting totally with the contractors who contract their construction services. Thus, many owners are not familiar with the safety issues on their projects, and may not have felt capable of completing the survey.

Because of the above reasons, the mail-out survey was regarded as a voluntary field experiment, with responses being received from those who had an interest in and had a strong focus on safety management. Therefore, the results are probably biased and not representative of all owner companies. This further supports the use of non-parametric statistics in the analysis. However, as mentioned in the previous chapter, the aim of the questionnaire survey was to identify the practices of the owners associated with better safety performances, and to develop hypotheses to be tested in the subsequent project interview phase of the research. The survey data, although limited and probably biased, can still serve a valuable purpose and provide enlightenment for the follow-up research study.

It should be noted that for non-parametric methods such as the Kruskal-Wallis tests, or Friedman two-way ANOVA, the objective is to compare the medians of different groups, and the response variable is treated as an ordinal variable. The mean ranks that will show in the analysis result tables simply mean the average rank of the coded response variable, and a larger mean rank suggests a larger median of the category.

Because only 19 of the respondents provided the TRIR of their construction projects in the past year, it was difficult to develop any strong conclusions about the types of projects that have better safety performance. However, among the 19 owners providing the TRIR data, ten had primary manufacturing projects (with the average TRIR

of 2.92) and four had primary petro-chemical projects (with the average TRIR of 1.13). In order to discover the underlying reason for the difference, the rating of the importance of safety performance when selecting contractors was considered as a safety index of each owner (ten was the most important and one was the least important). The ranking fo the importance of safety when selecting contractors was the primary measure used in the analysis since 31 respondents provided this information. If the TRIR had been used, the sample size was redeemed to 19, an unacceptable level. The use of the ranking measure was felt to be a viable approach as the ranking value was found to be relatively consistent with the TRIR.

Analysis Of The Mailed Survey Data

The Projects Context

Of the responding owners, the annual construction budget, the percentage of the construction budget on new projects, and the dominant type of construction projects were the characteristics of particular interest. These factors can influence the safety performance of the owner.

The Kruskal-Wallis test was conducted to test whether the ranking of safety importance was dependant on the major type of projects. The results of the test are shown in Table 4-1. Even with a small number of responses, it is apparent that petro-chemical project owners place a higher importance on safety when selecting contractors, while owners of building projects have the lowest importance. The underlying reason may be associated with the attitudes of the owner towards construction safety in their own businesses. For example, the chemical industry and nuclear power generation industry are famous for their strict concern for safety. Therefore, owners in these industry sectors may similarly prioritize safety in their construction projects, and actively

participate in safety management on the projects. The OSHA recordable injury rates of the four owners with petro-chemical projects (0.50, 1.10, 1.42, and 1.50, respectively) were also much lower than those of the other owners. This indicates that these owners have much better safety performances than the industry average.

Table 4-1. Importance of safety during selection of contractors to owners of different types of projects (1 to 10 with 10 being the highest possible rating)

Project Type	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
Building	5	5.2	5	6.5	0.05
Others	2	7.5	7.5	13.25	
Manufacturing	18	7.94	8	17.14	
Utilities	2	8	8	16.5	
Petro-Chemical	4	9.25	9.5	23.88	
Total	31	7.65	8		

Note: In this table, a higher Mean Rank means that the safety index of the group of owners tends to be higher, or the median of the safety index tends to be higher, and therefore, the owners are more concerned with safety. It is the same as in Table 4-2.

The same statistical test was conducted to determine if there was a difference among owners with different annual construction budgets. The result is shown in Table 4-2. It is evident that owners with larger construction budgets are more concerned with safety than owners with small construction budgets. The Mann-Whitney test is conducted to compare the importance of safety to owners with $25-100 million annual construction budgets to those with >$500 million annual budgets, and the results showed that those with budgets >500 million placed a higher priority on safety ($p<0.05$).

Table 4-2. Importance of safety when selecting contractors to owners with differing construction budgets

Annual Budget	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
25-100 million	12	7	7	12.46	0.05
100 - 500 million	13	7.62	8	15.96	
>500 million	6	9	10	23.17	
Total	31	7.65	8		

The percentage of new projects in the construction budget was examined, but this was not a significant factor influencing the owners' concern for safety. This is reasonable because owners with more new projects may not necessarily emphasize construction safety more than owners with fewer new projects, and they may not be good at construction safety performance, either.

Commitment Of The Owner To Construction Safety

Commitment of the owner to construction safety was measured by two questions: the earliest time the owner began to emphasize safety on the project (question 5) and the philosophy held by the owner concerning the responsibility for safety (question 13). In the questionnaire, both questions were coded with ordinal variables to show the degree of owner involvement in construction safety. The earliest stage to emphasize safety (e.g. during concept and feasibility phase) was coded as a smaller number, and beginning to emphasize safety at a later period (e.g., during construction) was assigned a higher number. For the philosophy concerning safety, a small number was assigned to more proactive attitudes (e.g. taking total control of safety).

Owners with different types of major projects and owners with different sizes of annual construction budgets were compared. The answers to question 5 (earliest stage to emphasize construction safety) were significantly different among owners with different annual budgets and owners of different types of projects (refer to Table 4-3 and Table 4-4). It is evident that larger owners and owners of petro-chemical projects started to emphasize construction safety at a significantly earlier stage of the projects. As to the philosophy towards construction safety liability, owners with different size projects did not show significant differences. It was noted that petro-chemical owners tend to have

more proactive attitudes towards safety (address safety in early project stages) and they would assume greater liability risks.

Table 4-3. Earliest stage to emphasize safety vs. annual construction budget

Annual Budget	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
25-100 million	12	3.33	3	20.96	0.03
100 - 500 million	13	1.92	1	13.54	
>500 million	6	2	1	11.42	
Total	31	2.48	3		

Note: In this table, a smaller Mean Rank means that the earliest stage to concern for safety is earlier, and therefore, the owners are more concerned with safety. It is the same as in Table 4-4.

Table 4-4. Earliest stage to emphasize safety vs. major type of projects

Project Type	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
Petro-Chemical	4	1	1	7.5	0.03
Utilities	2	2	2	13.5	
Manufacturing	18	2.33	2	14.67	
Building	5	4.2	3	22.8	
Total	29	2.48	3		

Note: Refer to footnote for Table 4-3.

Selection Of Safe Contractors

Most of the owners (80% of the respondents) would establish minimum safety performance requirements in addition to the OSHA regulations when selecting contractors to construct their projects. When selecting contractors, safety performances of the contractors were considered by most owners (84%). After counting the number of different safety approaches taken into consideration when selecting contractors, it was found that the mean number of such requirements was 2.4, ranging from a maximum count of 5 to a minimum count of zero. With the Kruskal-Wallis test, the number of the safety selection criteria was compared between owners of different sizes and owners with different project types. The results are shown in Table 4-5 and Table 4-6, respectively.

From the results, it is reasonable to expect that larger owners have more stringent safety criteria when selecting contractors. In order to analyze the relationship between the importance of safety and the criteria used, the Mann-Whitney test was conducted and the results are shown in Table 4-7. It is evident that using each criterion or not is significantly related to the importance of safety in the selection of contractors. The loss ratio was the only exception, which was implemented by very few owners.

Table 4-5. Number of safety criteria vs. annual construction budget

Annual Budget	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
25-100 million	13	1.58	1.5	11.85	0.04
100 - 500 million	12	3.15	3	17.21	
>500 million	6	4.00	5	22.58	
Total	31	2.71	3		

Table 4-6. Number of safety criteria vs. major type of projects

Project Type	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
Building	5	0.8	0	6.7	0.08
Manufacturing	18	3	3	16.14	
Utilities	2	3	3	15.25	
Petro-Chemical	4	4	4	20.13	
Total	29	2.71	3		

Table 4-7. Results of Mann-Whitney test: safety selection criterion vs. importance of safety in the selection of contractors

Contractual Safety Requirements	Ans.	Cnt.	Mean	Median	m. r.	s. r.	Sign.
Experience Modification Rating (EMR) of the contractor.	N	14	6.86	7.5	13	182	0.05
	Y	17	8.29	8	18.47	314	
OSHA recordable injury rate of the contractor.	N	19	7.05	8	13.24	251.5	0.02
	Y	12	8.58	9	20.38	244.5	
Loss Ratio of the contractor, should be less than	N	28	7.71	8	16.23	454.5	0.33
	Y	3	7	8	13.83	41.5	
Site-specific safety program prepared by the contractor.	N	16	6.88	7.5	12.38	198	0.01
	Y	15	8.47	9	19.87	298	
Qualifications of the safety staff of the contractor.	N	18	6.72	7	11.61	209	<0.01
	Y	13	8.92	9	22.08	287	
Quality of the overall safety program of the contractor.	N	9	6.11	6	9.17	82.5	<0.01
	Y	22	8.27	8	18.8	413.5	

Note: the title of the columns are: Ans = answers, Cnt = counts, mean = mean importance of safety (1-10, with 10 being the most important), median = median importance of safety (1-10, with 10 being the most important), m.r. = mean of rank, s.r. sum of rank, sign.= significance level (1-tail)

Safety Management Practices Of The Owners

1) Safety requirements in the construction contract

All the owners responded that they will include some safety requirements in their construction contracts. Two requirements, namely, "contractor must comply with the local, state and federal safety regulations", and "contractor must report all OSHA recordable injuries to the owner" were required by all responding owners. Less than 25% of the owners required contractors to place at least one full-time safety representative on the project, or that the contractor must submit a safety policy signed by its CEO. As to other safety requirements listed in the questionnaire, about 50% to 75% of the owners included them in the contract.

When the counts of contractual safety requirements of the owners were calculated, it was found that for owners with different types of facilities constructed, the counts are considerably different (refer to Table 4-8). Petrochemical companies included the largest number of safety requirements in their contracts, followed by utility owners. Owners of buildings and other manufacturing plants have fewer safety requirements included in their contracts. Also, it was found that owners with larger construction budgets have more contractual safety requirements (refer to Table 4-9).

Table 4-8. Number of contractual safety requirements vs. major type of projects

Project Type	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
Building	5	4.6	5	8.8	0.11
Manufacturing	18	6.7	7	14.75	
Utilities	2	7.5	7.5	17.5	
Petro-Chemical	4	9	9	22.63	
Total	29	6.77	7		

Table 4-9. Number of contractual safety requirements vs. annual construction budget

Annual Budget	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
25-100 million	12	5.33	5	10.96	0.05
100 - 500 million	13	7.85	8	19.65	
>500 million	6	7.33	8	18.17	
Total	31	6.77	7		

2) Safety management involvement of owners taken during construction

One question asked about safety management involvement of owners to promote construction safety on site. It was found that four of the seven listed safety management activities were frequently performed by owners, namely, owners' personnel conduct periodic job site safety inspections or safety audits; owners' personnel participate in some contractor safety meetings; owners' personnel participate in the investigation of all lost workday injury accidents; and owners monitor injury incidence rates on each project. More than 2/3 of the owners were involved in this manner. Other safety approaches were taken by less than 1/3 of the owners.

A Kruskal-Wallis test was conducted to identify the strength of the relationship between owner's involvement in safety management and the owner's annual construction budget/the major type of projects. The results were quite consistent with the previous findings (refer to Table 4-10 and Table 4-11). Petrochemical owners and owners with larger construction budgets were more actively involved in safety during construction.

Table 4-10. Total number of safety practices implemented vs. major type of projects

Project Type	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
Building	5	1.6	2	6.5	0.06
Utilities	2	3.5	3.5	14.25	
Manufacturing	18	3.89	4	15.39	
Petro-Chemical	4	5.75	5.5	24.25	
Total	29	3.74	4		

Table 4-11. Total number of safety practices implemented vs. annual construction budget

Annual Budget	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
25-100 million	12	2.75	2	11.38	0.05
100 - 500 million	13	4.23	4	18.04	
>500 million	6	4.67	5.5	20.83	
Total	31	3.74	4		

The Mann-Whitney U test was conducted to compare the rank of the importance of safety in the selection of contractors and whether or not owners were involved in construction safety in a particular way. The results are shown in Table 4-12. It is reasonable to suspect that owners who emphasize construction safety tend to be involved in more ways than owners who care less about safety.

Table 4-12. Importance of safety vs. safety approaches taken

Safety approaches	Ans	Cnt.	Mean	Median	m. r.	s. r.	Sign.
Owner's personnel conduct periodic job site safety inspections or safety audits.	Y	7	8	8	9.93	69.5	0.02
	N	24	6.43	7	17.77	426.5	
Owner places a safety person on the project to support the contractor on project safety.	Y	21	8.3	9	14.07	295.5	0.04
	N	10	7.33	8	20.05	200.5	
Owner provides a nurse or emergency medical technician (EMT) for the construction project.	Y	22	9.22	10	12.95	285	<0.01
	N	9	7	8	23.44	211	
Owner's personnel participate in some contractor safety meetings.	Y	7	8.12	8	8.86	62	0.01
	N	24	6	7	18.08	434	
Owner's personnel participate in the investigation of all OSHA lost workday injury accidents.	Y	9	8.05	8	11.28	101.5	0.03
	N	22	6.67	6	17.93	394.5	
Owner implements a safety incentive that can be earned by the contractor for completing the project below a specified OSHA recordable injury rate.	Y	26	8.8	9	15.02	390.5	0.01
	N	5	7.42	8	21.1	105.5	
Owner monitors injury incidence rates on each project.	Y	9	8.18	8	8.78	79	<0.01
	N	22	6.33	6	18.95	417	

Note: the title of the columns are: Ans = answers, Cnt = counts, mean = mean importance of safety (1-10, with 10 being the most important), median = median importance of safety (1-10, with 10 being the most important), m.r. = mean of rank, s.r. sum of rank, sign.= significance level (1-tail)

If Spearman's correlation (non-parametric correction) is calculated for the number of safety approaches, the number of safety requirements included in the contract, and the rating of safety performance during the selection of contractors (as shown in Table 4-13), it is evident that they are significantly positively correlated. Owners emphasizing safety tend to include more safety requirements in their contracts and utilize more approaches to promote safety on their projects.

Table 4-13. Non-Parametric correlation matrix between importance of safety, number of contractual requirements and safety involvement approaches

		Importance	**Contract**	**Approaches**
Importance	**Correlation Coefficient**	1	0.734	0.651
	Sig. (2-tailed)	<0.01	<0.01	<0.01
	N	31	31	31
Contract	**Correlation Coefficient**	0.734	1	0.578
	Sig. (2-tailed)	<0.01	<0.01	<0.01
	N	31	31	31
Approaches	**Correlation Coefficient**	0.651	0.578	1
	Sig. (2-tailed)	<0.01	<0.01	<0.01
	N	31	31	31

3) Safety training and safety in design

Safety training was one area of focus in this survey, namely to explore how owners addressed safety training on their projects. The Mann-Whitney test was conducted with the rating of safety performance as the dependent variable. Four questions related to safety training were tested against the dependent variable, namely, whether the owner's safety representative attends safety orientation (q07), whether the owner makes monetary allocations for safety training (q10), whether standardized training is required for all the projects (q14), and whether basic safety training is required for all workers (q17). The results are shown in Table 4-14. Owners who are more concerned about safety tend to emphasize the safety training and orientation program.

Table 4-14. Mann-Whitney test: Importance of safety vs. safety training inputs

Safety training inputs	Ans.	Cnt.	Mean	Median	m. r.	s. r.	Sign.
safety representative attends safety orientation (q071)	N	11	5.82	6	8.05	88.5	0.01
	Y	20	8.65	8.5	20.38	407.5	
does the owner make allocations for safety training (q10)	N	17	6.53	7	10.85	184.5	0.03
	Y	14	9	9.5	22.25	311.5	
standardized training is required for all the projects (q14)	N	7	6.29	6	8.86	62	0.02
	Y	24	8.04	8	18.08	434	
basic safety training is required for all the workers (q17)	N	6	5.67	5.5	6	36	0.01
	Y	25	8.12	8	18.4	460	

Note: the title of the columns are: Ans = answers, Cnt = counts, mean = mean importance of safety (1-10, with 10 being the most important), median = median importance of safety (1-10, with 10 being the most important), m.r. = mean of rank, s.r. sum of rank, sign.= significance level (1-tail)

The total number of positive answers to the four safety training and orientation questions was calculated. The Kruskal-Wallis test was conducted to examine the owners' involvement in training with the size of the construction budget and the major project type of the owners (refer to Tables 4.15 and 4.16). Not surprisingly, larger owners and petro-chemical owners tend to have more input into safety training and orientation.

Table 4-15. Total amount of safety training input vs. project type

Project Type	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
Building	5	1	1	6.5	0.06
Manufacturing	18	2.72	3.5	15.64	
Utilities	2	3.5	3.5	18.75	
Petro-Chemical	4	3.75	4	20.88	
Total	29	2.68	3		

Table 4-16. Total amount of safety input vs. annual construction budget

Annual Budget	Count	Mean	Median	Mean Rank of Kruskal-Wallis Test	Kruskal-Wallis Test Sign. (2-tail)
25-100 million	12	1.83	1	12.08	0.08
100 - 500 million	13	3.15	3	17.83	
>500 million	6	3.33	4	20.83	
Total	31	2.68	3		

Safety can be addressed as early as the design phase of a project. About half the owners stated they would address safety during the design stage. The Mann-Whitney U test was conducted with the importance of safety to the owners and whether or not designing for safety was a concern. The results are shown in Table 4-17. It can be concluded that owners addressing safety during the project design will also emphasize on the importance of safety performance during the selection of contractors.

Table 4-17. Relationship between the importance of safety and whether or not safety is addressed in the design phase

Address safety in the design phase	Count	Mean	Median	Mean Rank of Mann-Whitney U Test	Mann-Whitney U Test Sign. (2-tail)
No	12	6.67	7.5	12.08	0.05
Yes	19	8.26	8	18.47	
Total	31	7.65	8		

4) Ranking of different safety approaches

Question 23 of the survey asked respondents to rank the importance of different safety approaches. A Friedman two-way ANOVA (for repeated measures) was conducted to compare the means of ranking for different approaches (see Table 4-18).

Table 4-18. Priority of different approaches preferred by owners (1 to 5 with 1 being the highest possible priority)

Safety approaches	Mean	Median	m. r.*	Sign.
Owner selects safe contractors to carry out the work.	1.45	1	1.83	<0.01
Owner emphasizes safety and constructability in design.	2.1	2	2.5	
Owner participates in and monitors safety during the entire life of a construction project.	2.03	2	2.54	
Owner develops an effective safety recognition and reward program.	3.46	4	4	
Owner dedicates funds to support the contractor's efforts in safety.	3.63	4	4.13	

* mean ranking of Friedman two-way ANOVA test.

It is evident that significant differences exist between the priorities owners placed on different safety approaches. The order of approaches, beginning with the top priority, is as follows:

1. Owner selects safe contractors to carry out the work.

2. Owner emphasizes safety and constructability in design.
3. Owner participates in and monitors safety during the entire life of a construction project.
4. Owner develops an effective safety recognition and reward program.
5. Owner dedicates funds to support the contractor's efforts in safety.

A Wilcoxon matched-pair signed-rank test (for repeated measures) was conducted to compare the mean ranking of selecting safe contractors (referred to as variable Q232) and participating in and monitoring safety (Q233). It was found that the mean rank of selecting safe contractors is significantly higher than that of participating in and monitoring safety at the 0.04 level (refer to Table 4-19). This indicates that for many owners, the most efficient way for them to improve project safety performance is in selecting safe contractors, instead of actively participating in and monitoring safety.

Table 4-19. Comparison of the ranks of selecting safe contractor (Q232) v.s. participating in and monitoring safety (Q233)

		N	Mean Rank	Sum of Ranks	Sign.
Q233 - Q232	**Negative Ranks**	7(a)	15.36	107.5	0.04
	Positive Ranks	20(b)	13.52	270.5	
	Ties	4(c)			
	Total	31			
a Q233 < Q232; b Q233 > Q232; c Q232 = Q233					

Note: the mean ranks and sum of ranks are the results of Wilcoxon matched-pair signed-rank test (for repeated measures).

Summary

Based on the statistical analysis of the survey responses, the following hypotheses were developed for further testing:

- The main type of projects of the owner, which may suggest the main business of the owner, has strong effects on the owner's commitment to safety and practices to promote construction safety on their projects. Owners of petrochemical and utility projects tend to emphasize safety more than owners of manufacturing facilities and buildings.

- The size of the annual construction budget seems to be an important factor that impacts the safety practices of owners. Owners with larger construction budgets are more concerned about construction safety.

- Owners of projects with better safety performances tend to emphasize safety during the earlier stages of project development. They will emphasize safety performance more during the selection of contractors, and they will also include more safety requirements in their contracts.

- Owners with safer projects tend to be heavily involved in project safety management, especially by implementing various approaches to promote safety management. Although these approaches may not be extensively used in the construction industry, they are widely implemented by safe owners with large construction budgets.

- Instead of trying to contractually avoid liabilities from injuries, owners with safer projects tend to be more involved with contractors on project safety management, especially safety training.

- Owners who place greater emphasis on safety tend to address safety in the design of their projects.

- Among different approaches taken by owners to achieve success in project safety, owners proactive on safety tend to believe that selecting safe contractors to construct their projects and emphasizing safety in the design phase are important.

The relationship between the overall safety performances of projects and the different safety management practices of the owners could not be thoroughly examined, because only 19 owners provided their injury rate data. Despite this, the statistical analysis was able to identify some possible relationships between safety performance and the project type, selection of safe contractors, safety commitment, contractual requirements, and the safety involvement of owners.

CHAPTER 5
RESULTS: OWNER'S ROLE IN PROJECT SAFETY

In this chapter, the results obtained in the major data collection stage are presented. The methods of interviews and selection of projects are introduced. The most frequent practices implemented by owners are then presented. Statistical analysis was conducted to test associations between project safety performance and owners' practices. Finally, a model to describe the owner's influence on project safety and a scorecard to evaluate owner involvement in safety were developed.

The Interviews

The second and major phase of this study was to collect information from construction projects through interviews to determine the role and influence that owners have on construction project safety. As mentioned in the description of the research methodology, the focus of this study was to test the null hypothesis that project safety performance was independent of the facility owner's involvement, against the alternative hypothesis that project safety performance was dependent on the owner's involvement. Project safety performance was the dependent or response variable, and the responses to different questions were different factor levels or independent variables.

A total of 81 personal interviews were conducted. Each interview took about one and a half hours. When the data were analyzed, a constraint was imposed such that projects included in the analysis must have had at least 100,000 hours of worker exposure. This was to ensure that the safety performance measures gave a reliable

indication of the project safety performance. Since some projects were in their early stages of construction, they did not have the requisite number of hours to satisfy the criteria for inclusion in the data analysis. By excluding the projects with fewer than 100,000 hours of worker exposure and those projects for which complete injury data were not provided, the final analysis included 59 projects.

Safety performances of the projects were measured by using the total number of OSHA recordable injuries per 200,000 hours of worker exposure, commonly known as the Total OSHA recordable injury rate (TRIR). Whenever the term TRIR appears, it should be clear that the measure of safety performance consists of all OSHA recordable injuries, including lost-time injuries and restricted work injuries. For the 59 projects included in the analysis, the average TRIR was 1.95, with six projects reporting zero OSHA recordable injuries. One of the projects reporting a TRIR of zero had amassed nearly 500,000 hours of worker exposure.

The safety performances of projects were compared with the different responses to the questions in the questionnaire. The hypotheses were tested to determine if project safety performances were associated with each of the different responses. The major statistical methods employed were non-parametric methods, including the Mann-Whitney U test (for comparison between two factor levels) and the Kruskal-Wallis test (for comparison between more than two factor levels). The rationale for using non-parametric methods was the difficulty of satisfying the normality assumption and equal variance assumption in each factor level, which were required for t-test and analysis of variance (ANOVA) for comparing means of quantitative variables. By using non-parametric methods, the purpose was to compare the distribution or medians of project

safety performances for different factor levels. In these non-parametric tests, the response variable, TRIR, was treated as an ordinal variable, instead of an interval variable. No assumptions were required for the non-parametric tests. The level of significance indicated whether the medians of the response variable were different when responses differed.

As a comparison, the means (or averages) of TRIR of different factor levels were also compared by using the univariate analysis method, one-way analysis of variance (ANOVA). The statistical assumptions for ANOVA were: (1) the response variable, TRIR, had a normal distribution for different factor levels; and (2) the variance of the response variable in different levels were the same. Since ANOVA is a robust statistical method, which means the results are still correct even if the assumptions are slightly violated, the significance level of each ANOVA test is also shown in the tables.

When there were only two factor levels to compare, and the medians or means (or averages) of the TRIR were in the same direction as the literature suggested (which factor level might have better safety performances), a one-tail test was conducted. If there were more than two factor levels included in the test, a two tail test was conducted since the comparison of the response variable in multiple factor levels (more than two) cannot be made, even if the null hypothesis is rejected.

It was only when the differences of the TRIR medians were statistically significant at the 0.1 level (the significance level or P-value was less than 0.1) that the results are presented, unless specifically noted otherwise. Statistical significance was assumed when the level of significance was 0.05 or smaller, meaning that there was less than a five percent probability that the finding was due to chance. Since the study was an uncharted

and exploratory study, the results are also presented if the level of significance was between 0.05 to 0.1, suggesting a strong tendency toward statistical significance.

