



Construction Industry Institute®

Going Beyond Zero Using Safety Leading Indicators

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Construction Industry Institute

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GOING BEYOND ZERO USING SAFETY LEADING INDICATORS

by

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A Report to
Construction Industry Institute
The University of Texas at Austin

Under the Guidance of
CII Research Team 284
Leading Indicators for Safety

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EXECUTIVE SUMMARY

In the construction industry, safety performance has historically been measured with lagging indicators of safety performance, such as total recordable injury rates (TRIR); days away, restricted work, or transfer (DART) rates; and experience modification ratings (EMR). These metrics are *lagging* indicators because they are linked to after-the-fact assessments of safety performance. Alternatively, *leading* indicators are metrics that are linked to actions taken to prevent accidents which can also be used to predict future safety performance. Leading indicators are classified as passive (e.g., strategies such as policies or programs implemented to improve safety performance) and active (e.g., measures of the effectiveness of safety policies/programs). The three primary aims of this study were to (1) identify passive leading indicators that most effectively predict safety performance, (2) identify high potential active leading indicators that have proven to be successful or show high potential for success, and (3) to create resources that facilitate the effective implementation of policies/programs linked to leading indicators.

The first phase of the research involved studying passive leading indicators. Initial efforts to identify passive leading indicators were directed to the findings of past construction safety studies. Brainstorming sessions and extensive discussions were also held by the research team to identify potential passive leading indicators. The relative impacts of these metrics were quantified using statistical analyses of research data collected through interviews conducted with representatives of 57 construction projects. Statistical tests showed that 10 particular practices were associated with lower injury rates. The implementation of these strategies is inversely related to project TRIR, namely that as more strategies were implemented the injury rates were lower.

The objectives of the second phase were to (1) clearly identify and define active leading indicators that can be measured and monitored during the construction phase, (2) describe resources that were required on actual projects, (3) establish thresholds to trigger a response action, and (4) describe specific management actions required when an indicator fails to satisfy the threshold value. Active leading indicators were identified through a combination of case

studies, information extrapolated from descriptions of award-winning projects, and research team brainstorming. The research approach involved a unique triangulation of empirical and opinion-based data sources that produced internally and externally valid and reliable results.

1. INTRODUCTION

Since the passage of the Occupational Safety and Health Act (OSH Act) of 1970, workplace injuries and fatalities have decreased significantly; however, the construction industry still accounts for 17% of all fatalities, even though it only employs 6 to 8% of the US industrial workforce (BLS 2011). In fact, the number of fatal and disabling injuries among construction workers is three times greater than the all-industry average (Pinto et al. 2011). Because costs related to these accidents are very high, companies are forced to invest in safety. For example, it has been shown that injuries alone account for 7.9 to 15% of the costs of new construction (Everett and Frank, 1996).

Szymberski (1997) and Rajendran and Gambatese (2009) claim that safety management should be moved upstream and that pro-active safety management has a strong positive influence on performance. Strategies such as designing for safety have been investigated in past research (Gambatese et al. 1997; Toole 2002); however, pro-active methods of safety management also occur during the construction phase. For example, pre-task planning, stop work authority, and hazard recognition programs are all methods of identifying and controlling potential hazards before they are encountered in the workplace (Zohar 1980; Meridian, 1994; Hinze 1997; Hinze and Gambatese, 2003; Hallowell and Gambatese 2009; McDonald et al. 2009; Molenaar et al. 2009, Rajendran and Gambatese 2009, Zou 2011). Despite the importance of these methods, formal programs to measure and monitor these pro-active strategies have yet to become commonplace.

The passage of the Occupational Safety and Health Act (OSH Act) in 1970 accelerated work safety improvement. Figure1 shows that safety performance continues to improve year after year. Indeed, from 1989 to 2010, the total recordable injury rate (TRIR) dropped from 14.3 to 4.0 recordable injuries per 200,000 hours of worker exposure. To continue this improvement trend, researchers have been studying different organizational strategies with the ultimate goal of decreasing injuries, illnesses, and fatalities.

