DEVELOPING A SCORECARD TO EVALUATE THE USE OF PERSONAL FALL ARREST SYSTEMS

By

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To my father,
John Albert Harris,
an individual of visionary interests and magnanimous spirit

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DEVELOPING A SCORECARD
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THE USE OF PERSONAL FALL ARREST SYSTEMS

By

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Chair: Jimmie Hinze
Major Department: Design, Construction and Planning

The structural erection of buildings and other structures is associated with a high frequency of serious fall injuries and fatalities. Routine maintenance activities such as roofing replacement are also associated with high rates of occupational fall injuries. Falls from elevation is the leading category of serious injury and fatalities in the construction industry. Annually, more than 1000 construction worker fatalities (15% attributable to falls from elevation) occur in the United States. The Occupational Safety and Health Administration (OSHA) Construction Standard, Subpart M, Fall Protection, contains requirements for employers to follow to insure the health and safety of their employees that are exposed to fall injury hazards. Any employee working at a height of six feet or more above the walking surface is required to have fall protection. The requirements for fall protection may be satisfied by passive systems, such as 40 inch-height guardrails, or by the use of active systems. The typical equipment of an active system consists of a safety harness and lifeline assembly known as a personal fall arrest system (PFAS). By receiving the proper training and equipment, workers exposed to fall hazards may use PFASs to significantly reduce their risk of fall injury. A complete PFAS is typically defined as a full body harness (similar to a parachute harness), a lanyard to connect the harness and anchorage, and an anchorage (a heavy-duty steel alloy ring solidly connected to the structure). This study

investigated the implementation of fall protection practices and policies, specifically PFASs as used in large construction companies. A scorecard was developed to assist employers in effectively evaluating the safety performance of fall protection and PFASs at either the individual project or companywide level.

CHAPTER ONE
INTRODUCTION

Construction management is the management sub-discipline that has evolved parallel to other management disciplines in the industrial era to address the specialized processes and issues that exist when the planning and construction of a civil structure (buildings, roads, bridges, and industrial plants) commences on a specific site. These construction-related processes for civil structures have distinctive features regarding:

- Worker safety
- Risk management
- Ownership
- Financing
- Design
- Contracts
- Procurement
- Time management.

Of all these features, worker safety is paramount to creating a safe and rewarding basis or foundation from which construction enterprises and their employees can prosper. Construction projects are inherently hazardous environments. Of all the fatalities sustained in the construction industry, over a third of all fatalities are related to falls. Therefore, if a safety management system is to be implemented, fall injuries and fall protection must be included in that management process.

This study investigated the safety management aspect of personal fall arrest systems (PFASs), an engineered system (that is, a type of personal protective equipment) for the fall protection of construction workers. Complex safety management issues arise in the course of implementing, training for and controlling PFASs on a construction project. Drucker (2001) stated that the immutable task of management is to make people capable of *joint performance through common goals*. This task of managing people and their performance as a group or unit is fundamental to safety management problems and issues. Construction workers and managers must be properly trained to use personal protective equipment. Construction tasks performed by these workers and their managers should optimally take place within the context of a management philosophy or safety culture (Hinze 2006). And lastly, a well-conceived fall protection program on a safe project site requires careful consideration of supportive engineering measures (that is, engineered hardware and features that support fall protection practices and the PFASs).

A complete personal fall arrest system (PFAS) is typically defined as a full body harness (similar to a parachute harness), a lanyard to connect the harness and anchorage, and an anchorage (Ellis 2001). When a worker is tied-off to a single anchorage point, mobility is limited by the length of the lanyard. Standard lanyard lengths vary between six and twelve feet. Formal definitions for the components in a PFAS are defined in the Occupational Safety and Health Administration (OSHA) Construction Standards, Subpart M and the Safety Requirements for Personal Fall Arrest Systems as published by ANSI, the American National Standards Institute (ASSE 1992).

Fall arrest equipment was historically derived from rigging equipment and other sources. Full-body harness designs were borrowed from parachuting and adapted to fall arrest usage. A comprehensive catalogue of the different types of equipment manufactured in the United States would contain hundreds of individual pieces of hardware and fall arrest system components. Documentation of the full range and variety of equipment types is not in the scope of this research; however, the internet provides easy access to the most common types of equipment in use in the construction industry. This researcher frequently used a web search using the term *fall protection equipment* to gain access to the equipment sold by the major PFAS equipment manufacturers in the United States (Appendix A). A discussion of essential equipment features follows; all OSHA Subpart M defined terms have been italicized.

Most systems in use in the construction industry include a component feature within the lanyard (or connecting components) for shock absorption. The purpose of the shock absorber (or *deceleration device*) is the partial absorption of the fall forces (of a falling worker) generated by the acceleration of gravity. In the event of a fall arrest, the magnitude of the forces transferred to the body by the harness have the potential to cause injury. The research and development of the shock absorber was an important innovation in fall arrest systems.

PFAS user mobility while tied off to secure anchorage is greatly increased by the use of one or more of the following:

- **Horizontal lifelines** (HLL): Commonly used in floor decking operations, HLLs are considered connecting components in the same component category as lanyards.
- **Vertical lifelines** (VLL): Commonly used in steep roof operations, VLLs are also used in work involving vertical shafts, such as elevator shafts. VLLs are also in the same category as lanyards. In fact, lanyards and VLLs are usually used together, connected together by a *rope grab*, and ultimately tied to an anchorage.
- **Self-retracting lanyards** (SRL): A special type of lanyard that automatically retracts and extends by means of a spring. The spring action of the SRL is regulated by a safety mechanism that locks when a fall arrest condition occurs, thereby limiting the fall distance. A typical SRL allows up to twenty feet of movement about an anchorage.

Subpart M defines the *anchorage* as a secure point of attachment for *lifelines, lanyards or deceleration devices.* Strictly speaking, the anchorage is a combination of the anchor (the structural building component or material that is directly resisting the fall arrest loading condition), and the anchor connector (the engineered materials that connect to the anchor and provides an attachment point). The attachment point is typically a heavy-duty, cast metal *dee-ring* rated to withstand a 5000 pound fall arrest load (Figure 1-1).

The dee-ring has likewise been specified to perform the secure attachment point function for the body harness. The ANSI Z359 standard specifies that the primary secure attachment point for the body harness be located between the shoulder blades in the upper region of the user's back.

Dee-rings and *snaphooks* are members of the overall family of connecting hardware, known as *connectors*. Because dee-rings and *snaphooks* are the connecting hardware in PFASs, they are critical to the safe usage of fall arrest systems. Connectors are subject to frequent engineering improvements. Snaphooks have automatically closing and locking gates that permit the connector to receive an object and then remain closed until unlocked by the user. Snaphooks are typically specified for both ends of the lanyard (for attachment to the dee-ring located on the

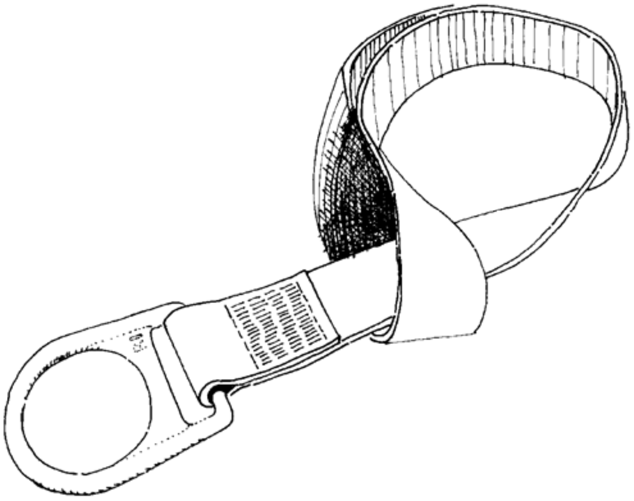

Figure 1-1. Anchorage connector strap; materials: drop-forged steel alloy dee-ring and polyester webbing with 5000 pound minimum breaking strength.

anchorage and the dee-ring on the back of the full-body harness). Unintentional opening of the gates on *snaphooks* has been associated with fall fatalities in OSHA accident investigations. Near-misses and injuries that occur when snaphooks malfunction are commonly referred to as roll-out. Roll-out problems have been greatly reduced by the adoption of new OSHA rules that require the use of only *locking type snaphooks* in PFASs. Connector hardware is an evolving engineering science. Roll-out is an example of why proactive safety programs must be updated to include developments in PFAS hardware materials and engineering issues.

Significance of Fall Injuries

Compared with other industries, construction contributes a disproportionate number of fatalities and disabling injuries to the national statistical rates as compiled by OSHA, the National Safety Council, and the Centers for Disease Control and Prevention. Utilizing occupational fall data found in the National Institute for Occupational Safety and Health (NIOSH) National Traumatic Occupational Fatalities database, Suruda, Fosbroke and Braddee (1995) showed that construction accounted for 80% (232/288) of the fall fatalities occurring at work over a three year period (1984 to 1986).

Compared with other injuries within the construction industry, *falls from elevation* constitute one of the most damaging and costly injury categories. A recent report on the construction industry by a leading provider of workers' compensation insurance stated that *falls from elevation* were the construction industry's second highest cause of financial loss due to worker injury. This statement of financial loss translates into substantial human suffering and medical treatment for traumatic injuries sustained by workers in the construction field on a regular basis (Liberty Mutual Insurance Co. 2006).

Worker deaths due to falls from elevation have been shown to be increasing in proportion to all deaths. Fall fatalities increased between two published falls studies even as OSHA was focusing attention on and making revisions in the fall protection regulations. In a 1990 report, looking at construction-industry fatalities recorded by OSHA, falls (from the same level and from elevation, 1985-89) constituted 33 percent of the total number of fatalities (U.S. Dept. of Labor 1990). In a subsequent study (Huang and Hinze 2003), also examining construction-industry fatalities recorded by OSHA (1990-2001), falls constituted over 36 percent of the total number of fatalities (Figure 1-2), an increase of nearly ten percent.

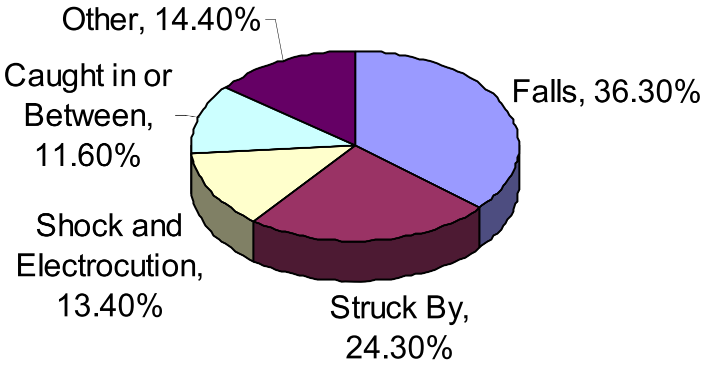

Figure 1-2. Causes of fatalities in construction investigated by OSHA, 1990 to 2001. Adapted from Huang and Hinze (2003).

During this same period (1990s), major modifications were made to the OSHA Construction Regulations:

- Effective Sept. 2, 1997, competent persons were required to determine the feasibility and safety of providing fall protection for employees erecting or dismantling supported scaffolds (Subpart L).
- Effective Jan. 1, 1998, body belts were no longer allowed as components of a PFAS.
- Effective Jan. 1, 1998, only *locking type snaphooks* were allowed in PFASs (Subpart M).

NIOSH and OSHA have also used safety bulletins to alert employers about accident reports associated with dangerous anchorage and inadequate fall protection practices (NIOSH 2004; U.S. Dept. of Labor 2004b).

Another study that investigated falls from elevation also reported similar results. That study investigated fatalities associated with the use of personnel lifts. Of the 339 fatalities examined in that study (1992-1999), thirty-six percent were associated with falls from elevation (McCann 2003). Personnel lifts are frequently used in the construction industry to give workers access to work sites that are 8 feet or more above the walking or working surface. Personnel lifts are regulated under the OSHA Construction Standards, Subpart L, as either *aerial lifts* or *mobile scaffolds.* In the case of aerial lifts, PFASs are required for operators standing in the work platform when the platform is elevated. In the case of mobile scaffolds, PFASs are recommended but not required by Subpart L for operators when working at elevation.

Overall, researchers believe that a substantial percentage of the falls from elevation that cause serious injury and fatalities in construction are associated with PFASs. Discussion of the frequency and strength of the association of fall injuries and PFASs occurs in Chapter Two (refer to Figure 2-1).

Fall Protection and Control Methods in the OSHA Regulations

The OSHA Construction Standards, Subpart M, contains definitions for PFASs and components as noted above. Fall protection regulations are also described for scaffolds (Subpart L) and steel erection (Subpart R). PFASs have customarily been considered a part of a series of fall protection and fall control methods that progresses from passive means to active, more complex means. This progressive methodology is referred to as the *hierarchy of fall hazard control methods*. The most common methods as described in subpart M are:

- Warning lines and controlled access zones

- Guardrail systems
- Hole coverings
- Safety net systems
- Personal fall arrest systems.

These methods are generally intended to be implemented in a progressive manner moving towards increasing levels of training and specialized user knowledge for the control method to function effectively (Ellis 2001). The range of control methods in this progression starts with what is considered a *passive* system (a warning line) with no required training or specialized knowledge, and progresses to the use of personal protective systems, such as PFASs, which require training and specialized user knowledge.

Although considered to be a fall hazard control measure of last resort in the hierarchy, personal fall arrest systems (PFASs) are frequently used in the construction industry, especially during the structural erection and exterior envelope installation phases of projects.

Research Objective

Because of the significance of fall fatalities and the frequency with which PFASs are used in construction, promoting effective and high-quality management of PFAS usage within an overall fall protection program is a critical component to overall safety performance success. The goal of this research was to develop an industry-specific fall protection evaluation system or scorecard to assist the construction industry in self-assessing and measuring the effectiveness of fall protection and fall arrest systems.

CHAPTER TWO
LITERATURE REVIEW

Total fall distance (TFD) is an important concept for understanding fall arrest mechanics. Comprehension of TFD and the resultant forces on the human body is considered a standard for PFAS user competency (p. 68, ASSE 1992). The component parts of a personal fall arrest system include the harness, lanyard and anchorage as described earlier. PFASs are designed to withstand the considerable forces generated by a human body in free fall. The velocity of a falling object is given in the following basic mechanics equation:

$$v^2 = v_0^2 + 2a\Delta s$$

where

- v = velocity
- v_0 = initial velocity
- a = acceleration
- Δs = displacement or change in position

Based on a free fall height of 28 feet above a lower floor and converting the result to miles per hour, the equation would result in the following value:

- v_0 = initial velocity = 0 ft/sec
- $a = 32$ ft/sec^2
- $\Delta s = 28$ feet

$$v = [\ 2\ (32)\ (28)\ ]^{1/2} = [\ 1792\ ]^{1/2} = 42.3 \text{ ft/sec}$$

$$42.3 \text{ ft/sec } (3600 \text{ sec./hr.})\ (1 \text{ mile}/5280 \text{ ft}) = 28.86 \text{ mph}$$

The calculation shows that from a height equal to a typical third floor level in commercial construction, a velocity of over 25 mph would be reached by a mass (or human body) in free fall at the point of impact at the floor level.

PFAS components are subject to elongation and stretching when exposed to the forces in a fall arrest. Durable nylon and polyester webbing have been used as typical materials in harnesses and lanyards; these materials have elastic properties. High-strength polyester rope (crosssectional diameter = 0.625 in.) is a typical specification for vertical lifelines. A rule of thumb used to estimate the elongation (in the event of a fall) is critical to safe system performance. Workers can be injured in construction by striking a lower floor level or other obstacle if elongation and total fall distance is not considered. The following formula of typical variables (all variables represent distances in vertical travel) found in a complete PFAS was adopted from one of the major equipment manufacturers (MSA 2006):

Total fall distance (TFD) = FFD + DD + HEFF + VEL + SF

WHERE

Free fall distance (FFD) is the vertical travel from the fall start to the point where the PFAS begins to arrest the fall force.

Deceleration distance (DD) is the vertical travel between activation of any shock-absorbing devices included in the PFAS and the final stopping point of the fall. Shock-absorbing and stretching of the lanyard is typically limited to 3 ½ feet by most manufacturers and is considered part of the deceleration distance.

Harness elongation effect (HEFF) is the travel attributed to stretch in the harness assembly.

Vertical elongation (VEL) is the travel attributed to stretch in any vertical or horizontal lifelines.

Safety factor (SF) is an additional factor of safety to account for any unforeseen variables. Safety factor distance should be determined by a competent person or an engineer knowledgeable about fall arrest systems.

Hierarchy of Fall Hazard Control Methods

At a conceptual level, the hierarchy of fall hazard control methods typically includes the complete elimination of fall hazards by means of design and engineering. Weisgerber and Wright (1999) presented a conceptual version of the hierarchy of control methods as follows:

- **Elimination**: Elimination of the hazard is understood to not be applicable in all cases in construction, for example, maintenance work on an existing structure. The intention of fall hazard elimination as a method is probably the most challenging to conventional engineering and construction practices. Elimination obligates all participants in the construction *and design* process to creatively rethink design specifications and construction assembly operations in search of hazard elimination opportunities.

- **Engineering controls**: Engineering controls include all safety systems on the construction site that do not require specialized knowledge inputs from the users, for example, guardrail systems.
- **Warnings**: Safety signage and warning line systems
- **Administrative controls**: this method includes all fall controls that have a companywide policy aspect, for example, specialized fall protection training for all superintendents.
- **Personal protective equipment**: this method includes positioning device systems, and PFASs.

Fall Injuries Relating to PFASs

The Fatality Assessment Control Evaluation (FACE) summary reports for falls from elevation in the construction sector (NIOSH 2000) were analyzed as a means of identifying factors contributing to falls. These summary reports provide investigative details collected at the incident sites of 91 fatalities (Figure 2-1). Of the injuries reported, fifty-nine percent of the cases required PFAS use. The other 41% of the cases concerned fall protection issues such as ladders, guardrails, holes and skylights. Of the cases where PFASs were required (labeled in Figure 2-1 as *Failures in Policy*), 43% did not have the correct equipment on-site for worker use. A safety policy that required trained workers with appropriate PFAS equipment to be present and donned before work started could have prevented accidents in these cases.

Equally tragic as the cases associated with policy failures were the cases where workers were wearing harnesses and lanyards, but failed to comply with safe PFAS practice and OSHA compliance regulations, e.g., lanyards not tied off to anchorage. These cases (labeled in the figure as *Failures in Compliance*) represent an almost equal number of injuries as the *Failures in Policy*. OSHA compliance failure represents a complex mix of unsafe behavior, weak enforcement, and poor safety culture.

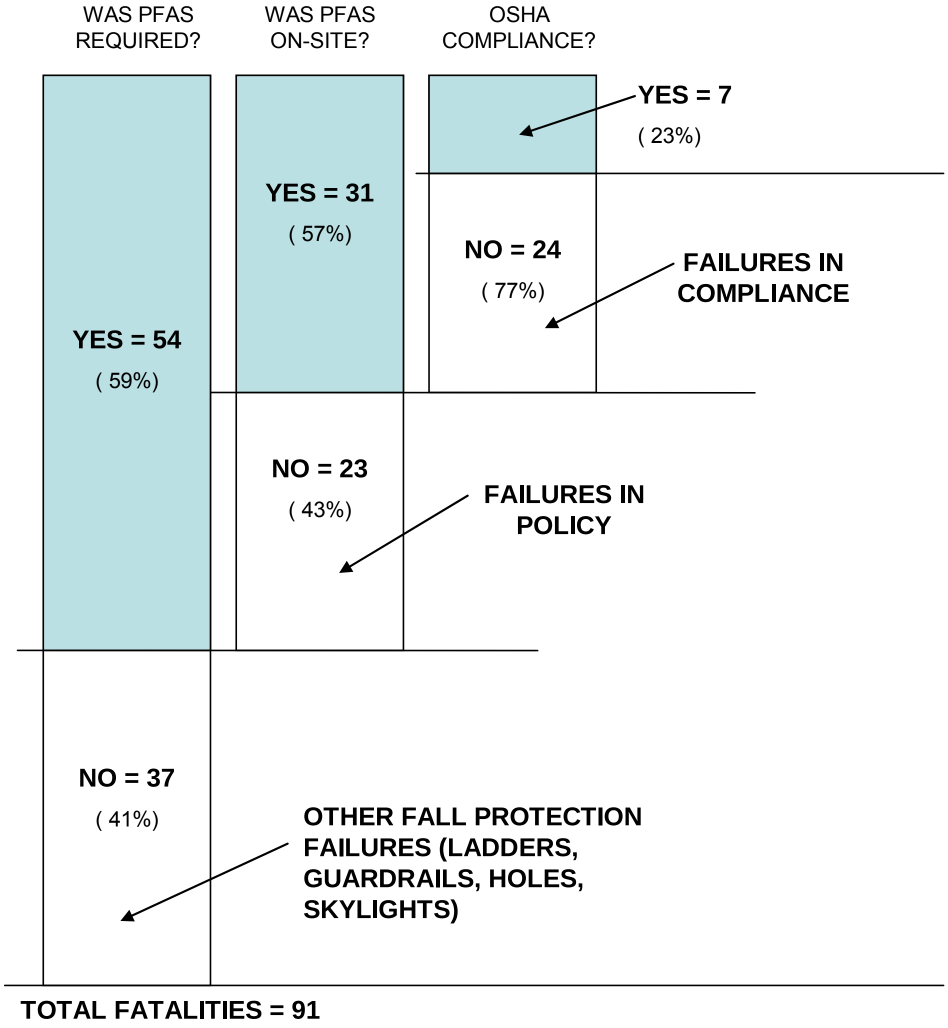

Figure 2-1. NIOSH fall injury (FACE) data.

The improper use of fall arrest systems has been noted in various types of construction accidents. A recent *NIOSH Alert* publication identified critical safety practices for workers and employers working in and around skylights and roof openings (NIOSH 2004). It was noted that four of the highlighted practice recommendations discussed the use and management of PFASs.

The article indicated that PFASs are an important component in protecting workers from fall hazards associated with skylights and roof openings.

As is well known in the industry, construction is a dynamic process. When a construction project is completed, control of the work site passes from the contractor to the facility owner, including responsibility for fall protection. Unfortunately, owners often take over the control of and liability for buildings that have no fall protection provision for the performance of maintenance operations. Safety nets and guardrail systems are rarely appropriate fall protection options for steep roofs. In the FACE report, 16 fatalities were investigated that occurred in association with a sloped roof that required rooftop anchor connectors (Fig. 2-2) to be installed for fall protection. In these reports, only one of the16 projects investigated had a rooftop anchor correctly installed.

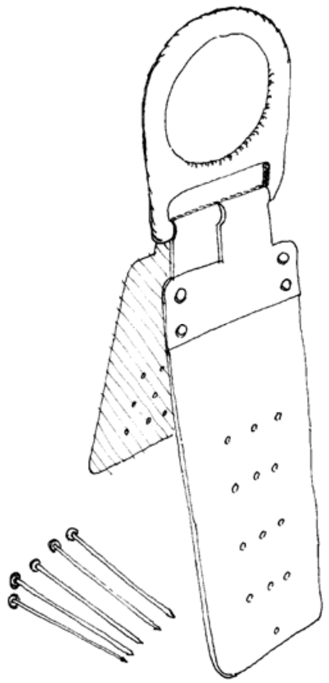

Figure 2-2. Rooftop anchor connector.

Rooftop anchors for PFASs facilitate working safely at elevation. Rooftop anchorage can be specified or installed at the following phases:

- design phase by an engineer or architect
- construction phase by a contractor
- maintenance phase (for example, roof replacement and repair) by a facility owner or contractor.

The importance of rooftop anchors to the safe use of PFASs and the ability of the facility owner and designer to influence their deployment indicate why design for safety is a critical area where significant reductions can be made in falls from elevation.

Many construction firms have been successful in preventing falls that might have resulted in fatalities and/or disabling injuries. PFASs have a complexity that requires careful site-specific PFAS planning and hardware selection, to the extent that even good fall protection programs have still resulted in fatalities. Of the 91 fatalities in the FACE report, three fatalities (less than five percent of the total) occurred where very good fall prevention practices were observed (anchorages, lanyards and body harnesses in use), but the fall protection program experienced a *systemic* type of failure (refer Appendix C for abstracts of selected FACE reports). One of these fatalities occurred where a lack of equipment inspection was indicated (damaged lanyard was not detected, FACE report no. 89-21). In another fatality case, insufficient worker training in safe fall arrest equipment usage was determined (victim disconnected the lanyard from the anchorage for an unknown reason, FACE report no. 96-21). In the third incident, the accident was not witnessed and the cause was not indicated (FACE report no. 97-10).

Four other fatalities occurred in cases where OSHA compliance was observed, but where lives may have been saved by stricter adherence to a 100% tie-off practice and the use of twin-leg lanyards (FACE reports nos. 89-03, 89-24, 90-12 & 92-05). Twin-leg lanyards support continuous tie-off by allowing the worker to use the secondary leg of the lanyard to connect across a gap in the system before disconnecting the primary leg (Fig. 2-3). These seven fatalities represent almost eight percent of the total (7 of 91 cases), indicating that even in the better fall protection programs involving PFAS, careful management of hardware usage and equipment inspection can save lives.

Figure 2-3. Twin-leg lanyard.

In a recent Construction Industry Institute study of large construction firms (firms having annual revenues in excess of $100 million), 100% tie-off for workers working at elevations six feet and above was required by several of the survey respondents as a positive fall protection policy, but no known studies have investigated the extent or usage of the 100% tie-off policy in the construction industry (Hinze 2002b).

Although no injury data were located, injuries associated with PFAS may occur after a successful fall arrest has taken place due to the physical stress imposed on a fall victim by their own body harness and the effects of being suspended mid-air for 15 minutes or longer. This physical stress imposed on the fall victim by the body harness is known as suspension trauma, and produces a physiological reaction known as orthostatic intolerance. Rapid rescue response times are critical to controlling the dangers of suspension trauma that may result from being suspended after a fall (Weems and Bishop, 2003). Documentation and training to insure safe rescue techniques and first aid for victims suffering from suspension trauma are critical elements in PFAS training programs.

Best Practices in Safety

In companies that have established zero injury incidents as a primary goal, new opportunities for refinement have been suggested to reside in theories and studies of continuous improvement. Construction safety frequently considers problems arising at the intersection of safe behavior and personal protective equipment. The human factors aspect of managing construction safety programs has qualitative characteristics in common with industrial firms engaged in all types of general industry and manufacturing; the qualitative constant is of course the human resource. Continuous improvement and total quality management (TQM) literature is closely related to construction safety theories and has useful precedents and methods for best practices.

Balancing Quantitative and Qualitative Measurement

Creating a balanced safety management approach composed of quantitative and qualitative methods and measurements is an important guidepost for continuous improvement-oriented safety programs. Accountability and quantitative measures must be balanced with behavior-based, qualitative considerations (Petersen 1997 and 1998).

In a strictly quantitative sense, injury incidence rates (a lagging indicator) cannot be used to assess safety performance related to a specific injury category without a revision in data collection. The most widespread and reliable injury incidence rate used in the construction industry has been the employer's total recordable injury rate (TRIR). TRIR is defined as the number of recordable injuries per 200,000 worker hours (the number of hours worked annually by 100 workers). Continuing the example, the TRIR does not report the rate of fall protection safety performance; TRIR reports the rate of overall safety performance across all hazards. However, by making a qualitative inference, national fall injury statistics can be used to ascertain an approximation of fall protection safety performance. A review of insurance injury data shows that fall injuries contribute approximately 15% to the total national construction industry injury frequency counts. It could be inferred that 15% of an individual firm's total recordable injury rate is equivalent to the fall injury-specific TRIR.

Experience Modification Rates (EMR), often used in the industry to assess contractor safety performance and qualification, have been cited for certain limitations. Hinze (1995) points out that the EMR is computed with input variables not affected by safety performance. To counteract this limitation, some safety managers have suggested that only direct observation of subcontractor safety behavior and conversations with jobsite superintendents and foremen can give a more accurate indication of expected safety performance.

A companywide commitment to achieving a zero-injury-incidence rate is felt to be an absolute requirement of a high-quality safety program (p.39, Hinze 2006). Hinze explains that planning and goal setting for anything other than a zero incidence rate is a form of tacit acceptance of unsafe behavior as an innate or predestined human trait. A quantitative proof of the necessity of the companywide zero injury philosophy, as a *precursor and first priority* to a high quality safety program, is not possible. The validity of setting the companywide zero injury philosophy as the penultimate feature of safety improvement must be understood on a qualitative level. This line of thinking reflects the progressive safety theory that explains why proactive construction safety innovators prefer the use of leading indicators.

A Balanced Measurement System

An article that discussed measurement systems in safety reasoned that a balance between quantitative and qualitative factors was important to effective safety management (Mohamed 2003). A checklist of management issues was presented that showed a balance of quantitative and qualitative factors. A management study that examined 12 case study companies for industry-leading performance measurement practices was cited as the source of the balanced factors approach to measurement (Kaplan and Norton 1992). Kaplan and Norton stated:

> What you measure is what you get. Senior executives understand that their organization's measurement system strongly affects the behavior of managers and employees. Executives also understand that traditional financial accounting measures like return-on-investment and earnings-per-share can give misleading signals for continuous improvement and innovation – activities today's competitive environment demands. The traditional financial performance measures worked well for the industrial era, but they are out of step with the skills and competencies companies are trying to master today.

Kaplan and Norton made it clear that managers should not have to choose one type of measurement to the exclusion of others. In safety, recordable injuries are going to be used to measure an aggregate safety performance. In considering how to construct an industry-leading measurement approach, Kaplan and Norton's *balanced scorecard* approach suggests that analogous to an airplane cockpit, safety managers need detailed information from more than one dial to effectively track safety's progress toward zero injuries.

Kaplan and Norton's *balanced scorecard* creates four important perspectives from which to consider four basic questions:

- How do customers see us? (customer perspective)

- What must we excel at? (internal business perspective)
- Can we continue to improve and create value? (innovation and learning perspective)
- How do we look to shareholders? (financial perspective).

In the context of construction, consumers of construction services, such as commercial building owners, are the customers. For example, these customers (the building owners) demand high quality safety services when they use safety performance as a bidding qualification. Safety customers are identified by Mohamed (2003) as also being individuals inside the company. For example, how do the employees perceive the benefits of the firm's safety programs?

The *internal business* and *innovation and learning* perspective in the balanced scorecard focus on operational improvements and inevitably employee training and learning, the same core values that are found in safety management theory. One case study firm in Kaplan and Norton's article (1992) conducted monthly surveys of 600 randomly selected employees to determine if they were aware of a new total quality management (TQM) program, had changed their behavior because of it, believed the outcome was favorable, or had become missionaries to others. Surveys designed to measure companywide attitudes and participation in safety are an important component of safety improvement measurement.

Considering the innovation and learning perspective in Kaplan and Norton's model for safety management, continuous improvement is dependent on upper management's willingness to learn or take suggestions for improvement from employees. Safety enforcement will certainly continue to be a required supervisory control. Creating better trained and educated workers that can lead (participative management) the firm into new territories of innovation and success is critical to the continuous improvement theory of Kaplan and Norton.

Mohamed (2003) translated Kaplan and Norton balanced scorecard concept into a safety management context. His interpretation of the balanced scorecard concept was summarized in a diagram (Fig. 2-4). The diagram was created to communicate an overall management theory for safety improvement with an emphasis on continuous improvement. Starting from twelve o'clock in the diagram and progressing clockwise, strategies for safety improvements are created, implemented and controlled by the company's executive management. At three o'clock, strategies have been implemented and safety performance measurement commences. Safety performance and productive activities are viewed as opportunities to learn from experience. The area labeled "Evaluating and Communicating" is the segment of the process where worker involvement and operational feedback occurs. Worker perception surveys should occur at this segment in the circuit. The circuit is completed by the training that reinforces the strategy and makes continuous improvement possible. The training that occurs at nine o'clock is informed by the "Learning and Improving" segment so that the training expands and adapts over time to include the best worker suggestions for company improvement.

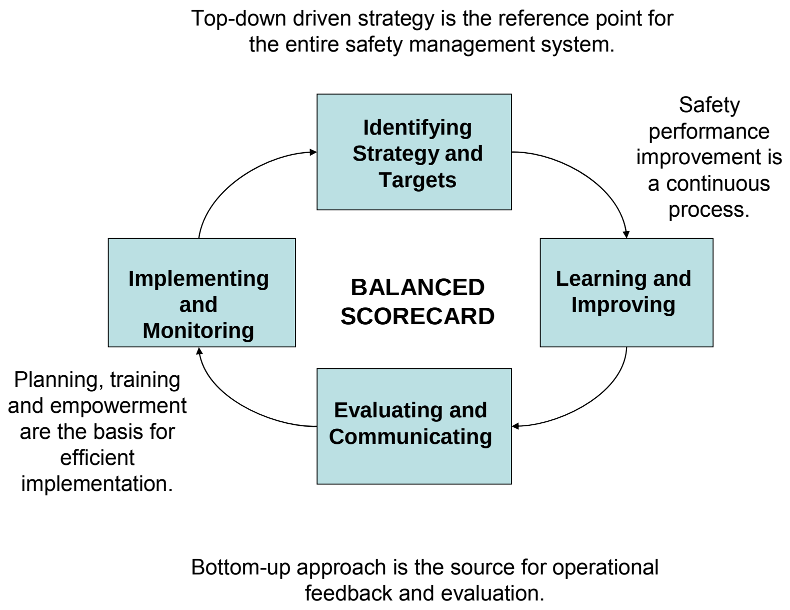

Figure 2-4. Safety management system for strategic and operational implementation. Adapted from Mohamed (2003).

Continuous Improvement in Construction Safety

Total quality management (TQM) techniques, many developed in the auto industry in Japan and the U.S., are similar to safety management techniques studied in the U.S., particularly research that has studied human factors rooted in work process and crew teamwork (Samelson 1977; Hinze and Parker 1978; Hinze 1987; and Geller 2002). TQM requires companywide commitment by management and workers to a systems approach with high levels of training, worker input and overall worker involvement. Where TQM was concerned with achieving zero defects in product quality (p. 21, Sasaki 1984), construction safety methodology was concerned with zero accidents (Hinze 2002b). An important distinction between TQM and safety theory that may have acted as a barrier between the two bodies of practice and theory in the past is that TQM typically attributes a completely nonhuman cost to nonconformance in product quality (p.345, Galloway et al. 2004). Nonconformance costs in safety are absolutely human and preferably measured in moral terms.