Projects Interviewed In The Study

Project size descriptors (as measured in terms of worker hours and in total contracted project cost) and the TRIRs of the 59 projects included in the final analysis are shown in Table 5-1. Of these projects, seven were in Canada, three projects were overseas with U.S. owners, and 49 projects were located in 18 states of the U.S, including one in the Virgin Islands. The numbers of interviews conducted in different states are shown in Figure 5-1. Although the safety performances and sizes of the projects ranged widely, it is apparent that the safety performances of most projects were much better than the construction industry average of about 7.8 for the year 2001 (BLS, 2003). Thus, the projects included in this research generally enjoyed much better success in safety than the construction industry as a whole. Prior research has shown that safer performances were noted among employers with larger numbers of workers. Thus, in general, larger projects would be expected to have better safety records than smaller projects. It was in this context that the analysis was intended to identify those practices of owners that had a particularly strong impact on the resultant TRIR. It may not be surprising to expect better safety performances on projects where CII members were the project owners, however, this research was not restricted to projects involving CII members. This may account for the relatively broad range in TRIRs. The average TRIR of CII members was reported as being about 1.03 in year 2000 (CII, 2001), significantly better than the industry average. This research investigated those owner practices that had a direct impact on influencing the safety performances realized on large projects. The interviews focused on obtaining information about the demographics of the projects, the manner in which contractors

were selected, the types of safety-related provisions included in the contracts, and the extent of owner involvement in safety management during project execution.

Table 5-1. Safety performances and sizes of the projects included in the research

		Total worker hours expended	Total estimated cost of the project	Total Recordable Injury Rate
Mean		2,426,210	$379,440,000	1.95
Mode		200,000	$15,000,000	0
Std. Deviation		5,155,050	$861,740,000	1.94
Minimum		100,000	$3,500,000	0
Maximum		26,300,000	$5,000,000,000	9.25
Sum		143,146,400	$21,248,700,000	115.11
Percentiles	**25**	275,000	$15,250,000	0.58
	50	627,000	$78,350,000	1.48
	75	2,284,000	$306,250,000	2.73

Note: These data are based on 59 projects, however, only 56 projects provided the project cost information.

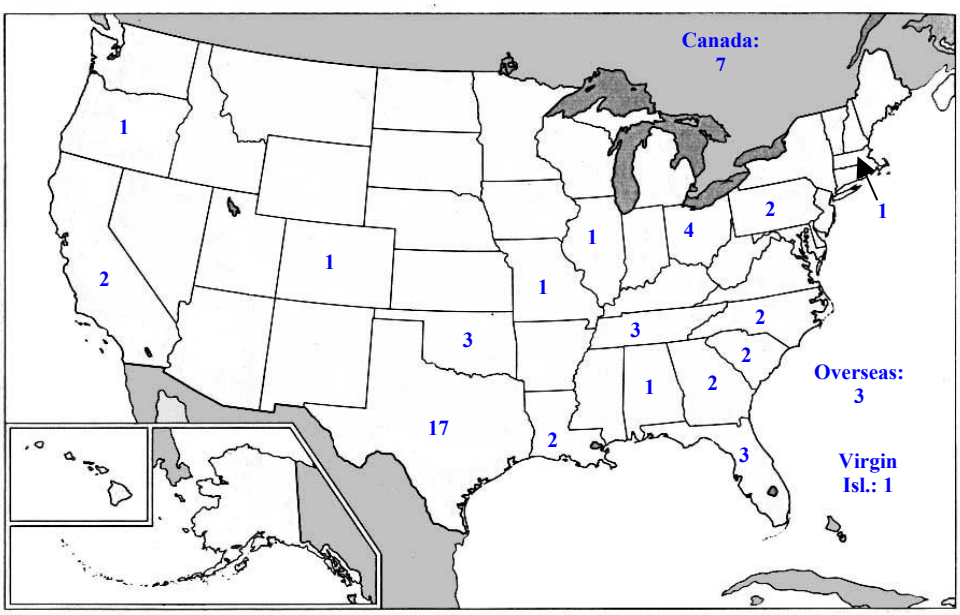


Figure 5-1. Locations of the projects included in the research

Although the 59 projects provided the information on OSHA recordable injuries (TRIRs), only 46 were able to provide information on all types of injuries, including lost-time injuries, OSHA recordables, and first-aid injuries. All the injuries occurring on projects were tallied by severity category, and the ratio between the different types of injuries was determined, as shown in the injury pyramid in Figure 5-2. The ratio that

exists between injuries on the basis of severity has been discussed for many years. While these ratios may vary, the general trend is relatively consistent. Heinrich (1959) suggested that the ratio between major injuries, minor injuries and no-injury accidents was 1:29:300. Note that Heinrich used different definitions of accidents than those used in this research. The pyramid in Figure 5-2 could be simplified by reporting the ratio between lost-time, OSHA recordable, and first-aid injuries as being roughly 1:10:300.

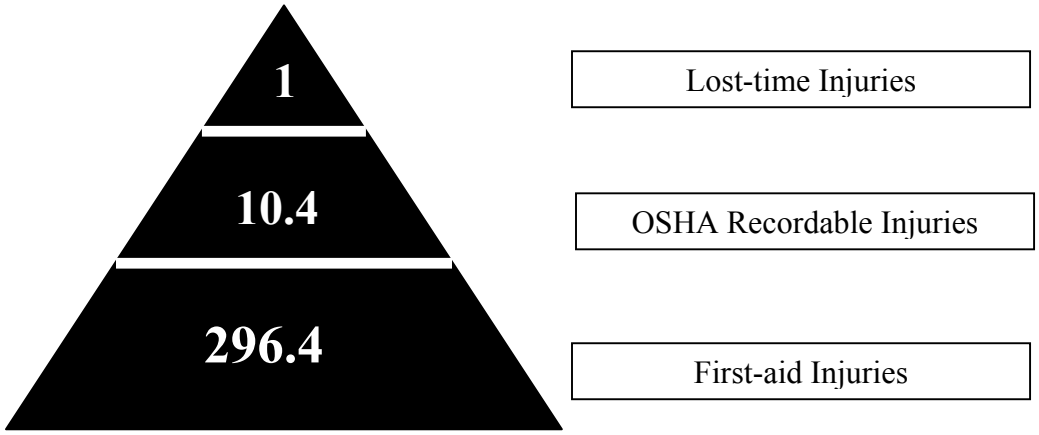


Figure 5-2. Injury pyramid for the projects

On the 59 projects, 42 different facility owners are represented, since several owners provided more than one project for inclusion in the study. Most of the owners (about 70 percent) were CII owner members with large annual construction budgets. Many owners were listed in the ENR (2001) top 425 owners. Although the data set cannot be referred to as representative of all the projects in North America, the projects were considered to be representative of the large-scale projects.

The Most Common Safety Practices

Before testing whether different practices of owners could make a difference in the safety performances achieved on their projects, the most popular and frequently used safety practices were listed. These practices included:

- Prime contractor reported injury statistics to the owner (100%), and the types of injuries reported were: OSHA recordable IR (100%); lost-time injury (100%); near misses (88.1%); environmental issues (91.5%).

- The owner's site safety representative was generally an employee of the owner (88.1%) instead of a consultant (11.9%). This person was generally a member of the project management team (91.5%), and had authority to stop unsafe work (94.9%). The job responsibilities of the safety representative generally included:

  - Monitoring safety management and performance of the contractor on a daily basis (89.8%)
  - Enforcing safety rules (89.8%)
  - Conducting site safety inspections and audits (89.8%)
  - Reviewing safety performance on site and submitting reports to the home office (88.1%)
  - Reviewing contractors' safety reports (88.1%)
  - Coordinating safety efforts on site (81.4%)

- Owner's site safety representative reviewed the safety performance of the contractor on a regular basis (98.3%). They would check the project lost-workday injury rate (94.9%), check the project recordable injury rate (94.9%), and check the project first-aid injury rate (88.1%).

- When selecting contractors, safety was generally a consideration of most owners (94.9%). Among the criteria used by owners to evaluate the safety performances of contractors, the overall quality of the safety program was the most frequently mentioned subject (88.1%). The owner's evaluation of contractor safety performance would make a difference between getting the contract or not (88.1%). If a contractor had some safety statistics of concern, the contractor could show that they had made major changes in the program and still be considered for contract award (94.9%).

- Owners had a variety of contractual safety requirements, the most frequently used provisions include the following:

  - Contractor must comply with the local, state and federal safety regulations. (100%)
  - Contractor must report all lost time injuries to the owner. (98.3%)
  - Contractor must report all OSHA recordable injuries to the owner. (96.6%)
  - Contractor must report all injuries to the owner. (96.6%)
  - Contractor is required to provide specified PPE (hard hats, safety glasses, gloves). (96.6%)

- Contractor must implement a substance abuse program. (96.2% of U.S. projects only, since drug testing is not allowed in Canada)
- Contractor must conduct weekly safety meetings for the workers. (93.2%)
- Contractor must comply with safety requirements beyond the OSHA regulations. (88.1%)
- Contractor must participate in site safety audits. (88.1%)
- Contractor must implement a permit system when performing hazardous activities (line breaks, lockout/tagout, excavations, proximity to power lines, confined space entry, hot work, etc.). (88.1%)
- Contractor must submit a site-specific safety plan. (84.7%)

- Owners impose the same safety requirements on subcontractors and lower tier subcontractors. (91.5%)

- Most owners require specific items to be included in the contractor's safety program (98.3%), and included the subcontractors in the safety program as well (94.9%). The items that were required by most owners included:

  - Regular safety meetings (94.9%)
  - Incident reporting and investigations (93.2%)
  - Conduct regular safety inspections (91.5%)
  - Training on the hazards related to the tasks being performed (89.8%)
  - Substance abuse program (89.8%)
  - OSHA specific regulations (88.1%)
  - Specific safety training sessions (86.4%)
  - Pre-project safety planning (86.4%)
- Other safety practices of owners included:

  - During the design of this project, construction safety issues were specifically addressed. (98.3%)
  - Owner required every worker on site to receive orientation training. (96.6%)

Project Descriptions And Safety Performance

The size of the project, labor arrangements for the project, type of project, and other characteristics of the project may all be related to the project safety performance. These factors may be influenced by the owner to some extent and therefore were also analyzed.

Shutdown Projects

Although new projects did not show a significantly better or worse safety performance when compared to renovation projects, shutdown projects (operating plants that must stop operations to perform upgrade and modification work) were found to have poorer safety performances. The median TRIR of the eight shutdown projects included in this research was higher than the median TRIR of the other projects (see Table 5-2). Shutdowns are characterized as having tight schedules (typically four to eight weeks), significant amounts of overtime work, frequently working multiple shifts, and generally having a rapid buildup of the workforce. When workers and managerial personnel work extended hours for one or two months, the possibility of human errors increases, and so will the probability of injury causation.

Table 5-2. Injury rates of shutdown projects and all other projects

Type of projects	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
All Others	51	1.80	1.76	1.30	0.06	0.07
Shutdown	8	2.91	2.76	2.20		
Total	59	1.95	1.94	1.48		

Explanation: In this table, for the Mann-Whitney test, the null hypothesis was: the median TRIR of shutdown projects was equal to the median TRIR of all other projects. The alternative hypothesis was: the median TRIR of shutdown projects was larger than the median TRIR of all other projects. The significance level was 0.07, which shows a strong tendency to reject the null hypothesis and to support the alternative hypothesis. For the ANOVA test, the results were similar to the Mann-Whitney test except it compared the mean (or average) TRIR of shutdown projects with the mean of other projects. The significance level of 0.06 suggested a tendency that the mean TRIR of shutdown projects was larger than the mean TRIR of all other projects. Other tables in this chapter are presented in a similar manner.

Public Or Private Project

The comparison of the TRIRs of public projects and private projects, excluding the shutdown projects (which were all private projects), is illustrated in Table 5-3. It was suspected that private projects may have an advantage in achieving better safety performances than public projects. Since many public projects must be awarded through

the competitive bidding process, public projects are frequently awarded to contractors without regard to their ability to deliver a safe project. Private owners may take into account factors other than simply awarding the contract to the lowest bidder. Nevertheless, some public agencies, especially federal agencies, may require the contractor to comply with their own safety requirements in addition to the OSHA 1926 regulations. However, the involvement of the owners in the safety management of the public projects was generally viewed as being minimal, when compared to the extent of owner involvement on private projects.

Table 5-3. Type of facility owner and safety performance (excludes shutdown projects)

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
Private	45	1.62	1.63	1.20	0.02	0.02
Public	6	3.16	2.28	2.67		
Total	51	1.80	1.76	1.30		

Petrochemical Projects And Manufacturing Projects

Petrochemical projects, which accounted for nearly half of the projects analyzed (30), reported better safety performances than manufacturing projects (see Table 5-4). Note that the shutdown projects have been excluded in Table 5-5 in order to provide an accurate depiction of the differences between the safety performances of petrochemical and manufacturing projects. Petrochemical owners interviewed consistently reported having strong upper management commitment to construction safety and having successfully integrated safety into their company culture. They had a clear understanding of the zero injuries philosophy, and jobsite safety responsibilities were defined to strengthen the safety culture. A behavior-based safety approach was widely accepted and implemented on petrochemical projects. Thus, many accidents were avoided by

addressing the front end of the accident causation chain. This will be further discussed in Chapter 7.

Safety performances on manufacturing projects were consistently not as good as on petrochemical projects. Note that residential and commercial projects were not included in this comparison, primarily because only a few such projects were in the entire sample. From the limited data, it appeared as if the residential and commercial projects were not as good as the manufacturing projects in the area of safety. It should be mentioned that owners of many manufacturing projects were aggressive in their efforts to improve project safety performance. Several respondents stated that the enhanced emphasis on safety in the manufacturing sector was a relatively recent initiative. Since it takes time to be successful in making significant changes in the safety culture of a company, it may be only a matter of time before additional improvements in safety performance are realized on manufacturing projects. Although their safety performances were not as good as the petrochemical projects, the manufacturing projects in this study were already much better than the overall construction industry TRIR average of 7.8 (BLS, 2003).

Table 5-4. Type of project facility (including shutdown projects) and injury rates

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
Petrochemical	30	1.23	1.04	1.03	<0.01	<0.01
Manufacturing	19	2.99	2.44	2.53		
Total	49	1.91	1.91	1.33		

Table 5-5. Type of project facility (excluding shutdown projects) and injury rates

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
Petrochemical	25	1.11	1.00	0.84	<0.01	<0.01
Manufacturing	16	2.66	2.07	2.47		
Total	41	1.71	1.67	1.20		

Union Projects Or Open Shop Projects

There was a fairly even distribution of the number of open shop projects, union shop projects, and merit shop projects in the study. In general, owners may have little to say about employing union shop or open shop contractors, as the local labor conditions often dictate the type of firms that are available to perform the work. Thus, in strong union areas, union shop contractors would generally be employed. Merit shop projects are those in which the labor arrangements are not a consideration in the selection of contractors. It is on the "merit shop" projects that both union shop and open shop contractors may be employed at the same time. Although labor conditions are not readily influenced by facility owners, it is interesting to note that there was a difference between the safety performances reported on union shop versus open shop projects (see Table 5-6). Since Canadian projects are all union shop and since international projects are in environments different from the United States, the table presents information on only the U. S. projects. Table 5-6 shows that safety performances tended to be better on open shop projects than on union shop projects. When the union shop project and merit shop projects were combined as a category, the median TRIR of these projects is significantly larger than open shop projects. Note that this same pattern of TRIR values was found to exist when only petrochemical projects (exclusive of shutdown projects) were examined.

Table 5-6. Type of labor and safety performance (US projects only)

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (2-tail)	Kruskal-Wallis Sign. (2-tail)
Open shop	16	1.32	1.23	1.05	0.12	0.13
Merit shop	19	2.07	1.51	2.00		
Union shop	14	2.71	2.64	2.03		
Total	49	2.01	1.87	1.62		

On projects, especially in the southern portion of the U.S., site safety personnel commented that union workers were more likely to refuse to follow their safety instructions than were workers on open shop projects, possibly because they were in a more secure job position than were open shop workers. It is often alleged that employing union contractors may cost more, but that the skill levels of the workers are consistently higher. On the other hand, some contend that open shop workers are more mobile and are more likely to travel considerable distances from one project to the next. The open shop workers are reportedly more willing to follow management's instructions to ensure that their jobs are not placed in jeopardy. Therefore, the owners may simply have to alter their style of management when promoting their safety initiatives with union contractors and open shop contractors. Obviously, this can be a delicate issue as any prejudice or discrimination in the implementation of safety management policies and in the enforcement of safety regulations could eventually cause more problems. When implementing the project safety program, the owner must ensure that the program is implemented firmly and consistently.

Type Of Contract

Two aspects of the project contract were investigated in the study: type of contract (how the owner would make payments to the contractor); and contracting methods (the contractual relationship between the owner and contractor). One reason that the contract type should be considered when addressing project safety is that the contract establishes the basis on which the owner will make payments to contractor. Essentially, the payments can be made on the basis of unit prices (unit price contracts), a schedule of values (lump-sum contracts), or a reimbursement of actual incurred costs (cost plus contracts). As safety can be enhanced through the concerted efforts of different parties

(owner, contractor, and designer), the manner in which the contract defines their relationships might readily impact project safety. For example, if the contractor has a close, long-term relationship with the owner, the owner and the contractor may be inclined to use a cost reimbursable contract (job order contracting or cost plus). Under such contracts, the contractor's investment in safety will be reimbursed by the owner. With greater support for the contractor's efforts in safety, there is less contractor reluctance to dedicate funds for safety.

If the owner and contractor emphasize safety on the project, there is naturally a greater probability that the project will have good safety performance. During the interviews, one safety manager expressed his preference for lump-sum contracts, since he thought that the contractor could not commence safely with site work until the design was finished. He argued that fewer design changes during project execution would reduce hazards on the project. However, another safety manager preferred reimbursable contracts, since reasonable safety costs were reimbursed and the contractor was never placed in a situation of having to decide between spending funds to enhance safety or increasing profits by cutting safety expenditures. This study did not identify any significant differences between the TRIRs of projects using lump sum contracts and cost reimbursable contracts.

Different approaches will influence the safety efforts of all parties involved, including the owner, designer, contractor and subcontractor(s). One method of enhancing safety is to conduct a constructability review as part of the design process (Hinze and Wiegand, 1992; Hinze and Gambatese, 1996; Jergeas and Van der Put, 2001). This review helps to coordinate the safety efforts of designers and the work performed on site

(Fischer and Tatum, 1997). Comparisons were made of the safety performances of design-build projects with projects constructed under other contracting arrangements. Design-build firms, including engineering, procurement, and construction (EPC) firms, have a direct incentive to focus on construction safety during the design phase as it is their own employees that are impacted by their design efforts. In other arrangements, the design team is often considered to be separate from the construction effort and does not address construction safety in the design. The owner could impose duties on the design firm to address construction worker safety, regardless of the contract type, but this was not examined in the study. Results (see Table 5-7) show that design-build (EPC) projects had significantly better safety performances than did projects with other forms of contracting arrangements.

Table 5-7. Type of contract used on the project

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
Other	44	2.22	2.08	1.68	0.03	0.03
Design-build	15	1.15	1.14	0.69		
Total	59	1.95	1.94	1.48		

Size Of The Projects

The size of the project may indicate the complexity of conducting site work and coordinating the related safety efforts. Size might 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. In this research it was felt that the total number of worker hours on site gave a more accurate portrayal of the difficulty of implementing a safety program. On small projects, with fewer hours of worker exposure (less than 100,000 worker hours), simpler designs or engineering plans, and a smaller workforce, safety efforts can often be more effective. On the other hand, on larger projects (with

more than one million hours of worker exposure) safety performances may also be expected to be good since a large prime contractor was selected to execute the project. Large contractors typically have safety programs that are formalized, and they employ more advanced techniques to promote safety. Despite the complexity involved, safety performances on the large projects were quite good (see Table 5-8). This held true for all large projects, including shutdown projects, petrochemical projects, and manufacturing projects. Strong safety performances on large projects have been reported in other construction safety research. In general, the very large and quite small contractors have better safety performances, while medium sized companies have poorer safety performances (Hinze, 1997).

Table 5-8. Worker hours expended (in thousands of hours) and safety performance

Hours Worked (1000s)	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (2-tail)	Kruskal-Wallis Sign. (2-tail)
100~200	8	1.72	1.31	1.51	0.193	0.14
200~1000	28	2.42	2.27	2.03		
1000 up	23	1.45	1.57	0.92		
Total	59	1.95	1.94	1.48		

Work Shift And Workdays

The number of shifts worked and the number of workdays worked per week are often dictated by the owner's schedule requirements. Tight deadlines often mean that shift work or overtime work will be necessitated. On the projects involved in this research, it was found that projects with one shift had significantly better safety performances than those with more than one shift (refer to Table 5-9). Projects with four-day (primarily those working four-tens) or five-day workweeks had significantly better safety performances than those working more than five days per week (refer to Table 5-10). From these results, it is reasonable to suspect that fatigue can contribute to

increasing the number of human errors, and that days off for rest and recovery are necessary to ensure injury-free work.

Table 5-9. Number of shifts worked and safety performance

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
1 shift	37	1.44	1.45	1.17	<0.01	<0.01
2 or 3 shifts	22	2.80	2.35	2.20		
Total	59	1.95	1.94	1.48		

Table 5-10. Number of days worked per week and safety performance

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
4 or 5	34	1.54	1.50	1.18	0.03	0.03
6 or 7	25	2.51	2.32	2.00		
Total	59	1.95	1.94	1.48		

Owner's Selection Of The Contractor

Selecting a safe contractor for project execution is an important function for the owner to achieve better safety performance. In this research, it was found that most owners emphasize the importance of selecting safe contractors in the pursuit of the zero-injury objective. Demonstrated safety performance is a major prerequisite for many contractors to be awarded contracts. While all owners seem to be aware of the need to select safe contractors, they differ in the approaches used to accomplish this objective. Most private owners will not consider awarding contracts to contractors with bad safety performances. Some owners maintain their own database of the safety performance history of all parties with whom they have contracted, including contractors, subcontractors, and vendors. From this, they develop and maintain an approved bidder list and only these firms are given the opportunity to submit bids on their projects.

Preferred Contractors List

Projects on which contracts were awarded through competitive bidding or through a negotiated process did not show any statistically significant difference in their safety

performances. Similarly, projects for which the contracts were awarded to contractors on a preferred contractors list (TRIR median = 1.32) reported safety performances that were not significantly different from those for which the bidding was open to all interested contractors (average TRIR=1.92).

Importance Of Safety During Selection Of Contractors

Safety appears to be an important consideration for most owners when contractors are selected. To get an impression of the importance placed on safety, each owner respondent was asked about the extent to which safety played a role in the evaluation of contractors in the selection process. The findings show that projects had better safety performances when the owners placed a higher priority on safety when evaluating contractors (see Table 5-11), i.e., projects had better safety performances when the contractors had already established a proven safety record on past projects.

Table 5-11. Emphasis placed on safety in the overall review of contractors (rating from 1 to 7 with 7 being the most important)

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
<=5	24	2.33	1.95	2.13	0.11	0.05
>=6	35	1.69	1.91	1.20		
Total	59	1.95	1.94	1.48		

Criteria Used To Evaluate Safety Performances Of Contractors

Questions were asked about how owners evaluated the past safety performances of contractors. Possible options for the question were developed based on the research results of Diaz and Cambrera (1997), Garza et al. (1998), Sawacha et al. (1999), and suggestions from the CII PT-190 members. The results show that owners used varying measures of safety performances. One such measure used was the experience modification rating (EMR) on the workers' compensation insurance. This is a measure that has been widely used in the past few decades, but has lost favor with some

companies as a viable measure of safety performance. The EMR is considered to be a lagging indicator in that it represents historical data rather than a current indication of a contractor's safety commitment (Hinze, et al., 1995). The EMR is based on three years of loss history, but the value of the EMR is dramatically influenced by the number of workers employed by the firm and by the hourly wages paid to the employees. Thus, it is difficult to make valid comparisons between firms; especially if they differ in size (number of employees) or in the wages they pay. Most owners stipulate that they will not employ a contractor whose EMR is greater than 1.0. Some owners recognize there are shortcomings associated with making comparisons between companies on the basis of the EMR. These owners no longer utilize EMRs because they are not sufficiently accurate for the owner to evaluate the probable safety performance of a firm for a project. Analysis shows that the average safety performances of projects where the owners did not use EMRs were just as good as projects where EMRs were used (see Table 5-12).

Table 5-12. Is the EMR used to evaluate safety performance of contractors? (No significant differences)

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
No	11	1.45	1.16	1.54	0.16	0.23
Yes	45	2.13	2.10	1.48		
Total	56	2.00	1.96	1.51		

Note: Three owner representatives did not answer the entire question in the questionnaire. These three projects were not included in the analysis in Tables 5.12 through 5.17.

The TRIR is also a lagging or after-the-fact indicator, but this is a measure that is widely utilized in the industry (Garza, et al., 1998). The TRIR is a measure of how many failures have occurred, as each injury represents a failure on the project. The results of this research show that safety performances of projects were significantly better when the owners used the TRIR as one of the measurements for evaluating contractors (see Table 5-13). Those owners using the TRIR were asked if a threshold value of TRIR was

established, namely a value above which safety performance was deemed to be unacceptable. The safety performances of projects with more stringent TRIR requirements (threshold values no greater than 2) tended to be significantly better than on projects using more lenient threshold values (threshold values greater than 2), and these were better than where no TRIR limits were established (see Table 5-14). The findings indicated that setting a stringent objective resulted in better performance. Conversely, setting a weaker objective results in weaker performance. Note that the category 'none' includes projects that did not use the TRIR as a requirement and also projects that used the TRIR, but that did not establish a specific threshold value.