Leading indicators pertain to attitudes, behaviors, practices, techniques, procedures or conditions that influence construction safety performance. Leading indicators can be subdivided into two groups: passive and active. Passive leading indicators are the safety strategies that may be

implemented to set a project up for success. Some of these practices cannot be adjusted once the project begins, e.g., contract language and prequalification criteria. Passive leading indicators may serve as predictors of safety performance during construction. Alternatively, active leading indicators are safety-related practices or observations that can be measured during the construction phase, which can trigger positive responses (Hinze et al. 2012). Active leading indicators can be measured and adjusted as the project progresses to dynamically monitor and improve safety performance. These metrics are analogous to health-related indicators (blood pressure and body composition indices) that serve as measures of personal health.

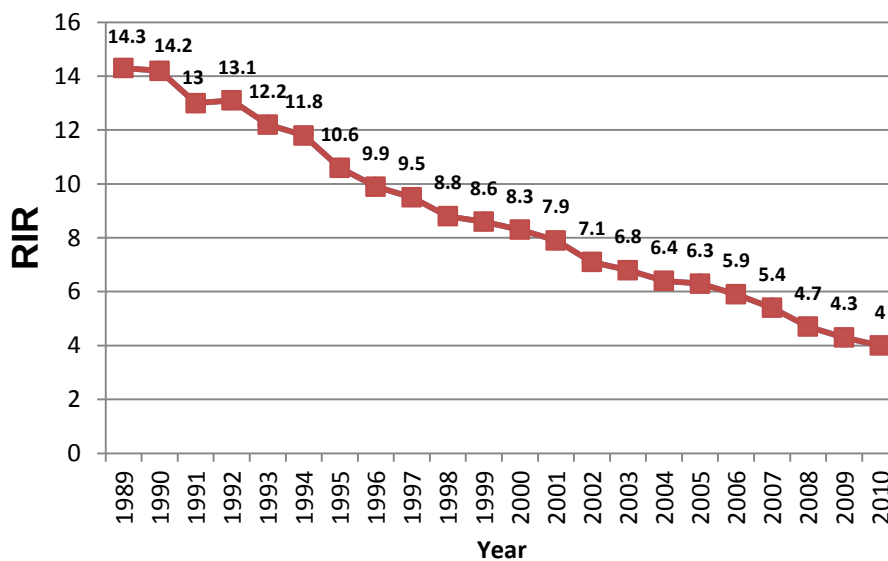


Figure 1. Construction industry TRIR from 1989-2010

2. OBJECTIVES

Passive Leading Indicators

The objectives of the first research phase were the following: (1) identify potential passive leading indicators of safety performance using a combination of literature and research team brainstorming; (2) quantify the usage of passive leading indicators on ongoing construction projects; and (3) identify passive leading indicators that are particularly effective in enhancing safety performance.

Active Leading Indicators

The objectives of the second research phase were the following: (1) identify and clearly define active leading indicators that can be measured and monitored during the construction phase, (2) describe resource requirements to implement active leading indicators on actual projects, (3) establish thresholds to trigger a response action, (4) describe specific management actions required when any indicator fails to satisfy the threshold value.

3. LITERATURE REVIEW

This study was built upon a large foundation of safety research that has been conducted by construction safety researchers, especially CII research teams. The topic of leading indicators is, in essence, a topic that crosses multiple topics of construction safety research, including zero injury strategies, roles and responsibilities, safety culture, and others. This review consists of a summary of the relevant body of literature, which is focused on zero injury techniques, relative effectiveness of safety strategies, site safety roles, and measuring safety performance. Note that depending on the way the threshold is set up that an intervention may be warranted when the threshold value is exceeded or when the measure of interest falls below the threshold value.