Positing safety improvement efforts on continuous improvement challenges organizations to engage in a companywide commitment at all levels of management and employees. This type of companywide commitment has been cited as the fundamental feature of an effective and high quality *safety culture* (p. 40, Hinze 2006).

Best Practices in Safety Studies

By the end of the 1980's, the construction industry had developed important safety practices that contributed to performance improvement. These safety practices were examined and summarized in the first major construction study of *zero accident* techniques (Liska, Goodloe and Sen 1993). A subsequent study was conducted to track the evolution and expansion of these best practices (Hinze 2002b). That study identified nine major safety practice categories contributing to improved performance:

- Demonstrated upper management commitment
- Staffing for safety
- Pre-project and pre-task planning
- Training (orientation and specialized training)
- Worker involvement
- Recognition and reward and evaluation programs
- Subcontracting activity (contracts and direct management)
- Accident investigations
- Drug and alcohol testing.

These practice categories were found to be statistically significant contributors to improved safety performance. In a closely related study, the nine best practices of the Making Zero Accidents a Reality investigation were applied to a sample of petro-chemical projects engaged in shutdown projects (Hinze and Godfrey 2002). Five of these practice categories (pre-project planning, safety training, subcontractor management, accident investigations and drug testing) were grouped into a single variable. Using this new variable, the researchers were able to show that on projects where adoption of most or all of the five practice categories occurred, statistically safer conditions also occurred ($p < 0.01$).

Upper Management Commitment

There are many ways that upper management in construction firms can lend support to improved safety performance. Hinze states that the key to effective participation by upper management is a physical presence and involvement at the project level (Hinze 2002b). The message sent to all employees when top managers engage in project safety visits and activities is that management is concerned enough about safety issues to require direct witnessing and personal engagement. Activities include:

- Field safety inspections
- Participation in training and orientation
- Accident and near-miss investigations
- Reviewing monthly safety reports.

Projects where company presidents were involved in all major accident investigations were shown to be significantly safer on a statistical basis (Hinze 2002b).

Strategic Planning for Fall Protection

Many important factors affecting fall protection and PFASs on a project are set in motion in the planning and preconstruction phase of a project. PFAS planning begins as soon as the constructor examines the proposed structure or facility. What is the extent of PFAS required to provide fall protection? Will a constructability review suggest opportunities to reduce PFAS requirements by means of the hierarchy of fall controls and elimination of active fall protection systems? If PFAS cannot be eliminated, what types of anchorage will be used and where will they be located?

Effective preconstruction planning for fall protection and fall control methods requires some amount of coordination between the designer and constructor. On traditional design-bid-build projects (with owner, design consultant and contractor) team partnering that encourages early communication between the parties can be beneficial to fall protection planning. On design-build projects, constructability reviews that include fall protection planning are likely to occur as a standard procedure (Hinze and Wiegand 1992). Fall protection best practices must include using the preconstruction planning phase to promote safety improvements (Hinze 2006). It is important to note that *eliminating fall hazards through design and engineering* (as contained in the hierarchy of hazard controls) is dependent on aligning the mindset of the designer (and owner) to the objective.

Goal Alignment and the Project Team

An owner plays a central role in establishing and controlling the goal alignment for the project. While the owner is not in absolute control of the design and construction process, the owner has budgetary control over the project and thereby sets the project's safety agenda. The agreement between the contractor and the project owner has been investigated in relation to safety issues. Upper management of the construction firm can negotiate with the owner on several key issues to influence a project's safety climate and culture. These key issues include:

- **Itemizing safety costs as a line item in the project budget**: A study of safety on industrial construction projects investigated this issue (Hinze and Godfrey 2002). Over 85% of the projects included in that study used explicit safety budgeting to improve performance. Overall, the industrial-type projects in that study had excellent safety records. The mean recordable injury rate for the typical project in the sample was 0.7 injuries per 200,000 worker hours.

- **Using an agreement that incentivizes safety performance**: The Hinze and Godfrey study (2002) of safety on industrial construction projects also investigated incentivized agreements. While the results of that study did not show a statistically significant association between safety performance and contract incentives, the researchers presented their investigation of this issue as a contributor to safety improvements.

- **Requesting that the project designers consider construction safety**: Researchers (Gambatese, Behm and Hinze 2005) have shown that designers who are required by the owner to consider design for construction worker safety in the design process are decidedly more knowledgeable and competent about safety. This finding was statistically significant ($p < 0.01$).

However, before concluding that the owner is exclusively in control of the safety agenda on a project, it should be noted that construction accidents are a reflection of broad systemic problems not fully understood by any single party in the owner-designer-constructor triangle. For example, financial market pressure on commercial real estate value is a variable that an owner or developer feels and understands more directly than a designer or constructor. Likewise, few owners fully understand the complexity of issues that act as barriers to safety for the designers and constructors that they hire.

A key deterrent to effective goal alignment for the project team is the lack of construction safety knowledge of the A/E designer (Hinze and Gambatese 1996). Except for the requirements of major building code regulations, the A/E designer is often deficient with regard to using safe design principles to control fall hazards or improve fall protection. Compounding the problem of the A/E designer's lack of construction safety knowledge is the risk management outlook of the A/E designer.

A common theory of contracts states that "contracts assign risk exposure to the parties best suited to manage a risk" (Abramowitz 2002). Ever since the case law precedent of Geer v. Bennett (1970), A/E designers have taken great care to limit their liability and contractual responsibility for construction worker safety.

Goal alignment, team partnering and integrated project management have become more common in commercial building construction in the last ten years. Forces influencing the increased level of interest in integrated project management include:

- Increased frequency of design/build and fast-track project delivery. Both of these delivery methods require increased levels of project team cooperation whether by contract or the owner's insistence.
- Research in industrial manufacturing that has shown the cost savings benefits of greater integration between design and manufacturing (Ettlie and Stoll 1990). For example, Ettlie and Stoll (p.68, 1990) state that when firms provide specialized training in *design for manufacturing* (training to promote better integration of design and manufacturing) or form teams tasked with design and manufacturing integration, improved productivity and cost reductions occur.

An exploratory study investigated the safety benefits of integrated design/manufacturing teams in a building construction context (Hecker, Gambatese and Weinstein 2005). The study was based on a case study of an integrated design/constructor team that was used in the project management of a semiconductor manufacturing facility. The project was constructed for the owner, a large semiconductor manufacturer, for a construction cost of approximately $700 million USD. In order to promote improved construction safety, an integrated team that included representatives of the owner, the architecture/engineering (A/E) consultant, and the construction manager was formed in the early design stages when conceptual design issues were still outstanding and easily modified by the integrated team.

Another aspect of the integrated design/constructor team included trade contractors who either had been pre-qualified or were planning to submit bids. Some trade contractors participated in the early design phases, but were dropped from the team later because they were not awarded contracts. The authors of the study stated that while explicit details about how to implement integrated design/manufacturing teams for improved construction safety are not common in the literature, the project had demonstrated that such a process is feasible.

Design-build contracting and project delivery has been on a steady upward trend and has become a major mode of project delivery. The Design/Build Institute of America estimates that design-build will become the dominant method of project delivery (Fig. 2-5) in commercial construction by the year 2015.

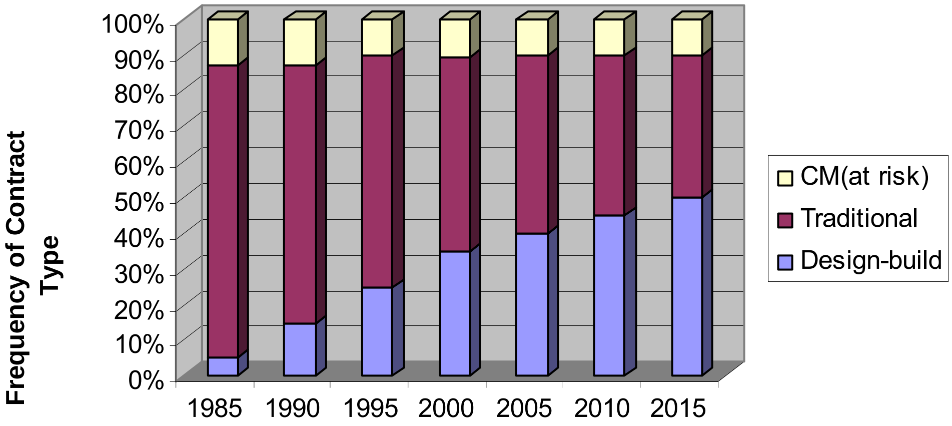

Figure 2-5. Market share of major project delivery methods for non-residential design and construction in the United States. Adapted from Design-Build (2007).

From the reference point of effective goal alignment, design-build contracts have the contractual advantage of placing the constructor and A/E designer under the same contract with unified obligations and duties. The design process operates with the benefit of shortened lines of communication between designer and constructor.

Design-build firms have been cited for their innovative construction safety practices (Gambatese, Behm and Hinze 2005). As part of a company mandate to improve A/E designer participation in construction safety, the following practices were adopted by the design department at a large design-build firm:

- Designers at the firm received a safety training course based on the 10-hour OSHA training format.
- Site hazards for projects were designated with special alert symbols to improve communication and awareness of hazards.
- Safety design guidelines were consulted for each project to promote thorough consideration of safety improvement options.

Design for Safety Resources

Computer software has been developed to provide construction safety resources for designers and constructors interested in using the design process to eliminate hazards (Gambatese 1996). Best practices for hazard mitigation were compiled and incorporated into a computer program, entitled "Design For Construction Safety Toolbox."

These design guidelines for improved worker safety were meant to be considered and incorporated during the project design and planning phase. Almost a third of the design guidelines address design features and improvements that directly impact PFAS. Included in the body of these guidelines are important fall arrest concepts such as the need to incorporate permanent anchor points into roofs and other high exposure areas in the structure so that construction workers (during construction) and maintenance workers (during occupancy) can readily find suitable anchor and anchor connector opportunities.

Pretask Planning

Pretask planning is a special form of participative management by workers at the craft level where employees plan tasks involving their trade but also must consider required safety equipment and compliance issues. The documentation of pretask planning allows the plans to be reviewed by management on the project, and also creates a record of safety performance. The implementation of pretask safety planning was shown to have a significant impact ($p < 0.05$) in lowering injury incidence rates in a study of industrial construction projects (Hinze and Godfrey 2002).

In the context of PFAS safety planning, pretask planning would be expected to consider:

- Anchorage placement and location
- Anchorage connector selection
- Horizontal lifelines (HLL) selection and engineering
- Leading-edge and deck perimeter fall protection
- PFAS system and task coordination.

No explicit descriptions for pretask planning in relation to fall protection and PFAS use were found for the literature review.

TQM literature often contains a discussion of quality improvement tools (Sasaki 1984; Galloway et al. 2004). The cause and effect diagram or fishbone diagram has been used in participative management as a quality improvement tool. The name, *fishbone* diagram, is attributable to the diagram's characteristic appearance of a fish skeleton. For illustrative purposes, a hypothetical safety problem involving utilities and site work is diagramed in Figure 2-6. Potential accident cause categories that form the ribs of the fishbone diagram are established before the exercise begins. Galloway et al. (2004) present possible starting categories:

- The four M's: men, machines, materials and methods
- The four P's: people, policies, places and procedures
- The four S's: skills, suppliers, systems and surroundings.

Possible starting categories for PFAS and pretask planning are materials, anchorages, lifelines, and tasks (MALT). The materials category would allow consideration of any issues relating to the specific structural and finish materials on the project.

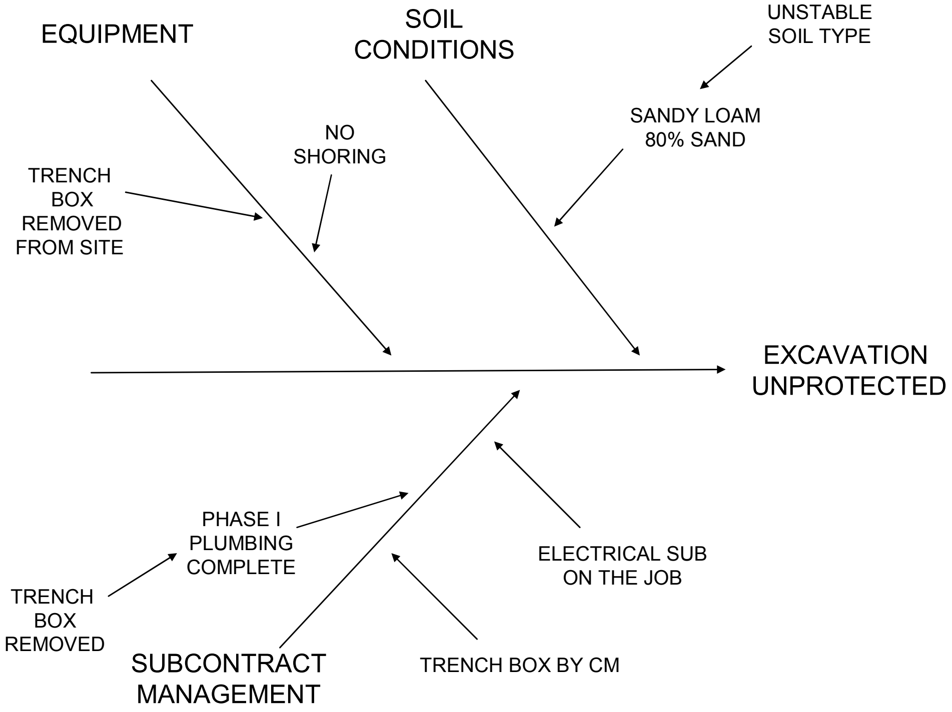

Figure 2-6. Fishbone diagram for causes of unprotected excavation.

Worker Involvement in Safety

Worker involvement is critical to successfully implementing safety best practices. Engaging in a sincere human interaction with individual workers as a daily activity and fundamental corporate value is one of the fundamental tenets of enlightened safety management. Leading safety theorists have been emphatic about the fundamental importance of worker and employee involvement and participation. Peterson stated that techniques to promote worker involvement and participation, such as safety perception surveys, were the top priority for initiating improvements in safety culture and best practices (Petersen 2007). As stated by Hinze, employees categorized as workers have the potential to contribute far more than manual labor if given the opportunity (p.261, Hinze 2007).

Cox (2001) states that “the ideal situation is when there is goal congruence among the workforce and the organization. Common goals, or even the opportunity for workers to attain personal goals on the way to helping the organization achieve its long-range objectives, certainly impact workers’ motivation and commitment to see a plan through.” The management goal of engaging the workforce in a dynamic interdependency of corporate and individual employee goal attainment is supported by a safety theory known as *goals freedom alertness* (Kerr 1957). The central hypothesis of this theory as stated by Kerr is that “great freedom to set reasonably attainable goals is accompanied typically by high quality work performance (p. 5).” Kerr’s theory regards an injury accident as an unsafe behavior by a somnolent individual with a low level of personal engagement with the job or task. Kerr recommends creating a company culture with a rewarding and rich psychological climate. This recommended company culture has diverse (economic and personal) opportunities for employee reward and goal achievement.

In a major study that investigated the attitudes and sentiments of construction workers (Hinze 1981), workers were surveyed about the extent to which their ideas for improvements received serious consideration from their supervisors and companies. The results indicated that workers who felt that their input was often given serious consideration had significantly lower injury incidence rates ($p < 0.01$).

Enforcement of safe behavior is the traditional method of assuring compliance with safety policies in the construction industry. While safety compliance enforcement is a required management control, Geller (p. 1, 2002) points out that emphasizing enforcement possibly creates a dependency mindset where passivity becomes the dominant mode of employee behavior. For example, if management exclusively emphasizes compliance with safety policies, workers might understandably adopt an attitude such as “my only obligation is to follow the rules and the boss will be satisfied.” Passivity in the face of witnessing unsafe work behavior or job site hazards is rarely a best practice. Achieving an effective best practice environment in safety requires empowering employees to contribute to and assist in improving safety programs.

Important techniques to promote worker involvement and participation in safety that have been studied in construction safety over the past twenty years are:

- **Toolbox Meetings**: Weekly worker meetings at the crew level, led by the crew foreperson are almost universal in construction. In a study of 27 petrochemical projects, every project without exception used weekly toolbox meetings to reinforce safe behavior (Hinze and Godfrey 2002).

- **Work Process Observations by Workers**: Safety observers typically receive special training to prepare them to make observations of safety behavior. In one study the average median time for an observation was 2.5 hours (Hinze and Godfrey 2002). Research has shown that projects where worker-to-worker observations were conducted had better safety performance.

- **Safety Committees**: Members are drawn from different trades on the project and may also include safety managers. The committees have been used on projects to perform weekly or monthly safety audits and to generally observe safety compliance and behaviors (Hinze and Godfrey 2002).

- **Employee Perception Surveys:** Typically surveys ask employees to comment on existing policies and practices, but may also request open-ended comments and suggestions for improvements (Petersen 2007).

Employee suggestion programs have been used in industry to solicit innovative feedback from employees. Human resource consultants have recommended that suggestion programs require that employees identify themselves when making suggestions. When the worker’s identity is included with the suggestion, the employer is obligated to implement well-designed policies for rewarding and recognizing high quality suggestions (Heathfield 2007).

Participative Management and Quality Control Circles

An example of how worker involvement has been extended in general industry is where production-level employees participate in and give direction to management. The general theory of *participative management* is that the craft workers have an intimate knowledge of the work processes that give them a distinct and valuable perspective on safety and productivity improvements that should be respected *and developed* (p. 17, Mohr and Mohr 1983).

Quality control (QC) circles are a form of participative management that was developed in post-WWII Japan, but were imported into American industry starting in the early 1980's. QC circles have been used in many notable firms to improve quality and safety, including Hewlett-Packard, Honeywell, Hughes Aircraft and Lockheed Martin (Mohr and Mohr 1983). There is a general acceptance of the fact that the ever-increasing market share of Japanese auto manufacturers rests predominantly on the stellar reputation that their products have for quality and reliability.

QC circles constitute a basic general improvement concept. Small teams of workers from the same operational area meet with first-level supervisors to examine operational problems and recommend solutions to the company. As one article points out (Hutchins 1984), this seemingly simplistic and familiar sounding quality committee:

> …differs radically from other techniques, both in concept and manner of operation. The Quality Circle works from the bottom up, drawing directly on the knowledge and skills at shop-floor level – an unfamiliar approach to those accustomed to applying top-down management techniques.

Hutchins went on to say that while "no single concept or management policy has been responsible for the extraordinary success of Japan, the employment of Quality Circles has been very important." Of course, part of the familiarity of the concept is due to the gradual importation of Japanese TQM techniques into U.S. business culture and continuous improvement theory over the last twenty years. What is still fairly distinct about quality circles is that workers establish their own target goals one after another from their own autonomous ideas, including strategies for achieving the targets. The quality circle concept has also been noted as being applicable to safety improvement as well as improving productivity and quality (p.21, Sasaki 1984).

Work Crew Dynamics

Investigations of the work crew have also taken place in the context of construction safety. The primary hypotheses of one study was that excessive pressures placed on workers and direct supervisors (presumably accountable to the company for results) to achieve production quotas or project schedule targets would lead to increased safety problems and injury rates (Hinze and Parker 1978). With the goal of investigating this hypothesis, the following factors were studied as influencers of increased injury frequency:

- Use of cost information (to measure the extent the project was meeting cost estimates);
- Use of project schedules (to measure the extent the foremen and superintendents were using scheduling tools to motivate workers);
- Competition between crews; and
- Perceived support for safety best practices from upper management policies or attitudes.

Influence of Crew Leaders, Foremen and Superintendents

The display of sincere concern for worker health and safety through policy and direct management practices of supervisory personnel (superintendents and foremen) is associated with better safety performance (Hinze 1987; Hinze 2002). A good leader from a safety perspective is:

- An effective planner
- A well-organized individual with a high-level of involvement and coordination with other members of the project team
- A good role model, especially regarding safety behavior (Hinze 1987).

The good leader in safety is also knowledgeable about the personal issues and concerns of workers in their charge (Hinze 1987). Fostering a work environment where the workers are afforded an opportunity to contribute their expertise about safety, productivity and quality in a meaningful and legitimate manner satisfies basic human needs for recognition and appreciation (Geller 1997).

Obstacles to Best Practice Program Effectiveness

Obstacles to achieving safety best practices program effectiveness may be avoided by monitoring factors known to cause problems for new programs. All the factors outlined in this literature review, as components of safety best practice, are subject to incompetence and failure. Safety practices that are known to be problematic or controversial have been identified in the literature.

Hinze (2002a) researched the use of safety incentives as a method for motivating safe worker behavior and improving safety performance. The study’s results showed that some construction firms feel that incentives are ineffective because they do not actually measure improvements in safety behavior and technical execution, but instead draw conclusions from the absence of injuries. Worst case, incentive programs may even reward employees for not reporting injuries. That study found that firms with better safety performances considered safe behavior and observations about work processes in conjunction with lower injury rates when awarding incentives.

The following list of obstacles was cited in regard to implementing TQM programs in general industry (adopted from Greshner 1984):

- Lack of approval and understanding of best practices by upper management
- Problems with supervisors and middle managers, including inadequate training in best practices for managers, resistance to innovation or change; or disinterest in best practice program

- Lack of comprehension of best practice philosophy
- Coordination problems in implementing and administering a new best practices program
- Employee turnover or other problems influencing the availability of properly trained personnel
- Obstacles to implementation rooted in marrying TQM techniques with existing management hierarchy
- Lack of resources or other issues relating to procurement of equipment.

Worker Training

Researchers of basic human motivations have proposed that humans have an innate interest in being able to successfully solve problems and complete tasks. This need has been characterized as the desire to be competent (White 1959). Because of the technical complexity and associated injury severity of improperly-implemented PFASs, worker competency to follow the recommended procedures and to understand risk exposure is critical to safety performance and the self-preservation of the individual worker. When workers learn the specific practices for 100% tie-off, they feel competent. When the individual feels a high level of competency, their overall performance and well-being as an employee is enhanced (Geller 2002).

OSHA Construction Regulation, Subpart C, states that “the employer shall instruct each employee in the recognition and avoidance of unsafe conditions and the regulations applicable to his work environment to control or eliminate any hazards or other exposure to illness or injury.” This regulatory clause is a statement of the employer’s duty to conduct a hazard analysis. This hazard analysis must be followed up by the employer’s commitment to train the employees to recognize and avoid these same hazards. Clearly, the employer is on the frontline of defending against working-at-elevation injuries and obligated to increase the PFAS user’s awareness of the risks associated with using anchorage and fall protection equipment effectively.

The safe use of PFAS requires intensive baseline worker training in equipment care, compatibility and safe anchor connection techniques in compliance with OSHA training requirements for employees exposed to fall hazards. A study (Hinze 2002) that examined the practices used by construction firms to lower worker injury rates found intensive safety training programs to have a significant ($p < 0.01$) impact in lowering injury rates. That is, firms providing more hours of worker training were associated with better safety performances. Intensive safety training programs were defined as projects that provided monthly training to each worker consisting of four or more hours beyond basic orientation.

Standards for worker training are given in the U.S. national PFAS standard (ASSE 1992). As mentioned above, comprehension of the influence of total fall distance (TFD) is considered a standard for PFAS user competency. Research focusing on the anchorage component of PFASs has shown that worker orientation training that is trade and project specific with regard to anchorage is critical to worker competency.

CHAPTER THREE
METHODOLOGY

The two objectives of this research were: 1) to identify best practices related to the use of PFASs; and 2) to synthesize the identified best practices into a tool for continuous improvement. Identification and analysis of root causes that place workers at risk through the improper use of PFASs was also considered by examining injury data available from OSHA. The methodology and analysis for the injury data are given in Chapter 4.

Research Design

The hypothesis for this research was that the companies within the ENR Top 400 general contractor population with the better safety records had implemented more robust and aggressive policies in fall protection and fall arrest systems than contractors with underperforming safety records, that is, with safety records that were not as good. These robust and aggressive policies were investigated to determine the specific best practices that significantly influence the injury incidence rate.

Sample Selection

Large construction firms were selected for investigation because these firms were expected to be more proactive in the use of aggressive and robust safety practices, including progressive fall protection and fall arrest systems. A list of large contractors, commonly known in the industry as the ENR Top 400, was selected as a sampling frame for the large contractor population. This list has been compiled and published annually by a leading publisher of construction industry information and data (ENR 2006). Other construction safety studies (Hinze 2002b) have also investigated the safety practices of these large construction contractors (ENR Top 400).

The specific Top 400 list used for the study was created from data provided on a voluntary basis by large construction contracting firms for the year 2005. The Top 400 reported combined total revenues of over $230 billion US Dollars for the year 2005. These contractors had annual domestic revenues that ranged from $120 million to over $10 billion US Dollars.

The ENR Top 400 population has been characterized as a population with a wide range of construction activities, commonly called a *general building market* (ENR 2006). The types of construction projects and market sectors in a general building market include:

- Building construction
- Buildings and structures for manufacturing
- Petroleum and chemical plant construction
- Water supply projects
- Sewer and waste treatment plants and piping systems
- Horizontal (transportation, highway and bridge) construction
- Hazardous waste projects
- Power plant construction
- Telecommunications (towers and underground) construction.

Construction safety practices would be expected to have a wide range and high degree of variance for a general building market population; however, the variance for the population selected was considered acceptable because the selection of this sample population was consistent with the research objective discussed in Chapter 1.

No attempt was made to classify fall protection and fall arrest system practices by project type. All employers are affected by the OSHA regulations for fall protection because working at elevation, that is, working at a height of 6 feet or more above the walking surface, is a common and widespread phenomenon. The character of fall protection and fall arrest systems practices of firms in the ENR 400 population was considered to be defined by two factors:

- The nature of a typical commercial or governmental construction contract with standard subcontracting and construction management practices.

- The transitory and dynamic nature of construction projects as compared to the fall protection and fall arrest systems practices developed and implemented for general industry that use permanent locations and facilities.

The injury data collected by OSHA (from which the significance of fall fatalities and serious injuries was determined) is associated with a liberal classification for the construction industry. The liberal characteristic of the general building market (as represented in the ENR Top 400 population) was deemed to be equivalent to the limits and bounds of the construction industry as defined by the OSHA injury recording and data management process. The ENR Top 400 contractors were selected for investigation because they reflected similar characteristics as the source population for the OSHA injury data. In summary, if the significance of the injury data was determined from a broad classification of the construction industry, then the significance of best practices implemented with the objective of reducing those same injuries should be determined from data collected and analyzed from a similarly broad classification (or sampling) of the construction industry.

Hypothesis Testing

Two parameters of interest (θ) in the population were investigated in this study: 1) the optimum group of safety practices (the best practices), specifically fall protection and fall arrest practices, that would effectively reduce fall fatalities and serious injuries; and 2) the contractor's total recordable injury rate (TRIR). Fatalities and serious injuries must be recorded by all employers with more than 10 employees as mandated by the OSHA regulations. The employer's total recordable injury rate (TRIR) is defined as the number of recordable injuries per 200,000 worker hours (the number of hours worked annually by 100 workers). The term, *recordable injuries,* is also defined by the OSHA regulations (section 1904.4 – "Recording Criteria").

The hypothesis test specified was a correlation of the construction contractor's TRIR and a given set of safety practices (implemented as a component of a contractor's safety plan). Because correlation assigns an equivalent status to the two variables, there was no dependent variable in this study. TRIR and the safety practices implemented (as a safety management treatment for fall protection) are both response variables given equal consideration in all respects.

In this research design, the null hypothesis is for independence. The null hypothesis tested was that the TRIR was not associated with an increase in the number of best practices in fall protection and fall arrest systems implemented. Stated in terms of the test statistic, the null hypothesis to reject or accept was that the true value for the correlation coefficient was equal to zero, indicating no association or zero correlation between the x-value (the best practices) and the y-value (the TRIR).

The historical source of the mean TRIR for the construction industry has been the Bureau of Labor and Statistics (BLS) and OSHA. The historical data for the population in this study has shown the following:

- The mean TRIR for the construction industry for 2005 was approximately 6.35 injuries per 200,000 worker hours.
- The assumption of a standard normal probability distribution for the population of TRIR values in the construction industry has not been considered reliable. Historically, the estimated range and variance of the TRIR population have not been published by BLS or OSHA.

Sample Size Determination

Sample size determination is related to the establishment of a decision protocol for either rejecting or accepting the null hypothesis. Two types of errors were taken into account in the design of this study:

- A type I error is committed if the null hypothesis is rejected when it is true. The probability of making a type I error is denoted by the Greek letter alpha (α). This probability is typically defined as *the level of significance* for the hypothesis test. To protect against committing a type I error, the significance level of α for testing was specified at or below 0.05.

- A type II error is committed if the null hypothesis is accepted when, in fact, it is false. The probability of making a type II error is denoted by the Greek letter beta (β). To protect against committing a type II error, the power of the test ($1-\beta$) for testing was specified at 0.90.

Hollander and Wolfe (1999) present a method for determining an approximate sample size *n* for a one-sided, Kendall sample correlation test for independence. This approximate value of n is

$$n = 4\,(z_\alpha + z_\beta)^2 / 9\,\tau^2 .$$

where
$z_\alpha = z_{.05} = 1.645$
$z_\beta = z_{.1} = 1.285$
τ = lowest level for the Kendall correlation coefficient at which significance could be detected = - 0.30
Thus,

$$n = 4\,(1.645 + 1.285)^2 / 9\,(-0.30)^2 = 42.39.$$

To be conservative, the minimum sample size was taken to be n = 43.

Data Collection

This research investigated safety practices in the ENR Top 400 population with a survey instrument. The survey instrument investigated the population in two phases as follows:

- A preliminary survey to measure response frequencies in the different categories of safety management (for fall protection and fall arrest systems).
- The fall protection and fall arrest systems survey to identify the most effective safety practices in PFASs.

These surveys were developed by an iterative process. The initial material considered for the survey form was derived from a precedent fall protection safety study (Hinze and Harris 2007b). The survey development process considered the following factors:

- Contractor demographics and standard industrial classification (SIC)
- The types of trades involved in different phases of construction and various types of structural erection that use fall protection and fall arrest systems
- The significance of engineering and preconstruction in the effective management of anchorage

- The importance of subcontractor management for promoting robust safety practices as a general contractor (a sample of subcontract agreements was considered)
- Lists of significant best safety practices from precedent construction safety studies
- Safety compliance checklists.

The final versions of the survey forms are presented in Appendix B.

Preliminary Survey

The preliminary survey was mailed to the sampling frame (the ENR Top 400 contractors); the completed surveys were returned in a postage-paid envelope. The survey inquired about the following practices:

- Practices for writing subcontracts and monitoring the PFASs used by subcontractors
- Extent and type of training received by workers
- Regular inspections of PFAS equipment
- Company requirements regarding the use of PFASs
- Company strategy to ensure that employees utilize PFASs
- Preconstruction and engineering coordination practices
- Extent to which OSHA-compliance was met or exceeded.

More than half of the questions were designed for a nominal yes or no response. The balance of the questions recorded a multiple choice or an open-ended comment response.

The exploratory nature of the preliminary survey was intended to investigate the attitudes and practices of the population. The use of a sequential survey structure with a preliminary data collection phase was chosen to improve the probability that the survey would collect statistically significant responses for the parameters of interest in the population. That is, some questions regarding certain safety practices in the preliminary survey were dropped from further exploration based on the results from the first stage of data collection. For example, the result for Question 10 in the preliminary survey (Is subcontractor compliance with the OSHA regulations mandated in your firm’s subcontract agreements?) was that 100% of the responding companies answered in the affirmative for this question. From this result, it was determined that, although this question presents an important safety practice, further exploration of this practice was unwarranted.

Fall Protection and Fall Arrest System Survey

In order to generate more specific data about certain policies and practices for which data had been collected in the preliminary survey, clarifications were sought from the population regarding particular parameters of interest. For example, several respondents to the preliminary survey commented that their companies had adopted an all inclusive tie-off rule for all workers on site (to exceed OSHA regulations). A question for the Fall Protection and Fall Arrest System Survey was created to collect data on the number of companies that had implemented similar all-inclusive tie-off policies.

A specific goal of the survey was to collect data on practices with a high probability of influencing the parameters of interest for the population. In order to meet this goal, the frequency of nominal questions was increased as the study progressed. In the preliminary survey, nominal yes-or-no questions comprised less than fifty-five percent of the questions. Nominal yes-or-no questions occurred at a frequency rate of almost 90% in the Fall Protection and Fall Arrest System Survey.

Another concern for the survey design at the completion of the preliminary survey (that is, during the second stage of data collection) was to assure a high response rate by controlling the length of the subsequent survey. Twenty-six questions were eliminated for the purpose of reducing the time and effort required to fill out the survey form. The mail-out format was used in both phases of the survey.

The Fall Protection and Fall Arrest System Survey (the second stage of data collection) was sent to the entire population of the ENR 400 contractors. Two versions of the survey were distributed in this second stage of data collection. A follow-up version of the survey instrument was required because of two interrelated factors:

- Fourteen questions from the preliminary survey were deemed to be useable data for use in the testing of the hypothesis.
- Forty-seven respondents provided their contact information for the purpose of receiving a copy of the final report. Because of the apparent interest in the research of these 47 respondents, it was decided to send the second stage of data collection directly to these individuals. Due to their expressed interest in obtaining the final report, it was concluded that they represented a group of the population that would be likely to respond to the second stage of data collection. Since they had already provided viable information to the preliminary survey (first stage), they were sent a shortened survey that asked for information on a few additional topics. That is, the information they provided in this shortened second stage survey was appended to the information they had previously given.

Forty-seven respondents to the preliminary survey were asked to participate in the second stage of the survey. Because they had already provided viable data that could be used in the final analysis of the survey results, it was determined that two versions of the second stage of data collection were necessary. These two versions are described as follows:

- The Fall Protection and Fall Arrest Systems survey (titled the same in Appendix B) was a 38-question version (14 questions reused from the Preliminary survey and 24 new clarification-oriented questions). This version was mailed to 353 companies in the ENR Top 400 sample frame (the total number of companies in the ENR Top 400 sample frame less the 47 respondents to the preliminary survey).
- The Fall Protection and Fall Arrest Systems survey, follow-up version (titled the same in Appendix B), was sent out with a personalized cover letter addressed to the 47 individual respondents to the preliminary survey. This version of the survey contained only the 24 new clarification-oriented questions. The actual survey form contained 25 questions as shown in Appendix B. The one extra question was a duplicated question because question 22 in the follow-up version also appeared in the preliminary survey (question 37).