Table 5-13. Is the TRIR used to evaluate safety performance of contractors?

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
No	7	2.88	1.82	2.50	0.11	0.04
Yes	49	1.91	1.96	1.43		
Total	56	2.04	1.95	1.58		

Table 5-14. Threshold value of TRIR set for contractor safety performance

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (2-tail)**	**Kruskal-Wallis Sign. (2-tail)**
<2	12	1.06	0.92	0.99	0.01	0.03
>=2	21	1.66	1.23	1.92		
None	23	2.89	2.51	2.18		
Total	56	2.04	1.95	1.58		

The most proactive owners turn to dynamic measurements of safety performance, which can better portray the safety performance potential and safety management capabilities of contractors. Generally, owners will not focus on a single measure, but will try to assess the overall safety performance of contractors based on a number of measures. Viable measures include an assessment of the contractor's safety program and the qualifications of the safety personnel. A thorough and careful investigation into the

underlying safety commitment held by the contractor is conducted to ensure that the selected contractor will be able to achieve an acceptable safety performance.

Qualifications of the contractor's safety personnel and qualifications of the project management team were used by some owners for the selection of contractors. The more proactive owners would review these qualifications by conducting personal interviews with them and also by making site visits to projects where they were assigned at the time. The resultant TRIR was found to be lower on projects where the owner's had a practice of considering the qualifications of the contractor's safety personnel and also the qualifications of the project management team (see Table 5-15 and Table 5-16).

Table 5-15. Are qualifications of safety staffs reviewed when evaluating contractors?

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
No	14	2.60	2.32	2.48	0.09	0.06
Yes	42	1.79	1.81	1.32		
Total	56	2.00	1.96	1.51		

Table 5-16. Are qualifications of the project team reviewed when evaluating contractors?

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
No	18	3.04	2.54	2.48	<0.01	<0.01
Yes	38	1.50	1.40	1.20		
Total	56	2.00	1.96	1.51		

Many owners asked contractors to provide copies of the OSHA log for the past year and any records of OSHA inspections on past projects. The analysis did not find any significant differences between the safety performances of projects when owners used or did not use these measures as criteria for the evaluation of contractors.

Further analysis was conducted on the merits of using the following proactive criteria to measure safety performance.

- Qualifications of the safety staff of the contractor,
- Qualifications of the project management team of the contractor, and

- Quality of the overall safety program of the contractor.

The impact of using none or some of these proactive criteria and of using all three was examined. The analysis essentially determined the TRIR of those projects when the owners used all three measures in their assessment of contractors, when owners used less than three measures, and those that did not evaluate contractors on the basis of safety when making their selection of the contractor. It should be noted that most owners (33) used all three proactive criteria. The relationship between the number of proactive criteria used and the resultant safety performances is shown in Table 5-17. From this, it is evident that the use of all three proactive criteria is associated with better safety performances than when none, one or two measures are used.

Table 5-17. Number of proactive criteria utilized for evaluating contractors on safety

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (2-tail)**	**Kruskal-Wallis Sign. (2-tail)**
Safety is not a factor	5	3.73	3.22	3.25	0.02	0.04
<=2	18	2.45	2.17	2.26		
3	33	1.48	1.39	1.19		
Total	56	2.00	1.96	1.51		

By using more proactive criteria for safety evaluations, owners make it clear that safety is important. As shown in Table 5-17, when safety did not influence the contract award or when fewer proactive criteria were used, safety performances on the projects were not as good.

Owner's Contractual Arrangement

The construction contract is the legal document that specifies the responsibilities of different parties involved in the project (Hinze, 2001). Many construction contracts include provisions for safety that specify additional requirements and responsibilities concerning safety. These provisions are often found in the general conditions or the supplementary provisions of the contract. In this study, the contracts between the owners

and contractors were investigated. The primary focus was on the safety requirements established by the owners. Findings show that contractual arrangements influence the safety performances realized at the project level.

The construction contract may impose a variety of requirements on the contractor. Only the provisions clearly focused on safety were examined in this research. Many different requirements were noted to be included in the contracts. While other contract requirements may have a favorable impact on safety, the nature of this influence could not be established when all respondents employed that contract requirement. There were questions related to seventeen different types of contract requirements. The frequency use of each contract provision is shown in parenthesis (see also appendix b).

- Contractor must comply with the local, state and federal safety regulations. (100%)
- Contractor must comply with safety requirements beyond the OSHA regulations (88.1%)
- Contractor must place at least one full-time safety representative on the project (83.1%)
- Contractor must submit the résumés of key safety personnel for the owner's approval (71.2%)
- Contractor must provide specified minimum training for the workers (62.7%)
- Contractor must report all lost time injuries to the owner (98.3%)
- Contractor must report all OSHA recordable injuries to the owner (96.6%)
- Contractor must report all injuries to the owner (96.6%)
- Contractor must include personnel from the owner in coordination meetings (67.8%)
- Contractor must submit subcontractor list to owner for approval (79.7%)
- Contractor must implement a substance abuse program. (93.2%)
- Contractor must participate in site safety audits (88.1%)

- Contractor must conduct weekly safety meetings for the workers (93.2%)
- Contractor must submit a site-specific safety plan (84.7%)
- Contractor must submit a safety policy signed by its CEO (52.5%)
- Contractor is required to provide specified PPE (hard hats, safety glasses, gloves) (96.6%)
- Contractor must implement a permit system when performing hazardous activities (line breaks, lockout/tagout, excavations, proximity to power lines, confined space entry, hot work, etc.) (88.1%)

Note that some contract provisions appear in all or nearly all contracts used on the projects. For the purpose of this research, only those requirements related to better safety performances are presented. Two particular provisions were noted to be associated with better safety performances. One was that better safety performances were reported on projects where the contractor was required to assign at least one full-time safety representative to the construction site (see Table 5-18). Also, better safety performances were reported on projects where the contractor was required to submit the résumés of the key safety personnel (to be assigned to the project) for the owner's approval (see Table 5-19). Impacts of other leading indicators used in the contracts are shown in Figure 5-3, although the differences between TRIRs were not statistically significant. When the total number of safety requirements in the contract was calculated, it was found that those projects having contracts that had more requirements had significantly better safety performances (see Table 5-20).

Table 5-18. Contract requires the contractor to place at least one full-time safety representative on site?

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
No	10	2.96	2.64	1.87	0.04	0.08
Yes	49	1.75	1.72	1.30		
Total	59	1.95	1.94	1.48		

Table 5-19. Contract requires the contractor to submit the résumés of key safety personnel for the owner's approval?

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	17	3.01	2.34	2.81	<0.01	<0.01
Yes	42	1.52	1.58	1.20		
Total	59	1.95	1.94	1.48		

Figure 5-3. Other leading indicators used in the project contract (not statistically significant)

Table 5-20. Relationship between TRIR and total number of contractual safety requirements

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
<=15	38	2.38	2.24	2.13	<0.01	0.02
16 and 17	21	1.17	0.74	1.2		
Total	59	1.95	1.94	1.48		

Based on the statistical analysis, five requirements of contracts were identified as being "leading indicators", as these can be used in a manner to predict safety performances. Leading indicators are practices that are associated with improved safety performances. These are listed as follows:

- 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 approval
- Contractor must provide specified minimum training for the workers
- Contractor must submit a site-specific safety plan
- Contractor must submit a safety policy signed by its CEO

The data analysis showed that there was a relationship between the number of leading indicator safety requirements and the safety performances realized on the various projects (see Table 5-21). Projects on which more leading indicator safety requirements were included in the contracts had better safety performances than projects with fewer leading indicator safety requirements.

Table 5-21. Number of leading indicator safety requirements included in the contract

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (2-tail)**	**Kruskal-Wallis Sign. (2-tail)**
1 and 2	11	2.77	1.89	2.73	0.14	0.07
3 and 4	34	1.99	2.16	1.64		
5	14	1.22	0.99	1.18		
Total	59	1.95	1.94	1.48		

Owner Involvement During Project Execution

In addition to promoting project safe performance through the careful selection of contractors and the inclusion of carefully selected safety provisions in the contract, owners can be active participants in safety management during project execution. Several questions were asked about specific practices of owners that were expected to favorably influence safety performances of projects. These practices included owner participation in safety recognition programs, monitoring of safety performance, funding safety initiatives, accident reporting, accident investigations, safety training and orientation programs, and so on. Only those practices that showed a clear influence on safety performances are presented.

Safety Program Of The Contractor

Questions were asked about specific safety topics that must be included in the project safety programs of contractors. Fifteen possible safety program elements were listed in the questionnaire, including:

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

The inclusion of the following safety program elements was associated with better project safety performances (see Tables 5-22 through 5-24):

- Emergency plans (medical and hazardous materials)
- Daily JSA (job safety analysis) conducted on the project site
- A substance abuse program must be implemented

Projects where these three elements were required in the safety program had significantly better safety performances (TRIR median=1.20, mean=1.75) than those that implemented one or two of them (TRIR median=2.46, mean=2.56) at the significance level of 0.01.

Table 5-22. Owner requires the emergency plan (medical and hazardous materials) to be included in the contractor's safety program?

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	8	2.39	1.05	2.59	0.24	0.04
Yes	49	1.86	2.07	1.22		
Total	57	1.93	1.96	1.43		

Table 5-23. Owner requires the daily JSA (job safety analysis) to be included in the contractor's safety program?

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	9	2.12	0.78	2.18	0.38	0.06
Yes	48	1.90	2.12	1.21		
Total	57	1.93	1.96	1.43		

Table 5-24. Owner requires a substance abuse program to be included in the contractor's safety program?

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	4	3.86	2.48	3.25	0.02	0.02
Yes	53	1.79	1.87	1.30		
Total	57	1.93	1.96	1.43		

Among these three elements in the safety program, drug testing is the most widely accepted on projects. Drug testing is the most important method to identify and screen substance abusers. Although drug testing has been controversial in the past, a majority of large projects require the implementation of substance abuse programs. Today drug testing is restricted or prohibited only in the states of Minnesota, Montana, Maine, Connecticut, Rhode Island, and Vermont. However, according to a Substance Abuse and Mental Health Services Administration (SAMHSA, 1999) report, the popularity of drug testing in the construction industry is still lower than the national average. For example, in 1997, 55.6% of all full-time construction workers between the ages of 18-49 reported that their workplace had a written policy concerning alcohol or other drug use (do not necessarily address testing), while the national average was 70.3%. Pre-employment screening tests were conducted for 25.8% of the construction workers and 38.6% of all other industries.

Various studies on drug testing programs have shown the effects of the drug testing programs on construction safety. During the past two decades, drug testing in the

workplace has gone from the point of virtual nonexistence to widespread employer acceptance. SAMHSA (1999) reported that in 1983, less than 1% of the employees were subject to drug testing, and today, approximately 49% of the full-time workers are subject to some type of workplace drug testing. Coble's study (1992) showed that drug testing was very much influenced by company size, i.e., most larger companies (those with over 100 employees) have drug testing programs, while few small companies would have a drug testing program. In a recent study by Gerber and Yacoubian (2001), it was found that companies with drug-testing programs experienced a 51% reduction in incident rates and a significant reduction in their EMR within 2 years of implementation. Also, most company officials believed that drug-testing programs had a positive impact on all organizational indicators, including safety, quality and costs.

It was discovered that owners requiring more of the 15 safety program elements listed in the questionnaire had better project safety performances. While not statistically significant, the following inclusions in the safety programs were associated with noticeable differences in the reported safety performances:

- Specific safety training program;
- Task specific PPE analysis;
- Safety responsibility defined for all levels;
- Emergency response team maintained on the project.

Owner Monitors Near Misses On The Project

It is almost an industry standard for project owners to monitor contractor safety performance on the basis of the TRIR. Since OSHA mandates that these records be kept, contractors can readily provide such information. A more proactive approach is for owners to monitor near misses. By doing this, the future occurrence of such accidents

may be prevented, before an injury actually occurs. Safety performances achieved on projects where the owner representatives monitored near misses were better than on those projects where this was not a practice (see Table 5-25). These results suggest that there is a beneficial impact of owners requiring near miss reporting and near miss investigations.

Table 5-25. Does the owner's representative monitor near misses on the project?

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	11	2.48	1.90	2.18	0.16	0.06
Yes	47	1.82	1.96	1.22		
Total	58	1.95	1.95	1.46		

Accident/Incident Investigations

Although all owners reported that they participated in the investigation of site accidents to a certain degree and generally maintained the accident records, the manner of using these accident records made a significant difference in project safety performances. Table 5-26 shows that owners tracking the individual safety performances of each contractor on site had significantly better safety performances. Evaluating the safety performance of each contractor can help in selecting safe contractors on future projects and this can also help the owner to identify any weaknesses in the current safety programs being implemented by each contractor. Additionally, it was found that if the owners incorporated the safety statistics of the contractors into their own safety performance statistics, the projects achieved better safety performances (see Table 5-27). By including the safety records of the contractors in their own safety statistics, the owners essentially adopt the philosophy that any injuries on the project are a negative reflection on their own safety performances. Ideologically, the owner actually regards

the contractor's employees as its own employees, and recognizes the value of protecting and caring for them.

Table 5-26. Does the owner maintain injury statistics by contractor?

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	26	2.50	2.26	2.13	0.03	0.03
Yes	33	1.52	1.53	1.19		
Total	59	1.95	1.94	1.48		

Table 5-27. Are the contractor's safety performance statistics included in the owner's safety performance statistics?

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	22	2.59	2.42	1.88	0.02	0.03
Yes	37	1.57	1.49	1.19		
Total	59	1.95	1.94	1.48		

Safety Recognition Program

Positive reinforcement is one mechanism by which individuals are encouraged to repeat certain types of behavior. One such approach in the area of safety is to implement a safety recognition program that recognizes and rewards workers who have exhibited good safety behavior.

Owners held different opinions about safety recognition programs. Such a program essentially reflects the owner's philosophy about safety and their general concern for the well being of the workers. For example, some owners' representatives stated that safety recognition and safety incentives were the same, and they would set aside certain monetary amounts to support safety bonuses and to award the workers who met specified performance criteria. Some would also set up incentives for the contractors. They believed that when more funds were set aside, the safer the projects would be. However, other owners' representatives held the opposite view with the belief that safety cannot be purchased through economic incentives. They would prefer spending money on better

training of workers and recognizing workers with better safety performances. They carefully structured the safety recognition program so that the workers would be positively encouraged to work safely, instead of trying to cover up the accidents to get the monetary reward. For example, the owner might recognize the qualifying safe workers with a baseball cap, a gas coupon, a lunch coupon, or some other small token to remind the workers about the priority being placed on safety. The impact of praising workers in front of their peers should never be underestimated. Some proactive owners would award workers based on both their safety performances and attendance performances, and some awarded workers based on their crew performances. These have proven to be useful and effective positive reinforcement approaches (Hinze, 1997).

Analysis of the data shows that when the owner provided some funds above and beyond the contract amount to promote safety, projects were more likely to achieve better safety performances (see Table 5-28). If the owner participated in the safety recognition program, the safety performance would also be better (see Table 5-29). These results demonstrated the positive influence owners could have on project safety performances.

Table 5-28. Are some funds provided to the contractor, above and beyond the contract amount, to promote project safety?

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
No	24	2.39	1.86	2.28	0.08	0.01
Yes	35	1.65	1.95	1.20		
Total	59	1.95	1.94	1.48		

Table 5-29. The owner participates in the safety recognition program

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
No	12	3.29	2.12	2.92	<0.01	<0.01
Yes	44	1.61	1.81	1.15		
Total	56	1.97	1.98	1.46		

Safety Education And Training

New worker orientation and safety training are considered by many to form the core of any project safety program (Hinze, 1997; Heinrich, 1959). Orientation of workers is essential to provide workers with necessary knowledge, so they can work safely. Orientation is the very foundation for the effective implementation of many other aspects of safety programs, i.e., training is required to successfully implement other safety initiatives. For example, without adequate safety training, pre-task safety planning cannot be effectively implemented within a crew. At the same time, safety training is an on-going program, which requires continuous and dynamic efforts to be expended by management. Some aspects of training may also be included in such safety initiatives as safety recognition programs, safety observation programs, job safety analyses (JSA), safety committees, and other programs that encourage worker participation. Opportunities to provide ongoing training should be recognized and understood. The primary objective is to help workers to always be aware of safety and to develop safe working habits. This is very important for the development of the project safety culture.

Owners can help make new worker orientation more effective and they can also assist in the continuing safety training efforts in many ways. This is especially true for owners who are quite familiar with the hazards commonly encountered on sites. Owners can stipulate the minimum requirements of safety training, and the site safety representatives of owners can participate in safety orientation sessions. Owners can provide funds and personnel for the safety orientation of the workers, and they can also assess the results of safety training by requiring a test to be administered at the end of each training session.

The results of data analysis support the fact that the owner's involvement in safety training can make a difference in project safety performance. The methods employed to deliver safety training include showing videos, contractor presentations, owner presentations, consultant presentations, and providing workers with reading materials. Of these, the contractor presentation along with owner presentations were identified as being particularly viable training approaches.

Statistical analysis showed that these two training methods were most effective at impacting safety performance. Table 5-30 shows that when both the owner and the contractor were involved in the safety training, projects reported better safety performances. Also, more hours (more than three) of monthly refresher safety training for workers can improve project safety performances (see Table 5-31). When the owner has a means to verify the comprehension of the safety orientation training received by workers, the safety performances are significantly better (see Table 5-32). Generally, the owner will require a test or exam after the safety orientation session to verify the comprehension of the training.

Table 5-30. Safety training methods used on the project

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (2-tail)	Kruskal-Wallis Sign. (2-tail)
Contractor only	11	3.11	2.74	1.69	0.05	0.06
Owner only	17	1.89	1.12	2.18		
Both	29	1.58	1.91	0.84		
Total	57	1.97	1.96	1.48		

Table 5-31. Hours of monthly refresher safety training received by the workers

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (2-tail)	Kruskal-Wallis Sign. (2-tail)
None	11	2.77	1.89	2.73	0.14	0.07
1 to 3 hours	34	1.99	2.16	1.64		
4 hours and above	14	1.22	0.99	1.18		
Total	59	1.95	1.94	1.48		

Table 5-32. Is there any means of verifying the comprehension of safety orientation?

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	11	3.20	2.13	2.53	<0.01	<0.01
Yes	48	1.66	1.79	1.20		
Total	59	1.95	1.94	1.48		

Responsibilities Of Owner's Site Representative

The owner's site safety representative is the person who expresses the owner's concerns for safety and helps to coordinate the contractor's efforts on safety management. The responsibilities and authority of the owner's representative will impact the project safety performance. On all projects included in this research, the owner would assign at least one manager as a full-time project safety representative. The responsibilities of the safety representatives were explored on the different projects. One of the responsibilities consisted of active participation in safety meetings. Active participation in safety meetings and/or tool-box meetings resulted in better safety performances (see Table 5-33).

Table 5-33. The owner participates in safety meetings and toolbox meetings

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	10	3.33	2.80	2.26	<0.01	0.01
Yes	46	1.67	1.66	1.19		
Total	56	1.97	1.98	1.46		

When more responsibilities were assumed by the safety representative, the project tended to achieve much better safety performance than when fewer responsibilities were assumed. Based on the statistical analysis, five key responsibilities assumed by the safety representatives were identified, 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

- Participating in safety and/or tool box meetings

The number of key safety activities performed by the owner's safety representative is related to project safety performance (see Table 5-34).

Table 5-34. Total number of key activities performed by the owner's safety representatives

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (2-tail)	Kruskal-Wallis Sign. (2-tail)
1 and 2	6	3.30	2.20	2.92	0.10	0.06
3 and 4	18	2.26	2.50	1.26		
5	32	1.55	1.49	1.23		
Total	56	1.97	1.98	1.46		

Another consideration relates to how the owner's safety representative monitors project safety performance. Nearly all the owner's representatives monitored project safety performance by monitoring the incident rates on the projects, including lost workday injury rate, TRIR, and first aid injury rate. It was noted that monitoring safety inspection records was associated with significantly better safety performances (see Table 5-35).

Table 5-35. The owner's representative monitors project safety inspection records on a regular basis

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	11	3.14	2.71	1.69	0.01	0.01
Yes	47	1.67	1.65	1.20		
Total	58	1.95	1.95	1.46		

Also, when the owner's safety representative monitored the project near miss rate on a regular basis, the project achieved better safety performance (see Table 5-25). The leading indicator measures were identified as (1) monitoring near misses and (2) monitoring project inspection records. Statistical analysis shows that projects where the owner did not monitor either of these two leading indicators had relatively weaker safety performances (see Table 5-36).

Table 5-36. The owner's representative monitors the project near miss rate and project inspection records on a regular basis

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
Neither	6	3.01	2.35	2.26	0.04	0.03
Both	42	1.65	1.71	1.16		
Total	48	1.82	1.83	1.27		

Setting Zero-Injury Objectives

Regarding the owner's expectations about safety performance, the results show that owners that established specific safety expectations reported better safety performances on their projects, especially those owners who set zero OSHA recordable injuries as their safety objective before project commencement (see Table 5-37). One owner commented "One can achieve the level of safety as he demonstrates to expect."

Table 5-37. Is zero TRIR set as a safety objective by the owner before project commencement?

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
Yes	19	1.38	1.14	1.43	0.06	0.10
No	40	2.22	2.18	1.64		
Total	59	1.95	1.94	1.48		

Additional Findings

In the research, there are some findings that are related to project safety performances, but not directly related to owner involvement. These are also of interest and would be described.

Safety Recognition Program

Projects with safety recognition programs achieved significantly better safety performances than projects without recognition programs (see Table 5-38).

Table 5-38. Is there a safety recognition program on the project?

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	9	3.47	2.31	2.53	<0.01	<0.01
Yes	50	1.68	1.75	1.21		
Total	59	1.95	1.94	1.48		

As to the extensiveness of the safety recognition programs, only subjective means are available to describe them. As discussed in the previous section of this chapter, safety recognition programs should be carefully developed, in order to positively reinforce safe behavior and establish the project safety culture. For example, an owner might reward only workers without any injuries and without any absences during a designated period of time (say, a quarter), with the belief that safety and attendance go hand in hand. Some owners awarded workers on a crew basis, in order to encourage workers to care for their colleagues. These efforts generally led to better safety performances through better recognition of the priority placed on safety and this resulted in higher morale. One way to recognize workers with particularly good safety records is through safety dinners. Statistical results also show that projects with safety dinners had better safety performances (refer to Table 5-39).

Table 5-39. Is safety dinner held on the project?

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
No	15	2.36	1.72	2.46	0.17	0.05
Yes	44	1.81	2.00	1.32		
Total	59	1.95	1.94	1.48		

Other owners implemented totally different approaches with the belief that safety performance should be proportionate to the rewards. However, this has resulted in new concerns that accidents might be covered up. Hinze (1997) had examined the effectiveness of safety incentive programs and drew similar conclusions.

Safety Observation Program

Although different owners and contractors may have different definitions for a safety observation program, it is widely recognized as one of the most effective practices that can help promote safety performance. The focus of the safety observation program

is on reducing unsafe behaviors and hazardous working conditions, instead of focusing on incidents only. The objective of the observation program is to prevent the occurrence of accidents by eliminating the front-end acts or conditions that might cause unexpected events. Although some owners may think that safety tours conducted by the safety supervisors or safety managers are essentially the same as safety observation programs, they are more accurately called safety inspections. A preferred definition of a safety observation program is a formal program in which some or all workers are trained and encouraged to recognize and report unsafe behavior or conditions. Management then tracks, records and analyzes these unsafe behaviors and conditions on a regular basis, and implements interventions to eliminate them. Some programs have designated foremen as full-time safety observers around the site to make continuously observation. Other programs have designated and trained workers making observations one to two hours each week. An observation program can encourage the participation of all or a portion of the workers on site. Whether or not a safety observation program was conducted on the projects tended to make a difference in the project safety performances (see Table 5-40).

Table 5-40. Are safety observers used on the project?

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
No	9	3.16	3.16	2.07	0.02	0.10
Yes	50	1.73	1.58	1.38		
Total	59	1.95	1.94	1.48		

Another important approach is the monitoring and investigation of near misses on projects. Generally, near misses were defined as “any unplanned event” or “any event that could have potentially caused personal injury or property damage or environmental issues.” Although different owners and contractors may have varying definitions for near misses, the degree to which near misses are tracked and investigated are quite different.

One question asked if the contractor reported near misses to the owner. The results show that a strong difference exists in the safety performances of projects depending on whether or not near misses were reported by the contractors (see Table 5-41). When the number of near misses recorded on each project was compared with the number of OSHA recordable injuries recorded on the same project, it was found that projects reporting more near misses than OSHA recordable injuries had significantly better safety performances (see Table 5-42).

Table 5-41. Does the contractor report near misses to the owner?

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
No	19	2.57	2.01	2.18	0.05	0.07
Yes	40	1.66	1.85	1.20		
Total	59	1.95	1.94	1.48		

Table 5-42. Comparison between number of OSHA recordable injuries recorded on the project with number of near misses recorded

	Counts	Mean	Std. Dev.	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
More recordables	26	2.75	2.20	2.43	<0.01	<0.01
More near misses	33	1.32	1.44	0.84		
Total	59	1.95	1.94	1.48		

Collaborative Efforts On Safety With Contractors And Designers

Collaborative efforts on safety between the owner, contractor and designer would appear to be essential to the achievement of better safety performance. As to the owner's cooperation with contractors on safety issues, many practices, such as the selection of safe contractors, the inclusion of safety requirements in the contract, and participation of the owner during construction, have been discussed in the previous sections. The contractor's commitment to safety and communications between the owner and contractor can also impact project safety performance. These were evaluated through the subjective assessment of the owner's safety representative.