As a quality assurance measure, the cover letters for the follow-up surveys were addressed personally to the individuals who had identified themselves in the preliminary phase. The personalized cover letters assured that the specific individuals that responded to the preliminary survey were the same individuals who were submitting information for the follow-up survey. At the conclusion of the data collection period for the study, the data collected from the preliminary-phase respondents (total survey data collected in two separate mail-out survey forms) were expected to be equivalent to data collected from new respondents (who were sent the 38-question survey version).

The second stage of data collection/survey instrument requested data on the company's OSHA recordable injuries. The total recordable injury rate (TRIR) has been widely used as a measure of safety performance in the construction industry. As noted above, the research was designed to use the TRIR as one of the response variables for statistical testing.

Because the respondents who had identified themselves in the first stage were assumed to have an active interest in the research, it was expected that the response rate would be high. A web search was conducted about response rates for panel studies, also called longitudinal studies (Flood et al. 2007; Jennings et al. 2007). The literature reported that 80-90% response rates (or 10-20% attrition rates) were typical for follow-up surveys in longitudinal studies. However, because the literature cited was not reporting on the population of interest for this study, skepticism towards these response rates was warranted. Data were sought from the balance of the population (the preliminary phase non-respondents) so as to improve the odds of receiving an acceptable sample size for the hypothesis testing.

Data Analysis

The data analysis in this study was concerned with the statistical relationship between two variables (TRIR and the safety management practices implemented) involved in a bivariate structure. The statistical procedure used was a test to determine whether or not these two variables were independent. The probability distribution-free method used for testing independence in this study is known as a *nonparametric statistic*. Nonparametric statistics are a broad family of methods that includes *rank correlation tests* (Kendall 1962; Kruskal 1958;

Hollander and Wolfe 1999). Rank correlation tests were the primary means of data analysis used in this study.

Assumptions

The lack of historical data for the population selected (ENR Top 400 contractors) made assumptions of a normal probability distribution for the population unreliable. By assigning ranks to the individual values for the two variables of interest (the TRIR and the safety management treatment), a distribution-free statistical test could be conducted. That is, a test was conducted without determining the distribution of the population.

The historical data provided the expectation that a bivariate correlation of TRIR and the safety management treatment would produce a coefficient limited to the bottom half of the interval [-1, 1]. That is, the TRIR is negatively correlated with the quantity of safety management practices. Data analysis from previous safety studies (Hinze and Godfrey 2002) showed that the assumption of a correlation coefficient value limited to the interval [-1, 0] was reliable. That is, TRIR was reliably decreased when more robust and aggressive safety practices were implemented. Therefore, a one-tailed statistical test to protect against an error (that is, an error in rejecting the null hypothesis) in the negative range of the sample was justified.

The Kendall rank correlation, type b, is a statistical correlation test that is useful when there are a number of tied data points in the in the sample data. Because tied observations were expected to occur in the sample data for the safety-practices-implemented variable (that is, it was expected that two or more cases in the sample could implement the same number of safety practices), the Kendall's tau, type b test of the Kendall rank correlation was used in this study.

Procedure

A software package for data analysis and statistical testing (SPSS 12.0 for Windows) was used for data input and analysis. From the SPSS menu list of bivariate correlation tests, the

Kendall tau, type b, test with the one-tailed test option was selected for testing the null hypothesis.

The first step in the procedure for this test was the computation of the Kendall sample correlation statistic, K. The computation methodology for Kendall's K statistic was presented in a textbook format in Kendall's book on rank correlation methods (Kendall 1962). The Kendall test for independence in the context of nonparametric statistical procedures was presented by Hollander and Wolfe (1999). Both of these textbooks were used as reference sources.

Previous safety studies (Hinze and Godfrey 2002) have used a data analysis procedure where associations were found by synthesizing important safety practices into a single ordinal variable for use in a correlation test. In this study, an ordinal value was assigned to the total number of practices implemented as scored from the total available safety practices investigated. Individual sample cases were assigned one point for each safety practice implemented; or a zero if the safety practice was not implemented.

Correlation tests were conducted that measured the rank correlation between the ordinal variable (created from the safety practices implemented) and the total recordable injury rate (TRIR) variable. In these correlations, the nominal values assigned to the safety practices could assume a value between zero (no practices implemented) and 9 (all nine practices implemented). The relative significance and importance of the specific nine variables that were tested was determined by investigating the individual frequencies and individual correlation coefficients (when correlated with the TRIR) for these variables.

An iterative process was then conducted that correlated various and alternate combinations of the nine nominal variables with the TRIR. These iterations continued until the strongest association was identified between a selected group of safety practices and the total recordable incidence rate (TRIR). In this study, a combination of five safety practices was found to yield the most compelling results or the strongest correlation with the TRIR. These five specific safety practices (that were found to have the strongest correlation with the TRIR) were used in the formal correlation that was used to test the study's hypothesis.

Data Collection and Analysis from a Related Sample

Because project designers can influence hazard elimination through design, data were sought from firms participating in integrated design and construction, either by design-build contracting or traditional A/E consulting. The population selected for investigation was defined by a sampling frame. The sampling frame was defined by a published list of attendees from a major industry exposition and conference for integrated design and construction (Design-Build 2006). This population was referred to formally as the *designer-builders* or *designer-builder population* in this study.

The concept of interest concerning the designer-builder population investigated in this study was that when designers (engineers and architects) and builders are in more frequent communication with each other (as is facilitated by a design-build contract or project management method), enhanced construction safety practices will be a measurable outcome.

The data for this sample were collected by an on-line survey. The population selected for sampling contained 40 companies with engineering and architecture design services (Appendix C). Initial contact was made via telephone. If the individual contacted was interested in participating in the survey, the individual was directed to a website address to complete the survey form. The 40 companies in the population were aggressively contacted, which included multiple contacts when deemed prudent to maximize the sample response level.

The surveys were designed to gather information about engineering and integrated design-build practices related to PFASs that had been implemented from the designer's perspective. A list of practices that had been collected from a leading design-build firm in an earlier study was used as a baseline of proactive design-for-safety practices. Insights into the importance of design and engineering for the effective management of anchorage and fall arrest planning gained from an earlier study were also used to develop the survey questions (Hinze and Harris 2007b). Fourteen questions were included in the survey. The final version of this survey form is presented in Appendix B.

The data collected and analyzed from this sample of engineering and design firms were considered an exploratory investigation to gain clarification and insight into design influences on construction and fall protection safety. Due to the small sample size and exploratory nature of this component, statistical tests were not used to analyze the data. Data were analyzed by descriptive statistics, for example, frequencies observed for individual engineering practices.

Development of the Scorecard

In order to allow implementation of best practices in fall protection and PFASs in a comprehensive and flexible manner, a scorecard (or evaluation tool) was created for implementation in the industry. Results of this study were used to develop a method that could be used to quantitatively measure PFAS policies and practices within a given company. A safety measurement system of this type that has the capability of evaluating safety conditions prior to actual safety failures, injuries, and fatalities is considered a leading-indicator or proactive safety measure.

The scorecard was created by combining best practices investigated in the test of the study’s hypothesis with supporting policies and practices derived from the literature review. Two scorecard versions were created to address the distinct evaluation needs of:

- Firms interested in companywide safety improvement
- Firms interested in safety improvement of field operations (evaluation per project).

It was believed that many of the best practices that would be used to develop the scorecard had already been implemented by large contracting firms with proactive safety programs. In order to test the hypothesis that the scorecard was well-designed, comments from practicing safety managers and safety experts were solicited on the basis of *purposive sampling* to assist in refining the content of the scorecard.

Purposive sampling, also known as directed sampling, uses the researcher's insight to identify cases that are information-rich or to identify individuals with expert knowledge as a means of efficiently discovering patterns and factors pertaining to the subject area under investigation (p. 82, Erlandson et al. 1993). The purposive sampling methodology was used to select individuals believed to have knowledge of critical importance to the overall assessment of PFAS. This review and comment process was considered a means of validating the scorecard by subjecting its content to the analysis and criticism of safety management practitioners. In this research, each individual instance of this process is presented as a case study.

The case studies were conducted by contacting safety managers who had participated in the survey of fall protection and fall arrest system practices and had given their contact information for the benefit of the researcher. These practicing safety managers were asked to review the scorecard and comment on issues and possible limitations. Safety experts known to the researcher through industry associations were also contacted to review and comment on the scorecard.

Generally the case study participants were asked to comment on the usefulness and limitations (strengths and weaknesses) of the scorecard. The following types of questions were suggested to the case study participants in the course of the discussion:

- Do you already have scorecards or checklists that you use in your business?
- Does the scorecard seem valid?

- If one of your company's projects was scored using these criteria, would you consider that to be a reasonable assessment?
- If not, what qualifications or exceptions would you want noted?
- Are there any questions that are poorly worded or that need to be adjusted?
- Are there any important issues that are missing from the scorecard?
- Could you use this scorecard in your business?

Profiles of the case study participants who had submitted completed surveys were developed from survey data. Survey data used in the profiles included

- classification of their company based on annual revenue
- Hypothetical scores for fall protection practices implemented that were created by filling in the scorecard with the case study respondent's survey data, if no additional specific clarifications were collected during the scorecard validation/case study process.

The criticisms received during the case studies were an important component of the scorecard development and refinement process. The results of the critique were incorporated into the final versions of the scorecards.

CHAPTER FOUR
ANALYSIS OF FALL INJURY DATA

Safety research often begins with an analysis of recorded injury data in order to find the root causes and factors contributing to the particular category of injuries being studied (Hinze and Russell 1995; Hinze, Pederson and Fredley 1998; Loosemore, M. et al. 1999). Two sources of injury data were investigated: 1) a National Institute for Occupational Safety and Health report; and 2) an Occupational Safety and Health Administration data set obtained directly from OSHA.

NIOSH Data

In 2000, the National Institute for Occupational Safety and Health (NIOSH 2000) published a summary of *surveillance data and investigative reports of fatal work-related falls from elevations*. The fatalities in the report occurred during the period from January 1982 through 1997; most of these fatalities occurred in the construction industry.

The injury data summarized events from ninety one fatalities in a narrative manner, and typically included the following information:

- Year of incident
- Age and gender of the victim
- Location (state) of injury occurrence
- Relative strength of the safety program
- Company safety policy and safety training
- Whether or not victim had been issued PPE
- Important details of PPE usage and condition
- Anchorage details observed
- Scope of work.

Extensive information about the fatality accidents was provided in this publication. Because of the high level of detail contained in the report, all of the injury cases were analyzed. The individual cases were reviewed and coded for the extent that they pertained to PFASs. A statistical software package (SPSS 12.0 for Windows) was used to code the data. The data were categorized by answering the following questions:

- Was PFAS usage and compliance required?
- Was PFAS equipment provided or available on the project for PFAS compliance?
- Was the worker in compliance with Subpart M when the accident occurred?
- Could non-compliance be characterized as a flagrant violation of safe PFAS practices?

OSHA Data

The OSHA data were collected through site investigations where construction workers were killed (U.S. Dept. of Labor 2004a). The data were provided in a form that was converted to an MS Excel file. The data represented information obtained from 1990 through mid-2004 and consisted of over 10,000 fatalities representing a multitude of injury categories. The descriptions for each injury case were recorded in a brief narrative form. For example, fall height, gender of the victim, and age of the victim were typically reported. Approximately half of the cases contained calendar dates of the occurrence time. The keyword, *harness,* was used to search the database for cases pertaining to PFASs.

The OSHA data were examined with a similar intent as the NIOSH data. Unfortunately, due to the brief nature of the accident descriptions, fault-tree analysis was not possible for these data. Data were examined to understand general causation of fall accidents involving PFASs. Because of an earlier study that comprehensively examined OSHA fall injury data (Huang and Hinze 2003), no further study of these data was deemed warranted.

Data Analysis

For both the NIOSH and OSHA data, some cases were eliminated from in-depth analysis. Cases were eliminated for the following reasons:

- The accident involved suspended scaffold systems and the worker(s) did not have a PFAS in use;

- By the logic of the hierarchy of fall control methods, PFASs were not deemed the appropriate fall control method;

- The workers were noted as not wearing their harnesses or not connected to competently-designed anchorages or lifelines in plain sight (a strictly behavioral violation). Conditions where workers temporarily disconnected their lanyards were often analyzed for insights into why workers violated the 100% tie-off objective;

- Confounding factors were involved that made characterizing the causes as strictly PFAS-related difficult; and

- The cases did not contain sufficient detail to make an informative analysis possible.

A sample of injury cases analyzed from the NIOSH and OSHA data are documented in Appendices D and E, respectively.

The overall analysis considered the following types of issues related to PFAS injuries:

- Was the employer committed to safety?
- Were fall arrest best practices reflected in administrative policies for correct equipment and practices?
- Was a hazard analysis of the task performed?
- Was a PFAS required?
- Were required anchorages and anchorage connectors identified at the planning stage?
- Was the PFAS inspected prior to use?
- Was the PFAS properly maintained?
- Was the PFAS properly used?
- Was the worker properly trained in the use of the PFAS?

Fault-tree Analysis

Fault-tree analysis was used by Loosemore et al. (1999) to identify causal factors in specific injury categories. Fault-tree diagrams have been used by engineers in general industry to analyze the interrelationship of various factors leading to failures of quality, reliability and safety. "A fault-tree diagram follows a top-down structure and represents a graphical model of the pathways within a system that can lead to a foreseeable, undesirable loss event" (Weibull 2007). The fault-tree analysis (from the top down) represented the following (Figure 4-1 and 4-2):

- The description of how the accident happened; a general narrative statement of the PFAS failure event
- Explanatory blocks containing general PFAS safety principles that were violated. A secondary level of narrative blocks was used in some cases if additional pathways for contributing factors were required
- Final level of the tree contained *failures of* specific safety management categories that were responsible for the loss. These categories were *safety culture, hazard analysis, administrative, supervision, training, and safe behavior.* These failure categories are the root causes of the fatality sought by the analysis.

Five fall injury cases from the NIOSH data were analyzed by the fault-tree analysis method (Fig. 4-3 through 4-7). The violations of PFAS safety principles that were identified from the initial analysis of the fatality reports were used as a starting point in the fault-tree analysis. If more than one central tenet of fall arrest system safety was not in compliance, the fault-tree diagram would show two main branches for PFAS safety principles violated. In general, the fault-tree analysis showed that fatalities associated with PFASs are complex events where a multitude of safety program features have underperformed or failed.

In order to comprehend the fault-tree analysis presented, the corresponding fatality report in Appendix D can be consulted. For example, Figure 4-3 refers to NIOSH report number 89-24. The report numbers listed in the left-hand column of Appendix D can be used to locate the transcript of the report. From the transcript of the report, it can be ascertained that the victim was a carpenter and that the victim fell 90 feet before coming to rest. The transcript explains in detail the noncomplying tie-off practice that was summarized in the Figure 4-3 as a lanyard that was *creatively tied-off to rebar*. This completes the first function of the analysis, which was to identify the failure event or general proximity of the problem. In other words, the simple explanation of the accident causation was that the lanyard came loose.

The fault-tree analysis is a root-cause oriented analysis technique. Therefore the analysis continues by examining the PFAS safety principles that would have been followed by knowledgeable safety engineers and managers in the construction industry. In Figure 4-3, this next level down in the examination of underlying causes (the safety principles violated) states that two aspects of the PFAS safety principles that were violated can be considered:

- Correct anchorage connectors were not used
- Correct personal protective equipment principles were not followed. That is, the PFAS user did not have a competent understanding of the required components in the fall arrest system. Specifically, the victim did not have the competency or correct training to choose the safe and appropriate anchorage for his task.

This is the level of underlying causation that would be subject to widespread recognition by knowledgeable safety professionals in the construction industry.

The final level of analysis in Figure 4-3 sought to further investigate the root causes by separating the causation into specific categories of safety management. As was noted above, when a fatality occurs on a construction site, the causation is fairly complex due to the fact that the project safety plan, the company safety program, and company safety culture are all contributors. In Figure 4-3, all of the management failures (hazard analysis, administrative, supervision, training, and safe behavior) are included in the diagram. The failure of safety culture as a root cause was not included in Figure 4-3, although it can be noted that a summation of all the management failure categories cited is equivalent to a safety culture failure.

This last observation about Figure 4-3 illustrates one limitation of the fault-tree analyses presented. The resulting analyses cite an average of four management category failures as root causes. Possible explanations for this result are as follows:

- Fatalities generally indicate a major or all-inclusive failure of safety management and culture
- The five cases presented in this chapter all examine fatalities.

The limitation of the analysis is that the fault-tree diagrams do not address accidents where serious and significant lost time injuries occur and the root causes that contribute to non-fatal injuries.

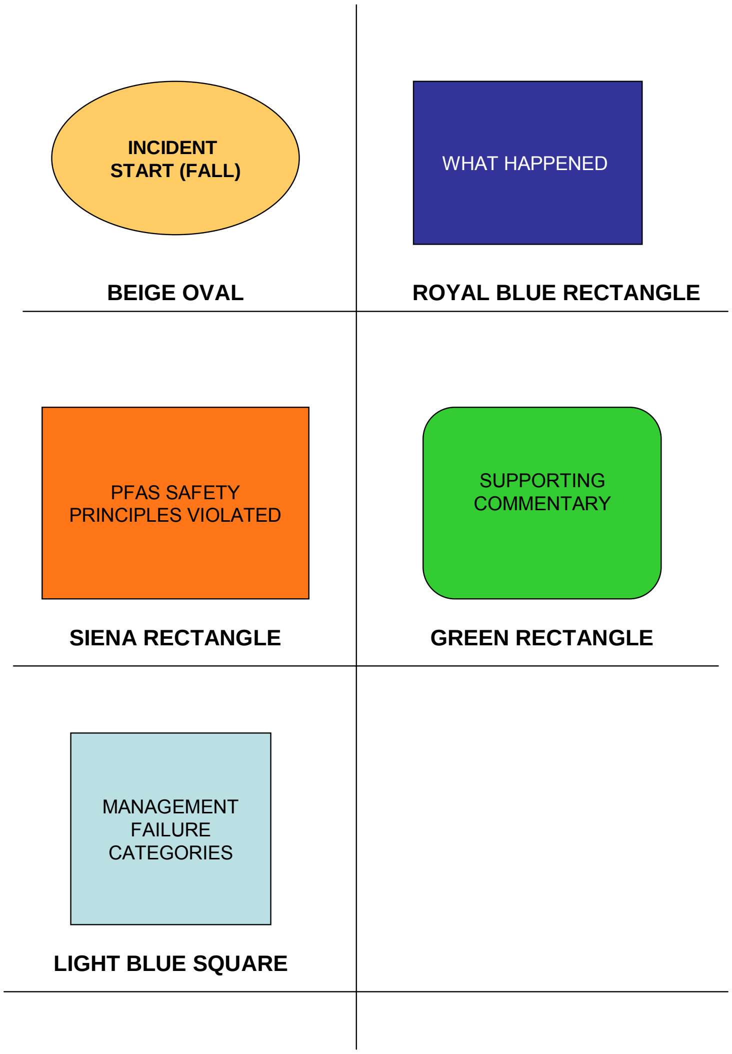

Figure 4-1. Graphic key to the fault-tree diagrams.

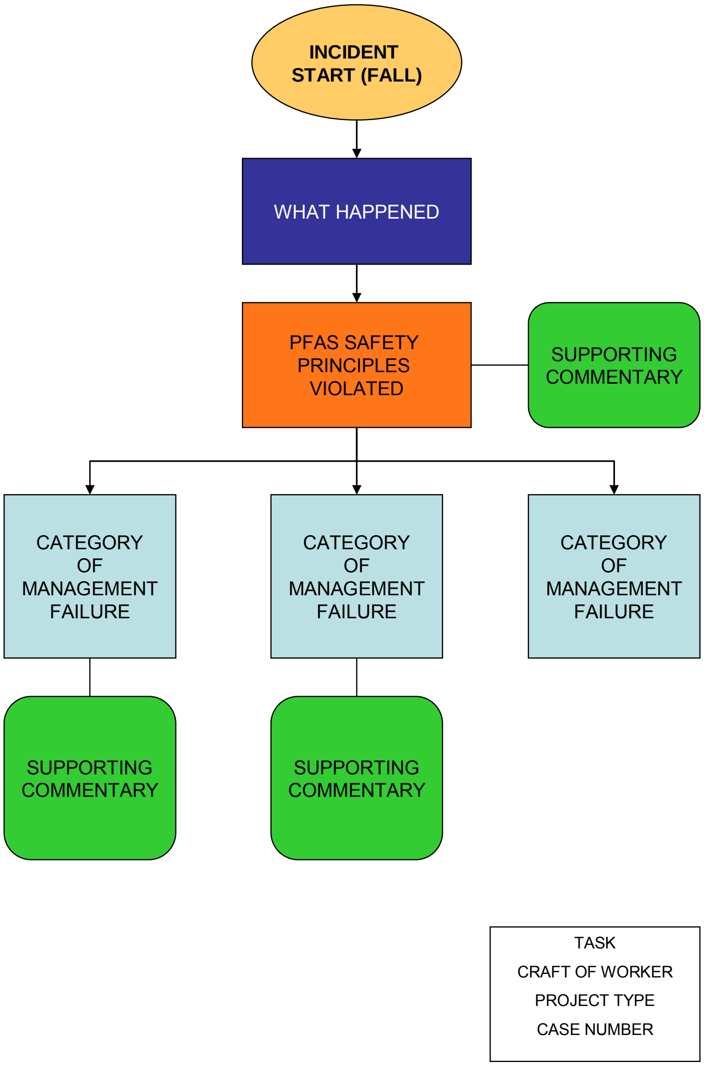

Figure 4-2. Sample fault-tree diagrams.

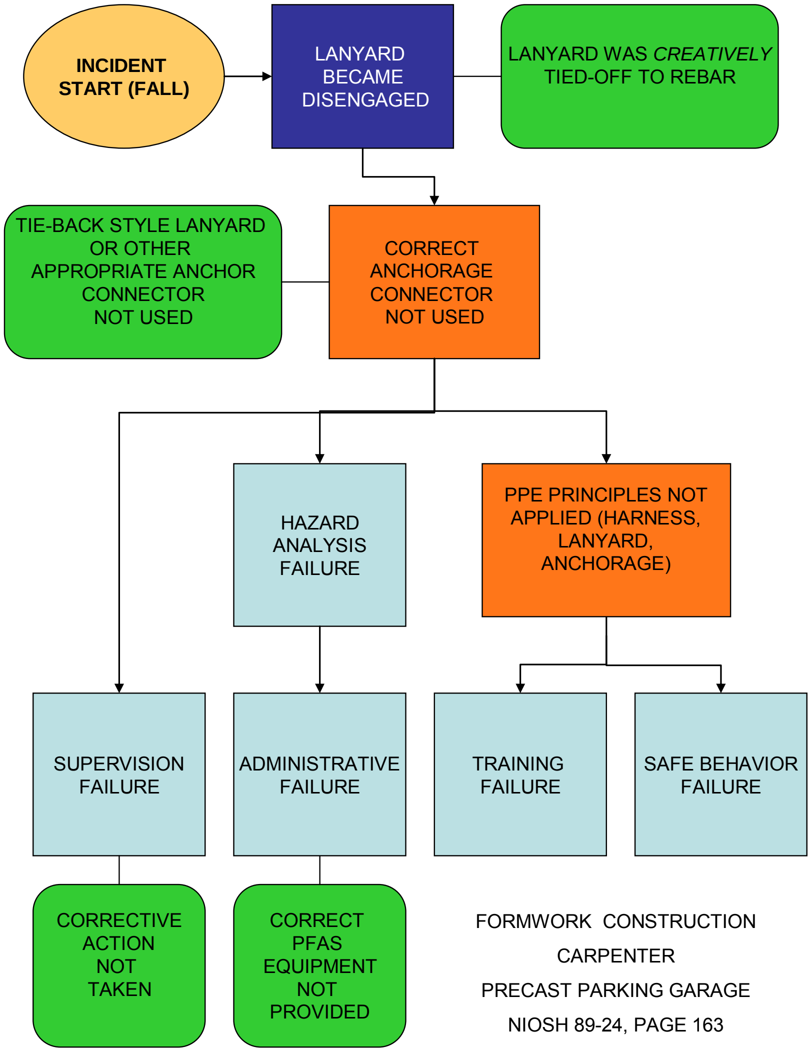

Figure 4-3. Formwork construction fault tree.

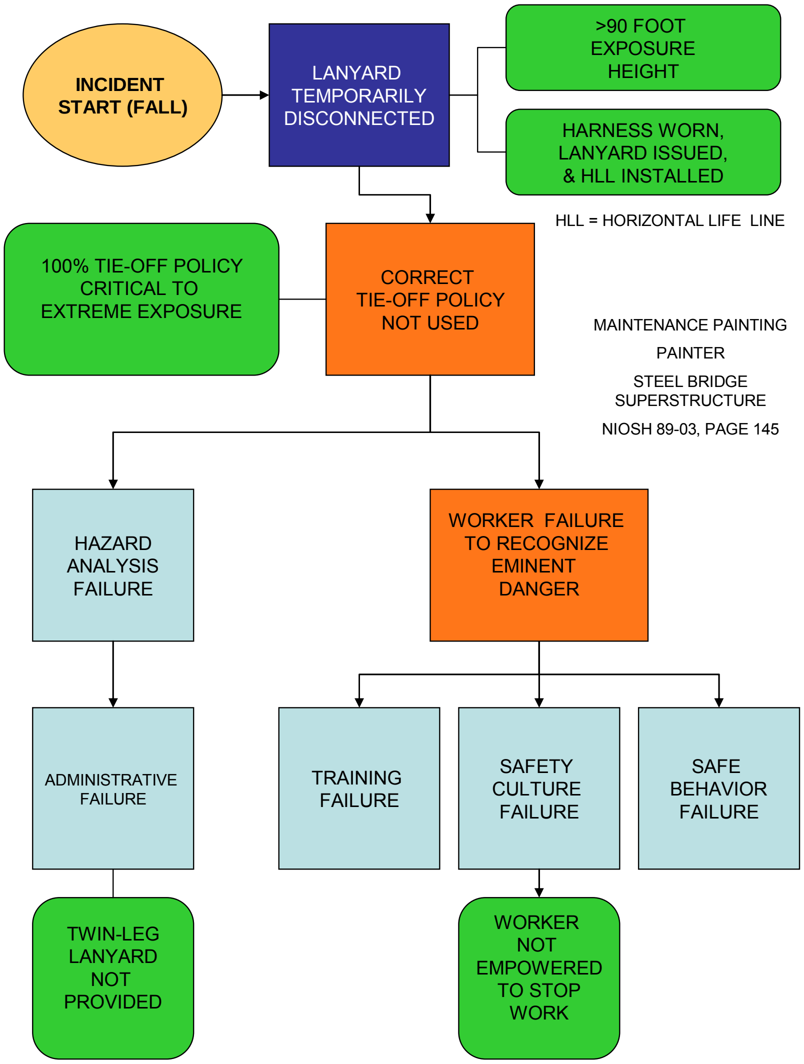

Figure 4-4. Maintenance painting fault tree.

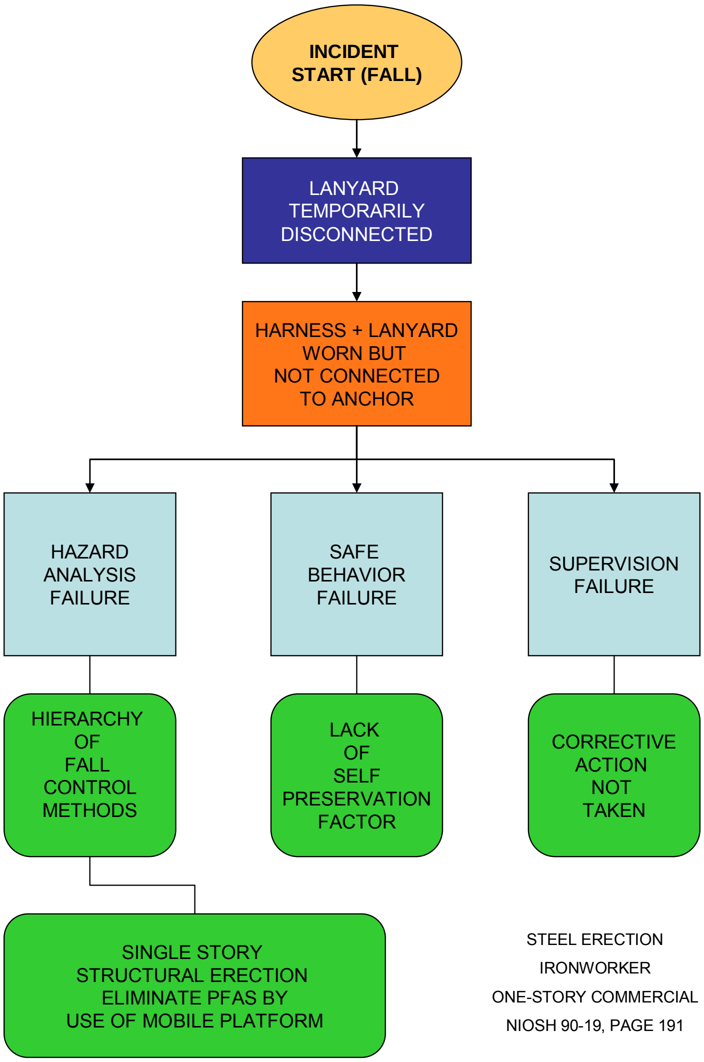

Figure 4-5. Steel erection fault tree.

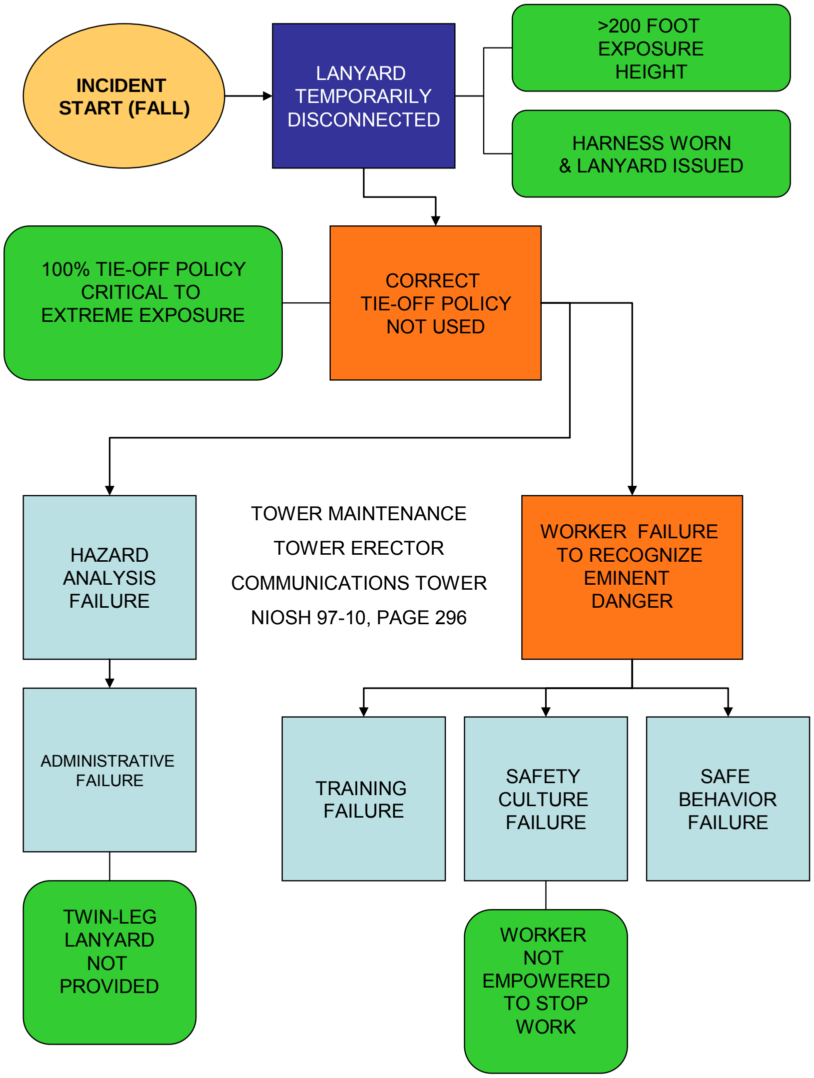

Figure 4-6. Tower maintenance fault tree

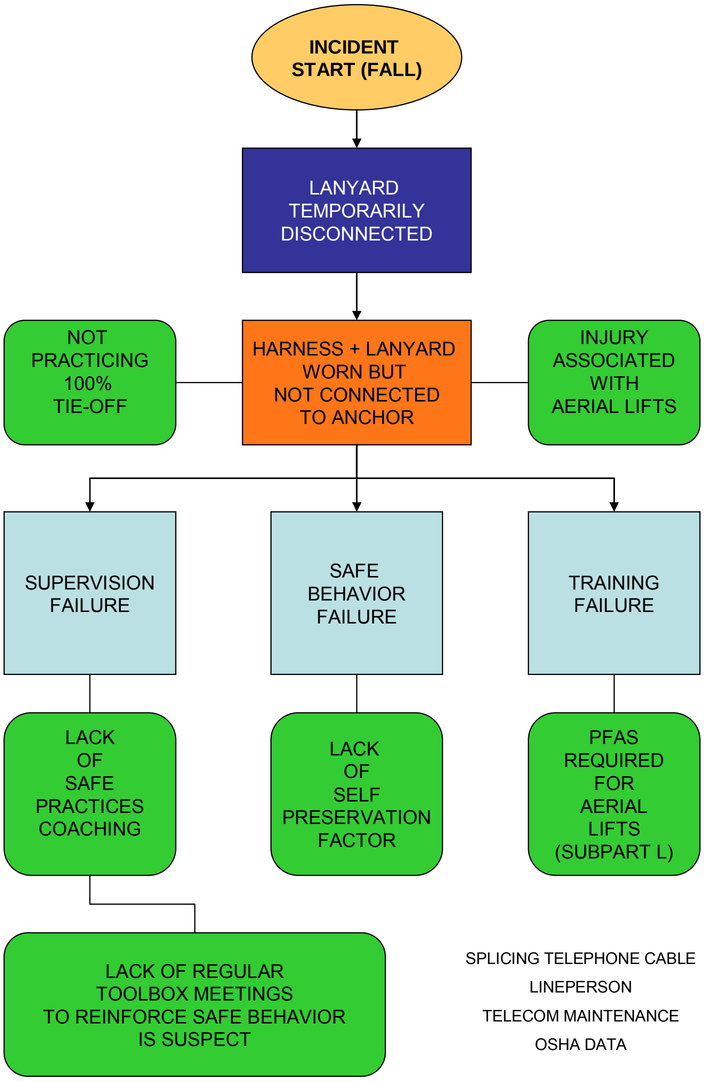

Figure 4-7. Splicing telephone cable fault tree.