Statistical analysis shows that when the owner's rating of the prime contractor's commitment to safety was larger than or equal to 6 (out of 7, as the highest rating), safety performances of the projects were significantly better (see Table 5-43). Table 5-44 shows that when the owner's rating of the communication and cooperation efforts between the owner and contractor was 7 out of 7, the project had significantly better safety performance. Although the ratings were subjective, the findings supported the expectation that a stronger commitment to safety by the contractor, and better cooperation and communication between the owner and contractor will help promote project safety performance.

Table 5-43. How does the owner rate the prime contractor's commitment to safety? (rating from 1 to 7, with 7 being the best)

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
<=5	23	2.47	2.08	2.00	0.05	0.03
>=6	36	1.62	1.79	1.18		
Total	59	1.95	1.94	1.48		

Table 5-44. How would the owner rate the cooperation and communication between the owner and contractor? (rating from 1 to 7, with 7 being the best)

	Counts	**Mean**	**Std. Dev.**	**Median**	**ANOVA Sign. (1-tail)**	**Mann-Whitney Sign. (1-tail)**
<=6	42	2.30	2.11	1.81	0.01	0.01
7	17	1.09	1.03	0.69		
Total	59	1.95	1.94	1.48		

Although design for safety was beyond the focus of this research, a few open-ended questions were asked to explore how owners could impact safety in the design stage. It was found that constructability reviews, accessibility reviews, operability reviews and maintainability reviews were addressed during the design or engineering phase. These reviews are conducted by in-house teams that typically include personnel with varied types of expertise. These reviews could also be performed by outside consultants. Most owners admitted that their efforts to emphasize safety in design or in the engineering

stage of their projects had occurred in the past decade. The underlying reasons for addressing safety in design include the following:

- Owners have realized that the economic costs of construction worker accidents, which have risen drastically in recent years, are a significant financial burden. Also, each injury accident negatively influences the owner's reputation and business profitability.

- Despite the contractual provisions, owners are not protected by indemnification provisions. Owners often share the liability for construction worker injuries because of defects or hazards resulting from the design or engineering of the project that are considered the responsibility of the owner.

- Many owners, especially industrial project owners, are taking a more proactive approach towards safety. They emphasize safety as early as possible, and try to eliminate unsafe physical conditions (through design for safety, and jobsite safety analysis) and unsafe human behavior (through safety training and safety observation programs).

- Owners have realized that many safety hazards not eliminated in the design phase will eventually pose a threat to their own employees in the operation and maintenance of the facilities.

- Many owners, especially industrial owners, are experienced in identifying hazards in the design of their facilities and they feel obligated and responsible for participating in the design for safety efforts of their projects.

As a result of these factors, owners are now taking a more active role in designing for safety. Owners of petrochemical projects appear to be most proactive at this time. The techniques they use to address safety during the design or engineering phases of their facilities include the following:

- Clearly define their expectations for safety, health and the environment on their projects, and clearly communicate this to all parties.

- Establish a standard procedure for regular safety reviews of the project design by the personnel of the owner, contractor/CM, and designer. Some owners will combine safety, health and environmental reviews with constructability, operability, and maintainability reviews in their total loss control program.

- In project design safety reviews, the owner will use a matrix to check different items included in the design and their related hazards. This includes a focus on accessibility and interference of different activities, fall protection, electrical

equipment safety, confined space entry, and hazardous materials. Many owners implement portions of the more stringent OSHA 1910 safety regulations (general industry) instead of OSHA 1926 safety regulations (construction industry) in their safety requirements.

- Focus of safety reviews in the design differs from project to project, depending on the characteristics of the facility to be constructed. When necessary, the design and schedule are reviewed and modified concurrently to avoid accidents.

- Computer graphical technologies are often applied in the safety reviews of project designs. Nearly half of the project owners reported reviewing the design through a 3-D model simulated by computers.

- Design modifications made solely because of safety reasons are common on projects. Although it might increase costs, owners regard the goal of zero injuries as outweighing the economic costs.

Answers To Open-Ended Questions

In the study, some open-ended questions were asked. One question asked about the most important way for the owner to improve project safety performance. This question was not formally included in the questionnaire, but was asked as a concluding question. Although the answers varied considerably, the following points were made:

- Owner's management commitment: Both site management and home office personnel of the owner should have a clear understanding of the value of safety. Safety is no longer regarded as a priority, instead, it should be integrated into the owner's values, always being placed first. Management should have a common view that zero-injuries can and should be the safety objective.

- Safety observation program: The philosophy is to eliminate the front end of the accident chain and remind everyone on the project about safety. Techniques can include training and encouraging everyone to report unsafe acts, hazards on site, and near misses. This is followed by tracking the records and intervening when necessary to avoid unsafe acts.

- Personal accountability: Safety responsibilities of each site person, whether employed by the owner or the contractor, should be clearly defined and closely related to the overall personal performance evaluations.

- Integration of the safety plan with the schedule and cost plan: Safety will be built into the project schedule and cost plan (by being directly included in the budget). Safety objectives, although set as the priority, are fulfilled along with time, quality and cost objectives.

- Safety communication: Owners should set their expectations on safety from the very beginning and strengthen their emphasis on safety through continual efforts. Safety communication conveys safety experience and knowledge to the contractor. This can be done by discussing safety issues at the beginning of each meeting and by providing firm and physical support of the safety efforts on sites.

- Implementation of the safety program: The safety program should be carefully developed, evaluated and modified in response to the changes on the project. Once defined, the safety program should be implemented firmly and consistently, and there should be no differences in the implementation for the employees of the owner, contractor or subcontractors.

- Evaluation of safety performance: Evaluations of workers should be based on their physical performance instead of incident statistics only. Characteristics of the project being constructed and site safety observation records should be considered when evaluating the safety performance of contractors. Overall quality of the safety program, as well as the project management team, should also be considered.

- Physical walk-out and inspection: Owner personnel should not focus solely on the safety statistics reported by the contractors. They should "walk the talk", and be visible on the site to monitor the contractor's safety performance and show their support of the contractor's safety efforts.

- Safety/constructability review of the design: Proactive owners start their safety efforts as early as the design phase, and it is an essential part of the total loss control program of many owners.

- Safety culture: Caring for human life and health, caring for colleagues, and recognizing safe acts are the philosophy commonly held on the project. The safety culture can be cultivated only through close cooperation of the owner and contractor, based on the values they share on safety.

Industrial Versus Commercial Construction (A Case Summary)

One of the findings of this research showed that petrochemical projects had better safety records than the other types of projects. Is there a logical explanation that industrial projects tend to have better safety records than do commercial projects? More specifically, is there any characteristic of commercial projects that prevent them from achieving the level of safety performance achieved on industrial projects? The experience of one particular construction company provides a clear answer to these questions and that is a clear "No!" This particular company has two large divisions,

namely an industrial division and a commercial division. From 1992 to 2002, these two divisions worked nearly 100,000,000 hours, with the industrial division being somewhat larger than the commercial division.

In 1992, the safety performances of these two divisions were quite different. The OSHA recordable injury rate of the industrial division was 3.26 while the injury rate of the commercial division was 9.74. At this point in time, the industrial division had implemented an aggressive safety program while the commercial division was not as fully engaged in safety. Over the next years, the commercial division began to adopt a more proactive stance on safety. This effort has continued to where the safety performance of the commercial division (0.60) has now slightly outpaced that of the industrial division (0.68). While the industrial division showed a sustained improvement in the injury frequency rate, the commercial division showed much more dramatic improvements. This is shown in Figure 5-4.

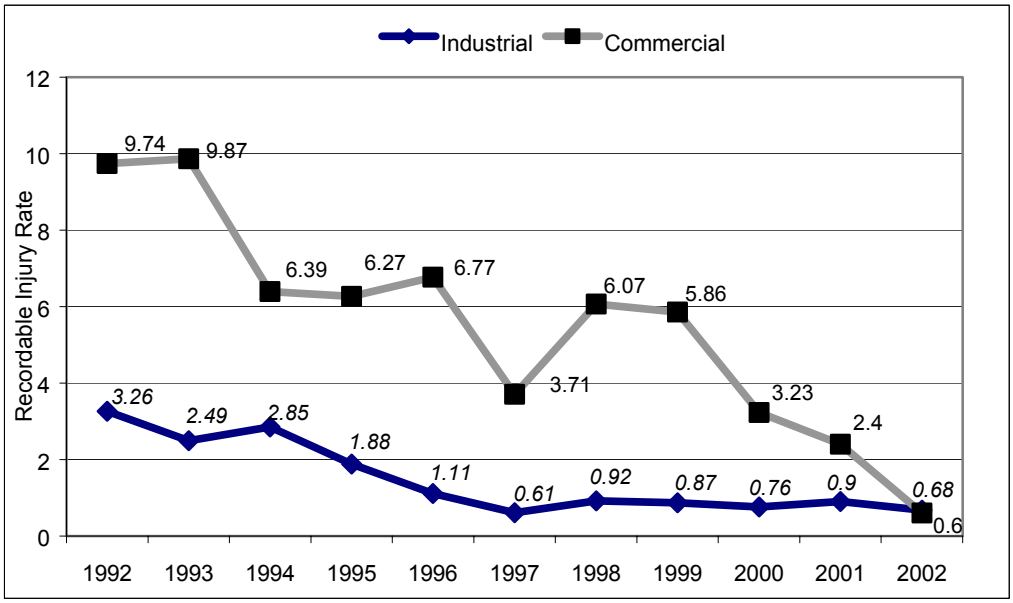


Figure 5-4. Corporate history of safety performance

From Figure 5-4 it is apparent that the safety performance on commercial projects can be as good as on industrial projects. Once a strong safety culture is established, the type of construction project makes no difference in the safety performance that is realized. Thus, one can state that the type of project should not be a factor in the safety performance realized. The zero accident objective seems to be a realistic goal for both industrial and commercial projects. Presumably, similar safety performances could be achieved on civil projects, and residential projects. It is perhaps realistic to then conclude that the zero accident objective should be pursued on every type of project.

Owner Safety Model Building

In the previous sections of this chapter, the relationship between different safety practices and the safety performances of projects were discussed. Those practices that make significant differences in project safety performances were presented with a brief explanation of the possible reasons. However, it is still not clear which factor has the most influential cause and effect relationship with project safety performance, i.e., what practices cause the greatest differences in the safety performances in the presence of other practices. According to Agresti and Finley (1997), a relationship must satisfy three criteria to be a causal one, these criteria are:

- Association between the variables;
- An appropriate time order;
- The elimination of alternative explanations.

At this stage, the first criterion is already satisfied, with the significant relationships shown between the safety performance and different practices discussed in this chapter. The second criterion should be reasonably satisfied, since safety performance (or accidents) occurred after projects commenced and different safety management practices were implemented. Therefore, the major task to conclude a causal relationship between

the safety performance and different aspects of the projects, especially the owner's involvement in safety management, is to discuss the relationship between the safety performance and each practice, after controlling for other factors. If statistical tests disclose that the relationship between safety performance and the selected practices is still significant, then conclusions can be made that a causal relationship between the factor and safety performance exists. Otherwise, the relationship could be superficial. It should be noted that since nearly all projects conducted the common practices, the analysis was conducted with the ignorance of the common practices.

In this section, several indices are generated to quantify different aspects of the practices that are significantly related to safety performance, based on the significant relationships presented in the previous sections. With a multi-linear regression model, their separate relations to project safety performance are evaluated, after controlling for other alternative explanations. Thus, a tentative cause effect relationship between project safety performance and different practices employed by owners are presented.

Quantification Of The Index

The response or dependent variable is the TRIR of each project, which is an effective measure of project safety performance. The explanatory variables are the indices generated based on the significant findings in this chapter, including:

- Project index: noted as P, which quantifies different significant factors that are helpful for the explanation of the injury rate of different projects. For the purpose of this study, these factors should only be those which are influenced by the owner;
- Selection of contractor index: noted as S, which quantifies different significant factors in the selection of contractors that are associated with differences in safety performances;
- Index of contractual safety requirements: noted as C, which quantifies different significant factors in the contractual safety requirements that help promote project safety performance;

- Owner's involvement index: noted as O, which quantifies different significant factors in the owner's involvement in project safety management that are significantly related to project safety performance.

All the significant factors or characteristics that are related to safety performance and can be influenced by the owners, can be included in one of the four groups above. The quantification of the variables in each index is based on the "all or nothing" principle. If the project implements a practice or possesses a characteristic which is significantly associated with better project safety performance, the factor value of this characteristic will be 1, otherwise, it will be 0. The values of all factors in each group are added up to form the index value of this group.

For the project index (P) with values potentially ranging from 0 to 2, the significant factors and their quantification include the following:

- Does the project work one shift? (q09: yes=1, no=0, q09 means the ninth question in the questionnaire);
- Does the project work five days a week or less? (q09: yes=1, no=0).

For the contractor selection index (S) with values potentially ranging from 0 to 4, the significant components and their quantification include the following:

- Is the TRIR requirement for the contractors less than 2? (q27: yes=1, no=0);
- Are the qualifications of the project team reviewed? (q27: yes=1, no=0);
- Are the qualifications of the safety staff reviewed? (q27: yes=1, no=0);
- Can the evaluation of the contractor's safety performance make a difference in the award of the contract? (q27a: yes=1, no=0).

For the contract index (C) with values potentially ranging from 0 to 4, the significant components and their quantification include the following:

- Does the project use a design-build or EPC type contract? (q03: yes=1, no=0);

- Does the contract require the contractor to place at least one full-time safety representative on site? (q29: yes=1, no=0);

- Does the contract require the contractor to submit all safety personnel résumés for the owner's approval? (q29: yes=1, no=0);

- Of the listed contractual safety requirements, is the total number of contractual safety requirements 16 or greater? (q29: yes=1, no=0).

For the owner's involvement index (O) with values potentially ranging from 0 to 10, the significant components and their quantification include the following:

- Number of critical indicators required by the owner to be included in the contractor's safety program (q33, if the number is equal to 3 the value is 1, otherwise it is 0). The critical indicators are:

  - Emergency plan (medical and hazardous materials)
  - Daily JSA (job safety analysis) conducted on the project site
  - Substance abuse program
- Does the owner's safety representative review the near miss rate on a regular basis? (q25: yes=1; no=0);

- Does the owner's safety representative review safety inspection records of the contractor on a regularly basis? (q25: yes=1: no=0);

- Are injury statistics on the owner's projects maintained separately for each contractor? (q37: yes=1, no=0);

- Are the contractor's safety performance statistics included in the owner's safety performance statistics? (q41: yes=1, no=0);

- Does the owner's safety representative participate in the site safety recognition program? (q24: yes=1; no=0)

- Does the owner make a presentation in the worker's safety orientation session? (q44b: yes=1, no=0)

- Does the owner have any means to verify the comprehension of safety training? (q44f: yes=1, no=0);

- Number of key responsibilities assumed by the owner's safety representative (q24, if the number is 4 or 5, the value is 1, otherwise the value is 0):

  - Enforcing safety rules
  - Reviewing site safety performance and submitting reports to the home office
  - Monitoring pre-task analysis programs

- Participating in safety recognition programs
- Participating in safety and/or tool box meetings

- Does the owner set zero injuries as its safety expectation before the commencement of site work? (q16: yes=1, no=0).

As noted, the total values of the different indices are different. If the owner's involvement in safety management is intensive, the value of owner's index (O) can be as high as 10. For the selection index and the contract index, the highest value is 4, and for the project index, the highest value is 2. The descriptive statistics of the different indices are listed in Table 5-45.

Table 5-45. Distribution of the indices

		Project index	Selection index	Contract index	Owner index
N	**Valid**	59	59	59	56
	Missing	0	0	0	3
Mean		1.20	2.49	2.15	6.93
Median		1	3	2	7.5
Mode		2	3	3	8
Std. Deviation		0.87	1.19	1.11	1.86
Minimum		0	0	0	2
Maximum		2	4	4	10
Percentiles	**25**	0	2	1	6
	50	1	3	2	7.5
	75	2	3	3	8

In order to investigate the relationship between each index and the TRIR, an analysis was conducted for each category index. The results are shown in Table 5-46 through Table 5-49.

Table 5-46. Relationship between TRIR and the project index (P)

P	N	Mean	Std. Deviation	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
0 and 1	30	2.50	2.35	1.85	0.01	0.03
2	29	1.39	1.19	1.17		
Total	59	1.95	1.94	1.48		

Table 5-47. Relationship between TRIR and the selection index (S)

S	N	Mean	Std. Deviation	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
<=2	25	2.52	2.40	2.07	0.03	0.05
3 and 4	34	1.54	1.40	1.20		
Total	59	1.95	1.94	1.48		

Table 5-48. Relationship between TRIR and the contract index (C)

C	N	Mean	Std. Deviation	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
<=2	31	2.72	2.30	2.50	<0.01	<0.01
3 and 4	28	1.09	0.83	1.15		
Total	59	1.95	1.94	1.48		

Table 5-49. Relationship between TRIR and the owner's index (O)

O	N	Mean	Std. Deviation	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
<=6	25	3.03	2.28	2.50	<0.01	<0.01
>=7 and <=10	34	1.15	1.12	0.70		
Total	59	1.95	1.94	1.48		

The means and medians of project safety performances of the different indices show that the safety performances of the projects were significantly different when the project index, the selection index, the contract index and the owner index were different, when ignoring the effects of the other indices (see Tables from 5.46 to 5.49). The groupings in the tables were established so that the selected values roughly split the samples into two categories with relatively equal counts.

If all the indices are included in the ANOVA model, the mean TRIRs of projects with different index values with the presence of other indices can be compared. For example, the mean TRIRs of projects with owner index (O) <= 6 can be compared with the mean TRIRs of projects with owner index (O) >= 7, after controlling for other indices (P, S, and C). Table 5-50 shows the ANOVA model with main effects only. From the table, it is evident that the main effects of the project index (P), contract index (C), and owner index (O) were significant. That is, the mean TRIRs of projects with project index (P)<=1 are statistically significantly worse (higher) when compared with the mean TRIRs of projects with a project index (P) = 2 at the 0.05 level, after controlling for the other indices (S, C and O). The mean TRIRs of projects with contract index (C) <= 2 was

significantly worse when compared with the mean TRIRs of projects with contract index (C) >= 3 at 0.01 level, after controlling for other indices (P, S, and O). The mean TRIRs of projects with owner index (O) <= 6 was significantly worse when compared with the mean TRIRs of projects with owner index (O) >= 6 at the 0.01 level, after controlling for other indices (P, S, and C). However, after controlling for P, C, and O, the TRIR with different selection index values (S) were not significantly different. This may suggest that selecting safe contractors is widely accepted by owners to guarantee project safety. Owners that focus on other aspects of the projects (P, C and O) are also careful in the selection of safe contractors. If the owner does not care about the other aspects (P, C and O), selection of safe contractor may also not be a major concern.

Table 5-50. ANOVA table for between-subject effects

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	78.979	4	19.745	7.711	<0.01
Intercept	224.409	1	224.409	87.636	<0.01
P	10.262	1	10.262	4.007	0.05
S	0.224	1	0.224	0.088	0.77
C	17.471	1	17.471	6.823	0.01
O	18.03	1	18.03	7.041	0.01
Error	138.277	54	2.561		
Total	441.82	59			
Corrected Total	217.256	58			
Dependent Variable: Total Recordable Injury Rate					

Multi-Linear Regression Between TRIR And The Indices

Spearman's correlation (a non-parametric correlation) between TRIR and the different indices and the sum of the indices are listed in Table 5-51. It indicates that TRIR has a negative correlation with the four indices and the sum of the indices. Meanwhile, the contract index (C), the selection index (S), and the owner index (O) are significantly positively correlated with each other. The negative relationship between TRIR and different indices is reasonable, since each index consists of different factors

that are strongly associated with project safety performance. The positive correlation between the different indices (C and S, C and O, S and O) indicates that owners who carefully select safe contractors also emphasize safety in contracts, and employ different practices and techniques to promote safety performance. It also suggests that safety cannot be achieved through a single effort. The relationships between the TRIR and the indices can be linear. A multi-linear regression model might disclose the more significant causal relationships between the safety performances and different aspects of the projects. The model may also help estimate the safety performance that can be realized on a project with the involvement of the owner in safety.

Table 5-51. Spearman's Correlation between TRIR and the index

	TRIR	**P**	**S**	**C**	**O**	**SUM**
TRIR	1	-0.328(*)	-0.318(*)	-0.452(**)	-0.484(**)	-0.636(**)
(Sign.)	.	0.011	0.014	<0.01	<0.01	<0.01
P	-.328(*)	1	0.228	-0.022	0.116	0.380(**)
(Sign.)	0.011	.	0.082	0.866	0.395	0.003
S	-.318(*)	0.228	1	0.434(**)	0.277(*)	0.579(**)
(Sign.)	0.014	0.082	.	0.001	0.039	<0.01
C	-0.452(**)	-0.022	0.434(**)	1	0.362(**)	0.664(**)
(Sign.)	<0.01	0.866	0.001	.	0.006	<0.01
O	-0.484(**)	0.116	0.277(*)	0.362(**)	1	0.752(**)
(Sign.)	<0.01	0.395	0.039	0.006	.	<0.01
SUM	-0.636(**)	0.380(**)	0.579(**)	0.664(**)	0.752(**)	1
(Sign.)	<0.01	0.003	<0.01	<0.01	<0.01	.

Note: * means significant at 0.05 level and ** means significant at 0.01 level.

Multi-variable regression was conducted, with TRIR as the response variable and the indices as the explanatory variables. A stepwise auto-selection of the explanatory variables procedure was applied, in order to first select the most significant variable. The final results of the regression are shown in Table 5-52, Table 5-53 and Table 5-54.

Table 5-52. Model Summary of the multi-variable regression

Model	Predictors	R	R Square	Std. Error of the Estimate
1	O	0.481	0.231	1.7561
2	O, P	0.580	0.336	1.6471
3	O, P, C	0.652	0.426	1.5466
The response variable was TRIR in all the models.				

Table 5-53. ANOVA of the multi-variable regression

Model		Sum of Squares	df	Mean Square	F	Sig.
1	**Regression**	50.05	1	50.05	16.229	<0.01
Predictors:	**Residual**	166.534	54	3.084		
O	**Total**	216.584	55			
2	**Regression**	72.806	2	36.403	13.419	<0.01
Predictors:	**Residual**	143.779	53	2.713		
O, P	**Total**	216.584	55			
3	**Regression**	92.203	3	30.734	12.849	<0.01
Predictors:	**Residual**	124.381	52	2.392		
O, P, C	**Total**	216.584	55			
Dependent Variable: Total Recordable Injury Rate						

Table 5-54. Coefficients of the multi-variable regression

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	**Std. Error**	**Beta**		
(Constant)	6.606	0.85		7.773	<0.01
Owner index	-0.36	0.123	-0.337	-2.939	<0.01
Project index	-0.752	0.237	-0.334	-3.178	<0.01
Contract index	-0.576	0.202	-0.326	-2.848	<0.01

In order to validate the linear regression analysis, several assumptions should be satisfied, including: the data are randomly selected, the response variable (TRIR) should be roughly normally distributed, the data should fit the linear model well, and the response variable should have constant variance at different levels of the explanatory variables. The selection of the data was described previously in this chapter. Although the data were not purely randomly selected, the sample projects were independent of each other. The normality assumption was tested by the histogram of regression standardized residuals (Figure 5-5) and the P-P plot (Figure 5-6). Figure 5-5 shows the histogram of the standardized residual of the TRIR, which represents the distribution of the

standardized value of the observed TRIR less the predicted TRIR (predicted by the calculated linear model). Figure 5-6 shows the level of conformity of the expected cumulative probability of the standardized residual of the TRIR when compared to its expected distribution (45 degree line). Both figures indicate that the normality assumption is roughly satisfied: the histogram roughly fits the normal distribution curve, and the P-P plot roughly fits the 45 degree line. The linearity and constant variance assumption was tested by the predicted value vs. standardized residual plot (Figure 5-7, if the equal variation assumption is satisfied, the scatters should be randomly scattered around the y=0 line), which shows that the assumption is roughly satisfied. Therefore, it can be concluded that the results of linear regression are valid, and the findings are reliable.

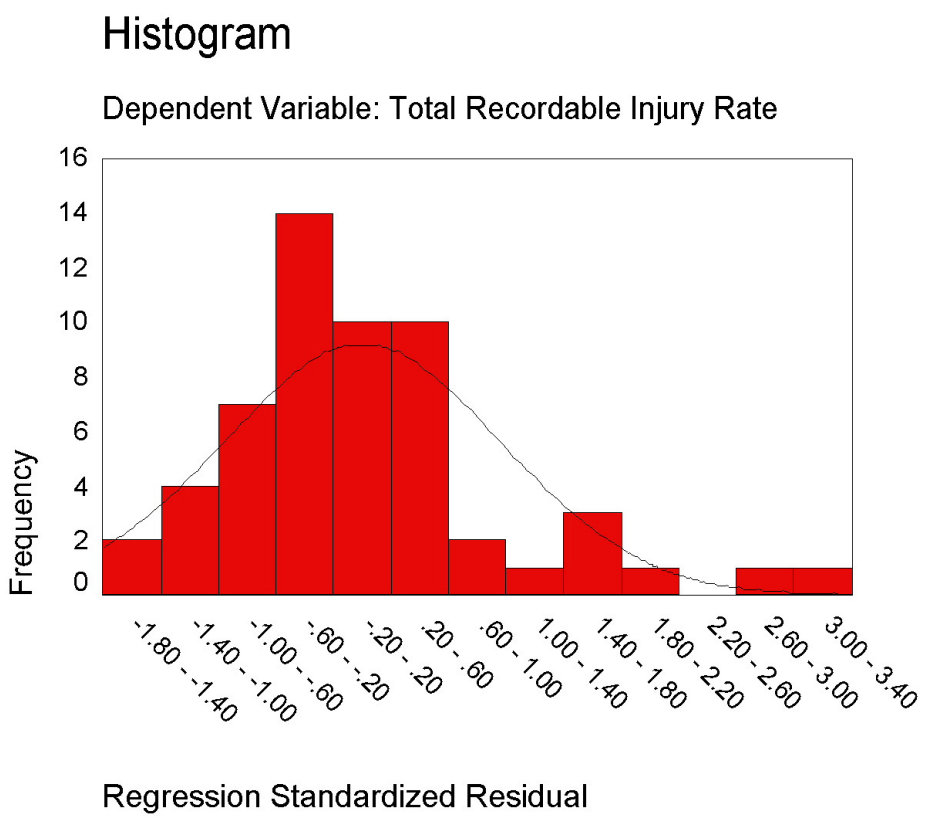


Figure 5-5. Histogram of the regression standardized residual

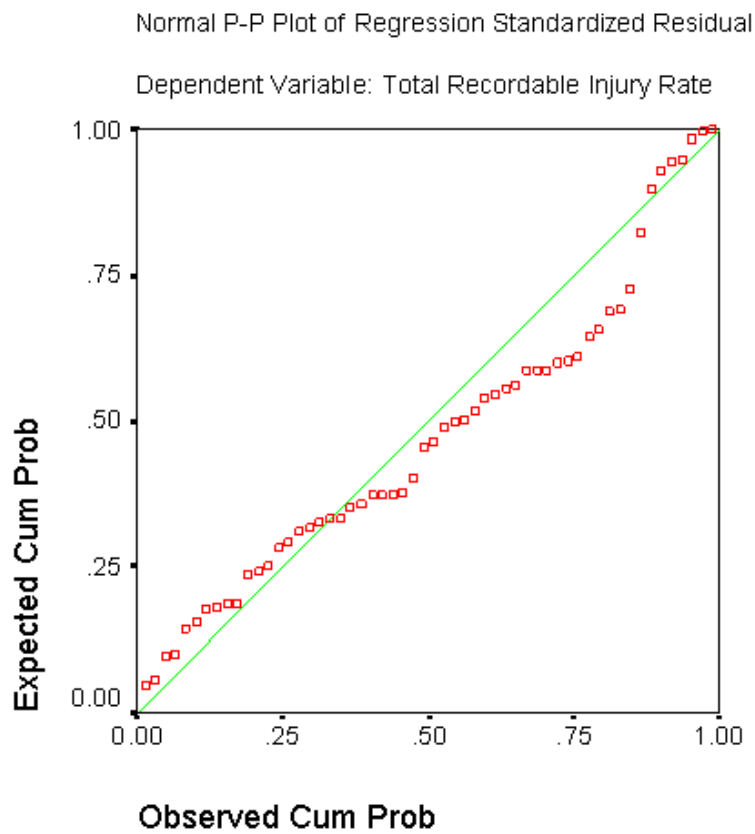


Figure 5-6. P-P plot of the regression

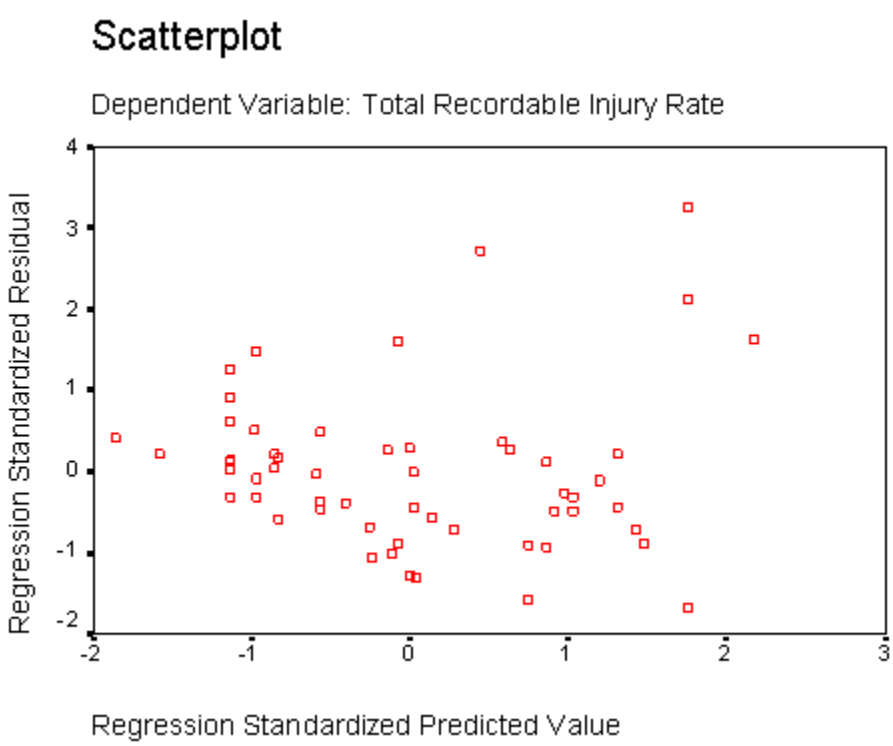


Figure 5-7. The predicted value vs. standardized residual plot

Explanation And Discussion Of The Regression Results

The results shown in Tables 5-52 through 5-54 demonstrate how the indices were selected in the multi-variable linear regression model. Tables 5-52 and 5-53 show that the first index selected was the owner index (O), which means that the owner index was the independent variable that can explain the largest proportion of the variability of the TRIR. The next independent variable selected was P, followed by C. With the inclusion of more explanatory variables in the model, the sum of squares explained by the model and R square increased, and the error sum of squares decreased (see Tables 5.52 and 5.53). In the final model selected in the multi-variable linear regression, the R square was 0.426, which means that 42.6% of the variation of TRIR could be explained by the three indices: project index (P), contract index (C) and owner index (O) in the linear model. The F value and significance level of the final model in Table 5-53 shows that the null hypothesis (that each of the coefficients of the indices is equal to zero) is rejected. The results in Table 5-54 indicate that all the three coefficients are not equal to 0 at the significance level of 0.01. The relationship between TRIR and the indices can be expressed as Equation (1).

$$TRIR = 6.606 - 0.752P - 0.576C - 0.36\,O \qquad \text{(Equa. 1)}$$

In which,

P means the project index ranging from 0 to 2,

C means the contract index ranging from 0 to 4,

O means the owner index ranging from 0 to 10.

If P = C = O = 0 (i.e., the owner does not take any practices included in P, C, and O), then the project TRIR might be as high as 6.61. If P = 2, C = 3, and O = 9 (i.e., the

owner takes most of the practices included in P, C, and O), then the estimated TRIR can be as low as 0.13.

The selection index is not included in the equation, because of the multi-collinearity effects that occur when the selection index and the other indices are significantly correlated. That is, the power of the selection index in explaining the variability of TRIR was trivial in the presence of the other explanatory variables (P, O, C). This does not mean that the selection of the contractor is not related to project safety performance, as the results in Table 5-51 illustrate that they are significantly related, although not as high as the other indices. Meanwhile, it also suggests that unlike twenty years ago, the selection of safe contractors is no longer the only and most effective way to improve project safety performance. Most owners consider safety performance when selecting contractors to execute their projects. More importantly, owners positively influence project safety performances by taking an active role in project safety management and by including stringent safety requirements in their construction contracts.

Referring to the standardized coefficients in Table 5-54, the owner's involvement index (O) is more influential than the other coefficients in reducing TRIR. This means that the owner's actual practices can be at least as important as the safety requirements in the contract and the project context. As all three indices in the regression model can be directly influenced by the owner, it can be concluded that owners do play a very strong role in influencing the safety performance realized on projects.

The R^2 of the regression (0.426) is not quite close to 1 (which would mean that all injuries are impacted by the owner). This finding is reasonable since the contractor-

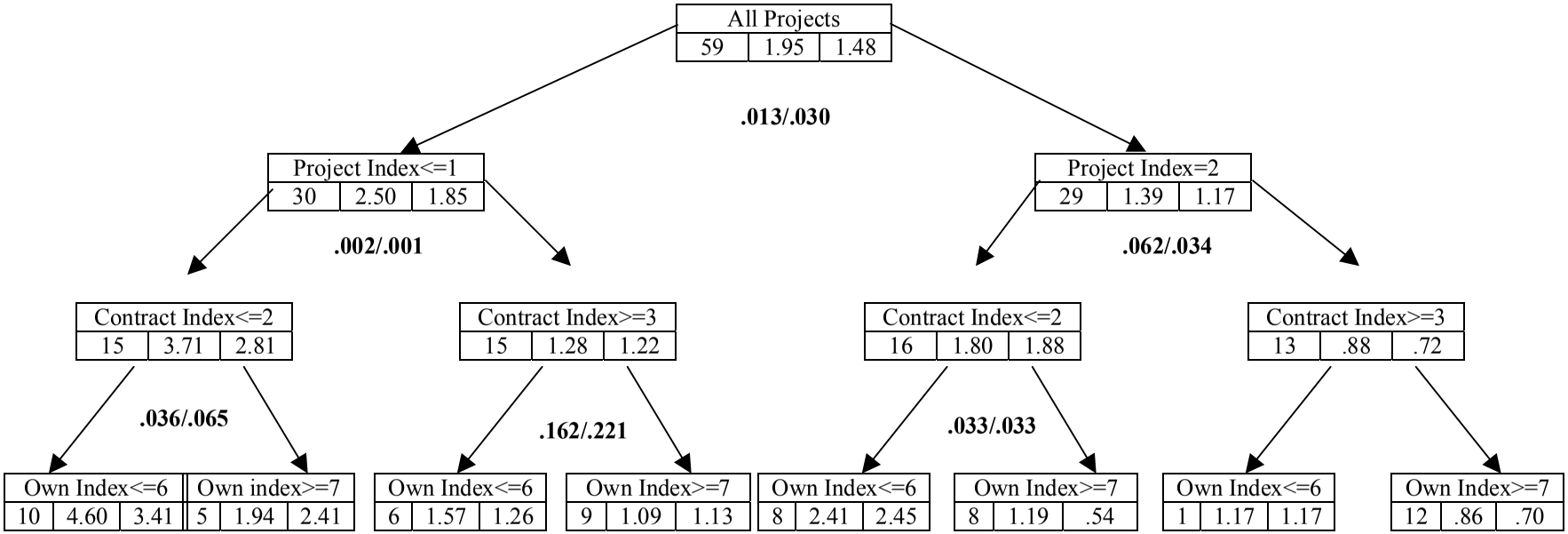
related factors have not been considered in this study. Although the safer owners tend to select safer contractors, and their safety performances tend to be better, there are also circumstances in which the contractor could take the leadership role in project safety management and achieve better safety performance without very much involvement of the owner. Also, with the active involvement of the designer (A/E firms), safety might be improved as well. Therefore, some of the variation of the project safety performance is left to be explained by the involvement of the contractors and designers. However, as explained in Chapter 1, because of the position held by owners on each project, owners are an important party that can influence project safety performance to a large extent.

Safety Performance Model: How To Achieve Better Safety Performance

To illustrate how owners can (help) achieve better safety performances on their projects, a safety performance model was developed, based on the data analysis in this chapter and the previous chapter. The three indices in Equation (1) were included this model. When comparing means and medians, it can be concluded that the project index, contract index, and owner index all make a difference in project safety performance. The model includes the indices of the project (P), the contract (C) and the owner (O) as shown in Figure 5-8. The TRIR means and medians shown on the right branch (with larger index values) at different levels are always less than the left branch (with smaller index values). At the lowest level, when controlling for the project index (P) and the contract index (C), it is evident that the owner's direct involvement can make quite a significant difference in the project safety performance. The leg on the very right, with high values for all three indices, has the lowest TRIR mean (TRIR=0.86) and median (TRIR=0.70) values, while the very left leg, with low values for all three indices, has the highest TRIR mean (TRIR=4.60) and median (TRIR=3.41) values.

Therefore, an increase of each index contributes to reducing the TRIR. To test this conclusion, the Spearman's correlation between TRIR and the total of the three indices (P, C and O) is -0.636 with a two-tailed significance level of less than 0.001 (see Table 5-51). This provides strong evidence that the owner's involvement, together with the project characteristics and the contractual safety requirements will significantly influence project safety performance.

Based on this model, a project scorecard was developed to evaluate the safety performance of a project. Any owner can use the scorecard to evaluate the possibility of its project achieving good safety performance by referring to the scores obtained in the card. Also, the score obtained in the different sections of the scorecard can help the owner identify which areas can be improved to achieve better safety performance. The scorecard is shown in Figure 5-9. Note that the scorecard is valid only after the following practices are already implemented on the projects: the owner requires the primary contractor reports OSHA recordable injuries; the owner assigns at least one site safety representative with high authority and responsibilities clearly defined; the owner's site safety representative monitors contractor's safety performance regularly; the owner prioritize safety when selecting contractors, and maintains an approved contractor list for awarding the contract; the owner specifies basic safety requirements in the contract document; the owner requires basic components included in contractor's safety program; owner address safety in the design phase.



Legend:

Sign. Of ANOVA (1-tails)/ Sign. Of Mann-Whitney test (1-tail)

Category		
Count	Mean	Median

Figure 5-8. Project safety model: owner's impact

Owner's Influence on Construction Safety Scorecard

Project Context, Contractor Selection, Contractual Safety Requirements and Owner Involvement in Project Safety	Answer	
Project context:		
(1) Does the project work one shift?	❒ Y	❒ N
(2) Does the project work five days a week or less?	❒ Y	❒ N
Selection of contractor		
(3) Is the TRIR requirement for the contractor selection less than 2.0?	❒ Y	❒ N
(4) Are the qualifications of the project team reviewed?	❒ Y	❒ N
(5) Are the qualifications of the safety staff reviewed?	❒ Y	❒ N
(6) Does the evaluation of each contractor's safety performance make a difference in awarding the contract?	❒ Y	❒ N
Contractual safety requirements		
(7) Does the project use a design-build contract?	❒ Y	❒ N
(8) Does the contract require the contractor to place at least one full-time safety representative on the project site?	❒ Y	❒ N
(9) Does the contract require the contractor to submit all safety personnel résumés for the owner's approval?	❒ Y	❒ N
(10) Does the contract require the contractor to prepare a site-specific safety plan?	❒ Y	❒ N
(11) Does the contract require the contractor to submit a safety policy signed by its CEO	❒ Y	❒ N
(12) Does the contract require the contractor to provide a minimum specified amount of training to the construction workers?	❒ Y	❒ N
Contractor Safety Program Requirements		
Which of the following are required to be included in the contractor's safety program?		
(13) Contractor must prepare a plan for site emergencies	❒ Y	❒ N
(14) Contractor must conduct pre-task safety planning on the project site	❒ Y	❒ N
(15) Contractor must implement a substance abuse testing program	❒ Y	❒ N
Owner's involvement in project safety management		
(16) Does the owner's safety representative investigate near misses?	❒ Y	❒ N
(17) Are injury statistics on the projects maintained separately on each contractor?	❒ Y	❒ N
(18) Are all project injuries included in the owner's overall measure of safety performance?	❒ Y	❒ N
(19) The owner actively participates (gives presentations) during worker safety orientation?	❒ Y	❒ N
(20) Comprehension of safety training is evaluated through testing?	❒ Y	❒ N
Which of the following activities are performed by the owner's site safety representative?		
(21) Enforcing safety rules and regulations	❒ Y	❒ N
(22) Monitoring of the implementation of pre-task planning	❒ Y	❒ N
(23) Participating in safety recognition programs	❒ Y	❒ N
(24) Participating in safety and/or tool box meetings	❒ Y	❒ N
(25) Does the owner set zero injuries as its safety expectation before the commencement of site work?	❒ Y	❒ N
Total Count of Yes Responses		
Multiply the Yes Count by 4 (X 4)	%	

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

Figure 5-9. Owner's influence on construction safety scorecard

The highest possible score of the scorecard is 100 percent. The scores of the projects in the study ranged from 40% to 92%. If the projects with at least 22 points (scoring over 88%) are compared with those with less than or equal to 52% scores, the TRIRs are significantly different (refer to Table 5-55). The Spearman's correlation of the TRIR and the score generated on the scorecard for the 59 projects is – 0.60, significant at the 0.001 level. This shows that the results of the scorecard are negatively correlated to TRIR, and the score can be used to evaluate the owner's impact on safety.

Table 5-55. The safety performances of projects with highest and lowest scores

Score	N	Mean	Std. Deviation	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
<=13 (52%)	8	4.64	2.90	2.92	<0.01	<0.01
>=22 (88%)	7	0.53	0.34	0.50		
Total	15	2.72	2.96	1.62		

Follow-up Survey: Contractors' Responses

As a supplementary effort of this study, a second survey (shown in Appendix c) was conducted to collect opinions from contractors on the owner's impact on construction safety. Owner involvement in safety management was the focus of the survey. Questions were asked about the owner's responsibilities in construction safety, which type of project tends to be safer, and preferences of contractors for owner's participation in safety management. Sixty questionnaires were sent to contractors with large construction projects in North American. Forty-one responses were received. It was a brief survey, but the results of the survey support several findings of the project interview study. Also the contractors' assessment of how safety is emphasized by owners, as well as the contractor's preferences for owners who participate in safety management were discussed. Since this was not the focus of this study, the results of the contractor responses are shown in Appendix d.

Summary

This research was focused on the owner's involvement in safety management as demonstrated through the project context, the selection of safe contractors, inclusion of safety requirements in the contract, and the owner's active participation in safety during project execution. Through analysis of the project interview data, it can be concluded that owners can favorably influence project safety performances. Better safety performances are related to the following project characteristics and practices of the owners:

- Project context: Project characteristics related to better safety performance include petrochemical projects, private projects, open-shop projects, projects with design-build contracts, projects of fairly large or small size (not medium size), projects working one shift, and projects working five or less workdays per week.
- Careful selection of safe contractors: Proactive criteria are used to evaluate and select contractors by owners aggressive in safety. These criteria include the TRIR on past projects, qualifications of the contractor's safety staff, qualifications of the contractor's project management team, and the assessed quality of the contractor's overall safety program.
- Contractual safety requirements: Contractual safety requirements should clearly convey the owner's emphasis on safety and the owner's expectation of a safe project. Five contractual requirements were identified as being leading indicators, and they are listed as follows:
    - 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 approval
    - Contractor must provide specified minimum training for the workers
    - Contractor must submit a site-specific safety plan
    - Contractor must submit a safety policy signed by its CEO
- Owner's proactive involvement in the safety practices of projects: In this study, the key measurements employed by the owners with better safety performances are identified as:
    - Owners set their expectations on safety from the very beginning of a project, especially the zero-injury objective;

- Owners impose requirements on the safety programs developed by contractors and emphasize specific items, including: emergency plan (medical and hazardous materials), daily JSA (job safety analysis) conducted on the project site, and substance abuse program;
- Owners monitor near miss rates and the safety inspection records on the projects, besides other types of injury statistics (TRIR, lost-time injury rate, etc);
- Owners maintain accident statistics by contractor on their projects, and also include the contractor's injury statistics in their own accident records;
- Owners establish a safety recognition program and contribute funds to the program;
- Owners actively participate in safety training and orientation and verify the comprehension of the training (such as by testing);
- Owners assign 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.

Based on the significant factors listed, four indices, namely the project index, the selection index, the contract index, and the owner index, can be generated to quantitatively measure the various types of involvement of the project owner in safety management. Statistical analysis of the data demonstrates all indices, except the selection index, have a strong relationship with project safety performance after controlling for the other indices. Using the multiple linear regression method, the impact of each index was evaluated. A model to describe the impact of the important indices was established. A scorecard was developed to evaluate the owner's overall impact on project safety.

CHAPTER 6
HOW CAN OWNER ACHIEVE PROJECT SAFETY

In this chapter, the safety management practices of two owners on several projects are examined. The scorecard developed in Chapter 5 is used to evaluate each owner's involvement in construction safety management and this score is compared with the safety performances achieved. The reasons why the projects may or may not achieve good safety performances are diagnosed, with recommendations for future improvement.

Case 1: Owner R

As part of the study, interviews were conducted on five projects of the same owner, hereinafter referred to as Owner R. These projects are coded as projects A through E. Arranged by Owner R, the individuals interviewed on these projects were all in project management positions, and they were all familiar with safety management on the projects. The information gathered can help develop an overall picture of how Owner R addressed safety issues on its construction projects. While keeping the similar pattern of safety management on the different projects, safety performances of these five projects varied. Analysis of safety management practices on these five projects can help explain the differences in the safety performances realized.

The scores for the projects were evaluated. The incident rates were calculated, together with the indicators to specify the owner's involvement in safety management and the cooperation between the owner and contractor. The data are listed in Table 6-1.

Table 6-1. Comparison of injury rate and scorecard evaluation

Project	A	B	C	D	E
Scorecard evaluation score	76%	84%	84%	92%*	92%
Near miss injury rate	109.60	8.70	31.38	75.00	16.45
TRIR	3.20	1.92	2.00	0.00	0.18
Lost-time injury rate	0.00	0.00	0.00	0.00	0.00
First-aid injury rate	58.40	34.78	12.31	0.00	6.89
Worker Compensation case injury rate	3.20	0.00	0.00	0.00	0.00
Contractor's Commitment	6.5	4.0	3.5	5.0	6.0
Importance of safety in selecting contractors	6.5	7.0	7.0	6.5	7.0
TRIR threshold for contractors	4.0	3.5	2.0	1.0	1.0
Rating of safety communication with contractors	4.5	5.0	3.0	6.0	7.0

*:Evaluation score of project D was calculated to estimate the owner's involvement although it did not satisfy the 100,000 worker hours criterion.

Among the five projects, three (Project A, C, and E) were completed or essentially completed, project D has just been started, and project B was at the point of half completion. While the project phase of construction may impact safety performance, this could not be assessed in this limited study. While the five projects (average lost-time injury rate of 0) were well below the average lost-time incident rate of both CII members (0.26) and the construction industry (3.55 in 2000), project A, B and C had higher recordable incident rates (TRIR = 3.20, 1.92, and 2.00) than the average of CII owners (0.92) and CII overall (1.03). With limited worker hours expended, the overall safety performances of project D and project B were still not clear, although the trend of safety management on both projects was promising. Project E achieved very good safety performance through sustained efforts of both the owner and contractor. The evaluation scores of the scorecard follow the same order as the safety performance, with project E being the best and project A being the worst (see Table 6-2).

Table 6-2. Comparison between TRIR and the scores of the scorecard

Project	TRIR	Score of scorecard (%)
A	3.20	76
B	1.92	84
C	2.00	84
D	0.00	92
E	0.18	92

By reviewing the information in Table 6-1, project E had the most stringent threshold for TRIR in the selection of the contractor (less than 1.0) and safety was regarded as the most important factor in the overall review of the contractor's performance (7 out of 7). With a good safety commitment of the contractor (6 out of 7) and good communication between the owner and the contractor (7 out of 7), the safety performance realized was a testimony of the success of the owner's involvement in safety management (with the evaluation score of 23 out of 25, or 92%). In the interview, it was found that project E employed other techniques to improve safety performance, including:

- Strict selection of the contractor: Besides a high threshold for past safety performance, the owner reviewed all the incident records of the contractor. When evaluating the contractor's safety personnel, the owner not only requested the résumés of the key safety personnel of the contractor, but also inspected the current projects for which they were responsible. During the construction of the project, one safety person of the contractor was laid off or dismissed by the owner because of incompetence in safety management, which sent a strong message of the owner's concern for safety.

- Management commitment: The construction manager took the responsibility for safety on the project. About 25% of the construction manager's responsibilities were related to safety management. Safety professionals and safety representatives were regarded as good resources for construction safety.

- Safety observation program: The project kept close track of unsafe activities. Both unsafe acts observed by individual workers and near misses were carefully investigated by the project management team and reported to the construction manager. If any trend of unsafe acts was identified, the safety plan was modified, and notice would be made to everyone on site.

- Effective safety recognition program: The safety reward program recognized an individual's safety performance by contributing 50 cents per hour per worker for a safety bonus for workers who worked for a month without any recordable incident. Also, safety lunches and random giveaways were used to recognize good safety performances of workers.

- Focus on communication between the owner and contractors: Safety bulletin that was "refreshed" every week provided necessary safety knowledge to workers based on the results of safety observations. The project manager specified the weekly

safety meeting topics. Safety was always the first issue discussed at the beginning of each meeting.

Project A and project C had weaker safety statistics than project E. Based on the scorecard, some contributing reasons were:

- Loose safety thresholds during selection of the contractors: The TRIR thresholds of the two projects were 4 and 2, respectively. Reviewing the current job site of the contractor and safety performance of the key safety persons was not carefully addressed, which might send a message to the contractors of the owner's lack of concern for safety. The contractor on project C was selected after completing another project for the owner without further evaluating the safety performance of the contractor and without reemphasizing the safety expectations of the owner. This might contribute to the low commitment of the contractor to safety on the project (3.5 out of 7).