CHAPTER FIVE

RESULTS OF THE FALL PROTECTION AND FALL ARREST SYSTEM SURVEY

Demographic and fall-protection-practices data were received from 99 survey respondents. There were 74 respondents who provided complete information regarding fall arrest system policies and practices implemented that were directly related to the research hypothesis. The response rates for data received from the three survey forms used in the data collection process are summarized in Table 5-1.

Table 5-1. Response rates for survey instruments.

Description	Preliminary Survey[1]	Fall Protection and Fall Arrest System Survey, follow-up version[2]	Fall Protection and Fall Arrest System Survey[3]
Data collection phase	First Stage	Second Stage[4]	Second Stage
Respondent	59	34	40
Non-respondent	341	13	313
Total surveys sent	400	47	353

1. Survey as presented in Appendix B. The first stage column count of respondents consists of 47 respondents (who gave contact information and were subsequently sent the follow-up survey version) and 12 respondents (no contact information, not included in follow-up survey) that sum to 59 respondents total. The response rate was 14.75%.
2. Survey as presented in Appendix B. This column presents the response rate for the companies that participated in the Preliminary survey and were subsequently sent the clarifications-oriented survey version with 24 questions. Regarding the count of total respondents, all thirty-four of the respondents in this column were counted as new survey respondents in the first stage column (that is, there were no new survey participants for this column). The response rate was 72.34%.
3. This column presents the response rate for the companies that were sent the safety survey version with 38 questions. Survey as presented in Appendix B. The response rate was 11.33%.
4. A total of 400 surveys were sent for the second stage data collection.

Thirty-four respondents to the first stage (who also responded to the follow-up survey) and forty respondents in the second stage of data collection sum to 74 total responses received. The response rate to the second stage data collection phase was critical to the study's objectives because the total recordable injury rate (TRIR) information was only sought in the second stage survey instruments. Testing the study's hypothesis was dependent on receiving data for each respondent's TRIR.

Data were collected in the following categories:

- OSHA compliance for various standard industrial classifications for workers
- Subcontractor management and safety clauses in subcontracts
- Project delivery methods and preconstruction coordination
- Design and construction integration
- Anchorage engineering
- Fall arrest system hardware management
- Worker and management safety training.

TRIRs were provided by sixty-three of the responding contracting firms. Two responses were removed from further consideration because of conflicting information in the data. It was determined in a comparison of these two cases that two safety managers from the same firm had inadvertently submitted information about the same company and that the information submitted was not consistent for all variables in the survey. With no way of resolving which responses reflected that company's policies, both of these responses were excluded from further analysis. The removal of these two responses resulted in a final sample size for analysis of 97 responses, with 61 providing information on the TRIR.

Descriptive Statistics for the Sample

This section gives results from the survey that includes information about:

- The specific fall arrest system practices implemented
- Qualitative comments collected from the respondent on an optional basis to clarify answers given or provide additional information.

As a baseline of compliance with the OSHA regulations for fall protection and fall arrest systems (as contained in OSHA, Subparts L, M, R & X), respondents were asked whether their firm's policies exceeded the regulations [Question 1, Fall Protection and Fall Arrest Systems (PFAS) Survey; refer to Appendix B]. Over 80% of the respondents (n = 72) answered in the affirmative for this question (Figure 5-1). Respondents answering in the affirmative were asked to specify which trades might be included in their company's mandate to exceed OSHA compliance:

- Steel erectors and ironworkers
- Scaffold erectors
- All trades without exception.

Of the 58 respondents that indicated in the affirmative for having a mandate to exceed OSHA regulations, 86% indicated the third option, which was interpreted as making the other options non-applicable by virtue of being an all inclusive answer (Figure 5-2). The fourteen percent of the respondents that did not select the all-inclusive policy option, instead indicated either steelworkers or scaffolding erectors or both steelworkers and scaffolding erectors as trades to which their firm's beyond-OSHA-compliance mandate applied.

The twin-leg lanyard is a PFAS component that gives workers the option of being continuously tied-off when used correctly. The secondary (or extra) leg of the lanyard is intended to be attached across any gaps in the anchorage or horizontal lifeline before the primary lanyard is detached. When used in this manner, workers remain tied-off to solid anchorage for 100% of the timeframe for a fall hazard exposure. Regarding the all-inclusive nature of the first question in the survey, respondents were then asked if their companies had a policy requiring all workers using PFASs to exclusively use twin-leg lanyards. Forty-two percent of the 72 respondents indicated that all PFAS-users were required to use the twin-leg lanyard. Four survey respondents declined to affirm the exclusive usage policy for twin-leg lanyards, but offered anecdotal comments that their firm did have either task-specific or trade-specific policies for the twin-leg lanyard equipment. One of these anecdotal comments also indicated that the adoption of a new policy requiring exclusive use of twin-leg lanyards was pending final approval (or soon to be implemented).

Subcontractor Management

A series of questions examined subcontractor management issues because of their importance to overall safety performance for general contractors. The respondents universally recognized the need to contractually clarify the importance of compliance with the OSHA safety regulations as a baseline of safe projects; all 97 responses in the survey answered in the affirmative when asked if OSHA compliance was specifically addressed in their typical subcontractor agreements. Other questions that asked about subcontracts included:

- To measure the extent that the contractors valued having a PFAS-competent person associated with each work crew, respondents were asked if their subcontract agreements required trade contractors to assign a foreman trained in fall arrest systems to each crew using PFASs. Over 75% of the respondents answered that assignment of competent persons was required by their subcontract agreements (Fig. 5-3).
- To measure the importance placed on monitoring the subcontractor's fall protection and fall arrest system planning by the general contractor, the respondents were asked about subcontract requirements and project specific fall protection plans (Fig. 5-4). Over 70% of the respondents answered that subcontractor submission of fall arrest plans was required by subcontract agreement.

Project-specific PFAS plans are important to fall arrest system safety performance because they provide a baseline level of documentation and planning for trade and task coordination. Fall arrest system plans also provide the opportunity to document that pre-project planning has considered specific project conditions pertaining to anchorage. The survey specifically asked for clarification regarding the anchorage component of the plans to measure the extent that contractors recognized the benefits of anchorage documentation (Question 9, PFAS Survey). When asked if anchorage was included in the fall protection and fall arrest system plans submitted by their subcontractors, the percentage of fall arrest plans that met this criterion was 77% (Fig. 5-5).

Project Delivery and Preconstruction Coordination

In addition to more well-known benefits accruing to design-build project delivery such as the elimination of change orders, the enhanced communication and coordination between the constructor and designer typically has provided better opportunities for safety improvements. To the measure the influence of design-build project delivery on safety performance, respondents estimated the percentage of recent projects that were under design-build contracts out of the total contracts within the company (Fig. 5-6). Design-build contracts were utilized by more than 30% (median of 20%) of the respondents.

Design and Construction Integration

Several survey questions pertained to fall protection and fall arrest systems and how they were influenced during the preconstruction phase by the communications between the project owners, the contractors, and designers. This area of the investigation was characterized as strategic planning for fall protection and arrest systems at the project management level in the literature review for this study. Questions were intended to investigate three aspects of strategic planning to reduce worker exposure to falls:

- Suggestions made to the owners that were intended to improve fall protection and arrest systems;
- Suggestions made to the designers (engineers and architects) that were intended to improve fall protection and arrest systems; and
- Suggestions made that indicated an awareness (within the responding contracting firm) of the elimination of fall exposure hazards per the hierarchy of fall controls theory (the hierarchy of fall controls theory was presented in the literature review of this study).

Eighty-five percent of the respondents indicated that they had provided preconstruction comments to the owners (Fig. 5-7) (Question 33, Preliminary Survey and Question 19, PFAS Survey). Several respondents commented that their firms had implemented *deck-to-deck* vertical net/guardrail systems as an improvement over the OSHA-compliant, 39-inch-height perimeter guardrail systems. Seventy-four percent of the respondents indicated that suggestions intended to improve fall protection safety were shared with the architects and engineers (Fig. 5-8) (Question 27, PFAS Survey).

In a recent study of fatalities that involved full-body harnesses, injuries associated with roofs and PFASs were shown to be the most frequent category (24%) for accidents when analyzed by location (Hinze and Harris 2007a). An important engineering measure that greatly reduces hazards for workers when applicable (as is the case with most low-slope roofs) is to include a permanent roof parapet (that complies with the OSHA guardrail safety standard) in the design of projects. To measure strategic fall protection activity in regard to these facts, respondents were asked if their communications with the design team had included raising a building's permanent roof parapet up to a safety guardrail height (Question 31, Fall Protection and Fall Arrest Systems Survey). Forty percent of the respondents answered that the parapet safety suggestion was made either frequently or on "every applicable project" (Fig. 5-9).

Comments were received (in the preliminary survey) about preconstruction communications with the project designer to improve fall protection and arrest systems. Respondents were asked to provide comments for applicable projects in two categories:

- General suggestions to A/E consultants and project designers; and
- Specific communications about parapet heights not in compliance with OSHA guardrail regulations.

The comments covered a wide range of sentiments about managing the design in the preconstruction phase. Comments ranged from proactive and positive actions to passive and negative approaches. Several proactive responses noted their companies had implemented a design-for-safety or "safer-design-principles" program. For example, one respondent noted that their superintendents were actively engaged in constructability reviews during the design phase.

On the negative end of the spectrum, one frustrated respondent stated that there had been a "huge resistance from architects to get involved in safety. Building operations/maintenance [safety] is easy to get architects to consider. Not so for construction [safety]." In regard to the suggestion that parapets be raised to comply with OSHA regulations, one respondent reported about their attempts that "it [the suggestion to raise parapet heights] changes their design so they are pushing back." In other words, some designers do not appreciate design suggestions offered by the contractors, and they generally ignore such input.

One respondent commented that on projects involving historic structures, permanent fall protection and arrest system improvements were limited by compliance requirements set by historical restoration standards.

Nonparametric statistical tests for independence were conducted on the data regarding the offering of suggestions to the project designers intended to improve fall protection safety (nominal answers to Question 27 in the Fall Protection and Fall Arrest System Survey). The Kendall tau-b correlation coefficient was computed using the data for Question 27 and the TRIR as the response variables. The resulting tau-b was not significant at the $\alpha = 0.05$ level, and the variables were deemed to be independent.

Anchorage Engineering and Fall Arrest System Hardware Management

In order to better understand the population's behavior regarding the occasional need for custom-engineered PFAS components such as specialized anchorage or horizontal lifelines, respondents were asked about engineering services (Questions 21-25, Preliminary Survey). Respondents indicated the type of engineering services they had obtained for engineered components (Fig. 5-10); any combination of four common types of service providers could be selected. The categories were not presented as mutually exclusive. That is, the respondents were instructed to select all responses that applied. Engineering services provided by the consulting groups operating within the major fall protection manufacturing companies were the most popular choice (nearly forty percent).

Other questions were asked about managing the risks inherent in the fall arrest hardware. In order to investigate the extent that the contractors were monitoring common risks in connector hardware (snaphooks, anchor connectors and lanyards), the respondents were asked about policies implemented to address the following issues:

- High impact side-loading of carabineer/snaphook gates
- Usage of connectors or lanyards with damaged webbing
- Usage of inadequately engineered rigging or anchor connectors
- Safe anchorage availability (or lack of the same)
- Unsafe usage of small diameter wire ropes.

Respondents were instructed to select all applicable categories (Fig. 5-11). Policies and practices implemented to control the availability (or absence) of safe anchorage and to control risk due to worn-out or damaged webbing (a material used in all of the three major components of PFAS: anchor connectors, lanyards and harnesses) were the most frequently selected (80% of the respondents) items in the group. Inadequately-engineered anchorage and other rigging (for example, horizontal life lines) was selected at a frequency of 72 % for the sample. High-impact side-loading on snaphook and carabineer gates was selected by forty-two percent of the respondents, a frequency that was considerably less than for the other choice categories.

Training

In order for supervisors to facilitate and enforce safety compliance, they would be expected to receive specialized fall arrest systems training. Respondents were asked about the percentage of their superintendents that had received specialized PFAS-training (Question 7, Preliminary Survey and Questions 12-14, PFAS Survey). Over seventy-five percent of the respondents answered that all (100%) of their firm's superintendents had received specialized fall arrest systems training (Fig. 5-12).

Respondents were also asked to provide information on the number of hours of specialized training in fall arrest systems that their managers and superintendents received. No attempt was made to assess the time frame or quality of the training. The mean quantity of hours of PFAS training for the sample was 5.4 hours and the median was 4 hours. Respondents were also asked if the training offered to superintendents and managers typically included a competency test (Figure 5-13). A majority of the responding companies have been requiring middle management to complete a competency test as a component of their fall protection and fall arrest system training.

In the preliminary survey, to measure the extent that the respondents relied on the major fall protection manufacturers for educational support, respondents were asked if their company had utilized the training seminars offered by the fall protection manufacturers (Question 55). Eighty-one percent of the respondents answered affirmatively (Figure 5-14).

Descriptive Data for the TRIR Variable

Information was requested on the total recordable injury rate of the responding firms. Sixty-one companies provided this information. These data are presented in Table 5-2.

Table 5-2. Descriptive data for the TRIR variable.

STATISTIC[1]	VALUES[2]
Mean	2.84
Std. Error of Mean	0.25
Median	2.41
Variance	3.89
Std. deviation	1.97
Range	10.04
Minimum	0.24
Maximum	10.28

1. Distribution for the variable is continuous.
2. n = 61.

Model for the Safety-Practices-Implemented Variable

The safety-practices-implemented variable (for use in the correlation test for independence) was created by synthesizing important safety practices from the Fall Protection and Fall Arrest System survey (38 variables total) into a single ordinal variable. A data analysis model was developed through an iterative process that explored and refined the safety-practices-implemented variable. The output objective of the model was a variable (an aggregate of safety practices and policies implemented) that had been selected and tested for its effectiveness in influencing the safety culture and fall protection program.

Descriptive statistics were generated for the 34 variables derived from the nominal survey questions; Table 5-3 presents a summary of the data from the Fall Protection and Fall Arrest System survey.

Table 5-3. Data categories in the Fall Protection and Fall Arrest System survey.

Measure of Variable	Count
Nominal (yes or no questions)	34
Scalar	4
Total	38

The following nine nominal variables were selected for testing using the model:

- Beyond OSHA compliance: tie-off applies to all workers without exception;
- Policy requires all workers using PFASs to exclusively use twin-leg lanyards;
- Subcontractors are required to assign a competent person to each work crew (PFAS);
- Subcontractors are required to provide project specific fall protection plans;
- Required fall protection plans specify the location of anchorage connection points;
- Worker attitudes toward PFAS safety are examined;
- Specialized PFAS-training for superintendents includes a competency test;
- One-hundred-percent ANSI label or manufacturer labels required on all fall arrest equipment on-site; and
- All custom-designed anchorage and lifelines must be stamped and signed by a professional engineer (PE).

In addition to the descriptive statistics already generated, correlation coefficients were also generated for these nine variables. The correlations measured the rank correlation between the nine nominal variables and the total recordable injury rate (TRIR) variable. The frequencies and correlation coefficients for these variables are presented in Table 5-4. The correlations were expected to be positive values because of the coding for the practice-implemented variable (yes = 1 and no = 2). The values for the TRIR variable were expected to increase if fewer safety practices were implemented (equivalent to a “no” answer). For example, a scatter plot diagram for the correlation of the all-inclusive tie-off variable and the TRIR variable reflects this result (Figure 5-15). Not all of the correlations followed this pattern; negative correlation coefficients were generated for a few of the variables tested.

Twenty-five nominal variables were not selected for analysis in the model. Justifications for these exclusions from the model were as follows:

- The answers to a survey question with an affirmative response rate (yes answers) between 90% and 100% were not expected to be significant in differentiating the proactive and robust fall protection programs from the balance of the sample (5 cases).
- The questions in the preconstruction section of the survey (*Project Management and PFASs* was the equivalent section in the preliminary survey) regarding the influence of owners and project designers were predominantly exploratory in nature. These questions were not deemed useful in developing the safety-practices-implemented variable. The responses to the questions in this area of the study are compromised by the presence of unresolved variance within the survey questions (12 cases). The meaning of the term *unresolved variance* can be clarified by consideration of the following example. When a respondent answered affirmatively to the question, “Has your firm made suggestions to the owner about using design for safety to lessen the extent of fall protection and arrest system usage,” a high degree of variance is imbedded in the nominal yes answer because it is not known if the owner appreciated the value of the information and intended to respond proactively to improve safety on the project. It is also not known what actions were taken by the owner to compel the project designers to address the safety of construction workers by adding safety features to the project.
- The question associated with answers 34-38 regarding practices implemented “to reduce risks” from any of five typical hardware problems was deemed to be too vague with regard to specifying the details of how the risk was being controlled (5 cases).
- The balance of the questions (3 cases) in the survey was associated with the first question in the survey regarding policies and practices that exceeded OSHA compliance. The data collected for these variables were important, but were superseded in importance by the affirmative answer that an all inclusive policy had been implemented.

The model used an iterative process where alternate configurations of the variables were tested. For example, a grouping of five practices was formed by ganging individual practices together and assigning a score from zero to five (0-5). This grouped and scored variable was then used in a rank correlation with the TRIR variable. This preliminary test was based on the expected format to be used later in the study with the formal test of independence used for testing the hypothesis.

The intensity of the rank correlation (where a higher value for the coefficient equals higher intensity of correlation) for the individual variables in the model was used to determine an individual iteration of the model. Due to the significance and high coefficient value ($\tau = 0.221$, $p < 0.05$), the implemented safety policy requiring 100% ANSI label or manufacturer labels on all fall arrest equipment on-site was used as a starting point for all the iterations generated. Although the coefficient for the implemented safety policy requiring the exclusive use of twin-leg lanyards for all PFAS-users on site had a relatively weak correlation coefficient, the strength of the original survey question was considered in the model.

At the conclusion of the testing using the safety-practices-implemented variable development model, the aggregate information determined to have the strongest association with the TRIR was formed into a variable by synthesizing the following five safety policies (descriptive data for the safety-practices-implemented variable are presented in Table 5-5):

- Beyond OSHA compliance – tie-off applies to all workers without exception
- Policy requires all workers using PFASs to exclusively use twin-leg lanyards
- Required fall protection plans specify the location of anchorage connection points
- One-hundred-percent ANSI label or manufacturer labels required on all fall arrest equipment on-site
- All custom-designed anchorage and lifelines stamped and signed by a professional engineer (PE).

Results of the Test for Independence

As described earlier in the methodology for this study, the null hypothesis to reject or accept was that the TRIR was independent of (or not significantly associated with) the best practices in fall protection and fall arrest systems. In terms of the statistical procedure used, independence was measured by the degree of association in a Kendall tau-b rank correlation. The null hypothesis to accept or reject using this procedure was that the value for the correlation coefficient was equal to zero, indicating no association or zero correlation between the x-value (the best practices) and the y-value (the TRIR).

Based on sixty-one valid cases (n=61) from the survey data, the statistical software package (SPSS) was used to run the Kendall tau-b correlation test, one-sided test option. A general overview of the data for this procedure is presented in a scatter plot (Figure 5-16) and a means plot (Figure 5-17).

The results of the test (the Kendall tau-b correlation procedure, one-sided option) showed that an association (or dependence) between TRIR and an increase in the best practices in fall arrest systems does exist ($p < 0.05$). The Kendall tau-b correlation coefficient for the procedure was -0.208. From this result of the test for independence, the null hypothesis was rejected.

A stronger association was thought to be obtainable by eliminating outlying values in the initial correlation test. A revised test of independence was conducted that eliminated the high and low correlation values in each of the six *scorecards for best practices* categories on the x-axis. Twelve outlier values were excluded according to this procedure (Fig. 5-18).

When observing the revised scatter plot for the test, it was noted that the small number of remaining data points in the zero and one categories of the x-axis made the inclusion of these two categories in the revised correlation test unreliable. These four data points were also eliminated from the final version of the revised test of independence.

The Kendall tau-b correlation coefficient for the revised test was -0.315. The significance level for this revised test was $p < 0.01$. A plot of median values (Fig. 5-19) and a final revised scatter plot were generated (Figure 5-20). The results of the procedure (when limited to the lower right quadrant of the scatter plot by applying the outlier exclusion procedure described earlier) showed a stronger association (correlation coefficient $\tau = -0.315$, $p < 0.01$) between TRIR and an increase in the best practices in fall arrest systems exists for those contractors scoring above 1.0 points (equivalent to 2 or more of the best practices implemented). This result ($n = 45$) was achieved by excluding sixteen of the total respondents.

Development of the Scorecard

The best practices in fall arrest system safety presented earlier and found to be statistically significant were incorporated into an evaluation tool called the *Fall Protection and Fall Arrest Systems Scorecard, project version* (Table 5-6). The supporting practices included in the evaluation process were not tested as rigorously as the core group of best practices and were weighted appropriately. The supporting practices were either 1) developed from policies and practices identified in the literature review; 2) directly and logically support the core group of best practices; or 3) were developed through conversations with safety managers working in the construction industry. This scorecard was intended to focus on the field operations of a construction firm.

A second scorecard was developed that incorporated the home office functions or companywide operations of a construction company. This second scorecard allowed for a focus on corporate level issues at a large contracting firm, including:

- Project delivery methods
- Strategic planning issues for safety management
- The third party (owners and designers) effects on fall protection and PFASs.

Many of these factors and effects were discussed under the Strategic Planning for Fall Protection subheading in the literature review of this study. This second version of the scorecard is presented in Table 5-7.

The scorecard was intended to be implemented as a self-evaluation tool by a firm seeking fall protection excellence, whether companywide or on a specific project. Because the items on the scorecard reflect management practices and policies, the scorecard does not require a physical inspection of the jobsites and the scorecard can be completed in the home office. All of the questions on the scorecard require nominal yes-no answers.

To complete the scorecard, answers must be provided on the top five questions (the core best practices). To compute a score, the number of yes answers would be added, and the sum multiplied by 10 points as noted on the scorecard. This process creates a subtotal score for the core best practices area. The same process is completed for the supporting practices section and the two subtotals (core best practices and supporting practices) would be combined to generate the final score. The highest score possible is 100 points.

Scorecard Validation Case Studies

Critical review by safety management practitioners was sought to test the validity of the scorecard with regard to implementation as a safety evaluation tool in the construction industry. The critical review of an individual practitioner is presented as a case study. The individual interviews with the safety managers are presented in series below. The series order does not imply any type of ranking and is based solely on the order in which the data was received. Table 5-8 presents five different classes of companies in the study's population that are classified according to the companies' total annual revenues (annual revenues for contracts signed). The data for this classification was collected during the study's data collection phase. These classifications are intended to augment the general profile of each respondent that is presented in the introduction to each case study.

All of the case study respondents were participants in the Fall Protection and Fall Arrest System survey (preliminary and follow-up versions). Generally, these respondents can be considered proactive and aggressive safety managers with excellent safety performance records (company TRIR values for the case study participants ranged from 0.5 to 2.5). Several of the case study interviews included the submission of scorecards that were completed by the respondents. Respondents were typically supportive of the content and wording of scorecard items that generated yes answers. Scorecard items that generated no answers often generated questions and clarifications that resulted in important suggestions for scorecard revisions.

Personal telephone conversations with the respondents were the primary means of data collection. These phone interviews were used to discuss the respondent's questions and criticisms of the scorecard's content and/or intention.

Scorecard Case Study 1

The case study 1 respondent was an upper management-level safety manager for a contractor engaged in commercial building construction. This company has nationwide operations and employs 750 field workers. Craft work is performed exclusively by subcontractors. Based on the revenue classification in Table 5-8, this company was classified as a class-A company ($1 billion and over in annual revenue). Overall, the respondent commented that the scorecard was a useful resource that could easily benefit companies in the construction industry. The respondent stated that checklists and audit forms similar to the scorecard were frequently used in the safety department at their company.

With regard to the project version of the scorecard, the respondent was concerned that the scorecard should address the "documentation trail" aspect of the project safety plan. Because the respondent's company acts as a construction manager on a typical project, their safety management system can be characterized as emphasizing safety metrics. Safety metrics is a term commonly used in the industry to describe document management systems and performance verification practices that rely heavily on computer systems and Internet-based communications. Internet communications with subcontractors and intranet communications between different levels of management play an important role in safety management, particularly in large construction companies with nationwide and/or global operations. Fall protection related items that could be addressed and documented with reports and logs include

- Coordination meetings with owners, designers, and vendors
- Project-specific hazard analysis
- Pretask planning
- Preconstruction meetings prior to subcontractors coming on site
- Orientation of workers
- Specialized PFAS-training of workers, foremen and superintendents
- OSHA reporting systems
- Testing of equipment and fall arrest systems
- Periodic formal safety inspections.

Line item 9, project version (Are workers empowered to stop any work deemed unsafe?) was specifically noted by the respondent for possible inclusion in a revised scorecard as a core best practice. The respondent felt that creating a project safety culture where all workers on site were trusted and empowered to assure safe behavior was critical to dispersing safety enforcement and participation over the entire project (regardless of the presence of a jobsite coordinator or safety manager).

Based on the discussion of the scorecard (and the respondent's survey data), the respondent's company scored 50 points of the possible 50 points for the core practices section of the scorecard on the majority of their projects (Figure 5-9). Regarding the obstacles that the respondent has encountered to full compliance with the core best practices, the respondent reported that ironworkers and their trade unions have resisted implementation of the twin-leg lanyard requirement for applicable trades and tasks. The respondent estimated that 60% of projects in the United States had been successful in implementing the twin-leg lanyard requirement.

The respondent stated that steel erection was a trade specialty where implementation of the twin-leg lanyards can be effective in reducing injuries. For example, when ironworkers move from one beam to the next beam in the structure, the redundant tie-off function of the twin-leg lanyard allows 100% tie-off. The respondent noted that the resistance to twin-leg lanyards implementation was decreasing as trade unions became better informed about the philosophy of 100% tie-off. With regard to the non-applicability of the twin-leg lanyard to certain tasks, the respondent confirmed this study's postulate that personnel lift operators are a common class of workers that can be exempted from the twin-leg lanyard requirement.

The respondent made comments on the companywide version of the scorecard that concerned upper management interaction with middle managers and workers. As a companywide indicator of a strong safety culture, the respondent recommended adding a line item in the scorecard that addressed the benefits of collaborative management efforts between all the different levels of managers and workers:

- Upper management
- Middle managers
- First-level supervisors
- Craft workers.

The objective of this collaborative management would be to work together on best practices development and other problems-solving tasks that can improve safety performance. Another progressive management practice that the respondent recommended for the scorecard was the implementation of a safety performance accountability system. The respondent felt strongly that a line item in the scorecard should address the importance of accountability and the individual employee's actions (positive or negative contribution to the overall success of the company's safety program).

Scorecard Case Study 2

The case study 2 respondent was the safety director for a contractor engaged in commercial building construction with regional operations. This respondent's company operates primarily as a construction manager and employs 200 field workers as general laborers. Based on the revenue classification in Table 5-8, this company was classified as a class-D company (annual revenue range from $200 million up to $300 million).

In the respondent's Fall Protection and Fall Arrest Systems survey response, a negative answer was given to question 1 (PFAS survey, follow-up version) regarding jobsite safety practices that exceeded the OSHA regulations. In the course of discussing the scorecard, the respondent clarified that under favorable contract conditions, the opposite was true for projects at his company. That is, the OSHA regulations were exceeded as noted in the scorecard (there are no exceptions to to the mandate that all workers shall be tied-off when working at 6 feet or more above the walking surface). The respondent stated that under these same favorable conditions (characterized as projects with proactive, safety-oriented owners and contract values at or above $ 25,000,000), a project scorecard for the core practices (50 total points possible) would typically be scored at 50 points (all 5 core practices implemented). A substantial discussion and explanation regarding the variables that contributed to the erosion of the *beyond OSHA compliance ethos* ensued.

The respondent's comments focused on the critical items in the owner's decision tree for project safety whereby proactive and robust safety practices can be nourished or discouraged. The general comment was that on the smaller projects (contracts less than $25,000,000 and structures less than 3 stories tall), the owner's behavior tends to reflect a laissez-faire attitude toward the project safety plan whereby OSHA compliance is the governing standard of safe behavior.

The respondent stated that the bidding process was the critical juncture for project safety on the smaller projects (contracts less than $25,000,000). An important characteristic of the laissez-faire owner attitude was the unwillingness to commit to an aggressive safety mandate whereby all bid documents (plans, specifications and submittals) can be required to support project safety by means of safety-oriented revisions and inclusions. Without the safety-oriented bidding mandate from the owner, OSHA compliance is the typical industry assumption in commercial building construction. The respondent provided examples of how the subcontractor's attitude towards project safety was typically influencing the general contractor's bid. For example, steel erectors had submitted bids about 25-30% higher when they were required to comply with the 6 foot tie off requirement. Masonry contractors had added about 15-20% when the 6 foot rule was applied to their scaffold building and worker access. Hence, the general contractor's bid would remain competitive only if the 6-ft. tie-off rule was owner-mandated for all bidders.

The respondent stated that when a general contractor acts as a construction manager, the owner's influence on project safety (by creating a safety-oriented bidding process) can be critical to receiving bids from proactive, safety-oriented subcontractors. When general contractors perform substantial amounts of structural erection and other craft work with their own workforces, actual costs for safety training, equipment and overall safety culture management can be easily absorbed into the operations budget. When the general contractor relies heavily on specialty trade contractors (as is a common condition for commercial building construction), the respondent stated that going beyond OSHA compliance is dependent on the directives from the owner to the extent that a fair, orderly and safety-oriented bidding process can be expected.

The respondent stated that another driver for the smaller projects (contracts less than $25,000,000) was the lack of a dedicated safety coordinator for the project. For example, if the scorecard was completed at the start of one of these projects, and the score generated was 80 points or more, the actual safety performance on the project could be comprimised due to the relatively weak safety coordination and enforcement effort. Without dedicated safety staffing, the superintendent is forced to bear the sole responsibility for safety enforcement and is inevitably worn down by the burden of managing the safety compliance issues pertaining to the trade contractors.

In reviewing the line items in the scorecard, the respondent cited typical fall protection-oriented practices that the safety department at his company was responsible for, including

- Fall protection training for the superintendents
- Weekly safety inspections which include checklists related to fall protection
- Pre-construction meetings with the subcontractors that involve safety issues including fall protection
- Periodic inspections of all jobsites by the corporate safety director (the respondent)
- Serious disciplinary actions for superintendents failing to enforce safety rules, especially fall protection safety rules.

Overall, the respondent summarized his commentary by stating that the score that an individual project would receive from the scorecard was dependent on which projects at his company were being evaluated. The respondent stated that "we [the safety department] have very strong support from management and the [company] owner himself but the realities of the variables listed above make this scorecard difficult to apply universally in the construction business."

Scorecard Case Study 3

This case study respondent was the safety director for a commercial building construction contractor with operations in one of the major regional markets. This contractor relies heavily on trade contractors to provide skilled labor for its projects. The trade contractors are expected to train the workers to conform to the general contractor’s safety culture. The company employs 750 field workers and was classified as a class E company (less than $200 million in annual revenue).

Based on the PFAS survey data submitted, the company scored 40 points out of the available 50 points for the core practices section of the scorecard (Figure 5-10). After the discussion began during the interview, the respondent clarified that anchorage locations were a strong component of preconstruction safety meetings with subcontractors (Line item 3 was the only core practice that the respondent had marked as a no answer in their survey response). The respondent stated that during the preconstruction subcontractor orientation process, the job safety plan was reviewed with the trade contractors and subsequently attached to their agreement with his company. The respondent was concerned that whatever the anchorage requirements were for the project, that these requirements can be described in the jobsite safety plan, not the site-specific fall protection plan submitted by the subcontractor. After discussion of possible language that might clarify the intent of line 3, the following alternate wording was proposed: Was anchorage identified in a site-specific job safety or fall protection plan?

The respondent stated that the scorecard’s omission of requirements for training documentation for individual PFAS-users employed by subcontractors was a source of concern. The respondent stated that if training documentation was not required of the trade contractors before their workers came on site, compliance with the jobsite fall protection plan was uncertain. Regarding line 6, project version, the respondent stated that terminating a subcontract agreement was not a preferred solution to safety non-compliance problems because of the impact on the project schedule. The discussion with the respondent suggested that line 6 could be reworded as follows

> Fall protection noncompliance: does your company have a threshold whereby retraining for entire subcontractor work crews can be required for noncompliance with safety rules?

The retraining of an entire subcontractor crew tactic came from an actual project safety intervention that the respondent offered as an example of an aggressive safety management action that could be used as an alternative to terminating a subcontract agreement.

Concerning line 4 and the procedures for inspecting PFAS harnesses and equipment, the respondent referred to an innovative use of radio frequency identification (RFID) technology that was being applied to PFAS equipment inspection and management by one of the major manufacturers. RFID tags were being sewed into the webbing of full-body harnesses to allow database integration and the generation of inspection reports in support of daily equipment readiness and inspection activities. For example, the safety coordinator conducts inspections of the condition of each worker's full body harness. The coordinator can use a radio frequency hand held device to collect data on

- The identification number of the harness
- The date of the last inspection
- The date the equipment was put into service
- Comments about wear and tear from previous inspections.

The respondent noted that the RFID technology could be helpful in improving efficiency in the equipment inspection process, especially on large projects where hundreds of individual pieces of PFAS equipment could be on-site.

The respondent inquired if the rescue of stranded or injured workers was considered for inclusion in the scorecard. It was noted by the researcher that the preliminary survey had included two questions designed to explore this topic. In support of the deferment of rescue operations to professionally-trained emergency rescue teams, an actual project incident witnessed by the respondent involving the local fire department was discussed. In summary, the respondent commented that professionally-trained emergency workers possess skills that his safety department would be reluctant to implement (due to a cost-benefit analysis) on a project with access to an emergency response network (911-telecommunications system). In support of contractor emergency readiness, the respondent commented that having superintendents that were informed about suspension trauma could facilitate the application of simple first aid activities for fallen PFAS users. For example, giving aid to a suspended worker can be a fairly simple practice to implement if individuals are trained to recognize first aid opportunities and take corrective action. The suspension pressure that acts on the legs and groin area can be relieved by standing in a foot harness, passed down to the victim from above if a knowledgeable person and the correct equipment are available.