- Lack of communication between the owner and contractor and between different levels of the project: The ratings of communication between the owner and contractor on the two projects were 4.5 and 3 out of 7, respectively. The high number of subcontracts (56) awarded on project C might be a contributing factor. Communication with the contractor's workers was regarded as the main problem on project C, and it was stated that the union workers were not as cooperative as open shop workers.

- Ineffective safety observation program: On both projects, the safety observations were essentially conducted by the owner's staff. Workers were not adequately trained to make the observations and to report to management. Unsafe trends were not easy to discover. The ratios between the total number of workers at the peak level and the number of owner staff on site were relatively large (more than 65 for project C), i.e., safety supervision may have been inadequate. Near misses were not thoroughly investigated, which limited the capability of management to identify potential hazards on site and prevent accidents.

- Lack of effective metrics for safety performance on site: Without major efforts focused on near misses and unsafe behaviors, project management used EMR (for project A) and the amount of training, dollars spent on safety issues, management commitment (in project C) as the main metrics to ensure good safety performance on site. As discussed in Chapter 5, the EMR is a lagging indicator of the contractor, instead of being project specific. It was unwise for the safety manager on project A to depend on the EMR in monitoring the project safety performance. For project C, dollars spent on safety may suggest that safety could be purchased, and the philosophy was not good to safety.

- Job complexity: Project A was a shutdown project, with 250,000 worker hours exposure within 2 months, and worked two shifts at six ten-hour days per week. Since project C involved considerable electrical equipment and specialty

subcontractors, these factors made safety management more difficult than on the other projects.

With reference to the experiences on projects A, C, and E, the strong points of projects B and D are listed below:

- Management commitment: Construction managers and safety managers on the projects understood the importance of safety and set their expectations of zero injuries for everyone on the project from the very beginning.

- Emphasis on design for safety: Project B was very cautious about rigging activities and implemented a lifting permit system, when considering that most of the elements of the project were prefabricated. During the safety review of the design plan for project D with virtual reality technology, more than 100 changes were made to eliminate safety hazards. This could help considerable to reduce hazards and improve safety performance.

- Thorough implementation of safety observation program: Project B had 10 supervisors and one group of workers that did weekly safety observations of the 150 workers on site. Project D had observations made by every worker and each submitted an observation card daily. All the unsafe trends would be tracked and analyzed. Near misses would also be carefully recorded and investigated to help modify the safety plan. This could help update the safety program regularly and reduce the unsafe behaviors on site.

- Safety communication: Communication on safety information between different levels on the project was enhanced by frequent safety meetings and other dissemination systems. Steering meetings on project D and a formalized injury prevention information system implemented on project D should effectively help communication on the projects.

- Significant safety incentive system for individuals and contractors: owners on both projects made significant contributions to recognizing good safety performance of the contractors and their workers. These rewards reinforce safety expectations of the owner.

The weak point of these two projects was the selection of safe contractors. The threshold value for the TRIR for project B was 3.5, and the contractor did not need the owner's approval when selecting subcontractors. Project D had not reviewed the résumés of the contractor's key safety persons or their performances on prior projects.

Projects B and D had established a good safety culture from the very beginning. Effective techniques were employed to promote construction safety on site. Good safety performance could be expected on both projects if the weak points were recognized and addressed.

In general, the five projects of Owner R had good safety performances. Performing work that consumed 3,857,000 worker hours with 19 recordable incidents, the average TRIR of 0.985 was slightly higher than the CII owner average 0.92 in year 2000. However, it was significantly less than the industry average of 7.8 in 2001. Success of safety management came from the commitment to construction safety from top management to the owner staff on each project. The owner's involvement in safety management on the different projects was intensive, although with different degrees. Approaches that Owner R employed to promote safety can be summarized as follows:

- Have high expectation on construction safety (zero-injury objectives);
- Implement safety recognition programs;
- Set safety requirements in the construction contract;
- Assign full-time safety representative on site;
- Monitor and investigate near misses and first aid cases, and
- Emphasize safety training and orientation programs.

It should be mentioned that certain characteristics of the projects made safety management more difficult. A good example was that most workers of contractors were far from their head offices, which generally causes difficulty in communications between the project and the contractor (Hinze, 1997). In turn, communications and cooperation between the owner and contractors suffered, resulting in some problems between management and the workers on the projects.

While the projects were working well with safety management, communications between owner staff on different projects appeared inadequate, i.e., there was little

sharing of lessons learned between projects. If management techniques and information concerning safety could be shared regularly among different projects, between management of both owner staffs and contractor staffs, safety performance should improve significantly in the future.

Case 2: Owner S

Project Description

A manufacturing plant, referred to as Owner S, was included in the study. It executed a shutdown project for one furnace, coded as project F, in year 2001. The project accumulated 627,931 field worker hours. There were no lost time injuries on this project. There were 29 OSHA recordable injuries for a TRIR of 9.24. There were two reported near misses or incidents without injury. While Owner S expended considerable efforts to achieve better safety performance on the project, the TRIR on the project was even worse than that of the industry average. At the time of the interview, the owner was eager to know the root causes of poor safety performance on the project. The scorecard developed in Chapter 5 was used to diagnose the owner's involvement in safety management on project F.

Project F employed one prime contractor and two large specialty contractors to execute the construction work. These three contractors and Owner S formed a construction team, and they developed and implemented a project specific safety program as one cohesive unit. Owner S and the union business agents participated in the review process after the initial plan was developed. Owner S and the three contractors developed and signed the project safety charter. The charter's 24-point safety program was designed specifically for project F.

The safety program included a crew incentive program and drug and alcohol testing. The program included: issuing work gloves with a project safety logo at the safety orientation class; providing luncheons for the crafts for good safety performances and awareness; and spot rewards for good safety practices. Gift certificates were issued to crews with no recordable injuries, violations, or observed unsafe behaviors for each two-week period. The CII Zero Injury Techniques, including the "Five High-Impact Techniques" were utilized for the project's 24-point program.

Task planners (a task plan sheet) were designed specifically for this project. Each day the foreman completed the planner and discussed the job with the crew. When the assignments were changed or the crafts were re-assigned to another activity, new task planners were completed and discussed with the crew. All employees of contractors and subcontractors went through a four-hour safety orientation and the foremen were required to have the 10-hour OSHA card. This safety orientation included project specific safety policies and procedures. The executive committee was required to investigate all lost time accidents within 24 hours, and to investigate recordable injuries and non-injury incidents within 48 hours. There was a daily update of worker hours and recordable injuries at the daily construction review meeting. A "target zero audit" was conducted about half way through the outage phase of the project. The audit determined that 87.5% of the CII techniques were being utilized. The overall total score for the audit was 77%, indicating good communications of safety practices.

Analysis And Diagnosis

The safety manager of Owner S showed a deep concern for construction safety during the interview. However, the poor safety record on project F was difficult to explain. The safety manager complained that there were two weak points on the projects

that might be contributing reasons: (1) During investigations of the recordable or lost-time injuries, management seldom asked the victims to participate, so valuable information concerning accident causation could not be discovered; (2) Injury management was inconsistent. The owner safety manager complained that some employees of contractors sustained first aid injuries but they were reported as recordable injuries.

The scorecard developed in Chapter 5 was used to diagnose the level of the owner's involvement in construction safety management on project F. The results of the assessment of owner involvement for project F are shown in Figure 6-1.

The score of project F was only 48%, which demonstrates weak involvement of the owner in safety management. From the results in the scorecard and some other findings presented in Chapter 5, the project had the following weak points unfavorable for safety:

Project context

- The project was a shutdown project, and a medium size project. It had a tight schedule, and therefore, used two work shifts, six workdays per week, and, at the least, 10 hours were worked per shift.

- The project employed union workers. The owner had great difficulties when trying to regulate safety among union workers. Even the monetary incentive program did not help to remind the workers of safety. During the outage of the furnace, only 58% of the employees were able to earn the incentive bonus.

Selection of contractors

- The owner did not conduct a stringent contractor evaluation procedure. The selection of the prime contractor was bound by a previous contract. The prime contractor was actually predetermined, because of its success (not measured in terms of safety) on a similar past project.

- There was no specified TRIR threshold value for contractors to satisfy to be selected. Qualifications of the project management team and safety staff of the contractors were not evaluated when selecting contractors, either. Safety was not a consideration in contractor selection.

- The project employed low-caliber workers to perform work on the project, in order to save about 5% of the labor cost. The foremen had essentially no more working experience than the workers.

Owner's Influence on Construction Safety Scorecard

Project Context, Contractor Selection, Contractual Safety Requirements and Owner Involvement in Project Safety	Answer	
Project context:		
(1) Does the project work one shift?	❒ Y	☒ N
(2) Does the project work five days a week or less?	❒ Y	☒ N
Selection of contractor		
(3) Is the TRIR requirement for the contractor selection less than 2.0?	❒ Y	☒ N
(4) Are the qualifications of the project team reviewed?	❒ Y	☒ N
(5) Are the qualifications of the safety staff reviewed?	❒ Y	☒ N
(6) Does the evaluation of each contractor's safety performance make a difference in awarding the contract?	❒ Y	☒ N
Contractual safety requirements		
(7) Does the project use a design-build contract?	❒ Y	☒ N
(8) Does the contract require the contractor to place at least one full-time safety representative on the project site?	☒ Y	❒ N
(9) Does the contract require the contractor to submit all safety personnel résumés for the owner's approval?	❒ Y	☒ N
(10) Does the contract require the contractor to prepare a site-specific safety plan?	☒ Y	❒ N
(11) Does the contract require the contractor to submit a safety policy signed by its CEO	☒ Y	❒ N
(12) Does the contract require the contractor to provide a minimum specified amount of training to the construction workers?	☒ Y	❒ N
Contractor Safety Program Requirements		
Which of the following are required to be included in the contractor's safety program?		
(13) Contractor must prepare a plan for site emergencies	☒ Y	❒ N
(14) Contractor must conduct pre-task safety planning on the project site	☒ Y	❒ N
(15) Contractor must implement a substance abuse testing program	☒ Y	❒ N
Owner's involvement in project safety management		
(16) Does the owner's safety representative investigate near misses?	☒ Y	❒ N
(17) Are injury statistics on the projects maintained separately on each contractor?	❒ Y	☒ N
(18) Are all project injuries included in the owner's overall measure of safety performance?	❒ Y	☒ N
(19) The owner actively participates (gives presentations) during worker safety orientation?	❒ Y	☒ N
(20) Comprehension of safety training is evaluated through testing?	☒ Y	❒ N
Which of the following activities are performed by the owner's site safety representative?		
(21) Enforcing safety rules and regulations	☒ Y	❒ N
(22) Monitoring of the implementation of pre-task planning	☒ Y	❒ N
(23) Participating in safety recognition programs	☒ Y	
(24) Participating in safety and/or tool box meetings	❒ Y	☒ N
(25) Does the owner set zero injuries as its safety expectation before the commencement of site work?	❒ Y	☒ N
Total Count of Yes Responses	**12**	
Multiply the Yes Count by 4 (X 4)	48%	

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

Figure 6-1. Owner's influence on construction safety scorecard

Contractual safety requirements

- The owner made detailed safety requirements in the contract. However, the number of safety representatives for every one hundred workers was one, which was probably too small for the type of work being performed.

- The contract did not specify minimum safety training requirements for the workers.

Owner's involvement during construction

- Safety observation program. The project had a safety observation program, but the workers were not among the observers. Also, near misses and first aid cases were not investigated on the project. Modifications to the safety program were based on the investigations of the lost-time accidents and OSHA recordable accidents.

- Accident investigation program. Only lost-time accidents and OSHA recordable accidents were investigated. The owner did not maintain the safety performances of different contractors, nor did it include the contractor's injury statistics with its own injury data.

- Safety recognition program. The owner participated in the recognition program, but the program was mainly based on the injury records. Since there were 29 injuries during the two months, only 58% of the workers earned the bonus. The effect of the recognition program was modest.

- Safety training program. The owner did not participate in safety training and orientation.

- Responsibilities of safety representatives. Owner's safety representatives did not participate in toolbox meetings, and they did not participate in job hazard analysis.

- Safety objective. The safety objective of the TRIR set by the owner was 2 per 200,000 workhours. This was a relative weak expectation.

If the model established in Chapter 5 was used to evaluate the owner's involvement in safety management, the project would be located on the left most leg of the model. Each index, P, S, C, and O was less than the median of the index. Thus, poor safety performance could be expected on the project.

In general, the safety program of Owner S was focused on the elimination of injuries through incentives and punishment. Compliance and enforcement of the safety regulations were the major characteristics of safety management. Near misses and safety observations were not emphasized. The safety management of Owner S was not as

proactive as Owner R in case 1. If Owner R was typical of owners with petrochemical projects and if Owner S was typical of owners with other manufacturing projects, this may be indicative of why petrochemical projects tend to have better safety performances.

Summary

In this chapter, two case studies were discussed and evaluated in terms of the owner involvement model and scorecard developed in Chapter 5. From the results obtained in both cases, it is evident that an owner's influence on project safety is important. The scorecard proved to be an accurate predictor of the level of safety performance actually realized. The model and scorecard can be used to effectively evaluate the owner's involvement in construction safety.

CHAPTER 7
CONCLUSIONS, DISCUSSIONS AND RECOMMENDATIONS

Conclusions

In the past decade, safety performance in the construction industry has been dramatically improved. This is due, in part, to the concerted efforts of owners, contractors, subcontractors and designers. In this study, the owner's role in construction safety was investigated. The relationship between project safety performance and the owner's influence was examined, with particular focus on the project context, selection of safe contractors, contractual safety requirements, and the owner's proactive involvement in safety management. It can be concluded that the owner's involvement can significantly influence project safety performances.

The findings show that the owner sets the tone of the safety culture for projects. The owner can impact safety management and the safety commitment of the designer, the contractor, and the subcontractors in various means. Figure 7-1 illustrates how owners can influence project safety through communicating safety, selecting safe contractors and participating in safety management. At the core of the owner's involvement is the zero injuries objective. Owners should consider using various evaluating measures of safety performance when selecting contractors, when setting performance objectives, when monitoring safety performance, and when participating in project safety programs. These measures include risk involved in the construction process, past safety performance (TRIR), overall quality of safety program, management safety commitment,

qualifications of project management team and safety personnel, worker participation, safety observation results, near misses, and so on. Although there are some aspects of the project that owners cannot impact significantly, such as the local labor conditions, owners can help promote safety performance by implementing a carefully designed, dynamic safety program. These programs can then serve as a viable model for the contractor to emulate. By being directly involved in project safety management, many proactive owners have achieved excellent safety performances.

It should be noted that the involvement of owners in safety management should be a continuous and integral effort. Simply implementing some proactive safety practices cannot guarantee a safe project. Owner's concern and participation in safety should start from the very beginning of the project design until the completion and even the operation and maintenance of the project.

Safety management should be a dynamic and flexible effort with a firm safety philosophy of zero injuries. Safety should not consist primarily of a safety manual left on the table or in the statistics that are generated. The safety program should be changed with reference to the site conditions and the dynamic evaluation of safety performance (e.g. safety observations, near misses, safety inspections).

While the specific practices implemented on the project can vary, the safety program should be implemented consistently and firmly once developed. There should be no gray area in safety management. A behavior or condition can be either safe, or unsafe. No unsafe behaviors or unsafe physical conditions should be ignored or tolerated.

Referring to the results in this study, the zero injuries objective is attainable, particularly with the owner's proactive involvement in safety. The study also found that petro-chemical owners are among the most proactive owners in construction safety. This may be due to the traditional concern for safety in the chemical industry. It was accepted by many petro-chemical owners that the safety attitudes in their major business also impact their philosophy in construction safety. Safety is necessitated by the considerable hazards existing in the petrochemical industry. It was said that one petrochemical owner who had been proactive in safety started to implement even more stringent safety requirements after they started to produce explosive materials. These reasons may help explain why the safety performances of petro-chemical projects are better than other types of projects.

Discussions

As to the safety management method, three levels of management can be identified. The first level of management is the accident-and-prevention method. All the efforts on construction safety are led by lessons learned from past accidents. The second level is the regulation-and-enforcement level. Unsafe behaviors are the target of the enforcement. The third and most advanced level is behavior-based safety. The focus is to establish a safety culture by discouraging unsafe behavior and recognizing/rewarding safe behavior, based on observations. The focus of the different levels is on different elements in the accident causation chain (refer to Figure 7-2). A comparison of the three levels of safety management is listed in Table 7-1.

Many petrochemical owners interviewed in the study were at the third level of the safety management method. In comparison, many manufacturing owners were either at the second level of the method, or they are moving from the second level toward the third

level. The effectiveness of the different safety management methods can be observed in the differences of the project safety performances.

As to the motivation of safety management for the owners, costs and legal entanglements are still the major reasons. Because of the high risks in project construction, many owners find that safety is an essential part of their loss control program. At the same time, caring for people and business reputation are also reasons why owners have become more inclined to participate in safety management in the past decade.

As to the challenges owners confronted in construction safety, some owners commented that labor conditions and the decrease of labor skill levels are the major problems. Although labor conditions largely depend on the location of the project, statistical analysis showed that open-shop projects had significantly better safety performances than merit shop and union projects. This result was also supported by the survey conducted with contractors. However, it should be noted that no matter what the labor conditions, the zero-injury objectives have been achieved by proactive owners through appropriate safety management methods. For example, among the six projects without any OSHA recordable injuries, one union project worked 380,000 injury-free hours, and a merit shop project worked 266,000 injury-free hours.

The means by which the owner can help improve construction safety was found to be similar to methods found in other studies to be used by contractors and subcontractors who had positive impacts on project safety (Hinze, 2002; Hinze and Figone, 1988; Hinze and Talley, 1988). From various studies, the practices related to better safety performance have been summarized in Table 7-2. Although the study on subcontractor

safety was conducted approximately 15 years before the contractor study and the owner study, the comparison still shows that the practices to achieve better safety performance are relatively consistent for these three parties. In effect, the contractor is acting as a bridge between the owner and subcontractor. The owner's role in construction safety can then be defined as the party to oversee and facilitate safety management on the project. Owners may not always take the leadership role for project safety management, but the owner's attitudes towards safety and their physical involvement in safety will favorably impact the safety performance of general contractors and subcontractors.

Recommendations

All owners, regardless of the type and size of their projects, should recognize that they have a responsibility for construction safety. Safety should be integrated into the overall project objective of the owner.

This study focused on the owner's individual impact on project safety performance. The influence of owners on designers and contractors was not thoroughly explored. Further research is suggested to develop a fuller understanding of how owners can impact the way designers address safety in their designs. Research is also needed to address constructability issues and to establish how owners can facilitate contractors in their efforts to implement safety programs. For example, more information is needed on how owners can develop an effective safety and constructability review procedure, and how owners can work in concert with contractors to combine their own safety programs with the safety programs of contractors. These studies could be conducted at both the company level and the project level. Thus, a fuller picture could be generated on how to achieve better safety performance.

While it is felt that findings of this research apply to all types of projects, research should be conducted to confirm this. The data were heavily influenced by industrial and manufacturing projects and further study could determine how well the findings can be applied to projects of all types. A larger and broader based research study could be focused on the role of owners on smaller projects. This would determine if the owner's role changes with project size.

This study did not conduct a cost and benefit analysis when owners get involved in project safety management. However, the benefit of a safe project should be apparent, for example, the increased morale, the increased productivity and so on. Also, by avoiding one singe lost-time injury (with the average cost of 25,000 dollars, according to Hinze and Appelgate (1991)), the owner can nearly employ a full-time safety supervisor on site. Future study can investigate how owners regard the benefit and cost of owner's involving in construction safety management.

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 model 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.

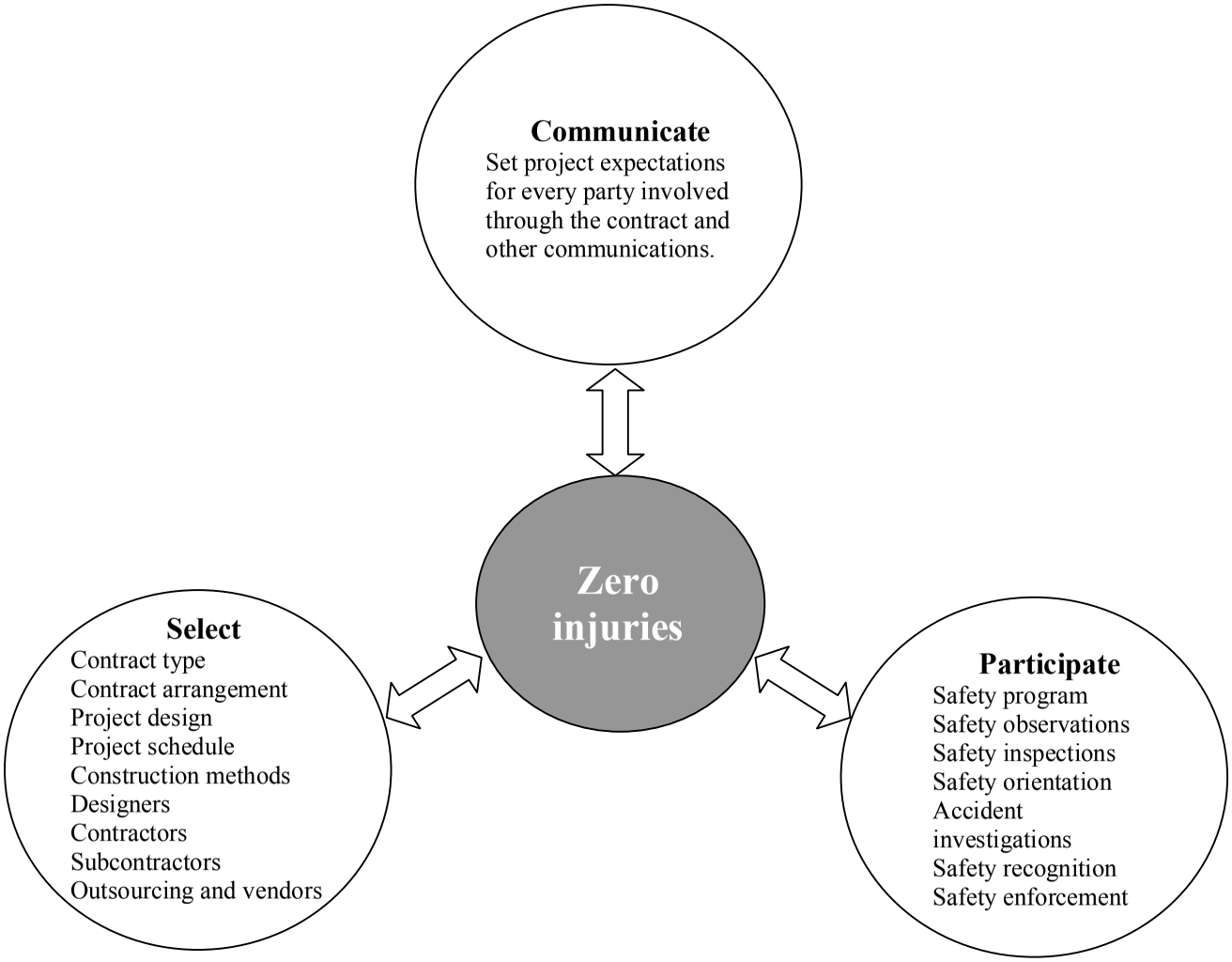


Figure 7-1. Owner's involvement in Safety management

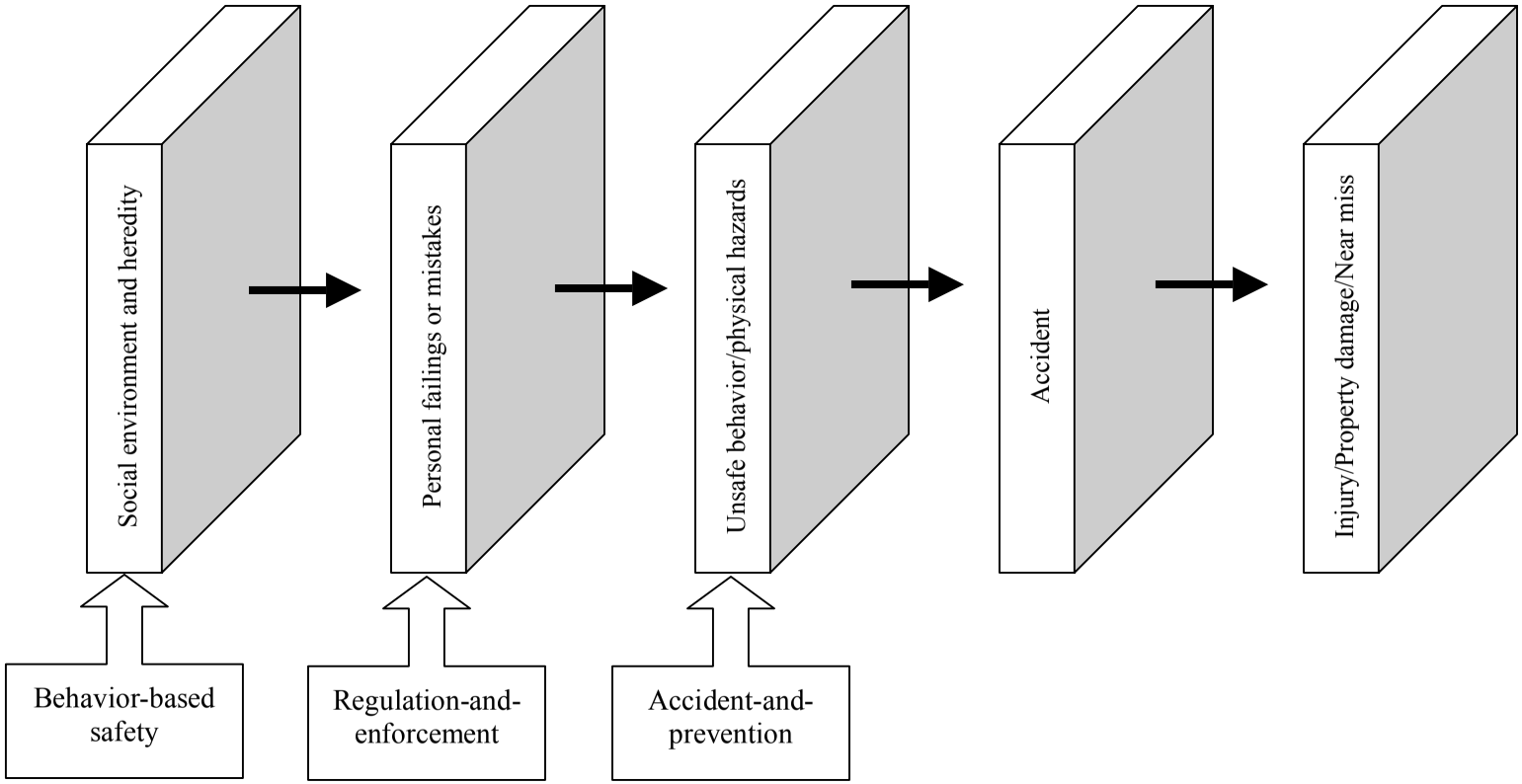


Figure 7-2. Focus of different levels of safety management methods

Table 7-1. Comparison of the three levels of safety management methods

	Driving event	**Aim**	**Means**	**Result**
Accident-and-prevention	Accident	Avoid repetition of the accident by not making the same mistake	Accident investigation, safety training, thorough safety program.	Good
Regulation-and-enforcement	Unsafe acts	Prevent accidents through the elimination of unsafe acts	Enforcement and punishment, safety inspection, training, thorough safety regulations	Better
Behavior-based safety	Unsafe and safe behavior	Zero-injuries through a total safety culture	Safety training, observation, near miss and first-aid investigation, safety recognition program, design for safety	Best

Table 7-2. Comparison of findings in different studies

	Owner study	**Contractor study**	**Subcontractor study**
Management commitment	No solid data support	Company president reviews safety reports Home office inspects safety frequently Top management involvement in every recordable accident investigation	Home office manager comes to visit the job frequently
Staffing for safety	Owner assigns full-time safety rep. on site Safety rep. assumes various responsibilities	Contractor employ full-time safety representative Safety representative reports to main office staff	A designated person for safety on the project.
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	General contractor reviews safety program of sub
Safety training	Owner involved in safety training; Owner has means to verify comprehension of training Owner's safety rep. participate in tool-box meeting	Formal safety training plan in print Safety training is a line item in the budget 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	Subcontractors are required to hold safety meetings 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
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
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 general contractor. General inspects sub safety
Accident Report and investigation	Incident stats. maintained by contractor Include safety stats. of contractor in owner's Safety rep. reviews accident reports	More near misses recorded on the project Top management investigates every accident	General contractor investigates accidents of subs
Drug test	Substance abuse testing required in safety program	Implement substance abuse test	No solid data support

APPENDIX A
OWNER SURVEY QUESTIONNAIRE

Project Owner's Role in Construction Worker Safety

Please provide answers for the following questions. For most questions, there is only one answer to check, however, in some cases a short written response is requested.