The respondent completed the companywide version of the scorecard during the interview process; as shown in Table 5-11. In regard to item 7 (upper management participation in fall protection compliance reviews per project), the respondent asked for clarification about whether the question required participation in a fall protection compliance review that included a physical walk-through on-site by the company upper management. The respondent commented that upper management at his company was aggressively supporting the safety director (the respondent) and the entire safety department even if they might not actually make a physical visit to the site.

In regard to line 13 (all inclusive staff safety perceptions surveys), the respondent commented that his company had not considered conducting a safety perception survey, although the respondent referred to a book published in 2006, *Safety 24/7* by R. Lorber and G. Anderson that concerned companywide safety culture. The respondent stated that the book had been influential in influencing his company's safety culture and had been widely read by the company's upper management.

Scorecard Case Study 4

The case study respondent 4 was the safety director for a heavy civil general contractor with projects throughout the southeastern United States. The company employs 1500 field workers and self-performs the majority of work on bridge, marine, transportation and industrial projects. Based on the classification in Table 5-8, this company was classified as a class-C company (annual revenue of $300 million up to $500 million).

The interview was structured by a copy of the scorecard which was completed by the respondent; a facsimile copy (which had been returned to the researcher) was used to direct the discussion about the scorecard content (Table 5-12). In regard to line 4, the respondent initially marked a no answer, which the respondent justified due to the fact that horizontal lifelines at the company were self-manufactured and engineered and therefore did not bear the label of a major fall protection manufacturer. The researcher clarified that a properly engineered lifeline was a legitimate exception to the intent of the question.

Similarly to the other case studies, the no answers to the scorecard were discussed in detail, in order to confirm that the negative response was warranted. In response to line 7, the respondent commented that the schedule of his firm's projects and structural erection in general proceeded at a pace that made the monthly time-frame cited in the question inappropriate. The respondent also commented about this same question that his safety program was oriented more towards a behavior-based safety management philosophy where unsafe behavior was managed on a daily basis by safety coordinators. He suggested that the scorecard revisions can consider the behavior-based perspective of general contractors who employ large numbers of skilled craftsman and self-perform large amounts of the work under contract.

The respondent challenged the importance given to ANSI Z359 fall protection standards in line 13. The respondent stated that practicing safety managers were obligated to carefully consider the formal education level of their average PFAS user and to design training materials accordingly. The respondent stated that fall protection standards created under the auspices of the American National Standards Institute were more appropriate for review by the safety director than craft workers. The respondent suggested that upgrades in hardware and other PFAS equipment can be reviewed by safety directors and managers, and then passed on to the worker and jobsite operations. For example, if ANSI Z359 is considering upgrading the standard for snaphook sideload resistance, then the information can be passed on to the users in a simplified version after review by the safety managers without reference to ANSI Z359 committees or standards. The respondent commented that as long as the company's fall protection training, procurement and hardware practices reflected the state-of the-art developments in fall protection equipment that the PFAS users in the field can rely on the safety managers to make recommendations in their best interest.

The researcher explained that the concern for implementing policies requiring the most robust and heavy-duty snaphooks available was deemed important due to the fatalities that had been recorded in association with large snaphooks (also known colloquially as *pelican hooks*). The respondent commented that workers at his company used the pelican hooks exclusively for positioning tie-off functions.

Scorecard Case Study 5

This case study respondent was the safety director for a private real estate company specializing in the development of high-quality multi-family residential properties nationwide.

The company's portfolio includes residential high-rise, mid-rise, mixed use and suburban projects. The company owns and constructs all of the properties in their portfolio; 100% of the company's projects are delivered using design-build contracts. All specialty trade work is performed by subcontractors and the company employs a relatively small workforce of 150 field workers. The respondent's company was classified as a class E company (less than $200 million in annual revenue).

Overall, the respondent commented that the scorecard content was reasonable and well conceived as a fall protection evaluation aid. The discussion began with a clarification by the researcher regarding the assumptions of the scorecard's applicability. That is, the assumptions for application of the information were based on the typical safety practices and management structure of the study's sample of large contractors.

Similar to case study 3, the respondent asked for clarification on the companywide version, question 7. The respondent asked if a vice-president level of the upper management team was required to play an active role in the fall protection safety practices in order to generate a yes answer to this question.

The respondent asked for clarification with regard to the project version, line 7 (does project safety plan require that a formal fall protection and PFAS compliance review be completed monthly?). The discussion that followed assisted in shaping the researcher's perspective regarding general contractors who function as construction managers and rely heavily on subcontractors to manage worker training and safe behavior. The respondent commented that because his company manages their typical projects as a construction manager with projects nationwide that they use audits and inspections as leading indicators of safety performance. The respondent stated that requiring their subcontractors to participate in these audits is an important aspect of his company's proactive safety culture.

In regard to the project version of the scorecard, line 13 (does all PFAS-user training include ANSI standards (Z359) for fall arrest equipment?), the respondent generally expressed that he was unfamiliar with the Z359 standard. The respondent continued by stating that he was under the impression that it was applicable to general industry and not applicable to the construction industry.

Revising the Scorecard

The critique of the scorecards (the review and comment process presented in the case studies) generated valuable suggestions that warranted making revisions to the scorecards. The discussions with the industry practitioners were a collaborative process that resulted in the scorecards being hypothetically implemented by the five construction contractors. The results of the industry critique (that is, the revisions incorporated into the scorecards) are presented in the following explanations and presentations of the scorecards. Discussion of the individual line items where adjusted wording or wholesale content revision occurred is presented with commentary regarding the logic and/or justification for the revisions. For example, line 6 in the project version of the scorecard was reworded based on the comments from the case study 3 respondent about the realities of terminating subcontract agreements (Table 5-13).

One of the respondents (case study 1) recommended that the implementation of a safety performance accountability system be added as a scorecard line item. The researcher agreed that individual accountability is an important value for a progressive management system. Accountability can have a positive effect on reinforcing the importance of the individual employee's contribution to the overall success of the company's safety program. However, if the fall protection focus of the scorecard is considered, deferment of this suggestion to other revisions to a company's safety program can be justified.

The commentary of the case study respondent 1, when taken as an aggregate, represents a safety management philosophy that includes elements of safety metrics (as defined in the same case study section) and behavior-based safety practices. This philosophy matches the analogy suggested by Kaplan and Norton (1992) whereby effective managers can consider the management system to be analogous to a modern aircraft cockpit with a multitude of gauges. That is, receiving feedback and data from a large number of point sources in the operations can be beneficial to building the safety managers understanding of their program's performance.

The construction manager (CM)-oriented contractors in the case studies responded that the scorecard was deficient in regard to subcontractor management requirements and the types of documentation that they typically required of their trade contractors. In contrast, the case study respondent 4 manages a large workforce of field workers and made comments that emphasized the concerns of an employer with direct control and responsibility for worker behavior. Discussion with this respondent (case study 4) suggested that either a self-performance-oriented contractor or a CM-oriented contractor might find line item 7 in the project version of the scorecard in need of adjustment. This suggested the creation of the two alternate versions of the project scorecard presented in Tables 5-13 and 5-14.

Scorecard line item 7 in the newly-created project version for construction manager-oriented contractors (Tables 5-13) was revised to emphasize subcontractor management and safety metrics documentation. The revised question was worded as follows:

> Does the safety manager receive subcontractor documentation for worker training and conduct periodic audits to verify compliance with the project safety plan?

The same line item in the scorecard was also revised to suit the needs of the safe behavior-oriented contractor. The revised version for line 7 in the behavior-based version of the scorecard (called the project version for traditional contractors with self-performance capability) is worded as follows:

> Is the safety program based on behavior-based safety management with safety-oriented foremen and superintendents and aggressive daily safety compliance inspections?

The clarification requested for line 4 (from Case study 4) regarding custom engineered lifelines was addressed with the addition of a clarification clause. The wording for line 3 was revised to reflect the common terminology used by safety managers in the construction industry. The question was revised as follows:

> Does the job hazard analysis and project safety plan identify all anchorage on the project?

Several of the respondents challenged the importance given to ANSI Z359 fall protection standards in line 13 in the project version. The researcher's intention for line 13 was that the highest standards of fall arrest system practices be reflected in the scorecard. Line 13 was revised to read as follows:

> Is the safety director or manager required to review and implement the latest fall protection standards (ANSI Z359 or A10.32)?

More than one of the respondents asked if a vice-president level of the upper management team was required to play an active role in the fall protection safety practices in order to generate a yes answer for line 7 in the scorecard, companywide version. The commentary of the case study respondents suggested a revised approach to the question. The wording of line 7, companywide version (Table 5-15) was modified to read:

> Does the safety director have the aggressive and proactive support of upper management to implement a state-of-the-art safety program?

Overall, the critical reviews received during the case study discussions were a useful process that resulted in important revisions to the scorecard.

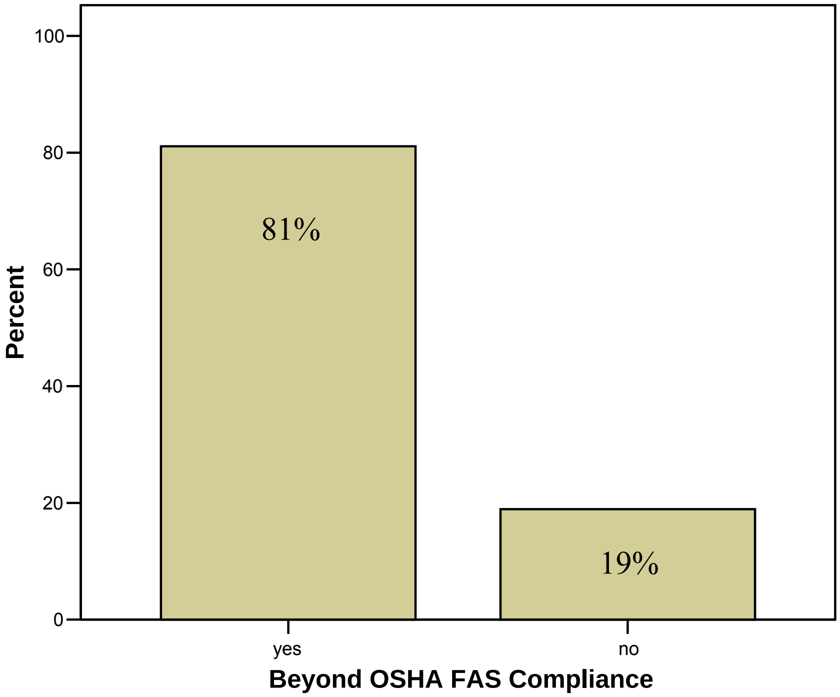

Figure 5-1. Frequency of OSHA compliance (n = 72).

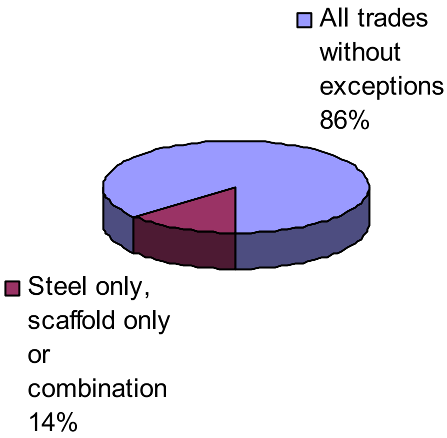

Figure 5-2. Exceeding OSHA compliance: which trades specified (n = 58).

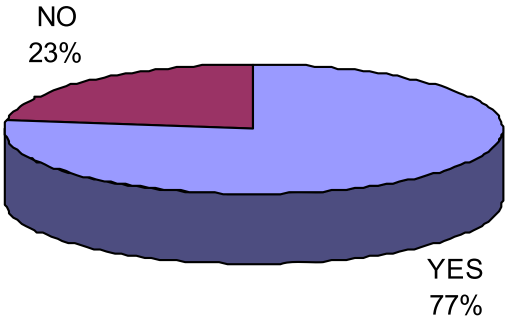

Figure 5-3. Assignment of PFAS-competent persons by subcontract agreement (n = 97).

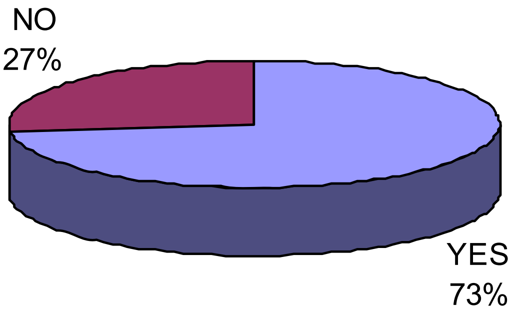

Figure 5-4. Requirement for project specific fall protection and fall arrest plans (n = 97).

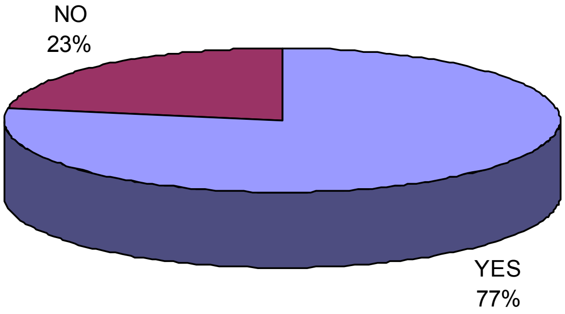

Figure 5-5. Subcontract agreements that require documentation of anchorage locations in PFAS plans (n= 71).

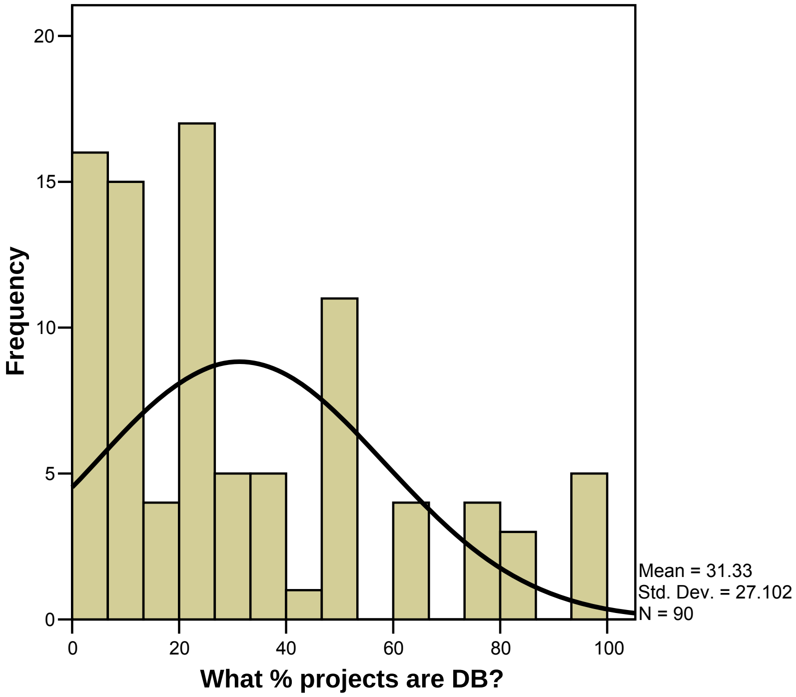

Figure 5-6. Percentage of contracts that are design-build contracts (n = 90).

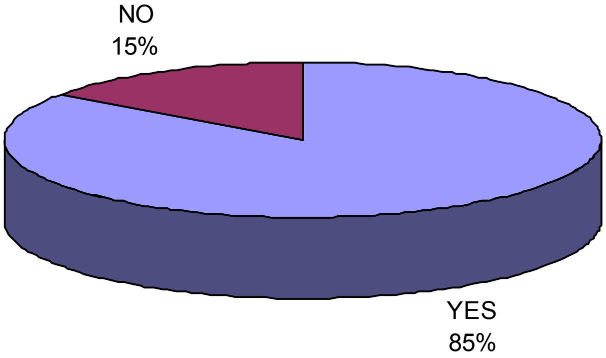

Figure 5-7. Comments are made to the owners that are intended to improve fall protection (n = 93).

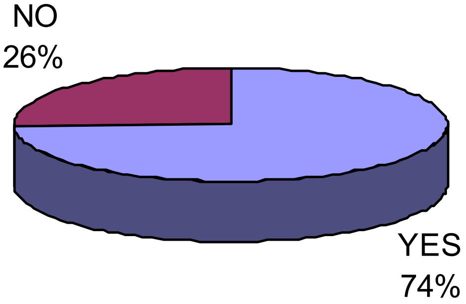

Figure 5-8. Suggestions are made to the design team that are intended to improve fall protection (n = 86).

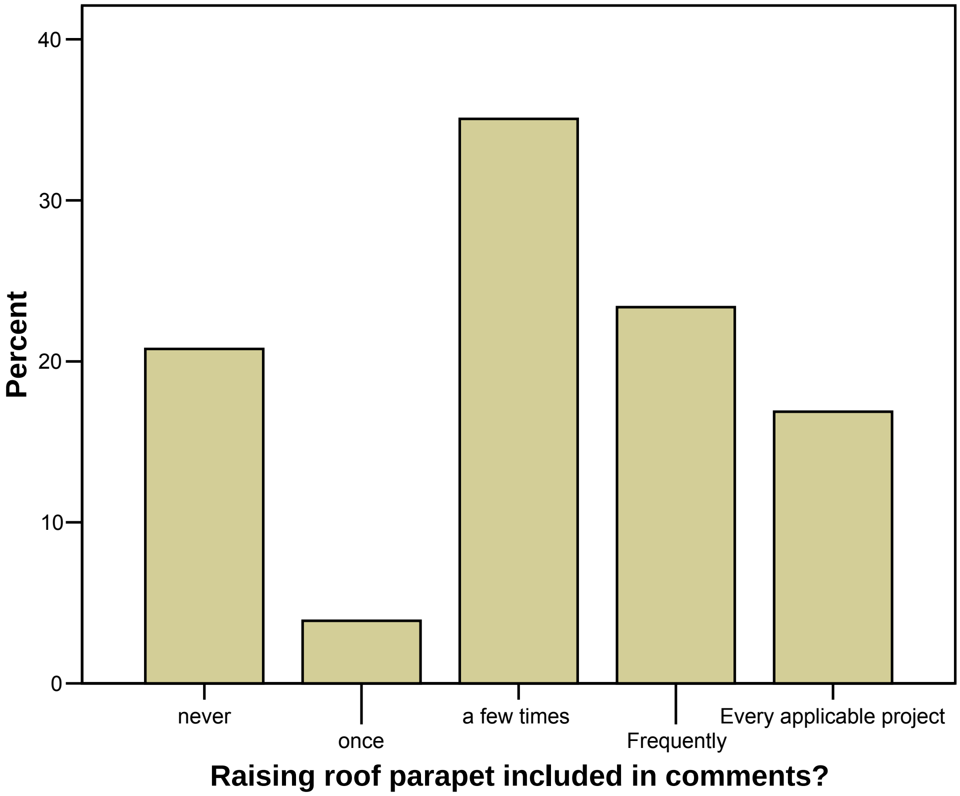

Figure 5-9. Suggestions to designers included raising height of roof parapets (n = 77).

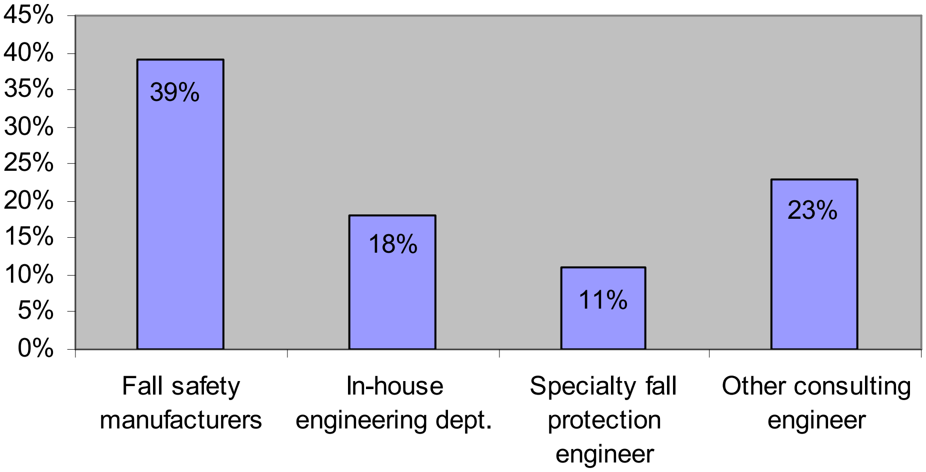

Figure 5-10. Types of engineering service providers utilized by contractors (n = 37).

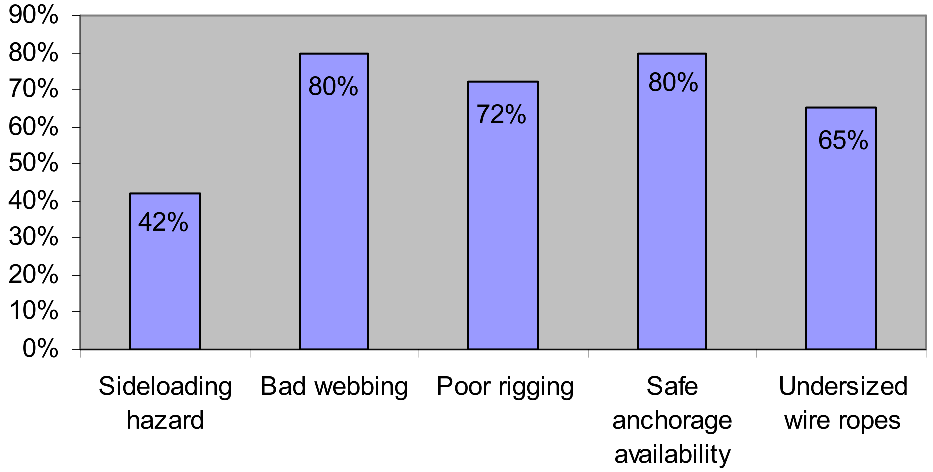

Figure 5-11. Policies implemented to control specific hardware risks (n = 91).

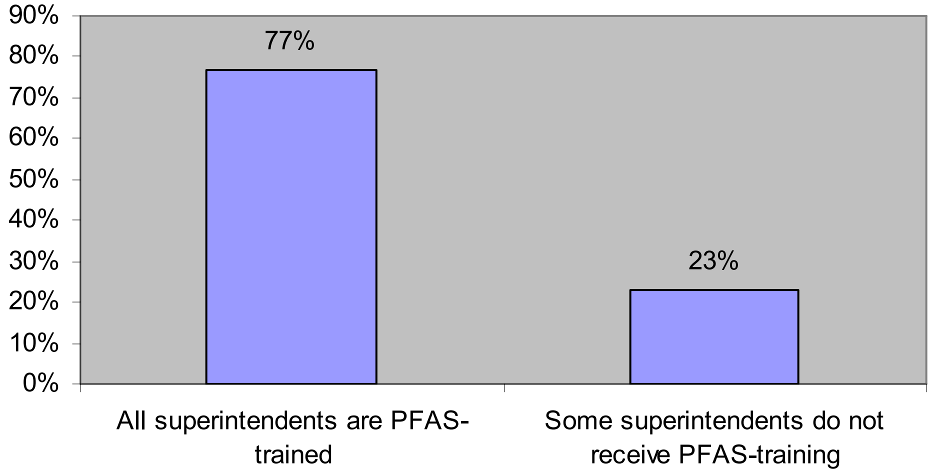

Figure 5-12. Percentage of superintendents that received PFAS-training (n = 96).

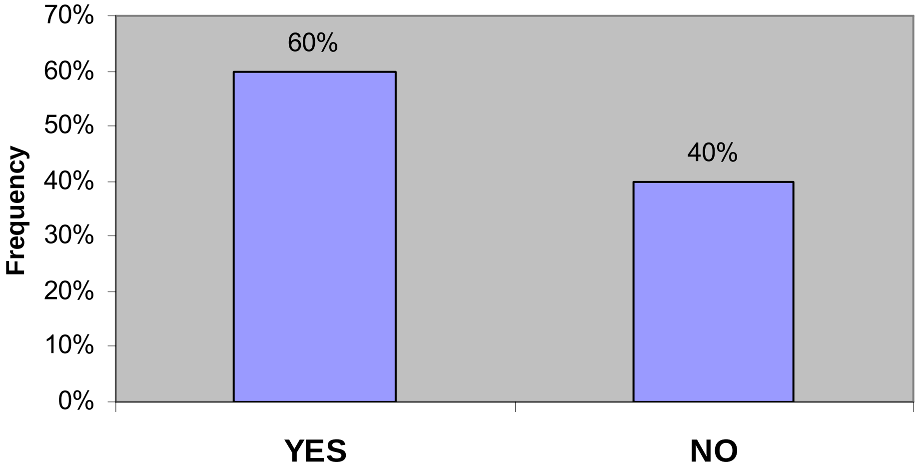

Figure 5-13. Superintendent training typically includes a competency test (n = 65).

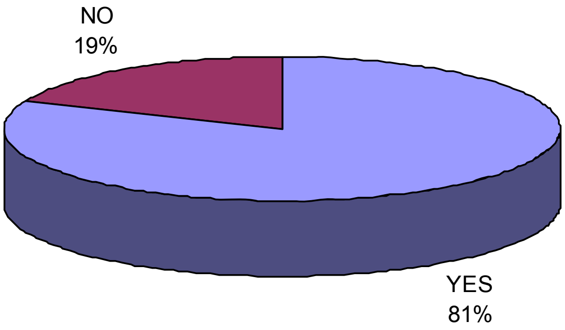

Figure 5-14. Contractors are customers of the major fall protection manufacturers' training seminars (n = 54).

Table 5-4. Descriptive data for individual variables used in the safety-practices-implemented variable development model.

Reference number[1]	Safety Practice Implemented	Yes (%)	No (%)	Sample size (n)	Kendall correlation coefficient (τ)
4	Beyond OSHA compliance: tie-off applies to all workers without exception	79	21	61	0.124
5	Twin-leg lanyards required	44	56	61	0.019
7	Subcontractors required to assign a competent person to each work crew (PFAS)	77	23	61	-0.036
8	Subcontractors required to provide project-specific fall protection plans	74	26	61	0.056
9	Anchorage shown in PFAS plans	58	42	60[2]	0.113
11	Measurement of worker attitudes toward PFAS safety conducted	35	65	57	-0.111
14	Specialized PFAS-training for superintendents includes a competency test	64	36	56	-0.006
32	100% ANSI label or manufacturer labels required on all fall arrest equipment on-site	70	30	60	0.221, $p < 0.05$
33	All custom-designed anchorage and lifelines stamped and signed by PE	78	22	60	0.117

Notes: 1. Parenthetical notation in Appendix B identifies each question by this reference number.

2. Cases coded as non-applicable [as warranted by the preceding variable (Reference 8)] were included in sample.

Table 5-5. Descriptive data for the safety-practices-implemented variable.

STATISTIC[1]	CONTINUOUS VALUES[2]	DISCREET VALUES
Mean	3.30	
Std. Error of Mean	0.163	
Median		3.5
Variance	1.75	
Std. deviation	1.32	
Range		5
Minimum		0
Maximum		5

1. Distribution for the variable is discreet.
2. n = 66.

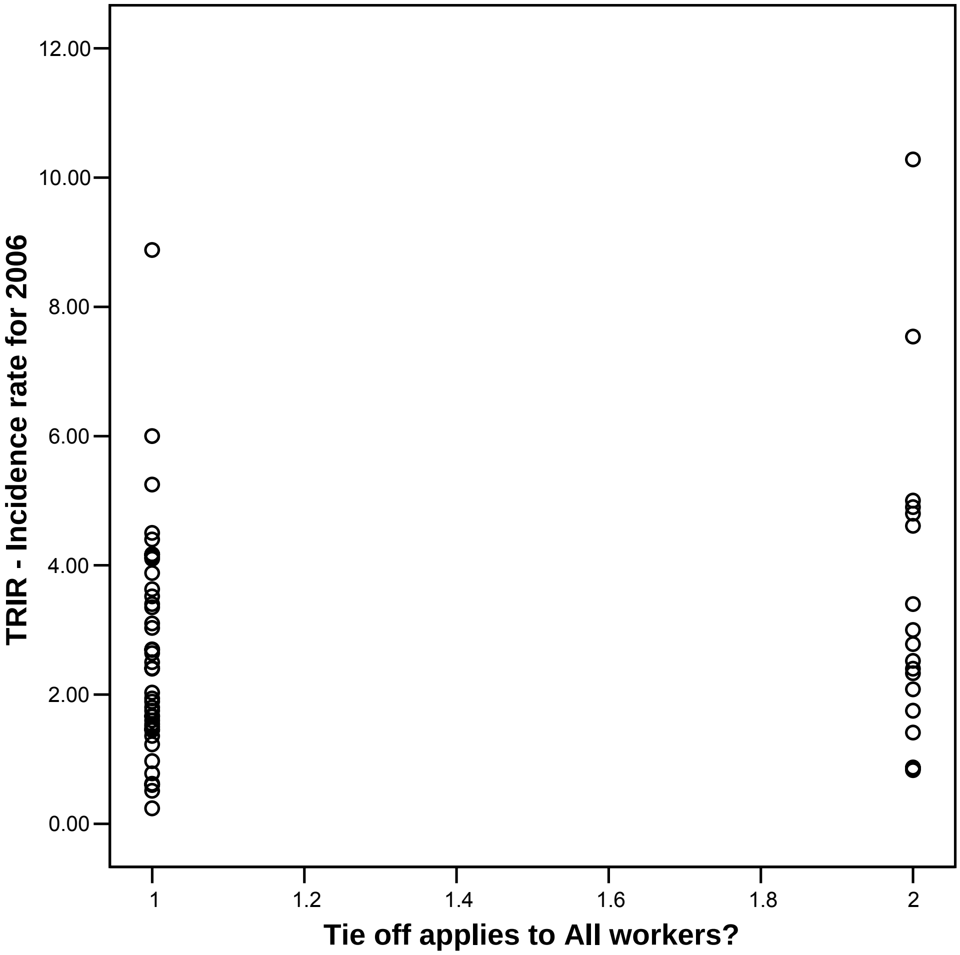

Figure 5-15. Scatter plot for the correlation of the all-inclusive tie-off policy and TRIR variables (n = 61).

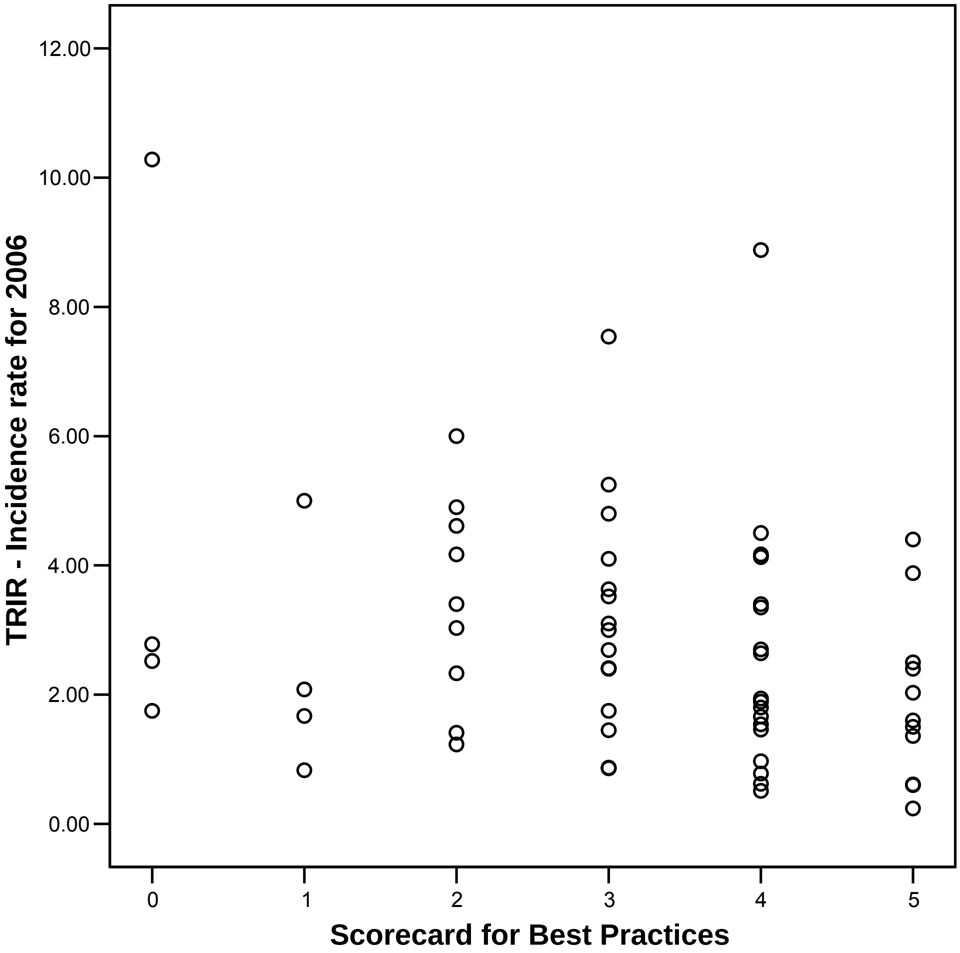

Figure 5-16. Scatter plot for the test of independence (n = 61).