A. General information

1 What is the typical annual capital budget of your firm for construction projects in North America? About $_____ Million per year.

(a) How was the budget distributed among construction projects in the last fiscal year?
____% for new projects; ____% for alteration, revamp or rehabilitation projects.

(b) What percent of the annual capital budget is spent on design services? _____%.

(c) What percent of the annual capital budget is performed by construction contractors (not done in-house)? _____%.

2 As the owner, does your firm track safety performance of contractors on the construction project(s)? ❑ Yes ❑ No

(a) If yes, how long has your firm kept track of the safety performance of contractors?
For the past _____ years.

(b) If yes, what was the overall OSHA recordable injury rate of contractors working on your capital projects in 2001?
About _____ OSHA recordable injuries per 200,000 work hours.

(c) What other safety performance measures does your firm monitor?
_____.

(d) Does your firm establish/negotiate <u>specific safety goals</u> for contractors performing capital work? ❑ Yes ❑ No

3 What is the dominant type of construction project in your firm's construction budget? (*Please check one and show the percentage*)

❑ Manufacturing facilities _____% ❑ Petro-chemical plants _____%
❑ Buildings _____% ❑ Utilities _____%
❑ Land development _____% ❑ Civil works _____%
❑ Other (please specify): _____.

B. Safety coordination of the owner

4 Does your firm include safety as part of the project performance review?
❑ Yes ❑ No

5 When, at the earliest, does your firm begin to <u>emphasize safety</u> on projects? (*Check one*)

❑ During the concept and feasibility phase. ❑ During the design phase.
❑ Before the start of bidding. ❑ During the bidding phase.
❑ After bidding, before starting site work. ❑ After the start of site work.
❑ Other (please specify):_____.

6 Does your firm assign full-time owner safety representative(s) to the construction projects being built? ❑ Yes ❑ No
If yes, what criterion is used to place safety representatives on projects?
_____.

7 Which of the following does the owner's site representative/manager attend? (*Please check all that apply.*)
❑ Safety orientations. ❑ Site safety meetings. ❑ Site safety audits. ❑ None of them.

8 In the past fiscal year, what percent of your projects were undertaken under an owner controlled insurance program (OCIP)? _____%
If applicable, what is the smallest size (cost) of project that would be constructed under an OCIP? $_____ million

9 Do you have minimum safety performance requirements for contractors, other than complying with the OSHA regulations?
❑ Yes (please specify): _____.
❑ No.

10 As the owner, does your firm make any allocation (personnel or financial) for the training of the contractor's employees? ❑ Yes ❑ No
If yes, please explain: _____.

C. Safety management practice in projects.

11 How are contractors initially selected?
❑ By competitive bid ❑ By negotiated contracts
❑ Through references and by reviewing past performance
❑ Other (please specify): _____.
What is the breakdown of the contracts?
Lump-sum contracts:_____% Cost reimbursable contracts:_____%

12 During the selection of a contractor, is safety performance a factor in the prequalification process?
❑ Yes ❑ No

(a) If yes, what measures are used to compare the safety performances of different contractors? (*Please check all that apply, and provide the related data requested*)
❑ **Experience Modification Rating** (EMR) of the contractor, should be less than _____.
❑ **OSHA recordable injury rate** of the contractor, should be less than _____ per 200,000 work hours.
❑ **Loss Ratio** of the contractor, should be less than _____.
❑ **Site-specific safety program** prepared by the contractor.
❑ **Qualifications of the safety staff** of the contractor.
❑ **Quality of the overall safety program** of the contractor.
❑ Other (please specify): _____.

(b) When selecting a contractor, how would you rate the importance of safety in your overall performance assessment of the contractor?
The rating of the importance of safety is _____. (assume 1 is very low and 10 is very high).

13 As the owner, which philosophy does the firm hold concerning safety?
❑ We assume as much liability for safety as possible, and we keep safety totally under our control.

- ❑ We equitably share the liability for safety with the contractor, and we emphasize cooperation with the contractor on safety matters.
- ❑ We try to avoid safety responsibility as much as possible, and expect the contractor to assume responsibility for project safety.
- ❑ Other (please specify): _____.

14 As the owner, does your firm require all employees of contractors doing capital projects to attend standardized site orientation training sessions? ❑ Yes ❑ No

15 As the owner, does your firm contribute funds for the implementation of a safety incentive program by the construction contractor? ❑ Yes ❑ No
If yes, please specify:_____.

16 What safety requirements are specifically included in the construction contract? (*Please check all that apply*)

- ❑ Contractor must comply with the local, state and federal safety regulations.
- ❑ 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 approval.
- ❑ Contractor must submit a 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 drug-testing program.
- ❑ Contractor must conduct weekly safety meetings for the workers.
- ❑ Contractor must submit a site-specific safety program.
- ❑ Contractor must implement a permit system when performing hazardous activities.
- ❑ Contractor must submit a safety policy signed by its CEO.
- ❑ Other (please specify): _____.
  _____.

17 As the owner, does your firm require basic safety orientation for all workers before they can work on your projects? ❑ Yes ❑ No
If yes, how is safety orientation conducted on your project(s)?

- ❑ We totally control the safety training by conducting the training sessions.
- ❑ Safety training is essentially a joint or shared effort between the contractor and us (the owner).
- ❑ Contractor conducts safety training for everyone who enters the site; we only monitor the records and results of safety training.
- ❑ Contractor is totally responsible for safety training, and we don't get involved.
- ❑ Other (please specify): _____.

18 Contractually, what sanctions can your firm impose on a contractor for non-compliance with safety requirements? (*Please check all that apply*)

- ❑ 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.
- ❑ Contract could be terminated.
- ❑ Other (please specify): _____.

What has been the most extreme sanction actually imposed on a contractor?
_____.

19 Please select among the safety practices that are implemented by your firm, as the owner, to support safety during construction. (*Please check all that apply*)

- ❑ Owner's personnel conduct periodic job site safety inspections or safety audits.
- ❑ Owner places a safety person on the project to support the contractor on project safety.
- ❑ Owner provides a nurse or emergency medical technician (EMT) for the construction project.
- ❑ Owner's personnel participate in some contractor safety meetings.
- ❑ Owner's personnel participate in the investigation of all OSHA lost workday injury accidents.
- ❑ Owner implements a safety incentive that can be earned by the contractor for completing the project below a specified OSHA recordable injury rate.
- ❑ Owner monitors injury incidence rates on each project.
- ❑ Other (please specify): _____.

20 Do any managers in your firm have their bonuses tied directly to the level of safety performance of contractors working on your projects being constructed?

❑ Yes ❑ No

21 Does your firm consider anyone in your firm accountable for injuries sustained by employees of the construction contractor?

❑ Yes ❑ No, this is the contractor's sole responsibility.

D. Safety in design phase and others.

22 Is construction safety actively addressed in the design phase, whether through designer decisions or engineering input during the design phase? ❑ Yes ❑ No

If yes, please specify how your firm evaluates designers (prior to obtaining their services) on their ability to address construction safety in their designs.

_____.

_____.

23 Please rank the following measures in terms of their priorities in achieving success in project safety? (*Please rank these, beginning with 1 as the most important.*)

( ) Owner emphasizes safety and constructability in design.
( ) Owner selects safe contractors to carry out the work.
( ) Owner participates in and monitors safety during the whole life of a construction project.
( ) Owner develops an effective safety recognition and reward program.
( ) Owner dedicates funds to support the contractor's efforts in safety.
( ) Other (please specify): _____,

_____.

24 Provide any additional comments or suggestions you wish to share regarding construction safety?

_____.

_____.

_____.

_____.

_____.

APPENDIX B
OWNER INTERVIEW QUESTIONNAIRE

Owner Study Interview Questionnaire

Information specifically focuses on one current project or a recently completed project.

Code:	Date: _____, 2002
Project:	Project location:
Owner Co.:	General contractor:
Interviewee:	Title of Interviewee:
Telephone:	Email:

A. The project

1 What type of project is this?

(a) ❑ public 53 (89.8%) ❑ private 6 (10.2%)

(b) ❑ new 30 (50.8%) ❑ renovation 11 (18.6%) ❑ maintenance 3 (5.1%) ❑ shutdown 8 (13.6%) ❑ other: _____combined 6 (10.2%)

(c) ❑ Residential 0 ❑ Commercial 1 (1.7%) ❑ Manufacturing 19 (32.2%) ❑ Petrochemical 30 (50.8%) ❑ Utilities 5 (8.5%) ❑ Civil works 1 (1.7%) ❑ Others _____

(d) ❑ union 19 (32.2%) ❑ open shop 19 (32.2%) ❑ mixed 21 (35.6%)

2 Was this project awarded through competitive bidding? ❑ Yes 43 (72.9%) ❑ No 16 (27,1%)

How was the contractor selected? ❑ negotiated with one firm 16 (27.1%) ❑ short bidder's list 34 (57.6%) ❑ open to all 7 (11.9%) Not known 2 (3.4%)

3 What type of contracting arrangement is used on this project?

❑ General Contract 21 (35.6%) ❑ Multiple Primes 11 (18/6%) ❑ Design-Build 15 (25.4%)

❑ C.M. at risk 6 (10.2%) ❑ C.M. (agency) 6 (10.2%) ❑ Other: _____

4 What type of contract is used on this project?

❑ lump sum 23 (39.0%) ❑ cost plus 19 (32.2%) ❑ time and materials (T&M) 17 (28.8%) ❑ other _____.

5 What is the total estimated cost of this construction project: $_____M.

6 Who provides the workers' compensation insurance on this construction project?

❑ Each firm provides their own 45 (76.3%) ❑ OCIP 13 (22.0%) ❑ CCIP ❑ PCIP NA 1 (1.7%)

7 What is the expected project duration (construction phase only): _____ months.

(a) What is the current percent of completion for this construction project? _____% of the duration

(b) Anticipated completion date (m,y): _____, _____ .

8 How many total worker hours have been expended on this project? _____thousand hrs

❑ Since January 1,2002 ❑ In the past 12 months ❑ _____

Does this include only the hours of the prime contractor or does it include subcontracted work?

❑ prime ❑ subs ❑ both

9 How many shifts are worked on this project? _____

How many hours per shift? _____ (hrs) and how many days per week? _____.days

10 Total number of workers at peak level for the project is: _____

(a) How many field workers are on the project at this time? _____ , which is about ____% the peak. This number includes: ❑ prime only ❑ all workers

(b) What percent of the workers do **not** speak English? _____%

11 What percent of the construction work is performed by the prime contractor? _____%

12 How many subcontracts have been awarded on this project: _____

13 How would you rate the prime contractor's commitment to safety? (1-7, 7=best) _____.

14 Does the prime contractor report accident statistics to you? ❑ Yes 59 (100%) ❑ No
If yes, what kind of data? ❑ OSHA recordable IR 59 (100%) ❑ Lost-time injury 59 (100%) ❑ Near misses 52 (88.1%) ❑ Environmental issues 54 (91.5%) ❑ Others, please specify _____

15 How many incidents have been recorded on this construction project?

_____ near misses _____ OSHA recordable _____ lost workday
_____ first aid cases _____ w. comp cases

Do these incidents include subcontractor statistics? ❑ Yes ❑ No

16 Does the owner establish/negotiate <u>specific safety goals</u> for contractors performing this project? ❑ Yes 47 (79.3%) ❑ No 12 (20.7%) *If yes please specify*
❑ The OSHA RIR should be < ____ ❑ Lost workdays should be < _____ ❑ Other _____

B. Safety representative of the owner

17 Who has field or site responsibility for the project from the owner's staff? _____
Total number of owner staff members who are full-time on the project? _____

18 Title of owner's rep. having the most safety responsibilities? _____
Is this an owner's employee or a consultant? ❑ Employee 52 (88.1%) ❑ Consultant 7 (11.9%)

19 What percent of the owner's rep's responsibilities relate to safety? _____%

20 Who does this person report to? ❑ Owner company 24 (40.7%) ❑ Project Manager; 21 (35.6%) ❑ Other_____14 (23.7%)

21 Is this person a member of the project management team? ❑ Yes 54 (91.5%) ❑ No 5 (8.5%)
Does the owner's safety rep have the authority to stop unsafe work? ❑ Yes 56 (94.9%) ❑ No 3 (5.1%)

22 Is this person copied on information related to the project progress (costs, scheduling, quality, etc.)? ❑ Yes 49 (83.1%) ❑ No 10 (16.9%)

23 Does this person have any responsibilities on any **other** projects? ❑ Yes 28 (47.5%) ❑ No 31 (52.5%)

24 What are the job responsibilities and duties of owner's jobsite safety rep.?

❑ Monitoring safety management and performance of the contractor on a daily basis 53 (89.8%)	
❑ Reviewing safety performance on site and submits reports to the home office 52 (88.1%)	
❑ Coordinating safety efforts on site 48 (81.4%)	
❑ Participating in site safety training and orientation sessions 42 (71.2%)	
If applicable, to what extent are the owner's personnel involved in orientation training? ❑ participate in every session 15 (25.4%) ❑ participate in some sessions 24 (40.7%)	
❑ Participating in safety meeting and tool box meetings 46 (78%)	*Frequency*: ❑ d 12 (20.3%) ❑ w 27 (45.8%) ❑ m 6 (10.2%)
❑ Conducting site safety inspection and auditing 53 (89.8%)	*Frequency*: ❑ d 21 (35.6%) ❑ w 25 (42.4%) ❑ m 5 (8.5%)
❑ Assisting in job hazard analysis 46 (78%)	*Frequency*: ❑ d 19 (32.2%) ❑ w 16 (27.2%) ❑ m 9 (15.3%)
❑ Issuing permits 27 (45.8%)	----------
❑ Monitoring pre-task analysis program 42 (71.2%)	*Frequency*: ❑ d 12 (20.3%) ❑ w 18 (30.5%) ❑ m 6 (10.2%)

❑ Participating in safety recognition program 44 (74.6%)		----------
❑ Investigating near miss 50 (84.7%)		----------
❑ Investigating first aid accident 46 (78%)		----------
❑ Investigating recordable accident 45 (76.4%)		----------
❑ Reviewing contractors' safety reports. 52 (88.1%)	*Frequency*: ❑ d 15 (25.4%) ❑ w 27 (45.8%) ❑ m 6 (10.2%)	
❑ Enforcing safety rules 53 (89.8%)		----------
❑ Other, please specify. _____		

25 Does the owner's rep. review the safety performance of the contractor on a regular basis? ❑ Yes 58 (98.3%) ❑ No *If yes, how?*

❑ By checking the project lost workday injury rate.	56 (94.9%)
❑ By checking the project recordable injury rate.	56 (94.9%)
❑ By checking the project first-aid injury rate.	52 (88.1%)
❑ By checking the project near miss rate.	47 (79.7%)
❑ By checking the project safety inspection records.	47 (79.7%)
❑ By checking worker training records.	41 (69.5%)
❑ Other, please specify_____	

C. Selection of the contractor

26 Does the owner have a preferred list of contractors to receive contract awards? ❑ Yes 48 (81.4%) ❑ No 11 (18.6%)

(a) If yes, is safety performance a consideration? ❑ Yes 56 (94.9%) ❑ No

(b) If yes, how is safety rated in the overall review of the contractor? _____.(1 to 7, 7= most important)

(c) If yes, who performs this evaluation? ❑ contract's/purchasing 31 (52.5%) ❑ safety person 34 (57.6%) ❑_____

27 During the selection of contractors, what measures are used to evaluate the safety performances of different contractors?

❑ **Experience Modification Rating** (EMR) of the contractor, should be less than _____. 45 (76.3%)

❑ **OSHA recordable injury rate** of the contractor, should be less than _____ per 200,000 work hours. 49 (83.1%)

❑ **Loss Ratio** of the contractor, should be less than _____. 7 (11.9%)

❑ **Qualifications of the safety staff** of the contractor. 42 (71.2%)

❑ **Qualifications of the project management team** of the contractor. 38 (64.4%)

❑ **Quality of the overall corporate safety program** of the contractor. 52 (88.1%)

❑ **Copy of OSHA log** for the past year. 40 (67.8%)

❑ **OSHA inspection history** on past projects. 27 (45.8%)

❑ Other (please specify): _____.

(a) How are these criteria used? In other words, can this information make the difference between getting the contract or not? ❑ Yes 52 (88.1%) ❑ No 7 (11.9%) If yes, has it ever? ❑ Yes 50 (84.7%) ❑ No

(b) If a contractor has some bad statistics, can the contractor show that they have made major changes in the program and still be considered for contract award? ❑ Yes 56 (94.9%) ❑ No

(c) What leading metrics or indicators do you use to predict and improve safety performance or to deliver a safe construction project? _____

28 During selection of contractors, how do you ensure that safety is given at least equal weight to quality, cost and schedule? _____

D. Construction contract

29 What safety requirements are specifically included in the construction contract?

- ❑ Contractor must comply with the local, state and federal safety regulations. 59 (100%)
- ❑ Contractor must comply with safety requirements beyond the OSHA regulations. 52 (88.1%)
- ❑ Contractor must place at least one full-time safety representative on the project. 49 (83.1%)
  Number of employee per safety representatives? _____ Sub requirement? ❑ yes 28 (47.5%) ❑ no 5 (8.5%)
- ❑ Contractor must submit the résumés of key safety personnel for the owner's approval. 42 (71.2%)
- ❑ Contractor must provide specified minimum training for the workers 37 (62.7%)
  If applied, please specify _____**hours per worker per month**.
- ❑ Contractor must report all lost time injuries to the owner. 58 (98.3%)
- ❑ Contractor must report all OSHA recordable injuries to the owner. 57 (96.6%)
- ❑ Contractor must report all injuries to the owner 57 (96.6%)
- ❑ Contractor must include personnel from the owner in coordination meetings. 40 (67.8%)
- ❑ Contractor must submit subcontractor list to owner for approval 47 (79.7%)
- ❑ Contractor must implement a substance abuse program. 55 (93.2%)
- ❑ Contractor must participate in site safety audits. 52 (88.1%)
- ❑ Contractor must conduct weekly safety meetings for the workers. 55 (93.2%)
- ❑ Contractor must submit a site-specific safety plan. 50 (84.7%)
- ❑ Contractor must submit a safety policy signed by its CEO. 31 (52.5%)
- ❑ Contractor is required to provide specified PPE (hard hats, safety glasses, gloves) 57 (96.6%)
- ❑ Contractor must implement a permit system when performing hazardous activities (line breaks, lockout/tagout, excavations, proximity to power lines, confined space entry, hot work, etc.). 52 (88.1%)
- ❑ Other (please specify): _____.
  _____.

30 Are the same safety requirements imposed on subcontractors and lower-tier subcontractors? ❑ Yes 54 (91.5%) ❑ No 3 (5.1%) NA 2 (3.4%)

If yes, has any subcontractors of you been refused by the owner for safety reasons? ❑ Yes 40 (67.8%) ❑ No 11 (18.6%)

Do you know why? _____

E. Owner's involvement in safety

31 As the owner, which philosophy does the firm hold concerning safety?

- ❑ We assume as much liability for safety as possible, and we keep safety totally under our control. 7 (11.9%)
- ❑ We equitably share the liability for safety with the contractor, and we emphasize cooperation with the contractor on safety matters. 43 (72.9%)
- ❑ We try to avoid safety responsibility as much as possible, and expect the contractor to assume responsibility for project safety. 4 (6.8%)
- ❑ Other (please specify): _____5 (8.5%)_____.

32 Are safety observers used on this project?` ❑ Yes 50 (84.7%) ❑ No 9 (15.3%) *If yes, how?* _____.

33 As the owner, do you require specific items to be included in the site specific safety program prepared by the contractor? ❑ Yes 58 (98.3%) ❑ No 1 (1.7%) *If yes, what are they?*

- ❑ OSHA specific regulations 52 (88.1%)
- ❑ Specific safety training session 51 (86.4%)
- ❑ Prime contractor's employees to have 10-hr OSHA cards 13 (22.0%)
- ❑ Prime contractor's supervisor's have CPR and First-Aid cards 18 (30.5%)
- ❑ Training on the hazards related to the tasks 53 (89.8%)
- ❑ Pre-project safety planning 51 (86.4%)

❑ Task specific PPE analysis 50 (84.7%)
❑ Conduct regular safety inspections 54 (91.5%)
❑ Incident reporting and investigation 55 (93.2%)
❑ Emergency plan (medical and hazardous materials) 48 (81.4%)
❑ Substance abuse program 53 (89.8%)
❑ Regular safety meetings 56 (94.9%)
❑ Safety responsibility defined for all levels 41 (69.5%)
❑ Emergency response team maintained on the project 27 (45.8%)
❑ Daily JSA (Job Safety Analysis) are conducted on the project site 48 (81.4%)
❑ Other, please specify:_____

34 Are subcontractors specifically included in the safety program? ❑ Yes 56 (94.9%) ❑ No 2 (3.4%)

35 As the owner, do you have safety program requirements that the contractors must follow? ❑ Yes 56 (94.9%) ❑ No 2 (3.4%)

36 When a prime contractor's employee sustains an OSHA recordable injury, what must be reported to the owner? ❑ Supplementary (101) ❑_____

37 How are injury statistics maintained? ❑ by project 45 (76.3%) ❑ by contractor 33 (55.9%) ❑ blended with owner 27 (45.8%)

38 Does owner monitor near misses? ❑ Yes 55 (93.2%) ❑ No 3 (5.1%) *If yes, how are they defined?*
❑ near death incidents ❑ any incidents that can hurt ❑ any unplanned event
❑ others (specify)_____

39 How are near misses handled?
❑ Carefully recorded and investigated; 36 (61.0%) ❑ Recorded without further investigation;
❑ Nothing is done with near misses, we only deal with accidents; ❑ Other_____

40 Are some funds provided to the contractor, above and beyond the contract amount, to promote project safety? ❑ Yes 35 (59.3%) ❑ No 24 (40.7%)
If yes, explain: _____

41 Is the contractor's safety performance included in the owner's safety performance statistics? ❑ Yes 37 (62.7%) ❑ No 22 (37.3%)

42 Does the owner participate in OSHA's Voluntary Protection Program (VPP)?
❑ Yes 17 (28.8%) ❑ No 34 (57.6%)

43 Is a nurse or EMT provided on the construction site? ❑ Yes 50 (84.7%) ❑ No 9 (15.3%)
If yes, who is responsible for providing these services? ❑ Owner 25 (42.4%) ❑ Prime Contractor 20 (33.9%) BOTH 4 (6.8%)

44 The following questions are concerning safety training and orientation.

(a) As the owner, does your firm make any allocation (personnel or financial) for the safety training of the contractor's employees? ❑ Yes 44 (74.6%) ❑ No 15 (25.4%)
If yes, please explain: _____.

(b) What is involved in orientation training? ❑ videos 50 (84.7%) ❑ contractor presentations 39 (66.1%) ❑ owner presentations 45 (76.3%) ❑ consultant presentations 10 (16.9%) ❑ reading materials 37 (62.7%)

(c) Does every worker on site receive orientation training? ❑ Yes 57 (96.6%) ❑ No 1 (1.7%)

(d) Do all workers receive the same orientation training? ❑ Yes 50 (84.7%) ❑ No 8 (13.6%)

(e) What is the typical duration of orientation training for a worker? _____ hours

(f) Does the owner have a means of verifying the comprehension of the orientation training? ❑ Yes 48 (81.4%) ❑ No 11 (18.6%)

(g) Is there any special safety training for non-English-speaking employees? ❑ Yes 23 (39%) ❑ No 34 (57.6%)

If yes, please specify: ❑ orientation ❑ tool box talks ❑ pre-task planning ❑ _____

(h) How many hours of training do workers and supervisors receive monthly, not counting toolbox meetings? _____hrs for workers; _____hrs for supervisors

45 Is there a safety recognition/reward program on this project? ❑ Yes 50 (84.7%) ❑ No 9 (15.3%)

If yes, please explain how it works: (distinguish between incentives for workers and for the firm)

Workers: _____

Supervisors: _____

Contractor: _____

(a) Are worker incentives based on safe behavior or on injury occurrences? ❑ behavior 15 (25.4%) ❑ injuries 18 (30.5%) BOTH 20 (33.9%)

(b) Is the owner involved in any way in the safety recognition/reward program? ❑ Yes 46 (78%) ❑ No 7 (11.9%)

Describe? _____

46 Are safety dinners held for personnel at the construction project? ❑ Yes 44 (74.6%) ❑ No 15 (25.4%)

If yes, are family members of workers asked to attend? ❑ Yes 5 (8.5%) ❑ No 42 (71.2%)

47 Is there a newsletter or a safety newsletter? ❑ newsletter 21 (35.6%) ❑ safety newsletter 14 (23.7%) ❑ none 24 (40.7%)

(a) If yes, what percent of the newsletter is devoted to safety? _____%

(b) If yes, is the newsletter also published in Spanish? ❑ Yes 1 (1.7%) ❑ No 29 (49.2%)

48 Other than toolbox meetings, how do you ensure the communication of safety information to all levels of the project? _____

_____

How do you rate the communication and cooperation efforts between the prime contractor and the owner on this project concerning safety? (1 to 7 points, with 7 to be the best.) _____

49 How do you ensure that the safety plan is kept active with frequent review and that it is modified as needed? _____.

_____.

50 During the design of this project, were construction safety issues specifically addressed? ❑ Yes 58 (98.3%) ❑ No 1 (1.7%)

If yes, please describe: _____

Can you think of any examples of how the design was changed to address safety?

_____

APPENDIX C
CONTRACTOR SURVEY QUESTIONNAIRE

The Owner's Role In Construction Safety

The following questions are to identify the owner's role in construction safety based on your general experience. Please check the appropriate option(s) and give brief answers. The questionnaire can be finished within five minutes. Thank you for your participation.

1 How long have you been working in the construction industry? _____ years.

2 What percentage of the safety burden is generally assumed by the owner? ____%

(a) What is the lowest level of owner involvement in safety you have observed? ____%

(b) What is the highest level? ____ %; Was it successful? ❑ Yes ❑ No

How did the owner show this involvement? _____

3 In the past decade, owner's involvement in construction safety on your projects has:

❑ increased ❑ remained the same ❑ decreased

Reason of change (if any):_____

4 In the past fiscal year, what is the firm's total construction volume? $_____M

What is the firm's overall OSHA Recordable Injury Rate? ____ per 200,000 work hours.

5 In your experience, what type of project has the best safety performance?

(a) ❑ Residential ❑ Commercial ❑ Manufacturing ❑ Petrochemical ❑ Utilities
❑ Civil works ❑ No difference

Reason: (optional)_____

(b) ❑ union ❑ open shop ❑ no difference

Reason: (optional)_____

(c) ❑ lump sum ❑ cost plus ❑ no difference

Reason: (optional)_____

6 When awarding contracts, what level of importance does the owner place on the following? (use 1 for top prior, 2 for the second, and so on)

___ economic ___ safety ___ schedule ___ quality

7 In general, do you think the owner's staff provides sufficient support on safety on your projects?

❑ Yes ❑ No ❑ Depends, please explain _____

8 In what area do you think the owner can do the most to promote safety? (check one)

❑ Safety training ❑ Safety inspection ❑ Safety incentive
❑ Accident investigation ❑ Job hazard analysis ❑ Other _____

9 What is the most efficient means for the owner to address their concern for safety?

_____

10 To what extent do you expect the owner to be involved in safety management?

❑ Show their concern, but let the contractor manage safety in their methods
❑ Set their expectation, support and guide the contractor in safety management
❑ Totally take control of the safety management on the project, taking the responsibility
❑ Other, please explain _____

11 What do you think is the key to the success of safety management on the owner side?

_____

APPENDIX D
ANALYSIS OF THE CONTRACTOR SURVEY

To supplement and verify the results obtained through the analysis of the interview data, a survey was conducted among contractors. Also, the purpose of the survey was to collect opinions of contractors on how they would like owners to facilitate construction safety management, and to share these opinions with owners. The questionnaire shown in Appendix c was used to obtain the information about contractor opinions.

The Contractors Interviewed

The survey questionnaires were sent to safety managers of contractors at the corporate or project level, who were familiar with safety management on large projects. A total of 41 responses were received. Among them, 10 responses were from Canada and the other 31 were from the U.S. Table A-1 shows the years of participation in the construction industry of the respondents, total construction volume of the respondents' firms in the last year, and the TRIR information for the last year.

Table A-1. Characteristics of the respondents

		Years of participation in the industry	**The firm's total construction volume**	**The firm's overall TRIR**
Number of replies		41	36	40*
Mean response		23.63	$854,000,000	1.56
Median response		24	$160,000,000	1.22
Minimum		3	$4,000,000	0.00
Maximum		50	$9,000,000,000	6.80
Percentiles	**25**	20	$26,000,000	0.59
	50	24	$160,000,000	1.22
	75	30	$622,000,000	2.23

Note:* number of replies was 41 with 40 providing the TRIR of the firm.

It is evident that most respondents have a long history of working in the construction industry and are quite experienced. The construction firms they are working with have much better safety performances (median TRIR of 1.22) than the construction industry average (average TRIR of 7.8 in 2001, BLS, 2003). Note that these respondents had a cumulative total volume of 30.75 billion dollars. The sample size is small, when compared with the large number of construction firms in North America. The data collected shed light on the owners' involvement in project safety management, and how these contractors would like the owners to get involved.

Project Content And Safety Performance

In answering the question "In your experience, what type of project has had the best safety performance", contractors gave different answers. Summarization of the answers is shown in Figures A.1 to A.3.

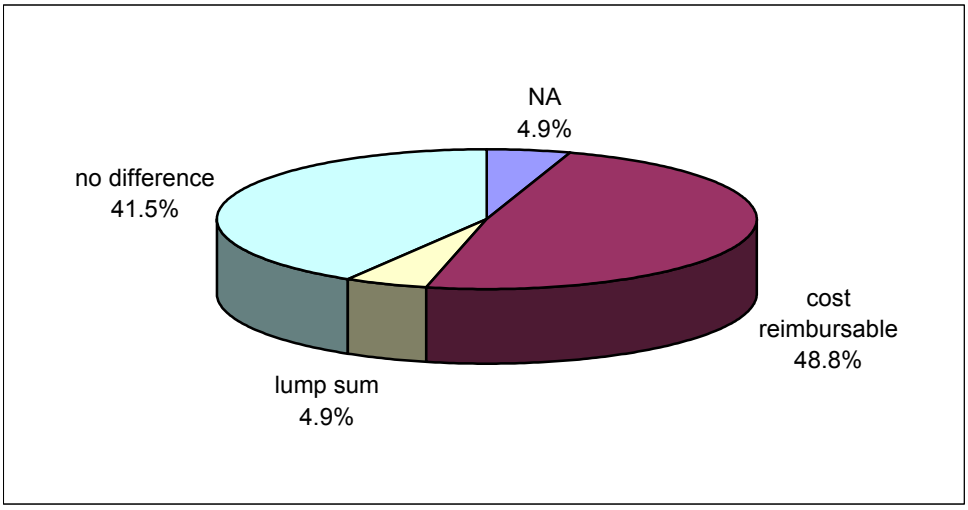


Figure A-1. What type of project has the best safety performance? (type of contract)

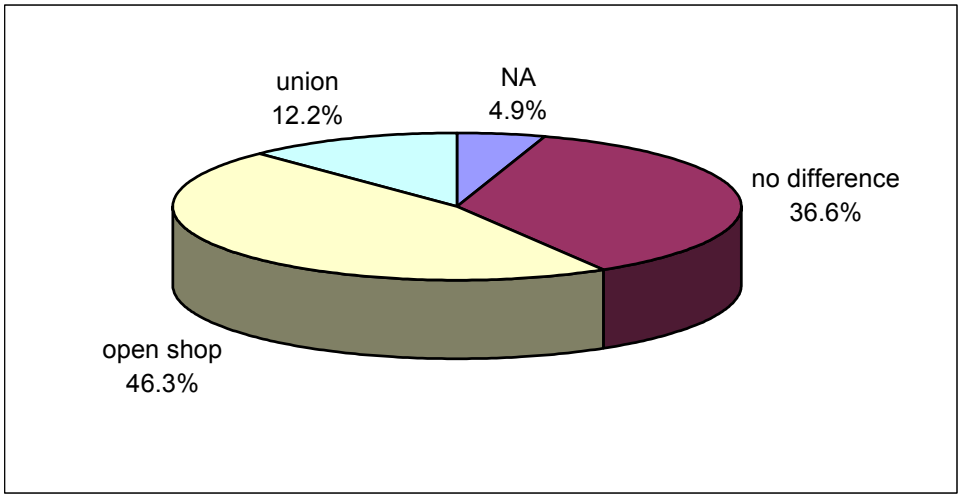


Figure A-2. What type of project has the best safety performance? (union or open shop)

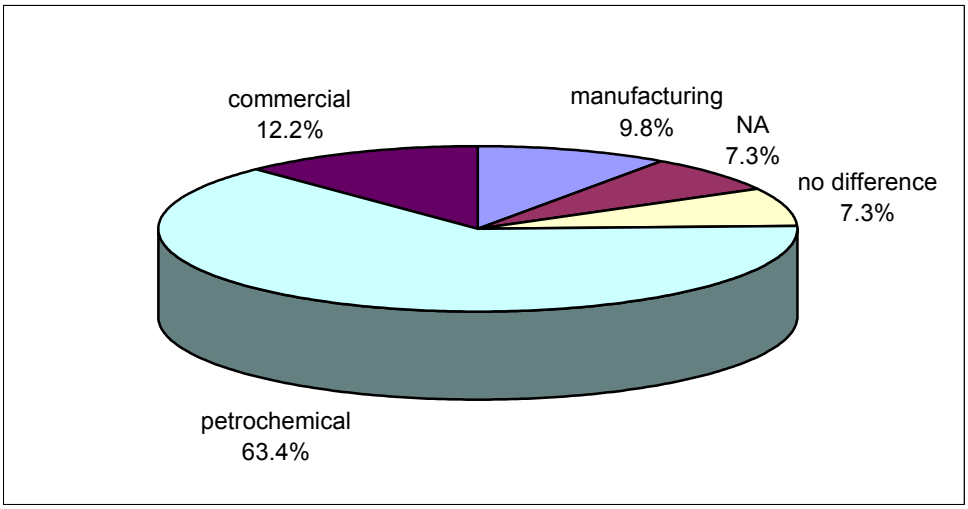


Figure A-3. What type of project has the best safety performance? (type of project)

The results are quite similar to the results obtained through the project interviews. Petrochemical projects, and open shop projects reportedly have better safety performances than other projects. Also, cost reimbursable contracts are preferred by more contractors to promote safety, although this was not supported by the interview data.

The Owner's Involvement In Project Safety Management

The survey asked questions about the involvement of owners in project safety management from various aspects. These questions were concerned with responsibilities owners assumed, level of importance owners placed on safety, and whether or not owners provided adequate support for safety on their projects.

What Percentage Of The Safety Responsibility Is Assumed By The Owner

The distribution of the contractors' answers is shown in Table A-2. It is reasonable to conclude that the general involvement of owners in project safety management is between the range of 20-30 percent. Although some owners may take 0 or 100% of the safety responsibilities on their projects, the overall involvement is generally modest.

Table A-2. What percent of safety responsibility is assumed by the owner

		Percentage of the safety responsibility generally assumed by the owner	Lowest level of owner's involvement (Percentage)	Highest level of owner's involvement (Percentage)
Mean		36.63	8.43	72.63
Median		25	0	80
Std. Deviation		32.45	15.26	26.98
Minimum		0	0	5
Maximum		100	70	100
Percentiles	**25**	10	0	50
	50	25	0	80
	75	63.75	10	90

Despite the owner’s overall modest involvement in safety, most contractors mentioned that the owner's involvement in project safety had increased in the past decade (see Figure A-4).

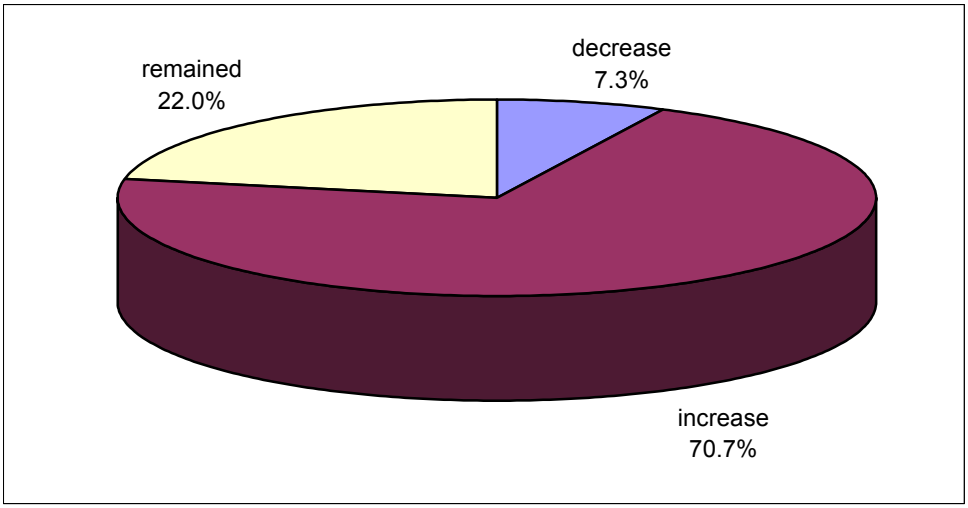


Figure A-4. Change of owner involvement in project construction safety in the past decade

Respondents gave various examples of increased involvement, including:

- Safety representatives of owner are generally assigned to each project;
- Participation in safety incentive programs;
- More limitations on bid lists based on safety performance;
- Participation in weekly safety audits;
- Detailed and constructive reviews of contractor health and safety programs;
- Require contractors to have a JSA on all project and tasks to be done, in addition to contractor pre-task checklists;
- More involvement in day-to-day activities
- Do not view contracted work as contracting away responsibility, but rather that the contractor is an extension of their internal workforce who possesses a unique skill set or has access to labor providers;
- More stringent reporting requirements, more emphasis on training and orientation;
- Higher standards are generally enforced, little or no tolerance for substandard practices;
- Assumption of responsibilities by management and supervision;

- Most plant owners at least show an interest in the statistical outcome of the project and support our programs and initiatives from a distance, a small number seek to actively participate;
- More emphasis on behavior based safety.

Level Of Importance Owners Place On Safety When Awarding Contracts

A question asked the levels of importance owners placed of different factors when awarding contracts (with 1 being the most important and 4 being the least important). In comparison with cost, schedule and quality, safety is not the most important consideration for many owners. The Friedman two-way non-parametric ANOVA shows there were significant differences between the ranks of importance owners placed on each of the four factors (refer to Table A-3). Cost is the most important concern for most owners, with schedule and safety being statistically tied for second, followed by quality.

Table A-3. Level of importance of the factors when owners award contracts

FACTOR	Mean	Std. Error	Median	Mean Rank	Sign. (two-tail)
Cost	1.27	0.55	1	1.442	<0.01
Safety	2.73	1.1	3	3.078	
Schedule	2.51	0.75	2	2.748	
Quality	3.39	0.8	4	3.644	

Does The Owner Provide Sufficient Support For Project Safety

Most contractors think that owners do provide sufficient support for safety on their projects (see Figure A-5). For those who mentioned "depends", the following explanations were offered:

- Depends on how concerned they are about human welfare.
- Depends on industry: petrochemical is best, civil and utilities are worst.
- Most contractors are able to provide the proper level of safety support for their employees if adequate funds are available to support it.
- The only complaint with reimbursable contracts is that contractors tend to abuse or overstate their need for safety expenditures.

- Depends, more interested in a good record than how it was achieved, hiding of injuries acceptable in some cases, or spending large sums to keep workers on modified work (working wounded) to maintain LTI free status.

- It varies from owner to owner. Money is key with some and safety is key with others.

- There is a wide range in the level of support coming from the owners. Many owners view safety performance solely through statistics. You cannot improve safety by managing statistics better.

- Each owner has a different approach, some support well and others not enough.

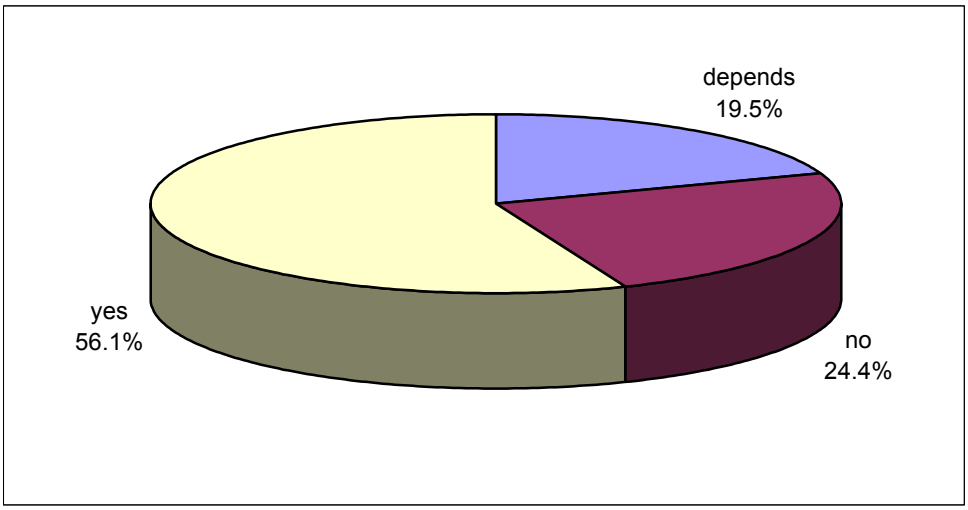


Figure A-5. Does the owner provide sufficient support for safety on the projects

How Can Owners Facilitate Contractors In Project Safety Management

In the questionnaire, questions were also asked how owners generally help contractors with safety management and how contractors would like owners to facilitate their safety efforts.

In What Area Can The Owner Do The Most To Promote Safety

The question listed six options, including safety training, safety inspections, safety incentives, accident investigations, job hazard analysis, and "others". The responses of contractors varied considerably, and many provided expanded answers or several answers to this question. Among the listed options, 13 responses mentioned safety training, 6

responses mentioned safety incentives, 5 responses mentioned safety inspections, 5 responses mentioned job hazard analysis, and none mentioned accident investigations.

Other than the five specific options, respondents also mentioned:

- Behavior based safety incentives.
- Show leadership in safety.
- Reduce double standard, same rules for contractor employees and owner employees.
- Contractor review, comparison.
- Overall support, being visible and participating.
- Contract terms and conditions combined with full compliance.
- Complete engineering and develop a schedule that is reasonable and able to be accomplished safely.
- Leadership: setting the stage for success and holding contractors accountable for compliance to the established management processes and taking action on noncompliance.
- Continuing the evolution of OHS&E in a management system, integrated into every aspect of business.

What Is The Best Way That Owners Can Address Their Concern For Safety

This was an open-ended question. The answers provided by contractors varied.

These answers can be grouped into different categories:

(1) Intensive involvement:

- 100% proactive participation in a project safety program, one that is not owned by the owner or contractor but by the project
- Be involved in the process by performing audits and assisting in training programs
- Support and be involved in the process
- By showing their willingness to stop a project in order to make it safe for construction employees

- Continuous involvement: can assist the contractor with regular assessments and audits

- VISIBLY lead by example - get involved at a personal level

- They need to help promote and drive the overall site safety program

(2) Partnering with contractor:

- Discussing with the contractor on the project and addressing concerns in a team approach

- Work with the contractor to identify and resolve potential hazards, forget cost and schedule issues

- By supporting the efforts of the contractors and requiring the same actions of their employees, one program for all

- Make safety a priority and work with the contractor to perform to a high standard

- Demonstrate their commitment to the project team and the workers regularly by being part of the team. The owner's representative should be visible. Owners could support the constructor by understanding the effort being made to be injury free and not get focused on statistics only

- Show leadership and integrate their team with the contractor team

(3) Carefully selecting contractors and set high safety expectations in contracts

- Bid list open only to companies with good safety levels

- Set expectations in the contract and hold contractors accountable

- Draft contracts that focus on safety activities and actions, NOT numbers. Measure positive performance and compliance, allow time and monies for training and manage proactively

- Work with the contractor to address concerns and be willing to award work on parameters other than just price

- Select the correct GC or CM and have a great contractor selection process for every contractor who performs work

(4) Other safety practices

- Walk the talk. No double standards.

- Have regular safety meetings, with all primes and subs involved
- Support the cost of training and safety professionals with resources
- Training seminars - focus on job hazard analysis
- Do not start field construction until the engineering is 80% complete and do not allow contractors to start work until the complete construction package, including material, is available; also complete each phase of the project before starting the next phase,
- Continue to place a priority on safety, insist on trained persons from contractors, do not place schedule above safety, always try and take a practical approach, do not have double standards, i.e., owner forces, direct hire forces, nonunion forces and other forces should not be treated differently
- Safety meetings (communications)
- Hold their employees to the same level as contractors

Many contractors pointed out the importance of treating the employees of owners and contractors equally on safety issues. Once safety regulations are developed, they should be implemented firmly and consistently. This is a very important point which was not included in the interview questionnaires for owners. However, some results in the interview data analysis also support this argument. For example, owners who include the project injury statistics in their own injury statistics reported significantly better safety performances.

To What Extent Do You Prefer Owners To Be Involved In Project Safety

Twenty-five respondents prefer owners "setting their expectations, support and guide the contractor in safety management". Seven respondents would like the owners to "show their concern, but let the contractor manage safety". Only two respondents prefer owners to totally take control of safety on the projects. Other responses include the following:

- 100% participation in a jointly owned project safety program
- Attract experienced safe workers to projects if necessary
- Set expectations, let the contractor manage safety and hold the contractor accountable
- Set their expectations, demonstrate leadership through regular participation at the project management level but let the contractor manage safety

The research results support the importance of owners setting expectations before project commencement. This is also preferred by the contractors: setting high safety expectations at project start, followed by support and guidance in safety management throughout project execution.

Summary

From the analysis of the survey to contractors, it is evident that owner involvement in construction safety is increasing in recent years. Many findings obtained from the project interviews are supported by the contractors. Also, contractors expressed their opinions on how they would like owners to be involved in safety management, that is, carefully selecting safe contractors to execute their projects, setting safety objectives, facilitating contractors in safety during construction, and never setting double safety standards on the project. The suggestions offered by contractors can be helpful for owners in the future.

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BIOGRAPHICAL SKETCH

Xinyu Huang was born on October 21, 1975, in Kunming, China. In September 1993, Xinyu was admitted to the Department of Civil Engineering at Tsinghua University in China, where he achieved both his bachelor's (in 1998) and master's (in 2001) degrees majoring in construction management. In the fall of 2001, Xinyu was admitted to the University of Florida to pursue his Ph.D. under the guidance of Professor Jimmie Hinze. He was admitted to doctoral candidacy in September, 2002, and has since been working on his dissertation as well as other avenues of research.

Xinyu's research interests include construction safety and project management. He has published several safety-related articles and conference papers. He has co-authored a textbook in China with his supervisors for master's study and Ph.D. study.

Xinyu Huang married Jie Bai in 2002.