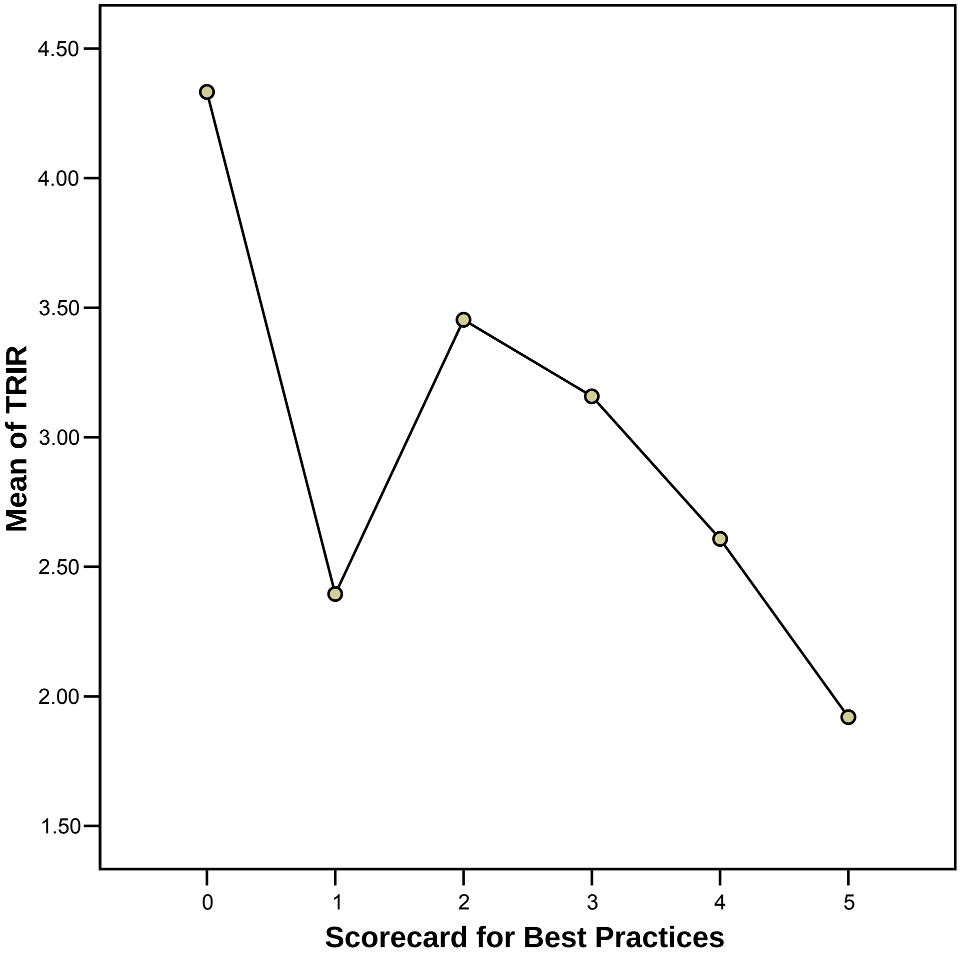

Figure 5-17. Means plot for test of independence (n = 61).

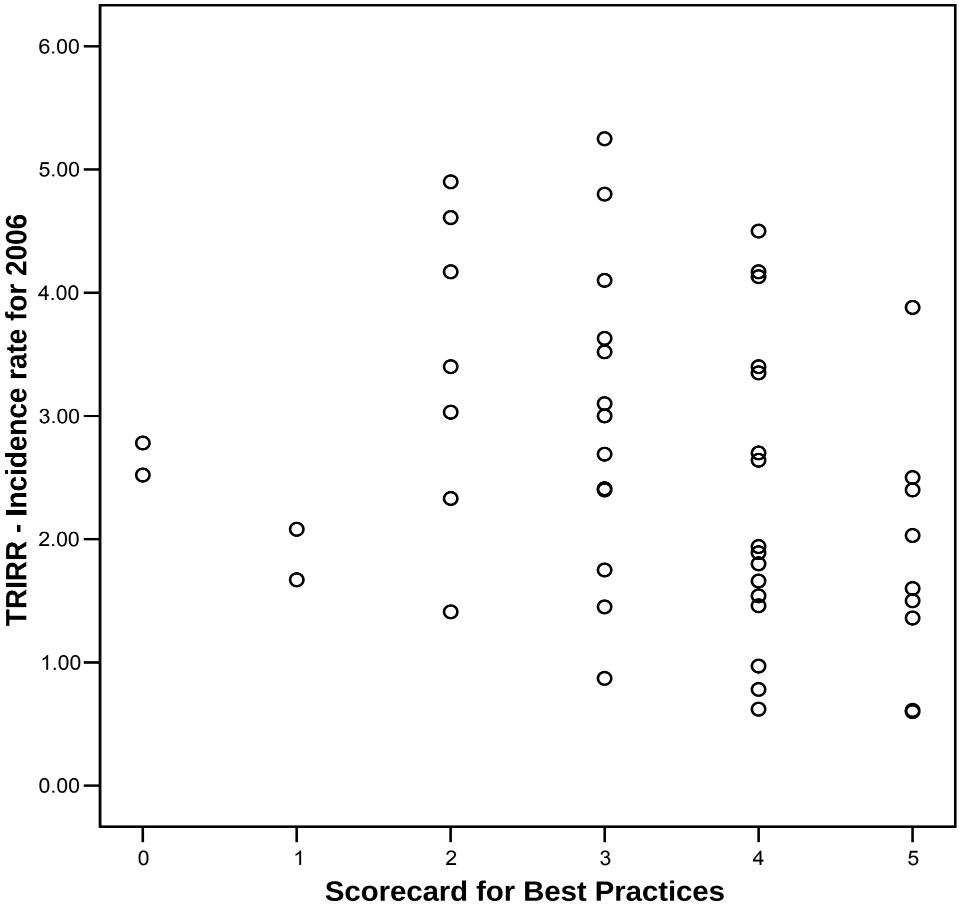

Figure 5-18. Revised scatter plot for the test of independence, preliminary version (n = 49).

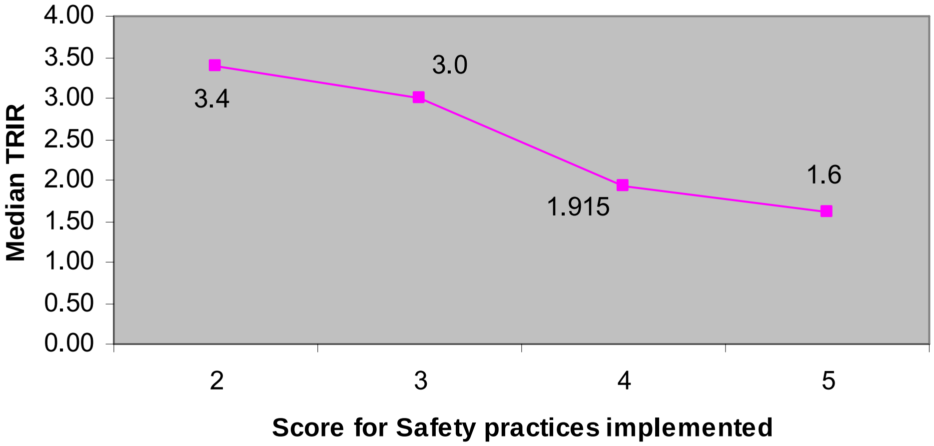

Figure 5-19. Median plot for the revised test of independence (n = 45).

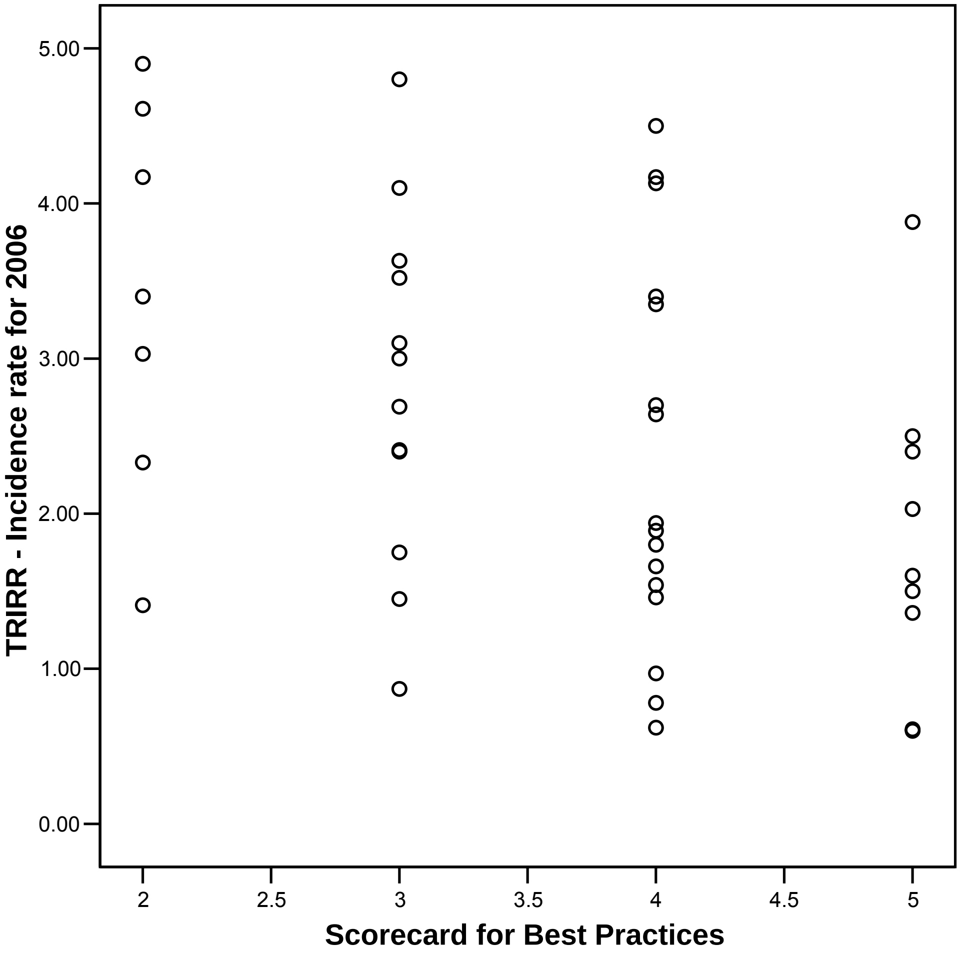

Figure 5-20. Revised scatter plot for the test of independence, final version (n = 45).

Table 5-6. Fall protection and fall arrest systems scorecard (project version)

	CORE BEST PRACTICES (10 points each)			POINTS
1	Beyond OSHA compliance: 100% tie-off (tieoff applied to all workers on site at or above 6 feet above the walking level)?	☐ yes	☐ no	
2	Twin-leg lanyards requirement for all applicable personal fall arrest system (PFAS) users? (typical exceptions: PFASs with self-retracting lanyards and users in personnel lifts)	☐ yes	☐ no	
3	Anchorage shown in project-specific PFAS plans?	☐ yes	☐ no	
4	Major fall protection manufacturer label or ANSI-label requirement for all fall arrest equipment on-site?	☐ yes	☐ no	
5	All custom-designed anchorage and lifelines stamped and signed by a professional engineer (PE)?	☐ yes	☐ no	
	Subtotal count of “yes” responses			
	Multiply the yes count by 10 (10x)		Subtotal	
	SUPPORTING PRACTICES (5 points each)			POINTS
6	Does your company have a policy whereby a subcontract agreement could be terminated for noncompliance with fall protection and PFAS requirements?	☐ yes	☐ no	
7	Does project safety plan require that a formal fall protection and PFAS compliance review be completed monthly?	☐ yes	☐ no	
	Worker Involvement			
8	Are workers’ suggestions about safety improvement encouraged through a reward or recognition program?	☐ yes	☐ no	
9	Are workers empowered to stop any work deemed unsafe?	☐ yes	☐ no	
	Training			
10	Is safety orientation required for all workers and management on site?	☐ yes	☐ no	
11	Do all superintendents receive a minimum of 4 hours of specialized training on PFASs?	☐ yes	☐ no	
12	Do all PFAS users receive a minimum of 4 hours of specialized training on safe system use and equipment?	☐ yes	☐ no	
13	Does all PFAS-user training include ANSI standards (Z359) for fall arrest equipment?	☐ yes	☐ no	
	Engineering Coordination and Planning			
14	Does comprehensive fall protection planning occur for all phases and tasks of the project?	☐ yes	☐ no	
15	Does project safety plan require that all fall protection engineered systems and anchorages be identified?	☐ yes	☐ no	
	Subtotal count for Supporting Practices			
	Multiply the yes count by 5 (5x)		Subtotal	
Total Score (100 points maximum)				

Table 5-7. Fall protection and fall arrest system scorecard (companywide version)

	CORE BEST PRACTICES (10 points each)			POINTS
1	Beyond OSHA compliance: 100% tie-off (tieoff applied to all workers on site at or above 6 feet above the walking level)?	☐ yes	☐ no	
2	Twin-leg lanyards requirement for all applicable personal fall arrest system (PFAS) users? (typical exceptions: PFASs with self-retracting lanyards and users in personnel lifts)	☐ yes	☐ no	
3	Anchorage shown in project-specific PFAS plans?	☐ yes	☐ no	
4	Major fall protection manufacturer label or ANSI-label requirement for all fall arrest equipment on-site?	☐ yes	☐ no	
5	All custom-designed anchorage and lifelines stamped and signed by a professional engineer (PE)?	☐ yes	☐ no	
	Subtotal count of “yes” responses			
	Multiply the yes count by 10 (10x)		Subtotal	
	SUPPORTING PRACTICES (5 points each)			POINTS
6	Is the company owner (or chief executive) committed to a zero incidence rate (TRIR) for serious injuries?	☐ yes	☐ no	
7	Does upper management participate in fall protection compliance reviews per project?	☐ yes	☐ no	
8	Does constructability review include fall protection and strategies to eliminate fall arrest systems through engineering and design options (on every applicable project)?	☐ yes	☐ no	
9	Are recommendations for permanent roof anchorages forwarded to the owner (on every applicable project)?	☐ yes	☐ no	
10	Does the company maintain a design for safety database of safe design principles and design-for-safety guidelines?	☐ yes	☐ no	
11	Is safety for maintainability (including fall protection) coordinated with owners operations (on every applicable project)?	☐ yes	☐ no	
12	Does your firm coordinate fall protection policies and practices with risk management officer (in-house or with firm’s insurance company)?	☐ yes	☐ no	
	Worker and Staff Involvement			
13	Has your company ever conducted an all inclusive, companywide survey of safety perceptions (must have included all employees)?	☐ yes	☐ no	
14	Are workers’ suggestions about safety improvement encouraged through a reward or recognition program?	☐ yes	☐ no	
15	Are workers empowered to stop any work deemed unsafe?	☐ yes	☐ no	
	Subtotal count for Supporting Practices			
	Multiply the yes count by 5 (5x)		Subtotal	
Total Score (100 points maximum)				

Table 5-8. Classification of population based on annual revenue.

Company Classification	Total annual revenue[1]	Ranking	Count
A	1000 or more	1- 41	41
B	500 to < 1000	42 - 87	46
C	300 to < 500	88 - 171	84
D	200 to < 300	172 - 260	89
E	Less than 200	261 - 400	140
Total			400

1. Values are given in U.S. Dollars; one unit equals one million dollars.

Table 5-9. Scorecard for Case Study 1

	Core Best Practices	Points
1	Beyond OSHA compliance: 100% tie-off	10
2	Twin-leg lanyards requirement for all applicable PFAS users	10
3	Anchorage shown in project-specific PFAS plans	10
4	ANSI-label requirement for all fall arrest equipment on-site	10
5	All custom-designed anchorage and lifelines stamped and signed by a PE	10
	Total	50

Table 5-10. Scorecard for Case Study 3 (based on their PFAS survey response)

	Core Best Practices	Points
1	Beyond OSHA compliance: 100% tie-off	10
2	Twin-leg lanyards requirement for all applicable PFAS users	10
3	Anchorage shown in project-specific PFAS plans	0
4	ANSI-label requirement for all fall arrest equipment on-site	10
5	All custom-designed anchorage and lifelines stamped and signed by a PE	10
	Total	40

Table 5-11. Scorecard (companywide version) for Case Study 3

	CORE BEST PRACTICES (10 points each)	POINTS
1	Beyond OSHA compliance: 100% tie-off (tieoff applied to all workers on site at or above 6 feet above the walking level)?	10
2	Twin-leg lanyards requirement for all applicable personal fall arrest system (PFAS) users? (typical exceptions: PFASs with self-retracting lanyards and users in personnel lifts)	10
3	Anchorage shown in project-specific PFAS plans?	10
4	Major fall protection manufacturer label or ANSI-label requirement for all fall arrest equipment on-site?	10
5	All custom-designed anchorage and lifelines stamped and signed by a professional engineer (PE)?	10
	Subtotal	50
	SUPPORTING PRACTICES (5 points each)	POINTS
6	Is the company owner (or chief executive) committed to a zero incidence rate (TRIR) for serious injuries?	5
7	Does upper management participate in fall protection compliance reviews per project?	5
8	Does constructability review include fall protection and strategies to eliminate fall arrest systems through engineering and design options (on every applicable project)?	5
9	Are recommendations for permanent roof anchorages forwarded to the owner (on every applicable project)?	5
10	Does the company maintain a design for safety database of safe design principles and design-for-safety guidelines?	0
11	Is safety for maintainability (including fall protection) coordinated with owners operations (on every applicable project)?	5
12	Does your firm coordinate fall protection policies and practices with risk management officer (in-house or with firm's insurance company)?	5
	Worker and Staff Involvement	
13	Has your company ever conducted an all inclusive, companywide survey of safety perceptions (must have included all employees)?	0
14	Are workers' suggestions about safety improvement encouraged through a reward or recognition program?	5
15	Are workers empowered to stop any work deemed unsafe?	5
	Subtotal count for Supporting Practices	40
	Total Score	90

Table 5-12. Scorecard (project version) for Case Study 4

	CORE BEST PRACTICES (10 points each)	POINTS
1	Beyond OSHA compliance: 100% tie-off (tieoff applied to all workers on site at or above 6 feet above the walking level)?	10
2	Twin-leg lanyards requirement for all applicable personal fall arrest system (PFAS) users? (typical exceptions: PFASs with self-retracting lanyards and users in personnel lifts)	10
3	Anchorage shown in project-specific PFAS plans?	10
4	Major fall protection manufacturer label or ANSI-label requirement for all fall arrest equipment on-site?	10
5	All custom-designed anchorage and lifelines stamped and signed by a professional engineer (PE)?	10
	Subtotal	50
	SUPPORTING PRACTICES (5 points each)	POINTS
6	Does your company have a policy whereby a subcontract agreement could be terminated for noncompliance with fall protection and PFAS requirements?	5
7	Does project safety plan require that a formal fall protection and PFAS compliance review be completed monthly?	0
	Worker Involvement	
8	Are workers' suggestions about safety improvement encouraged through a reward or recognition program?	5
9	Are workers empowered to stop any work deemed unsafe?	5
	Training	
10	Is safety orientation required for all workers and management on site?	5
11	Do all superintendents receive a minimum of 4 hours of specialized training on PFASs?	5
12	Do all PFAS users receive a minimum of 4 hours of specialized training on safe system use and equipment?	5
13	Does all PFAS-user training include ANSI standards (Z359) for fall arrest equipment?	0
	Engineering Coordination and Planning	
14	Does comprehensive fall protection planning occur for all phases and tasks of the project?	5
15	Does project safety plan require that all fall protection engineered systems and anchorages be identified?	5
	Subtotal count for Supporting Practices	40
	Total Score	90

Table 5-13. Fall protection and PFAS scorecard (project version for construction manager-oriented contractors) with revisions based on case study respondent comments.

	CORE BEST PRACTICES (10 points each)			POINTS
1	Beyond OSHA compliance: 100% tie-off (tieoff applied to all workers on site at or above 6 feet above the walking level)?	☐ yes	☐ no	
2	Twin-leg lanyards requirement for all applicable personal fall arrest system (PFAS) users? (typical exceptions: PFASs with self-retracting lanyards and users in personnel lifts)	☐ yes	☐ no	
3	Does job hazard analysis and project safety plan identify all anchorage on the project?	☐ yes	☐ no	
4	Major fall protection manufacturer label requirement for all fall arrest equipment on-site (with exception of engineered lifelines)?	☐ yes	☐ no	
5	All custom-designed anchorage and lifelines stamped and signed by a professional engineer (PE)?	☐ yes	☐ no	
	Subtotal count of “yes” responses			
	Multiply the yes count by 10 (10x)		Subtotal	
	SUPPORTING PRACTICES (5 points each)			POINTS
6	Fall protection noncompliance: does your company have a threshold whereby retraining for entire subcontractor workcrews can be required for noncompliance with safety rules?	☐ yes	☐ no	
7	Does the safety manager receive subcontractor documentation for worker training and conduct periodic audits to verify compliance with the project safety plan?	☐ yes	☐ no	
	Worker Involvement			
8	Are workers’ suggestions about safety improvement encouraged through a reward or recognition program?	☐ yes	☐ no	
9	Are workers empowered to stop any work deemed unsafe?	☐ yes	☐ no	
	Training			
10	Is safety orientation required for all workers and management on site?	☐ yes	☐ no	
11	Do all superintendents receive a minimum of 4 hours of specialized training on PFASs?	☐ yes	☐ no	
12	Do all PFAS users receive a minimum of 4 hours of specialized training on safe system use and equipment?	☐ yes	☐ no	
13	Is the safety director or manager required to review and implement the latest fall protection standards (ANSI Z359 or A10.32)?	☐ yes	☐ no	
	Engineering Coordination and Planning			
14	Does comprehensive fall protection planning occur for all phases and tasks of the project?	☐ yes	☐ no	
15	Does project safety plan require that all fall protection engineered systems and anchorages be identified?	☐ yes	☐ no	
	Subtotal count for Supporting Practices			
	Multiply the yes count by 5 (5x)		Subtotal	
Total Score (100 points maximum)				

Table 5-14. Fall protection and PFAS scorecard (project version for traditional contractors with self-performance capability) with revisions based on case study respondent comments.

	CORE BEST PRACTICES (10 points each)			POINTS
1	Beyond OSHA compliance: 100% tie-off (tieoff applied to all workers on site at or above 6 feet above the walking level)?	☐ yes	☐ no	
2	Twin-leg lanyards requirement for all applicable personal fall arrest system (PFAS) users? (typical exceptions: PFASs with self-retracting lanyards and users in personnel lifts)	☐ yes	☐ no	
3	Does job hazard analysis and project safety plan identify all anchorage on the project?	☐ yes	☐ no	
4	Major fall protection manufacturer label requirement for all fall arrest equipment on-site (with exception of engineered lifelines)?	☐ yes	☐ no	
5	All custom-designed anchorage and lifelines stamped and signed by a professional engineer (PE)?	☐ yes	☐ no	
	Subtotal count of “yes” responses			
	Multiply the yes count by 10 (10x)		Subtotal	
	SUPPORTING PRACTICES (5 points each)			POINTS
6	Fall protection noncompliance: does your company have a threshold whereby retraining for entire subcontractor workcrews can be required for noncompliance with safety rules?	☐ yes	☐ no	
7	Is safety program based on behavior-based safety management with safety-oriented foremen and superintendents and aggressive daily safety compliance inspections?	☐ yes	☐ no	
	Worker Involvement			
8	Are workers’ suggestions about safety improvement encouraged through a reward or recognition program?	☐ yes	☐ no	
9	Are workers empowered to stop any work deemed unsafe?	☐ yes	☐ no	
	Training			
10	Is safety orientation required for all workers and management on site?	☐ yes	☐ no	
11	Do all superintendents receive a minimum of 4 hours of specialized training on PFASs?	☐ yes	☐ no	
12	Do all PFAS users receive a minimum of 4 hours of specialized training on safe system use and equipment?	☐ yes	☐ no	
13	Is the safety director or manager required to review and implement the latest fall protection standards (ANSI Z359 or A10.32)?	☐ yes	☐ no	
	Engineering Coordination and Planning			
14	Does comprehensive fall protection planning occur for all phases and tasks of the project?	☐ yes	☐ no	
15	Does project safety plan require that all fall protection engineered systems and anchorages be identified?	☐ yes	☐ no	
	Subtotal count for Supporting Practices			
	Multiply the yes count by 5 (5x)		Subtotal	
Total Score (100 points maximum)				

Table 5-15. Fall protection and PFAS scorecard (companywide version) with revisions based on case study respondent comments.

	CORE BEST PRACTICES (10 points each)			POINTS
1	Beyond OSHA compliance: 100% tie-off (tieoff applied to all workers on site at or above 6 feet above the walking level)?	☐ yes	☐ no	
2	Twin-leg lanyards requirement for all applicable personal fall arrest system (PFAS) users? (typical exceptions: PFASs with self-retracting lanyards and users in personnel lifts)	☐ yes	☐ no	
3	Does job hazard analysis and project safety plan identify all anchorage on the project?	☐ yes	☐ no	
4	Major fall protection manufacturer label requirement for all fall arrest equipment on-site (with exception of engineered lifelines)?	☐ yes	☐ no	
5	All custom-designed anchorage and lifelines stamped and signed by a professional engineer (PE)?	☐ yes	☐ no	
	Subtotal count of “yes” responses			
	Multiply the yes count by 10 (10x)		Subtotal	
	SUPPORTING PRACTICES (5 points each)			POINTS
6	Is the company owner (or chief executive) committed to a zero incidence rate (TRIR) for serious injuries?	☐ yes	☐ no	
7	Does the safety director have the aggressive and proactive support of upper management to implement a state-of-the-art safety program?	☐ yes	☐ no	
8	Does constructability review include fall protection and strategies to eliminate fall arrest systems through engineering and design options (on every applicable project)?	☐ yes	☐ no	
9	Are recommendations for permanent roof anchorages forwarded to the owner (on every applicable project)?	☐ yes	☐ no	
10	Does the company maintain a design for safety database of safe design principles and design-for-safety guidelines?	☐ yes	☐ no	
11	Is safety for maintainability (including fall protection) coordinated with owners operations (on every applicable project)?	☐ yes	☐ no	
12	Does your firm coordinate fall protection policies and practices with risk management officer (in-house or with firm’s insurance company)?	☐ yes	☐ no	
	Worker and Staff Involvement			
13	Has your company ever conducted an all inclusive, companywide survey of safety perceptions (must have included all employees)?	☐ yes	☐ no	
14	Are workers’ suggestions about safety improvement encouraged through a reward or recognition program?	☐ yes	☐ no	
15	Are workers empowered to stop any work deemed unsafe?	☐ yes	☐ no	
	Subtotal count for Supporting Practices			
	Multiply the yes count by 5 (5x)		Subtotal	
Total Score (100 points maximum)				

CHAPTER SIX
RESULTS OF THE INTEGRATED DESIGN AND CONSTRUCTION SURVEY

The *designer-builders*, defined in the methodology chapter as the firms that had attended the Design-Build Exposition, were investigated to explore the influence of designers on the construction process. The concept of interest concerning the designer-builder population investigated was that when designers and builders work under the same contractual agreement with the owner, the design tends to support design-for-safety practices that are more conducive to construction safety improvements.

Forty-three different companies were contacted. Appendix C presents a detailed explanation of companies included in the sample frame. Not all companies that participated in the Design-Build Exposition offer architectural or engineering services and therefore not all exposition participants were included in the survey. The response rate for the integrated design and construction survey was 23% (n=11). Design services offered by the respondents were provided within one of the following types of firms:

- Predominantly architecture services
- Predominantly engineering services
- Combined architecture and engineering services
- Fully-integrated design and construction services (defined as companies with self-performance capabilities in either design or construction).

The data set included descriptive information defining the type and quantity of projects completed by the individual designer (the respondent) and at the company-wide level. Over 60% of the respondents were employed by firms where the annual design-build contracts equaled or exceeded eighty percent.

Having design-build projects for eighty percent or more of all their contracts should be noted as being definitive of leaders in the design-build industry. It could be assumed that leading companies of design-build practices would be more proactive in implementing design-for-safety practices into their typical projects; however, the findings of this investigation are limited due to the small sample size. Caution should be exercised in attempting to draw inferences about the overall designer-builder population.

The balance of the data collected were nominal (yes or no) answers to questions about design-for-safety engineering practices. Thirty percent of the nominal practice and policy questions referred to fall protection or fall arrest system issues that were directly related to the research hypothesis. In addition to fall protection and fall arrest systems, data were collected in the following categories:

- OSHA regulations and compliance
- Hazard analysis and control documentation by the engineering team
- Lessons-learned databases and continuous improvement
- Safety-for-maintainability design review and quality assurance
- Use of *safer design principles* to eliminate hazards from the project by means of design.

In order to understand the response frequencies of the nominal practice and policy questions in relation to each other, a table was prepared to present an overview of the sample (Table 6-1). Nine of the respondents indicated that training in the OSHA regulations, fall protection, and other aspects of construction safety had been implemented at their companies. Training and instruction in how to use safety principles and engineering means to eliminate construction safety job site hazards was noted as being an implemented practice by seven of eleven respondents. Three of eleven respondents (27%) indicated that they regularly specified roof anchorage. Seven of the respondents use dedicated sheets or notes in the construction documents to highlight construction safety concerns. The implementation and usage of databases of design-for-safety guidelines that improve safety conditions for construction workers were indicated as an implemented practice by six of the respondents.

Table 6-1. Response frequencies for designer-builders.

Question	Counts yes	no	n/a
(1) Training on the OSHA regulations?	9	2	0
(2) Training on fall protection anchorage?	9	2	0
(3) Instruction in how to use engineering to eliminate construction hazards?	7	4	0
(4) If yes, does this instruction cover fall protection and the elimination of the need for fall arrest systems?	5	2	4
(5) Dedicated sheets in the construction drawings to highlight safety hazards?	7	4	0
(6) Database of design-for-safety guidelines?	6	5	0
(7) If yes, do these guidelines cover safety for construction workers?	6	0	5
(8) Do designers at your firm specify roof anchorages?	3	8	0
(9) Safety-for-maintainability review for every applicable project?	4	7	0
(10) Do company designers make job-site visits to observe safety performance?	6	5	0

1. Numbers assigned to the questions in this table do not reflect numbers assigned in Appendix B documentation of the actual survey and survey questions.

CHAPTER SEVEN
CONCLUSIONS

This study investigated a select set of personal fall arrest system (PFAS) safety management policies and practices that constituted the best safety practices in the fall protection area of construction safety. In order to validate the best practices, the study sought to determine whether or not a typical ENR Top 400 contractor's TRIR was dependent on the successful implementation of the best practices for PFASs. Important topics for fall protection safety management and the safe use of fall arrest systems included OSHA compliance policies (within an individual contracting company), PFAS-user training, and engineering coordination. It was concluded that a select set of best practices for fall protection and PFAS management does exist and that the contractor's TRIR (and improved safety performance) depends on the successful implementation of this same set of fall arrest system policies and practices.

Basic Fall Safety Compliance and Subcontractor Management

The findings show that the contractors with better safety records had adopted company policies that exceed OSHA regulations for fall protection. The most proactive contractors in the study had adopted the policy of requiring the use of PFASs (when other fall protection measures are not applicable) for all trades and workers working at an elevation of 6 feet or more above the walking surface, often referred to in the industry as "100% tie-off." The findings demonstrated that this policy was a frequently used and effective management technique for eliminating the exceptional clauses and loopholes for the various trades that can weaken the intent of Subpart M of the OSHA Construction regulations. From the standpoint of compliance facilitation and field operations, the 100% tie-off policy has a simplicity and elegance to it that makes it a fundamental building block to controlling unsafe worker behavior and creating an effective safety culture for a given project.

The results show that although many contractors require subcontractors to submit fall protection plans that are project specific, almost one-fifth of these plans do not address anchorage locations for projects when applicable. Requiring subcontractors to address anchorage in the preconstruction and task coordination context (whether included in subcontract agreement or not) is a corollary to an effective 100% tie-off policy. When safe anchorage is unavailable or rendered ineffective by work flow conflicts, for example, removing horizontal lifelines (HLL) located at the perimeter of a floor plate to allow the movement of large building components, 100% tie-off is vulnerable to unsafe behavior pressures, for example, no HLL is available for tie-off.

The requirement for project-specific fall protection plans that specify anchorage locations allows the project manager to more easily examine potential task coordination conflicts in critical areas such as the installation of the exterior cladding or wall system. For example, potential coordination conflicts frequently exist for mid-rise and high-rise condominium projects where large windows and patio doors must be installed at the floor plate perimeter. Since the large windows and patio doors span from floor to ceiling, fall arrest systems, specifically HLLs, may need to be removed during the installation of exterior glazing components.

Design and Construction Integration

In order to investigate global and project-wide factors that could be used to give the fall protection safety culture the most robust and aggressive features possible, the influence of 1) the project owner(s) and 2) the project design team were investigated. Because of the observed improvement in overall project coordination and other benefits such as the elimination of change orders, design-build contracts are continuing to be used to a greater extent in the construction industry. In this research, the mean total percentage of design-build contract agreements with owners equaled almost one-third of all construction contracts. Although data were not sought on specific explanations for the frequency of design-build project delivery, the overall project enhancement of coordination issues between owner, designer and constructor, including improved safety culture, are well-known in the industry.

Although no significance was found in any of the statistical tests performed for owner and designer effects on fall protection and fall arrest system safety practices, this study identified important items associated with fall protection and PFASs that can be controlled for when the constructor has an aggressive and proactive role in the design phase, such as is the case when design-build and engineer-procure-construct (EPC) project delivery methods are used. Those important items include:

- The consideration for the placement of anchorages as permanent fixtures for the project when applicable
- The coordination of rooftop equipment requiring regular maintenance and the provisions for fall protection, such as guardrail systems, single-point anchorages, and horizontal lifeline systems
- The elimination of fall exposure hazards by means of design-for-safety design and engineering strategies that consider wholesale revisions to the erection and cladding concepts.

Although fall protection and fall arrest system performance factors that are governed by the design team cannot be controlled by the contractor (excepting the design-build and EPC project delivery options), contractors can continue to promote greater involvement in fall protection by design professionals through their project coordination phase communications and suggestions for safer structures. The high frequency (over seventy percent on typical projects) of suggestions shared with the design team indicates that contractors remain optimistic and assertive when it comes to promoting a better understanding of fall protection requirements with designers.

Fall Arrest Equipment and Engineered Components

This study did not include a comprehensive description of fall protection equipment although the products and services of the major fall protection manufacturers (as defined by the list in Appendix A) were an important source of information for this study. Simply based on the fundamental nature of and volume of goods and services associated with the fall protection equipment, the manufacturers clearly have a major influence on fall protection and construction safety. The results for the role served by the fall protection equipment and services showed:

- The respondents' preference for utilizing the services and expertise of the engineered-systems consulting groups operating within the manufacturing companies

- The high frequency (82%) of the respondents that utilizes the specialized training seminars offered by the fall protection manufacturers

- The important role (statistically significant) played by the safety policy requiring 100% ANSI label or manufacturer label on all fall arrest equipment on-site.

These results showed that the contractor population strongly depends on the fall protection manufacturers for:

- Their expertise and assistance
- The research and development behind the published inspection and maintenance protocols
- The availability of technical and educational support.

The support given to the contractor population through the specialty engineering consulting services and the training seminars (responsible for educating the "competent person(s)" as defined in the ANSI Z359 standard) clearly ties the contractors utilizing personal fall arrest systems to the major fall protection manufacturers. The degree of this interrelationship and dependency indicates that strong mutual objectives exist between contractors proactive in safety and the fall protection manufacturers.

The results showed that of the safety policies tested on an individual basis for their association with the TRIR, the safety policy requiring 100% ANSI label or manufacturer label on all fall arrest equipment on-site had a statistically significant correlation with the TRIR, i.e., this policy was associated with lower injury rates. This result was cited above for its role in the overall character of the relationship between the major fall protection manufacturers and the large contractor (ENR Top 400) respondents. Another important aspect of this result was its implications for:

- Safety facilitation, supervision and enforcement
- Formal equipment inspection in the field
- Worker training for equipment and hardware knowledge.

Taken together, these three issues were characterized as the critical components of field operations and fall arrest system use. The importance of maintaining a trained workforce of PFAS users and middle managers that recognize and understand fall arrest equipment in the context of the industry standards (as adopted by the ANSI Z359 committee) was concluded to be a fundamental feature of a best practices safety program. Furthermore, it is imperative that the construction industry's goals for PFAS-competency recognize the technical nature of PFAS equipment and the manufacturing and testing standards that assure the equipment's performance integrity. The recognition and comprehension of industry-standard marks (or identification tags and labels) for assuring the quality of PFAS equipment (that is, the system integrity represented by the presence of an ANSI or major fall protection manufacturer label) should be considered a component of baseline PFAS training for all users and supervisors.

Workforce competency is also strongly influenced by the expectations from the company's upper management. Upper management's expectation that PFASs will be used with integrity on all company projects is of paramount importance. Corporate-level management support for high-quality training and high-quality equipment procurement is an integral component of the company policy and culture for the safe use of fall arrest systems. In summary, as a baseline of a best practice-PFAS safety program and safety culture, a contractor must train middle managers (superintendents and safety managers) to recognize and facilitate quality assurance for fall arrest equipment. The better safety programs will add to this baseline objective, the aggressive and proactive safety training features and content that will promulgate this same equipment quality assurance behavior and competency in all PFAS users (direct-hire employees and workers managed through subcontract) on a given project.

Associations between Better Safety Records and Fall Arrest System Best Practices

The significance of the test for independence (from which the null hypothesis was rejected and the research hypothesis was validated) shows that an influential and important set of best practices in PFASs does exist. A reasonable extension of the research hypothesis is that a distinctive subcomponent of an overall safety culture, a component that is specific to fall protection and fall arrest system safety, does exist and can be defined as the best practices in fall arrest system safety.

These best practices were used as the basis for an evaluation criterion (the scorecard). The scope of best practices associated with lower TRIRs is well balanced across the spectrum of project safety management categories. When implemented as a scorecard for project evaluation, these five practices represent a balanced and durable range of evaluation criteria across the full range of PFAS management issues for a typical project.

Definition of Better Safety Records

The results of the revised procedure where the outliers were excluded from the test procedure showed that a reliable definition for the term, *better safety record*, could be ascertained. Using the median plot shown in Figure 5.19, contractors who had implemented at least 4 out of the 5 best practices had a mean TRIR value below 2.0 recordable injuries per 200,000 worker hours. A contractor with an injury incidence rate (TRIR) below 2.0 was thereby shown to be a reasonable definition for the statement (from the study’s hypothesis), *contractors in the population with the better safety records.*

Conclusions about the Scorecard

Because the best practices for PFAS were validated, the concept of developing a process to implement, evaluate and continuously improve the best practices is viable. Rather than making safety performance evaluations based on TRIR (a lagging indicator), a scorecard is a means of implementing a leading indicator method of safety improvement and evaluation. At the company level, the scorecard can be used as an assessment tool for evaluating fall protection practices and overall company safety culture issues that need strengthening and modification. At the project level, the policies and practices contained in the scorecard can be used to shape and guide the project safety plan including preconstruction meetings with subcontractors and project training needs.

The respondents to the case study comment and review process engaged in a collaborative process with the researcher whereby questions and clarifications resulted in generating important revisions to the scorecards. One of the respondents commented on how the scorecard would be implemented and integrated into a construction company's operations. Specifically, the respondent asked what action might be suggested by the researcher if any of the scorecard items generated a "no" answer. This question (what procedure is suggested for addressing a "not applicable" answer?) can best be interpreted by the safety manager or company using the scorecard. Does the company agree that a "yes" answer would likely generate improvements in fall protection safety performance for their projects? Safety managers and upper management should consider that the items in the scorecard are validated by the following methods applied during this study:

- The literature review which presents best practice recommendations from other safety experts and research
- The data collection and hypothesis testing
- The critical review process presented in the case studies.

Companies can use the scorecards as presented in this study or as materials to be incorporated into other scorecards that can be created to address the specific needs of an individual company's operations or projects. Companies within this study's sample of large construction contractors represent a wide diversity of construction operations and safety needs. Different scorecards for fall protection can be created that address variations in

- Emphasis within fall protection safety for different construction tasks
- The detail level of fall protection equipment included and evaluated by the scoring criteria
- The detail level of safety behaviors monitored by the scorecard.

Safety checklists and scorecards are widely used in the construction industry to monitor and evaluate safety issues and performance. In order to effectively serve as continuous improvement tools, these scorecards must be reviewed and revised on a periodic basis with regard to changes in the best practices and current events in construction safety.

Conclusions about the Designer-Builders

The concept of interest concerning the designer-builder population investigated in this study was that when designers (engineers and architects) and builders are in more frequent communication with each other (as is facilitated by a design-build contract), enhanced construction safety practices will be a measurable outcome.

Although the designer-builder investigation did have limitations with regard to making inferences about the true population due to the small number of respondents, the process of conducting the integrated design and construction survey yielded some interesting information and a template for future research projects. The ten nominal practice and policy questions in the survey do serve to define a working list of progressive practices for fall protection and PFAS safety in the context of design-build and EPC projects.

Although unconfirmed by any direct communications, this researcher concluded from the prevailing climate of legal liability for professional engineering consultants that designers (engineers and architects) are reluctant to provide information about any of their consulting activities that could increase their exposure to legal liabilities. Construction safety-related topics are commonly perceived by architects and engineers to have a strong tendency to increase their exposure to legal liabilities, whether justified or not. These liability concerns of designers are based on the legal precedents (Geer v. Bennett 1970) and customary project management practices that result in a formal separation between the designer's specifications (and recommended engineering measures contained within those specifications) and the constructor's responsibility for engineering measures that concern the means and methods of construction.

Design-build contracts and employment by companies organized on a design-build model (fully-integrated design and construction services) do ease the liability concerns of designers to some extent. However, based on the data collection phase of this research, the researcher concluded that the quantity of companies organized on a true design-build model (defined as companies offering fully-integrated design and construction services and possessing self-performance capabilities in both design and construction) was a small percentage (that is, approximately ten percent) of the overall number of companies participating in design-build contracts.

CHAPTER EIGHT
RECOMMENDATIONS

This study has focused on fall protection safety as a subcomponent of a safety plan. Although an important core group of best practices was identified, contractors and other employers interested in applying the findings and conclusions must recognize that the effectiveness of these best practices in PFASs is dependent on their effective integration into an extensive, fully-developed, and proactive safety culture. The long range success of safety programs and a companywide safety culture will be positively affected by the integration of these best practices into a contractor's safety management plan and it is strongly recommended that every employer in the construction industry consider the immediate implementation of these best practices in PFASs. Further, the best practices in fall arrest systems identified will be effectively implemented when integrated across all operations and on multiple projects within an individual company.

Recommendations for Regulatory Revisions

Building code revision to protect maintenance workers against significant fall hazard exposures. The discontinuity of the major health and safety codes that apply to structures at various points in the lifecycle of the building are deemed to be responsible for avoidable conflicts and waste in the industry. The lifecycle of the building is defined as any activities occurring in a temporal sequence during

- Erection and construction process
- Conventional use by the end-user occupants
- The operational maintenance.

For example, the facility owner's maintenance operations frequently involve access to rooftop equipment. The major building codes do not typically address the health and safety of maintenance workers. Studies have shown that when workers do not have access to anchorage, particularly in roof areas, safe behavior and correct use of PFASs are compromised (Hinze and Harris 2007a).

The major building codes, by not cross-referencing the OSHA regulations, create conflicts and inefficiencies between designers and constructors that are wasteful and can unnecessarily endanger maintenance workers. The expense and burden of resolving these conflicts often is assumed by the owner, who is placed in the position of retrofitting a new building to bring it into compliance with OSHA standards after the project is delivered.

Revising and amending the major building codes is a complex process. Initial discussion and debate should consider the opportunities and obstacles to including permanent roof anchorage in the major building codes. This permanent roof anchorage requirement for applicable building permits would target the protection of maintenance workers.

The energy expended by owners, constructors and designers to address and manage this type of discontinuity in the regulations is wasteful and unnecessary. The consideration of permanent roof anchorage in every applicable project should be addressed at the building permitting stage by the major building codes.

Improve fall protection and anchorage requirements in Subparts L and X of the OSHA regulations. Many opportunities to improve the field operations of contractors exist in the elimination of fall risks arising during the use of 1) scaffolding, whether stationary or mobile, and 2) ladders. Because scaffolding (Subpart L) and ladders (Subpart X) are regulated outside of the main fall protection section (Subpart M), discrepancies pertaining to fall protection and safe fall arrest system use are detectable, particularly in regard to anchorage requirements. The same conclusion could be applied to Subpart R, but for the majority of cases, contractors with robust and aggressive safety plans recognize that the reduction of risk for steel erection and ironworkers is controlled by specialized training. Steel erectors and ironworkers should receive the highest level of training possible, in terms of training hours required and specialized content offered during that training.

Recommendations for Changes in Practice

The scorecard is recommended for use in evaluating the status of fall protection and PFAS usage and management for the construction industry. The scorecard provides proactive companies interested in safety with a means to quickly assess the status of fall protection and PFAS practices and policies. The immediate concerns of safety performance on current projects can be addressed by the project version of the scorecard. When a company commits to using the scorecard on applicable company projects, earlier recorded scores from the scorecard can be used to assess safety improvement over a period of time. The scorecard can also be considered for project implementation at major milestones as follows:

- Preconstruction planning with owners
- Preconstruction meetings with subcontractors
- Pretask planning
- Risk management reviews
- Major training milestones
- Post-project review and assessment.

For example, major project training milestones occur when large numbers of subcontractors and workers commence working on a project. The peak in the total number of PFAS users on a project site might warrant evaluation by the scorecard. When training is outsourced, the scorecard could be used as a checklist by fall protection instructors to assure that the best practices in PFASs are addressed.

Large contractors concerned about the influences on fall protection performance and company safety culture from

- Upper management attitudes

- Staff attitudes
- Contracts and project delivery methods
- The owner effects on fall protection and PFASs (also described as strategic planning)
- The designer effects on fall protection and PFASs.

can consider using the companywide version of the scorecard. Making significant inroads into the companywide safety culture and strategic planning issues influencing fall protection and PFAS usage is an ambitious agenda. The intention of creating a companywide version of the scorecard was that the effects the home office operations and departments, for example, the preconstruction department, would be considered for their impact on fall protection in the field. Another aspect of the companywide evaluation criteria is the behavior and practices of upper management, also a department or group of individuals that spend a significant amount of time in the home office. The companywide version of the scorecard should be used as an annual management audit tool, or integrated into existing periodic safety program reporting and evaluation systems.

A process of continuous improvement that integrates the scorecard and its best practices into the safety program and culture of a company is highly recommended. When the scorecard is placed in this context, new policies and practices not included in the scorecard presented in this study can be added to future scorecard versions. When a no answer is given to an item in the scorecard, management should consider

- Revising company practices and policy to reflect the recommended best practices from the scorecard
- Establishing a collaborative improvement process including the participation of upper and middle managers, safety managers, fall protection equipment vendors, fall prevention training consultants and PFAS users to review and implement fall protection improvements.

In summary, the three versions of the scorecard are recommended to be used together to achieve maximum benefit to a company; one scorecard applied to all applicable projects, and the other applied to the home office.

Recommendations for Changes in Engineering Coordination

Closer coordination between the ENR Top 400 population and the fall protection manufacturers. Based on their interaction and customer-supplier relationship, the leaders of the ENR Top 400 population and the major fall protection manufacturers should be more obligated and committed to working together. In the United States, the existence of two separate committees charged with fall arrest system standards for general industry (ANSI Z359) and construction (ANSI A10.32) appears to be wasteful and imprudent.

The OSHA regulations for general industry (Standard 1910) do not contain a fall protection standard. The fall protection standards for general industry and the construction industry reside in one location, Subpart M of the OSHA Construction Standards. The development and standards committees of the American National Standards Institute should logically follow this same structure.

Recommendations for Future Research

Certain issues in future improvements in fall protection and PFASs that have been identified in the process of conducting this research require additional investigation. Some of the proposed topics for future research may have already been initiated in the construction industry by large contracting companies and fall protection manufacturers and should receive additional exploration in the context of peer-reviewed research.

Research recommendation 1: Twin-leg lanyards were shown to be a type of equipment that is frequently selected due to its benefits in improving safety performance and 100% tie-off compliance. A study that investigates unidentified unsafe behaviors should be a high priority for the industry leaders, safety professionals and researchers.

Research recommendation 2: Investigation of the role of engineering and design for their potential for eliminating and reducing risks in fall protection and fall arrest systems through the application of design-for-safety principles should be a priority for future research. This would be an excellent topic for exploration in the context of 4D visualization and engineering. This is also an excellent interdisciplinary research opportunity between architectural engineering and construction management researchers and academics.

Research recommendation 3: An investigation focused on the assessment of PFAS-user competency would be an important study for better understanding worker participation and conceptual understanding of the technical aspects of PFASs. The technical nature of PFAS equipment presents safety managers with the challenge of training workers to participate in a technically complex safety system. One of the differences between the ANSI Z359 and A10.32 fall protection standards concerns the requirements (and definitions) for PFAS user competency that can be ascertained from comparing the training sections in each standard. This research could address the following questions:

- Who is competent and qualified to evaluate and monitor the safe usage and protocols for anchorage?
- Is the current competent person approach (typically a foreperson) to safe anchorage compliance effective in minimizing unsafe behavior associated with anchorage?
- How well do PFAS users understand fall arrest equipment quality assurance and inspection protocols in general? How well do PFAS users recognize and understand the importance of the major fall protection manufacturer or ANSI-compliant labels for quality assurance? These questions are asked because they relate to assessing the extent that PFAS users can participate in the equipment inspection process.

Research recommendation 4: Additional studies designed to confirm the validity of the following statement would be important for supporting the growing body of literature that has investigated the construction safety benefits of design-build contracts.

> The overall project enhancement of design-build agreements between the owner, designer and constructor, includes significant improvements in the safety culture for a given project.

Research recommendation 5: An exploratory study that investigated the engineering and design implications of implementing a fall protection-oriented revisions to the major building codes (one that addressed the protection of maintenance workers working in hazardous roof areas) would be an important study in support of the regulatory changes proposed earlier in this chapter. The following issues could be considered in the study:

- Design standards (typical details and specifications) that would be required for the construction documentation of permanent roof anchorage
- Risk management strategies and policies that would be acceptable to owners, design consultants and companies with direct liability for and control over workers.

An important population for this investigation is the specialty engineering consultants that possess specialized knowledge about anchorage and fall arrest system design. These engineering firms provide engineering services to general and construction industry clients with regard to custom-designed anchorage and fall arrest system components such as horizontal lifelines and certified anchorages (anchorages with lower test load levels that are allowed when accompanied by the stamp and signature of a licensed engineer). Because of their active consulting practices in the fall protection area, these engineers possess valuable experience with appropriate risk management practices that address liability issues for designers.

Future research about the designer-builder (or other designer-related) population would be well-advised to carefully consider a data collection methodology which addresses the designer’s reluctance to provide data for research purposes. As was noted earlier, avoiding liability for damages and injuries associated with construction safety is an active category of risk management for architects and engineers. Future research could be most effective if care and consideration were devoted to a research design that accounts for the predominant attitude of designers with regard to construction safety.

Final Remarks

The management of PFASs includes many components that could potentially be permanent engineered features of a structure, such as roof top anchorages and horizontal lifelines. These components are influenced by the project planning and procurement areas of a construction project. The primary legal obligations for the safety of employees reside with the employee's direct employers, who must provide overall management and safety leadership to control risks associated with PFASs and their usage on construction projects. However, employers, project owners, and members of the engineering community need to work together to assure that fall protection and PFAS usage receive careful attention in the constellation of construction safety issues. Roof environments in particular pose high risks for all construction and maintenance workers and should be a special focus of all discussions regarding safety culture and project safety improvements.

APPENDIX A
FALL ARREST EQUIPMENT MANUFACTURERS

Table A-1. Website addresses for major U.S. fall arrest equipment manufacturers

Company	Website
Buckingham Manufacturing	http://www.buckinghammfg.com/linemen/
The Crosby Group, Inc.	http://www.thecrosbygroup.com/
DBI/SALA	http://www.dbisala.com/us/
Guardian	http://www.guardianfall.com/
Miller Fall Protection	http://www.millerfallprotection.com/miller/index.html
MSA Safety	http://www.msanorthamerica.com/catalog/catalog506.html
Reliance Industries	http://www.relsafe.com/
Summit Anchor Company	http://www.summitanchor.com/index.html

APPENDIX B
SURVEY FORMS

Preliminary Survey

Section I: General

(1)Please estimate what percent of your firm's projects are design/build contracts: ________%

(2)Does your firm have a worker tie-off and personal fall arrest systems (PFASs) rule for all workers on-site, including all subcontractors? ☐ yes ☐ no

(3)If yes, please describe: ____

(4)As a general contractor, does your firm typically monitor the PFAS usage of subcontractors? ☐ yes ☐ no

(5)How many field workers does your firm typically employ? __________ (6)Of those workers, how many are trained in the use of PFASs (per OSHA Construction Regulations, Subpart M)? _________

(7)Please estimate what percent of your firm's superintendents receive specialized training in PFASs? ________%

(8)Are your project managers required to develop fall protection plans on projects that use fall arrest systems? ☐ yes ☐ no

(9)If yes, do these plans include or incorporate work performed by subcontractors using fall arrest systems? ☐ yes ☐ no

Section II: Subcontractor Management (skip this section if no work is subcontracted)

(10)Is subcontractor compliance with the OSHA regulations mandated in your firm's subcontract agreements? ☐ yes ☐ no

(11)Are your subcontractors that use PFAS contractually required to assign a foreman (who meets the OSHA definition of a competent person) to each work crew using PFASs? ☐ yes ☐ no

(12)Are your subcontractors that use PFAS contractually required to keep documentation of training provided to workers (per OSHA Construction Regulations, Subpart M)? ☐ yes ☐ no

(13)Are your subcontractors that use PFAS contractually required to provide project specific fall protection plans? ☐ yes ☐ no (14)If yes, do these plans specify the location of anchorage connection points or lifelines to be used? ☐ yes ☐ no

(15)Has your firm ever exercised its right to intervene or suspend the work of a subcontractor due to poor safety practices? ☐ yes ☐ no

(16)If yes, in the last three years how many such instances have occurred? __________

(17)If yes, how many of these instances were related to PFASs? ______________

(18)Does your firm have specific safety requirements that subcontractors must comply with that are more stringent than the OSHA regulations? ☐ yes ☐ no

(19)If yes, do any of these safety requirements relate to PFASs? ☐ yes ☐ no

(20)Please describe any PFAS requirements implemented by your firm?

____

Section III: PFAS Hardware

(21)Has your firm ever enlisted the services of an engineer to design components of a PFAS? ☐ yes ☐ no

If yes, was this engineer employed by: (*Check the best description*)

(22) ☐ Manufacturer of PFAS hardware and equipment
(23) ☐ In-house engineering department
(24) ☐ PFAS consulting engineering firm
(25) ☐ Other type of consulting engineer

Do you have any policies or practices to reduce risks from any of following hardware problems (*Check all that apply*):

(26) ☐ High impact sideloading of carabineer/snaphook gates
(27) ☐ Usage of connectors or lanyards with damaged webbing
(28) ☐ Usage of inadequately engineered rigging or anchor connectors
(29) ☐ Safe anchorage availability (or lack of the same)
(30) ☐ Unsafe usage of small diameter wire ropes

(31) How often are equipment inspections performed? ____________________________

(32) What percentage of these inspections are performed by a safety coordinator? _________%

Section IV: Project Management and PFASs

(33) During preconstruction, has your firm made suggestions to the owner on ways to improve safety conditions for the construction worker? ☐ yes ☐ no

(34) If yes, were any of these suggestions intended to reduce worker exposure to falls? ☐ yes ☐ no

(35)If yes, please comment: ____

(36) Are job hazard analyses conducted for each project that is built? ☐ yes ☐ no

(37) If yes, are suggestions for improvements in fall protection ever communicated to the design team (architect or engineer)? ☐ yes ☐ no (38) If yes, please comment:

____

____

(39) Did these fall protection concerns and communications include raising a building's permanent roof parapet up to a safety guardrail height (per OSHA Construction Regulations, Subpart M)?
☐ Never ☐ Once ☐ A few times ☐ Frequently ☐ Every applicable project

(40) Have you had a project where permanent PFAS roof anchorage was designed for the project? ☐ yes ☐ no

If yes, which of the following anchorage types were specified:

(41) ☐ Window washing davits
(43) ☐ Parapet anchors
(42) ☐ Bollard-type anchors
(44) ☐ Other: ____________________________

(45)Were any other types of permanent PFAS anchorages designed into the project? ☐ yes ☐ no

(46)Does your firm typically prepare a project specific emergency preparedness plan? ☐ yes ☐ no

(47)Does your firm have specific provisions for the rescue of workers who have fallen? ☐ yes ☐ no

Section V: Training

Please estimate by percentage the source of worker training for PFAS usage:

	Union	**Other classes**	**On the job**	**Total**
Source of Training	(48)	(49)	(50)	100%

(51) Does your firm conduct in-house safety training sessions? ☐ yes ☐ no

(52) If yes, to what extent is the promotion of positive safety attitudes incorporated into your firm's safety training programs? low ☐ medium ☐ high ☐

(52) Does your firm offer safety recognition rewards (monetary or material prizes) to promote safe behavior or attitudes for PFAS-certified workers? ☐ yes ☐ no

(53) Does your firm have required content of competent person training? ☐ yes ☐ no

(54) Does your firm train new competent persons in house? ☐ yes ☐ no

(55) Does your firm utilize the training seminars offered by the major manufacturers of fall protection hardware? ☐ yes ☐ no

(56) To what extent do you rely on existing competent persons to mentor the trainees and to manage the training process? low ☐ medium ☐ high ☐

(57)Does your firm conduct field observations of PFAS worker behavior? ☐ yes ☐ no

(58)Does your insurance provider conduct loss control audits that evaluate PFAS use? ☐ yes ☐ no

(59)Does your firm engage in any measurement of worker attitudes toward PFAS safety? ☐ yes ☐ no

(60) If yes, what is the most important safety attitude(s) for workers using PFASs? (Please comment) _______________

(61) Does your firm have a policy for specific fall protection or PFAS safety violations that will result in disciplinary action? ☐ yes ☐ no (62) If yes, please specify? ___________________

(63) Does your firm have a policy for specific fall protection or PFAS safety violations that will result in required retraining? ☐ yes ☐ no

(64) If yes, please specify? ____

Optional

A Summary of this research study will be prepared. If you would like to receive a copy of a summary report as soon as it is available, you may include your name and address below and one will be provided to you. Note that your firm's identity will not be used in any way other than to transmit a report to you. Thank you for your participation in this research study.

Name: ____
Firm: ____
Street Address: ____
City: __________________________ State: _____ Zip: ____________

Fall Protection and Fall Arrest Systems Survey

(1)Does your firm have a worker tie-off and personal fall arrest systems (PFASs) policy that goes beyond OSHA-compliance? ☐ yes ☐ no

If yes, to which trades does the tie-off at six feet above the walking surface rule apply? *(please select all applicable categories)*

(2) ☐ Steel erectors and ironworkers

(3) ☐ Scaffold erectors

(4) ☐ All trades without exceptions

(5) Does your firm have a policy that requires all workers using arrest systems to exclusively use twin-leg lanyards? ☐ yes ☐ no

(6) Is subcontractor compliance with the OSHA regulations mandated in your firm's subcontract agreements? ☐ yes ☐ no

(7) Are your subcontractors that use PFASs contractually required to assign a foreman (who meets the OSHA definition of a competent person) to each work crew using PFASs? ☐ yes ☐ no

(8) Are your subcontractors that use fall arrest systems contractually required to provide project specific fall protection plans? ☐ yes ☐ no

(9) If yes, do these plans specify the location of anchorage connection points or lifelines to be used? ☐ yes ☐ no

(10) What was your firm's recordable injury rate for 2006 (or other recent recording period)?

____

(11) Does your firm engage in any measurement of worker attitudes toward PFAS safety? ☐ yes ☐ no

TRAINING

(12) What percent of your firm's superintendents receive specialized PFAS training? ________%

(13) How many hours of specialized fall arrest systems training do they receive? ______ hours

(14) Does this training include a competency test? ☐ yes ☐ no

(15) On large projects (contracts over $50 million), does your firm require safety orientation training for all workers starting on the project? ☐ yes ☐ no

(16) If yes, does this training include fall arrest tie-off rules and enforcement policies? ☐ yes ☐ no

(17) On small projects (contracts under $10 million), does your firm require safety orientation training for all workers starting on the project? ☐ yes ☐ no

(18) If yes, does this training include fall arrest tie-off rules and enforcement policies? ☐ yes ☐ no

PRECONSTRUCTION

(19) Has your firm made suggestions to the owner about using design for safety to lessen the extent of fall protection and arrest system usage? ☐ yes ☐ no

(20) Please estimate what percent of your firm's projects are design/build contracts: ________%

What types of relationships to designers exist on projects at your firm?
(please select all applicable categories)

(21) ☐ In-house design department

(22) ☐ Design-build alliance (independent A/E firm working under D-B contract)

(23) ☐ A/E consultants under separate contract with owner

(Please fill out applicable sections below)

In-house design departments and design-build alliances

(24) Does your firm provide any specific instruction to designers in how to use engineering to eliminate the need for fall arrest from projects? ☐ yes ☐ no

(25) Does your firm provide any construction safety instruction to designers, for example, a 10-hour OSHA training course? ☐ yes ☐ no

(26) Do your designers participate in planning and drawings for fall protection and arrest system pre-task planning? ☐ yes ☐ no

A/E consultants under separate contract with owner:

(27) Are suggestions for improvements in fall protection ever communicated to the design team (architect or engineer)? ☐ yes ☐ no

(28) Has your firm participated in any team partnering or integrated project delivery mandates at the request of the owner? ☐ yes ☐ no

(29) If yes, was safety for construction workers a topic for coordination with the design team (architect or engineer)? ☐ yes ☐ no

(30) If yes, was fall arrest anchorage a topic for coordination? ☐ yes ☐ no

(31) Did these fall protection communications include raising a building's permanent roof parapet up to a safety guardrail height (per OSHA Regulations 1926, Subpart M)?

☐ Never ☐ Once ☐ A few times ☐ Frequently ☐ Every applicable project

FALL ARREST HARDWARE

(32) Does your firm have a policy that requires 100-percent ANSI label or manufacturer label on all fall arrest equipment on-site? ☐ yes ☐ no

(33) Except for widely recognized standards, such as wire rope splices with U-bolts, does your firm have a policy that requires all custom-designed arrest components on-site to be engineered (signed and sealed by a PE)? ☐ yes ☐ no

Do you have any policies or practices to reduce risks from any of following hardware problems (Check all that apply):

(34) ☐ High impact sideloading of carabineer/snaphook gates

(35) ☐ Usage of connectors or lanyards with damaged webbing

(36) ☐ Usage of inadequately engineered rigging or anchor connectors

(37) ☐ Safe anchorage availability (or lack of the same)

(38) ☐ Unsafe usage of small diameter wire ropes

Contact Information

If you would like to receive a copy of a summary report as soon as it is available, you may include your name and address below and one will be provided to you. Note that your firm's identity will not be used in any way other than to transmit a report to you. Thank you for your participation in this research study.

Name: ____
Firm: ____
Street Address: ______________________________________
City: _________________________ State: _____ Zip: ___________

If a follow-up call for clarifications is needed, may we contact you by phone?

Phone:____________________

Fall Protection and Fall Arrest Systems Survey, follow-up version

(1) Does your firm have a worker tie-off and personal fall arrest systems (PFASs) policy that goes beyond OSHA-compliance? ☐ yes ☐ no

If yes, to which trades does the tie-off at six feet above the walking surface rule apply? *(please select all applicable categories)*

☐ (2) Steel erectors and ironworkers

☐ (3) Scaffold erectors

☐ (4) All trades without exceptions

(5) Does your firm have a policy that requires all workers using arrest systems to exclusively use twin-leg lanyards? ☐ yes ☐ no

(6) What was your firm's recordable injury rate for 2006 (or other recent recording period)? ___

In regard to specialized fall arrest system training for superintendents,

(7) How many hours of specialized fall arrest systems training do they receive? ________ hours

(8) Does this training include a competency test? ☐ yes ☐ no

In regard to training for workers,

(9) On large projects (contracts over $50 million), does your firm require safety orientation training for all workers starting on the project? ☐ yes ☐ no

(10) If yes, does this training include fall arrest tie-off rules and enforcement policies? ☐ yes ☐ no

(11) On small projects (contracts under $10 million), does your firm require safety orientation training for all workers starting on the project? ☐ yes ☐ no

(12) If yes, does this training include fall arrest tie-off rules and enforcement policies? ☐ yes ☐ no

In regard to anchorage and engineering,

(13) Does your firm have a policy that requires 100% ANSI label or manufacturer label on all fall arrest equipment on-site? ☐ yes ☐ no

(14) Except for widely recognized standards, such as wire rope splices with U-bolts, does your firm have a policy that requires all custom-designed arrest components on-site to be engineered (signed and sealed by a PE)? ☐ yes ☐ no

Preconstruction

(15) Has your firm made suggestions to the owner about using design for safety to lessen the extent of fall protection and arrest system usage? ☐ yes ☐ no

What types of relationships to designers exist on projects at your firm?
(*please select all applicable categories)*

☐ (16) In-house design department

☐ (17) Design-build alliance (independent A/E firm working under D-B contract)

☐ (18) A/E consultants under separate contract with owner

(Please fill out applicable sections below)

In-house design departments and design-build alliances

(19) Does your firm provide any specific instruction to designers in how to use engineering to eliminate the need for fall arrest from projects? ☐ yes ☐ no

(20) Does your firm provide any construction safety instruction to designers, for example, a 10-hour OSHA training course? ☐ yes ☐ no

(21) Do your designers participate in planning and drawings for fall protection and arrest system pre-task planning? ☐ yes ☐ no

A/E consultants under separate contract with owner:

(22) Are suggestions for improvements in fall protection ever communicated to the design team (architect or engineer)? ☐ yes ☐ no

(23) Has your firm participated in any team partnering or integrated project delivery mandates at the request of the owner? ☐ yes ☐ no

(24) If yes, was safety for construction workers a topic for coordination with the design team (architect or engineer)? ☐ yes ☐ no

(25) If yes, was fall arrest anchorage a topic for coordination? ☐ yes ☐ no

Contact Information

Name: ____

Company: ____________________________________

Phone: _____________________________________

Integrated Design and Construction Survey

1. How many projects did you work on in the last year? ________________

    2. How many of these projects were design-build contracts? _____________

3. How many projects does your firm undertake each year? _____________

4. What percentage of your firm's projects were design-build contracts? _________%

5. Does your firm provide any training on the OSHA regulations? ☐ yes ☐ no

6. Does your firm provide any training on fall protection anchorage? ☐ yes ☐ no

7. Does your firm provide any specific instruction in how to use engineering to eliminate construction hazards from projects? ☐ yes ☐ no

    8. If yes, does this instruction cover fall protection and the elimination of the need for fall arrest systems? ☐ yes ☐ no

9. Does your firm include special notes or dedicated sheets in the construction drawings to highlight safety hazards and concerns for construction workers? ☐ yes ☐ no

10. Has your firm developed a database of design-for-safety guidelines to be designed into applicable projects? ☐ yes ☐ no

    11. If yes, do these guidelines cover safety for construction workers? ☐ yes ☐ no

12. Do designers at your firm specify roof anchorages (for worker tie-off)? ☐ yes ☐ no

13. Does your firm have a policy implemented that requires every applicable project to go through a safety-for-maintainability checklist? ☐ yes ☐ no (Safety for maintainability is defined as coordinating the design with the owner's maintenance operations)

14. Do company designers make job-site visits to observe safety performance in relation to design-for-safety features that were specified? ☐ yes ☐ no

APPENDIX C
POPULATION DATA FOR DESIGN-BUILD EXPOSITION ATTENDEES

Table C-1. Population for the Designer-builders.

A - E

3Com Corporation*
3D/International, Inc.
Abbott Laboratories*
ADP Marshall, Inc.
American Institute of Architects*
American Red Cross*
Amtrak*
Anheuser-Busch Cos.*
Army Corps of Engineers*
Army National Guard*
Aspen Group
AT&T*
The Austin Company
Baker Concrete Construction*
Barton Malow Company
BE&K Engineering
Bechtel Corporation
Beers Construction Company*
The Beck Group
BFW Construction Co., Inc.*
Black & Veatch
The Boeing Company*
Bovis Lend Lease*
Boyle Engineering Corporation
Bread Loaf Corporation*
Brown & Root Services (KBR)
Bureau of Naval Personnel*
Burns & McDonnell Engineering
Butler Manufacturing Company
California Dept. of General Services*
Cannon Design
Carlson Design/Construct Corp.
Carter & Burgess, Inc.
Caterpillar, Inc.*
CDM Engineers & Constructors, Inc.
Centex Construction Company*
CH2M Hill
Charles Pankow Builders, Ltd.*
Chicago Metro. Pier & Exposition Auth.*
Chicago Utilities Commission*
Church Building Architects, Inc.
Cisco Systems*
City of Atlanta*
City of Los Angeles / Department of Public Works*
City of Orlando*
City of Toronto -- Works & Emergency Services*
The Clark Construction Group, Inc.*
Clayco Construction Company*
Colorado DOT*
Comfort Systems USA*
CORE Construction*
CSX Transportation Director Facilities Design*
Dan Vos Construction*
Dick Corporation*
Dick Pacific Construction Co., Ltd.*
Dillingham Construction Corporation*
DMJM + Harris
Donley's, Inc.*
E-470 Public Highway Authority*
Earth Tech
Exxcel Contract Management*

Table C-1 (continued).

F - R

Fannie Mae*
Federal Bureau of Prisons*
First Industrial Realty Trust*
Florida Department of Transportation*
Fluor Daniel
Frederic R. Harris, Inc. (merged with DMJM)
Frito-Lay*
Fru-Con Construction Corp.*
General Services Administration*
Gerber Products Company*
Gilbane Building Company*
Glaxo Wellcome Inc.*
Goodkind & O'Dea
Granite Construction Inc.*
H+M Construction*
Harkins Builders*
Harold O'Shea Builders*
The Haskell Company
HBE Corporation
HBG Constructors Inc.*
HDR, Inc.
Hellmuth, Obata & Kassabaum, Inc.
Hensel Phelps Construction Co.*
HNTB Design/Build, Inc.
Hoffman Corporation
Honeywell Corporation*
Integrated Electrical Services*
Intel Corporation*
J.R. Filanc Construction Company*
J.S. Alberici Construction Co., Inc.*
Jacobs Engineering Group
James McHugh Construction*
James N. Gray Company*
Kajima Construction Services*
KINETICS/ U.S. Filter Bio/Pharm Div.*
Korte Construction Company*
Los Alamos National Laboratory*
M.A. Mortenson Co.*
Marnell Corrao Associates*
Martin K. Eby Construction Co., Inc.*
McCarthy Building Company*
McShane Construction Corporation*
Mercedes-Benz USA*
Minnesota Dept of Transportation*
MWH
National Cancer Institute – NIH*
National Corrections Corporation*
National Park Service*
Naval Facilities Engineering Command*
New York City School Constr. Authority*
O'Brien/Atkins Associates, PA
Ohio Department of Transportation*
Opus Companies
Oracle*
Orange County Government*
Oregon Department of Transportation*
P.J. Dick Incorporated*
Parsons Engineering
PB Constructors Inc.*
PCL Construction Services, Inc.*
Kiewit*
Philip Morris USA*
The Pillsbury Company*
Proctor & Gamble*
RTKL Associates
Rudolph & Sletten, Inc.*
Ryan Companies US, Inc.

Table C-1 (continued).

S – Z
Sega Inc.*
Skanska, Inc.*
State of Arizona Dept. Construction Services*
State of California Franchise Tax Board*
The Stellar Group
STV Construction Services*
Suitt Construction Company*
Sundt Construction, Inc.*
Trane Company*
Trauner Consulting*
Turner Construction Company*
Union Pacific Railroad*
U.S. Army Community & Family Support Center*
U.S. Dept. of General Services*
U.S. Dept. of State*
U.S. Dept. of Veterans Affairs*
University of Chicago*
Utah Department of Transportation*
ValleyCrest Companies
The Walgreen Company*
Walker Parking Consultants
The Walsh Group*
Walt Disney Imagineering
Washington Group International
Webcor Builders*
The Weitz Company*
Western Summit Constructors, Inc.*
Whirlpool Corporation*
Wight Construction Services, Inc.*
York International Corp.*

Notes:
1. Company names followed by an asterisk (*) do not offer architecture or engineering services and were not contacted.
2. Note from Design-Build Institute of America about the population: "Organizations who have recently attended the Design-Build EXPO (Partial List)."

APPENDIX D
FALL INJURY CASES ANALYZED FROM THE NIOSH DATA

Table D-1. Fall injury cases analyzed from the NIOSH data.

Face No.	PFAS Safety Principle Violated	NIOSH Data[1]
89-03	Not 100% tie-off.	The victim, working as a member of a three-man crew, was painting a highway bridge spanning a large river. The victim and his co-workers had been working on the same bridge for approximately 6 weeks prior to the incident. On the day of the incident the victim and one co-worker had just finished lunch and were moving materials from one "bay" beneath the roadway to an adjacent "bay" prior to beginning the afternoon's work. Both men were wearing a safety belt and lanyard, with the lanyards secured to a steel lifeline running along the side of the bridge. To reach the new work area it was necessary to step from one steel "I" beam to another approximately 4 feet away. An expansion joint in the area prevented the workers from making this step while their lanyards were connected to the lifeline. Although the incident was not witnessed, it appears that the victim, while carrying a partially filled 5-gallon paint bucket, disconnected his lanyard and attempted to step across the 4-foot gap to the next beam. In doing so, he either slipped or lost his balance and fell 96 feet, striking the back of his head on the rocky ground below. The co-worker, and a supervisor who arrived on the scene just as the incident occurred, immediately summoned local police and rescue personnel. The victim was pronounced dead at the scene by the local medical examiner. Strong association with exterior painting
89-21	Equipment failure; Lack of regular equipment inspection may have been a cause.	At the time of the incident the men had completed the interior finish of the third silo and had begun to disassemble the scaffolding. Each man was using a nylon rope lanyard attached to a chain on a scaffold bracket. The brackets were spaced 6 feet apart. As each man reached a point in the operation where he was ready to drop a bracket to the ground, he hooked his lanyard to the chain on the next bracket. At some point the victim lost his balance and fell off the end of the scaffolding. The co-worker stated that he saw the victim fall and jerk upwards as the lanyard caught him. As the victim's weight dropped back on the lanyard, it snapped, causing him to fall 160 feet to the concrete floor below. When the lanyard was inspected, burn damage was discovered in several places, including the point at which it had snapped. This damage probably occurred during welding or burning operations from a previous job. Association with concrete finishing

Table D-1 (continued).

Face No.	PFAS Safety Principle Violated	NIOSH Data[1]
89-24	Improper use of anchorage	A male carpenter fell 90 feet to his death from the top of a precast concrete parking garage which was under construction. The victim, working from a wooden beam, was tied off to a 1 1/2-inch- diameter rebar in the following manner. The victim secured one end of a 6-foot lanyard to one "D" ring on his safety belt, fed the other end of the lanyard through a second "D" ring on his belt, and then secured it to the first "D" ring. This created a loop with the lanyard. He took an 8-foot lanyard and, at its midpoint, wrapped it several times around the 1 1/2-inch rebar. He took one end of the 8-foot lanyard, passed it through the loop of the 6-foot lanyard and fastened the snap hook to the snap hook at the other end. The victim asked his co-worker to get him a portable power saw. The co-worker turned and saw the victim fall off the edge of the building. Association with concrete erection
90-12	Not 100% tie-off.	A journeyman painter died when the swing scaffold he was using to access the interior of a 68-foot-tall by 32-foot-diameter municipal water tank fell. The painter was working from a single point suspension scaffold near the top of the tank. The painter was wearing a safety belt and lanyard secured to a lifeline. When he finished painting the upper area of the tank the painter disconnected his lanyard from the lifeline and moved to the other end of the scaffold to hand the spray paint gun he was using to his foreman. The foreman had just taken the spray paint gun from the victim when he heard a "pop" and saw the scaffold on which the victim was standing fall to the floor of the tank 65 feet below. Investigation after the incident revealed that the two "U" bolts on the cable which supported the block and tackle from which the scaffold was suspended had loosened enough to allow the cable to slip through them, causing both the scaffold and all of its supporting hardware to fall. Strong association with painting and water tanks.
92-05	Not 100% tie-off.	A 31-year-old painter (victim) died from injuries sustained in an 80-foot fall from a 120-foot-high electrical transmission tower. The victim was a member of a four-man crew painting the tower. The crew had painted one side of the tower, from top to bottom, and had begun to paint the other side. The four crew members were working at the same level on the tower and all were wearing safety belts and lanyards. As the victim unhooked his lanyard to reposition himself on the tower, he lost his balance and fell to the ground. Strong association with transmission tower work

Table D-1 (continued).

Face No.	PFAS Safety Principle Violated	NIOSH Data[1]
92-08	No personal fall arrest system or other fall protection used.	The company had been contracted to re-roof a private residence that was currently occupied. The main roofing work had been completed approximately 2 weeks prior to the incident. However, the homeowner complained about a section of the roofing which was misaligned. The victim was working alone on the roof, which had a pitch of 4:12 (4 feet of vertical rise to 12 feet of horizontal width). He had realigned all but two shingles, when he fell from the edge of the roof to a concrete patio deck 16 feet, 3 inches below (Figures 1 and 2). The victim was not using any type of fall protection devices or systems. Although no one saw the victim fall, the estimated time of occurrence was 6:42 p.m. The homeowner reported hearing an unusual sound and looked out a window. She saw the victim lying on the patio; he was unresponsive and bleeding from the back of the head. She called 911 and an emergency medical service (EMS) team arrived at the scene approximately 3 to 4 minutes later. They found the victim traumatized, unresponsive, and in cardiac arrest. The EMS team administered CPR, stabilized the victim, and transported him to a local hospital. He remained in a comatose condition and died 3 days later. Association with residential roofing
92-11	No personal fall arrest system or other fall protection used.	A 41-year-old male ironworker (the victim) died after falling from a structural steel framework to a concrete floor during the construction of an automobile repair shop. The victim and two other ironworkers (coworkers) were assembling the steel frame "skeleton" (measuring 50 feet wide, 86 feet long and 18 feet high at the roof edge) of the structure. Sway-bracing rods had not been installed between the beams (combination column-roof truss units) , the bolts at the base of the beams had not been fully tightened, and two steel beams had not yet been connected at the roof-line apex. As the victim walked on top of a stack of unsecured purlins (steel joists) along one edge of the frame to make a final measurement, the frame began to sway. The victim lost his balance, and fell 18 feet to the concrete floor, receiving fatal injuries. There was no fall protection equipment in place, and the victim was not wearing a helmet. Strong association with steel erection.

Table D-1 (continued).

Face No.	PFAS Safety Principle Violated	NIOSH Data[1]
95-09	No personal fall arrest system or other fall protection used.	A male carpenter died after falling 16 feet from a roof onto a concrete porch floor. The victim was a member of a five-man (foreman and four carpenters) crew laying roofing felt on the gable roof of a newly-constructed, prefabricated church and sacristy. The roof was 48 feet wide by 106 feet long. The crew had completed applying the felt to one half of the roof and was applying the eighth course to the second half of the roof when the incident occurred. The victim was walking backward on the roof unrolling the felt. Approximately 8 feet in front of the victim, a second crew member was temporarily nailing down the felt. A short distance behind the second crew member, the two additional crew members were permanently nailing the felt to the roof sheeting. The foreman was on the roof observing the crew. The men were only unrolling 8 feet of felt at a time because it was a windy day, with gusts up to 25 miles per hour. As the men approached the end of the roof, the foreman was called to the ground to discuss the color of the shingles with the church preacher. The worker temporarily affixing the shingles looked up to see the victim approaching the edge of the roof and yelled for him to "watch out." The victim lost his balance and fell backward off the roof. The victim fell approximately 6 feet, struck a cross brace on the framework of the church's porch, then fell another 10 feet, striking his head on the concrete floor of the porch. The crew members left the roof and ran to the victim, finding him unresponsive, bleeding from the nose and ears. The victim was later pronounced dead at the site. Strong association with residential roofing
96-01	No personal fall arrest system or other fall protection used.	A male sign installer died after falling from a canopy located above a loading dock, and striking his head on the bed of a truck crane. The victim and a co-worker had been assigned to remove four wooden signs above a loading dock at a food distribution warehouse. While attempting to remove the fourth sign, the victim was standing on a canopy which was about 15 feet above the ground and was not using any personal protective equipment (Note: a safety belt and lanyard were available in the truck crane). The co-worker positioned the truck crane beneath the canopy where the sign was located and extended the boom above the sign. The victim attached the crane's load line around one of the metal brackets which secured the sign to the building. He then removed five lag screws which secured the sign to the building. As he removed the fifth screw the sign swung free. At that time the lag screw which attached the metal bracket to the wooden sign frame pulled out of the wood. The sign dropped and struck a diagonal canopy pipe support. The sign then slid down the support and struck the victim, knocking him off the canopy. The victim fell about 12 feet and struck his head on the corner of the truck bed. The coworker, who witnessed the event, ran to aid the victim. He found the victim unresponsive and bleeding profusely. Association with sign installers.

Table D-1 (continued).

Face No.	PFAS Safety Principle Violated	NIOSH Data[1]
96-21	Not 100% tie-off.	On June 27, 1996, a 27-year-old laborer (the victim) was fatally injured when he fell through an unguarded roof opening while repairing the rubber roof membrane of a college sports coliseum. The victim and his foreman were repairing the membrane after it had been sliced open to provide access to the underlying roof structure. The victim had been cleaning the existing membrane while his foreman, working behind him, was completing the patch. The victim had progressed to the peak of the arched roof, out of sight of the foreman, and had disconnected his fall protection lanyard from the lifelines. For an unknown reason, the victim stepped on an exposed ceiling tile which gave way, allowing the victim to fall 90 feet to the gym floor. Workers inside the gym saw the victim fall and hit the floor. One of the workers, an EMT, immediately went to the victim and began CPR while another worker notified 911. The campus emergency medical squad (EMS) responded within 8 minutes and transported the victim to a local emergency room, where he was pronounced dead. Association with roofing.
97-08	No personal fall arrest system or other fall protection used. Behavioral failure (failure to respect warning line).	A 22-year-old male carpenter's helper (the victim) died of injuries he received after crawling from an unprotected floor edge onto an unsecured piece of plywood and falling 120 feet to the ground. At the time of the incident, concrete forming work had been completed on 12 floors of a condominium under construction. The victim was part of a crew removing form materials (plywood, etc.) and was assigned to work on the 10th floor. The victim had been on the 12th floor obtaining a safety harness and was en route to the 10th floor via a personnel hoist when he stopped the hoist and exited at the 11th floor. A co-worker from the floor above had yelled down to the victim, asking him to plug in an extension cord that was hanging from the 12th to the 11th floor. He crawled under a red tape warning line at the floor edge of the atrium onto a piece of unsecured plywood. The plywood gave way and the victim fell 120 feet to the ground. The local emergency medical service responded in less than 10 minutes, but the victim was pronounced dead at the scene. Association with concrete formwork and erection.

Table D-1 (continued).

Face No.	PFAS Safety Principle Violated	NIOSH Data[1]
97-10	Not 100% tie-off.	A male tower erector died as a result of injuries sustained in a 200-foot fall from a telecommunications tower. The incident occurred while the victim and a co-worker were connecting antenna-support brackets onto a leg of the tower. The victim apparently disconnected or was attempting to re-connect his fall protection and was climbing down the leg of the tower from 220 feet to 200 feet when he fell to the ground. Strong association with telecommunication towers.

Notes:
1. Selected excerpts of the original NIOSH transcripts (National Institute for Occupational Safety and Health. 2000).

APPENDIX E
FALL INJURY CASES ANALYZED FROM THE OSHA DATA

Table E-1. Fall injury cases analyzed from the OSHA data.

Case	PFAS Safety Principle Violated	OSHA Data
1	Correct tieoff policy not used (continuity)	The employee was working in a personnel basket hoisted by a 100 ton Linkbelt [crane]. The victim was equipped with a full body harness with lanyard and a chain wall hook. The victim exited the basket to station himself on the outside face of the bridge column. He failed to first attach his lanyard prior to exiting the personnel basket. He had climbed onto the horizontal rebar of the bridge column and attached his wall hook to the outside rebar band. The victim leaned back to retrieve his lanyard and shifted his full body weight to the wall hook attached to the horizontal rebar. The wire ties broke from the excessive weight of his body causing the wall hook to slide off the end of the rebar. The victim fell 90 feet to the concrete footer of the column resulting in fatal injuries. Strong association with positioning devices
2	Positioning device - no PFAS	On 12/28/98 at approximately 10:15 a.m., the victim was removing bolts on a vertical concrete form inside of a bridge pier. He was wearing a body harness with one lanyard and also had a wall chain for a positioning device. The victim fell approximately 43 feet to the base of the pier. His lanyard was not being used, and the hook on the wall chain had a defective safety latch. Strong association with positioning devices
3	Anchorage not installed	Employee 1 was using a pry bar to position a 6 ft by 20 ft by 1/4 in. steel sheet on the roof of a tank. He fell 43 ft from the roof to the inside floor of the tank. Employee 1 died. He was equipped with a safety harness and a lifeline, but did not have a place to tie off on top of the tank. No association
4	1. Not 100% tie-off 2.Either anchorage not installed or not used properly.	At approximately 11:20 a.m. on July 22, employee 1, an apprentice carpenter employed by [construction] co., fell approximately 76 feet from the temporary deck of the Bridge to the ground. Employee 1 was wearing a full body harness with a lanyard, but was not attached to a secure anchor point while placing form panels. Employee 1 received severe internal injuries and broken bones. He was pronounced dead at approximately 12:20 p.m. at the medical center. Strong association with concrete formwork

Table E-1 (continued).

Case	PFAS Safety Principle Violated	OSHA Data
5	Roll-out	Shortly after 2:00 pm on may 8, 1996, employees were installing sheet metal decking on the 3rd level of a steel structure building under construction. An employee was placing short sections (16') of decking on 3 joists. As he progresses with this task, he kicked the last sheet placed to make it fall into place and interlock with the previously laid sheet. The sheet slipped away from the 3rd joist and the employee started falling through to the lower level. At the time of this event, the victim was wearing a full body harness and was tied-off to a retractable cable block about 15'-18' away. As he fell, somehow the cable hook came undone/slipped out of the "d" ring attached to the body harness. (Note:) the block had been recently purchased and put into service just a couple of days before the event. The victim fell approximately 36' to a concrete floor below.
6	Not 100% tie-off	Employee 1 and a coworker were unloading 20 ft sheets of metal roofing material on a two-story, multi-family building. While unloading the material, employee 1 was using a full body harness and safety line. Witnesses said he unfastened his line from the harness and attempted to walk across four metal panels to another roof line. He slipped and fell 19 ft to the concrete, striking his head. He was taken to the hospital, where he died the next morning. Strong association with decking
7	100% Tie-off for aerial lift users	On 2-22-01 at a manufacturing site, a contracting company, that has had a long standing contract with the manufacturer for performing contracting work, such as constructing buildings, was demolishing a wood existing building. The contractor had previously built a new building over the existing building that was being demolished on this date. An employee, approximately 1 yr in the employment of the contractor had been working from a boom lift man basket. A harness and lanyard were in the basket but had not been worn by the employee. Although it was company policy to wear the PPE, the employee had not at this time, and apparently had exited the man basket and stepped onto the roof of the wooden structure that was being demolished. The employee apparently had fallen through one of the openings in the roof. There were no direct witnesses, but 2 other employees (supervisor and laborer) working nearby heard a thump and discovered that the employee had fallen. Strong association with aerial lift
8	100% Tie-off for aerial lift users	Employee 1 was working in an elevated bucket approximatley eleven feet above the ground splicing telephone cables. He was wearing a harness and lanyard that had not been tied off to the boom. Somehow he either leaned or otherwise shifted his weight onto the door of the bucket and the door opened, causing him to fall to the ground and suffer fatal head/neck injuries. The door latch was found to be defective. Strong association with aerial lift

Table E-1 (continued).

Case	PFAS Safety Principle Violated	OSHA Data
9	100% Tie-off for aerial lift users	The deceased age 50, was operating an aerial lift when he was thrown from the basket per eye witnesses. Employees who had been using the aerial lift were not wearing body belts or harnesses with appropriate lanyards attached to the boom or basket. Mr. [name] was operating the condor 48 foot aerial lift at a height of approximately 14 feet above the pavement when he fell. Demolition of the curtainwall (back wall) of the 2 story motel involved removing glass windows and wooden soffits. Employees pried with bars and the lift basket to remove the soffit from the underhang/wall and had been using the lift this morning to reach the 2nd floor and to lower windows once removed. The lift gave some indications of erratic action but was not removed from service. Another operator believed it "jumped" or reacted rapidly to control input at one point before the deceased took over operating the aerial lift this morning. After the incident the equipment was tested and the platform leveling mechanism failed to respond. This may have been what caused the deceased to be thrown from the basket. The eyewitness did not see the action of the lift but did turn in time to observe the victim travel in an arc over the guardrails and fall headfirst to the pavement. Strong association with aerial lift
10	No anchor connector installed	Employee 1 was working on the seventh floor level of an office building under construction. The building was in the process of having the floors formed and poured. Employee 1 was on the perimeter edge on the east side of the structure. He was patching/filling post tensioning holes with concrete on the exterior side of the outer columns, between the floors, when he fell approximately 80 feet. Employee 1 was wearing a safety harness and lifeline. There were no witnesses (from the seventh floor level) who saw employee 1 fall. Employee 2 was on the second floor level when employee 1's body passed by. Employee 2 (site superintendent) thought that it was trash being tossed over the side and went to the perimeter to see what it was. He then saw employee 1 laying on the ground. Employee 3 who was facing the building at ground level about 100 feet away looked up and saw employee 1 fall to the ground. Strong association with Concrete formwork
11	100% tie-off for aerial lift users	Employee 1 was working from a Skyhook Aerial Crane with a manbasket attached to the end of the boom. He was approximately 80 feet in the air cutting brackets which held a sign. Another crane was used to lift the sign once the sign was cut away from its support. The large sign was actually two signs bolted together and held in place by six brackets. Four brackets held the lower sign and two brackets held the upper sign. Employee 1 was going to cut the four lower brackets with an oxy-acetylene torch and then reposition his aerial lift on top to cut the final two brackets. This was he would be above the sign when making his last cuts. When the fourth bracket was cut on the lower sign, it became detached from the upper sign and fell striking the aerial lift. Employee 1 was not wearing a harness and was bounced out of the basket fall 80 feet to the ground below. He died from injuries sustained in the fall. Strong association with aerial lift

Table E-1 (continued).

Case	PFAS Safety Principle Violated	OSHA Data
12	Correct tieoff policy not used (continuity)	On 05/15/97, employee 1 was involved in the erection of a communications tower located in [deleted name] county. Employee 1 was working on the tower at a level of 200 feet from the ground. He was issued and wearing a body harness with a 10 foot lanyard, no energy absorbing, and a short positioning lanyard with a large hook designed to quickly snap onto the structure to keep the employee centered. Employee 1 was in the process of moving from one face of the tower to another, when he fell to the ground sustaining multiple fatal injuries to chest, back, head, and other portions of the body. The tower was a steel lattice structure being erected for a [telecom co.] and would have a completed height of 300 feet. Employee 1 was working bolting the legs of the tower together and had erected 20 feet that morning and was working at the 200 foot level when he attempted to move from one side to the other. A witness stated that he heard a noise possibly as employee 1 attempted to hook onto the structure with the large positioning hook, and miscued and fell 200 feet to his death. strong association with telecom tower
13	Correct tieoff policy not used (100% PFAS)	On 6-26-2001 the employees of [telecom co.] were in the process of erecting a telecommunication cellular tower, they working at approximately 100 feet. The foremen and another employee had just finished bolting a section of the tower. The employee next to the foreman stated the foreman hooked his positioning belt to a bolt and leaned back. The hook apparently slipped off and the foreman feel 100 feet to his death. The foreman was wearing a harness but did not have a lifeline or lanyard attached. He was only using the positioning belt which had a chain attached in the front and a hook, the employees called a pelican hook, attached to the chain. When the hooked slipped he had no secondary fall protection. strong association with telecom tower
14	Roll-out (Locking snaphook not used)	Employee working at an elevation of 28 feet above the next level. The employee was making a double connection and was removing the last 2 bolts from the existing beam, the employee was using a body harness and lanyard when he bent over to remove the 2 bolts he rolled out of his lanyard and fell to the concrete pad below. The lanyards self-closing latch remained fully open. Association with steel erection

Table E-1 (continued).

Case	PFAS Safety Principle Violated	OSHA Data
15	Not 100% tie-off	A bridge was being constructed. On one span of that bridge, sheet metal decking had been incorrectly installed over the openings (bays) between the concrete bridge beams. It was at the wrong angle. A three-man work crew was assigned to remove the decking, cut off the supporting angle iron, re-install the angle iron and then replace the decking. Two employees were actually placing the sheet metal panels over the opening and screwing them down while the other employee was handing the panels to them. These employees were all wearing safety harnesses with double lanyards. They were instructed to be tied off to the shear connectors in the bridge beams at all times. The shear connectors were resin-coated 5/8 inch rebar that ran virtually all the way through the beams and had a pull out strength well over 5000 pounds. The decking had been replaced over almost all of one of the bays between the beams. The only remaining opening in the bay was smaller than a sheet of metal decking. The workers disconnected their lanyards from the shear connectors and moved away from the opening to cut off a sheet of decking. When they had cut the sheet off, they returned to the opening but did not tie off, the worker who did not fall said that he thought that the sheet metal would provide fall protection. The decking apparently did not fit down on the angle iron sufficiently, possibly because it had been cut off. The victim stood with both feet on the sheet metal panel which was in position over the opening. As he was about to screw it down, the decking gave way. He fell through the opening about 56 feet to the ground below. After the event, the sheet of decking was hanging in the opening. Strong association with decking
16	Correct anchor connector not used	A carpenter/laborer was placing pins at the top of a column form with the safety lanyard of the full body harness looped around the steel rebar sticking up from the top. The form and employee fell from the 12th floor to the ground level deck approximately 130 feet. Strong association with concrete formwork
17	Anchorage not installed	Two iron workers were assigned to close up an opening on the roof and install fascia along the edge of a section of roof which had been left open on the top floor of a highrise building so that the final roof could be installed. This work was to have been done from the protected floor below, however, for some both employees climbed on to the roof which was covered with a light ice or frost. Both employees were wearing full body harnesses and had lanyards attached, but did not have a tie off point at the area where they were working. They slipped and fell approximately 84 feet and were killed . Association with ironworkers
18	Not 100% tie-off	Steel worker was working at the site address of [deleted]. The worker was connecting a steel beam at the highest point of the new building being built. He was in the center of the building when he fell twenty eight feet five inches to the ground. The worker was wearing a full body harness with two lanyards. The worker unsnapped his lanyard from the attachment point, and reached out to disconnect a steel choker used to set the beam in place when the fall occurred. Mild association with steel erection

Table E-1 (continued).

Case	PFAS Safety Principle Violated	OSHA Data
19	Inspect equipment before each use	An employee of [company name] erectors was killed when he fell while installing steel roof trusses at a height of about 20 feet. He was wearing a safety harness with the lanyard properly attached to a point having the required load carrying strength. The lanyard, a ripstich shock-absorbing type, broke before the ripstitch shock absorber functioned. The victim struck steel floor joists that had already been installed at the floor level to accommodate removable flooring typical for a computer room. Mild association with steel erection
20	Fall hazard analysis must be project specific (pendulum swing)	An employee of an electrical contractor fell while attempting to adjust lights on a newly constructed light system at a [university] Stadium. The light pole reaches more than 116 feet above a concrete base below. The employee had attached his safety harness and 6 foot lanyard to the safety sleeve which he attached to the cable that was fixed to the side of the pole. He climbed up to the bottom of the first section of lights which where about 96 feet above the ground. He lost control before leaving the pole; he never entered the cat walk to adjust the lights. He fell 81 feet down the side of the pole while still attached to his safety harness, lanyard, and safety sleeve (cable grab). The safety sleeve (cable grab) did not arrest his fall. His body apparently struck foot pegs and cable guides along the way down the pole, which produced injuries that caused his death. The employee had no vital signs when the medical emergency team attempted to rescue the man.
21	Not 100% tie-off	A steel erector working 24' to 28' above concrete floor was not using personal fall protection system when he accidentally stepped off of steel decking and fell 24' to floor. Victim was wearing personal fall protection equipment (harness) but was not tied off to a lanyard or life line. Mild association with decking
22	Not 100% tie-off	Two workers were in the process of removing concrete panels from a wall that was approximately 38 feet high. The victim was wearing a full-body harness with a chain positioning device and "d" ring in the front. The employees would use the positioning device by attaching to re-bar or taper-ties at waist level and remove the tie at shoulder height and then move down to the next taper-tie. The employee would then reattach his positioning device and remove the next tie. The employees were not utilizing lanyards on the full-body harnesses nor were they protected from falls when moving from point (a) to point (b). It was when the employee had unhooked to move down to the next taper-tie that he fell falling approximately 32 to 36 feet to the ground. Strong association with positioning device

Table E-1 (continued).

Case	PFAS Safety Principle Violated	OSHA Data
23	Temporary change in work area	The accident victim was part of a crew that was in the process of removing a flying-form from the seventh floor of the concrete building which was under construction. During normal construction activities the open sides of all floors are guarded with chain guardrails. Employees are provided with safety harnesses and lanyards and they are instructed to tie off anytime they are required to work within 6 (six) feet of an open sided floor. At the time of the accident the chain guardrail was removed so the flying-form could be removed from the seventh floor. As the crew was pushing the form one of the support rollers, located on the floor 25 inches from the edge of the floor, did not appear to be turning freely. The victim went over to the roller and hit it with a sledge hammer to free it up. The victim did not tie off to perform this work. The crew supervisor saw what was going on and he told the victim to stop. After the victim hit the roller, and heard the supervisor yell, he quickly spun around to come back to the crew but he became tangled with his own two feet. The victim fell backwards on his buttocks at the edge of the floor and then fell backwards off of the edge of the floor, to the ground below. Strong association with concrete formwork
24	Not 100% tie-off (continuity)	The deceased was working on the roof (west side) of a three story apartment building installing 4 x 8 sheets as roof decking. Another employee was performing the same type of work on the east side of the roof. Both employee were wearing safety harnesses and were tied off. At the end of the day, both employees discussed finishing up and going home. Each employee went back to their work area and shortly after this it was noticed that he was lying on the concrete ground level three stories below, near his work area on the roof. There were no witnesses to his fall. He had been wearing a safety harness and was attached to a life line secured to the trusses as he worked throughout the day, but had removed the safety harness, and apparently was in the process of climbing down the structure to leave the work area, and slipped, falling to his death three floors below because of the lack of a ladder to be used by employees to reach the work area. Mild association with decking
25	100% PFAS for aerial lifts	A 19 year old employee of [company name] Erectors, Inc. fell from a second floor balcony after unlatching his lanyard from his harness and leaving a man basket elevated by a forklift. Employees were installing windows at the time of the accident. Mild association with aerial lift
26	Special inspection protocol for SRL (SRL failure)	An employee fell 60 feet while decking a metal roof. The employee was wearing a full body harness and a self-retracting lanyard, however, the lanyard did not activate until he had fallen 29 feet. At that time the self retracting lanyard cable broke and the employee fell another 31 feet. Strong association with decking

Table E-1 (continued).

Case	PFAS Safety Principle Violated	OSHA Data
27	Special inspection protocol for SRL (SRL failure)	The victim was laying the initial metal decking on the steel beam of bridge 610 (an elevated highway) under construction over Interstate [deleted] at Interstate [deleted] in Virginia. He was tied off wearing his body harness and retractable fall protection device. While placing the metal decking down on the bridge, he fell through the opening. The fall protection (the retractable cord) broke and he fell one hundred feet to the ground below He had multiple injuries to his body and died at the accident scene. There were two other co-workers in the area, (on the elevated highway to the rear of the victim) but they did not see him fall. Strong association with decking
28	100% PFAS for aerial lifts	Employee 1 was in bucket of an extensible boom crane truck to repair/replace a light bulb for a [deleted] Hotel sign. A grounds man was stationed at the rear of the truck operating the crane boom to lift the employee up to the sign (approximately 42 feet high). The groundsman heard a loud "Pop" and the boom suddenly retracted to approximately 25 feet high. Upon coming to an abrupt stop, employee 1 was thrown through the side of the fiberglass bucket (which was apparently already in disrepair) and fell 25 feet to the ground where he either died upon impact or shortly thereafter. Employee 1 was wearing a safety harness, but had not been tied off. Strong association with decking
29	PFAS user training for pendulum swing hazard	The deceased was involved in connecting a steel beam approximately 15 feet above the ground. He was on the beam, and was wearing appropriate personal fall protection equipment. After completing his connections, he stood, and then fell from the beam. His harness and lanyard limited his fall to approximately three feet, and prevented him from falling to the ground. The lanyard caused him to swing into the support column, and to strike his head. The Medical Examiner's report stated that his manner of death was "natural", and the probable cause of death was "severe centrilobular emphysema and generalized pleural fibrosis." Strong association with steel erection
30	Hierarchy of fall controls - use aerial lift	Victim fell approximately 15 feet to concrete floor while installing roof trusses. Victim was wearing full body harness with lanyard. Victim had unhooked lanyard from roof truss to move to, or reach to, next roof truss so he could fasten cross brace in place which would secure roof truss in position. No other employees present actually saw victim fall. All previous trusses had been 24" on center, span to roof truss that victim was installing was 45" on center due to ventilation passing between. Association with building erection (specific trade unknown)

Table E-1 (continued).

Case	PFAS Safety Principle Violated	OSHA Data
31	Not 100% tie-off	At approximately 1:05 PM on January 13, 2004 the victim and another employee had been working on wingwall C removing wood falsework form from a concrete form. Both employees were working on opposite sides of the 28 foot high wall. The victim was wearing a full-body harness and using one positioning hook for fall protection. With this particular system it would not protect the victim when moving from one work position to another. Both employees were in the process of moving to a lower work elevation, at approximately the 20 foot elevation. The other employee did not see the victim fall. After attaching the grid reinforcement bar in front him, he looked in the direction where the victim should be; at that moment he heard another employee yelling that the victim fell. He then ran to a fellow employee to make a phone call to 911 and the superintendent. The victim was attended by local EMS personnel, he was pronounced dead at the scene by [deleted] County Coroner. Strong association with positioning device
32	Total Fall Distance problem	On 5/14/04, at approximately 10:25am, two employees were installing sheet metal roof on a section of highrise building. Both employees were tied off to a rope via body harnesses and lanyards. Employee B lost his balance and slid off the roof taking employee A with him. Employee B was stopped by the fall protection system above the concrete floor which was approximately 15 feet below. Employee a hit a 46 inch concrete wall with his head. Both victims were transported to a local hospital where employee B was released following an exam for bruised ribs. Employee A expired at the hospital on 5/15/04. Strong association with decking

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BIOGRAPHICAL SKETCH

Matthew Albert Harris was born in Redwood City, California. He grew up in a family with one other sibling (sister, Jennifer Ann Harris) and spent his formative years in the San Francisco Bay Area. He went to elementary school at Willow Elementary School in Menlo Park. Mr. Harris completed college preparatory courses at Palo Alto Senior High School in Palo Alto, California. He began his college education at Foothill Junior College in Los Altos Hills. After completing his general education requirements, Mr. Harris transferred to a four-year-degree-granting university and graduated with a Bachelor of Arts degree in Art History from the University of California, Santa Cruz. After attending the University of Oregon, where he was awarded the degree of Master of Architecture, Mr. Harris spent several years working in the architectural services industry as an architect. Mr. Harris' interests in healthcare systems design, risk management, and other design issues pertaining to complex institutional facilities (such as, airport terminals, research laboratories and fire stations) compelled him to return to school to study construction management and worker safety. He enjoys sea kayaking, cycling and hiking for recreational activities. He plans to live in Texas with his wife and daughter after graduation.