Zero Injury Techniques

In the past twenty years, tremendous quantities of funds have been allocated to develop and implement safety strategies with the goal of increasing compliance with safety regulations and reducing injuries, illnesses, and fatalities. Rajendran and Gambatese (2009) found that there are over 300 different injury prevention strategies in the construction industry. Examples include job hazard analyses, written safety plans, safety audits, emergency response plans, personal protective equipment, and many others. According to CII Research Team 160's Research Summary (Hinze 2001), an effective foundation for safety management includes the following nine strategies: (1) demonstrated management commitment; (2) staffing for safety; (3) pre-project and pre-task planning; (4) safety education and training; (5) employee involvement; (6) safety recognition and rewards; (7) accident/incident investigations; (8) drug testing; and (9) subcontractor management. These nine strategies, along with designing for safety which was investigated by CII Research Team 101, are discussed briefly because the present research team assumed that these CII zero injury techniques are present within organizations pursuing excellence in safety. They serve as a basic foundation for safety management. Organizations without such program elements should first build the basic structure of a safety program before employing a program to monitor leading indicators.

Demonstrated management commitment

Every safety strategy or program implemented in an organization should be supported by top management. Safety performance is exceptionally good when top management is visibly

involved in safety (Hinze 2001). The time upper management spends with field safety representatives correlates positively with safety performance. Hallowell and Gambatese (2009) found that experts agree that active upper management support and commitment is one of the important factors for the reduction of injury rates.

Staffing for safety

To ensure that the safety needs of large projects are satisfied, resources should be allocated to fund a full-time safety representative. As the number of workers on a project increases, it is important to proportionally increase the number of dedicated safety managers (Hinze 2001). Safety managers should be intimately involved with the development and execution of safety programs on site, including but not limited to: pre-task plans, safety audits, safety training, drug testing, and incident investigations.

Pre-project and pre-task planning

For many years research has shown that safety planning activities are essential to safety success. This begins with pre-project planning during which hazards are identified and addressed before construction work begins. At the crew level, pre-task planning helps to ensure that the workers have thought through the work process and that the workers are fully prepared to perform the work safely (Hinze 2001). It is essential to ensure that pre-task planning meetings occur at the location where the work will be conducted, is incorporated into the daily work routine, and that supervisors are engaged in this planning process.

Safety education: orientation and specialized training

Injuries in the workplace are caused by a combination of hazardous exposures and unsafe worker actions. The inability of workers to identify hazards and respond appropriately is a principal cause of worker injuries (Hinze 2001). To respond to these potential shortcomings, employers are encouraged to implement hazard recognition programs, provide site orientations, and offer other specialized training.

Worker involvement

The inclusion of workers in all facets of safety planning and execution is an important aspect of proper safety management. In fact, this is one of the top strategies by which safety performance can be improved. Worker involvement is known to be effective because it encourages positive perceptions toward safety policies and workers adhere to policies that they help create. Thus, any changes that are implemented to encourage safe work behavior should directly involve the workers to ensure their support or buy-in of the program (Hinze 2001).

Evaluation, recognition, and rewards

Positive reinforcement in the form of verbal praise or public recognition is an effective means by which to reward workers for good safety performance. Workers will then be inclined to repeat those actions that resulted in the positive reinforcement. These are not lavish programs and merely require that supervisors and managers fully understand how to effectively reward workers who perform their work tasks in a safe manner (Hinze 2001).

Incident investigations

To identify root causes of and positively react to injuries, a well-established protocol for incident investigation should be developed. Investigations should focus on identifying root causes and developing controls to prevent future incidents. Near misses should be included in investigations because they can serve as learning opportunities without injury occurrence (Hinze 2001).

Drug and alcohol testing

A vital aspect of safety management, after pre-employment drug screening, drug and alcohol testing should be conducted randomly and after the occurrence of any OSHA recordable injuries. In addition to this testing, the organization should have consistent and clearly communicated policies regarding employees who fail a test. The policies may include rehabilitation efforts, which are generally directed toward first-time offenders (Hinze 2001).

Subcontract management

The general contractor must ensure that the safety plan and activities extend to subcontractors. Because worksites typically involve many employers who influence project safety culture, it is important for the subcontractors to be included in orientation and training sessions, pre-task planning activities, drug and alcohol testing, and so forth (Hinze 2001).

Relative effectiveness of safety strategies

Some researchers have quantified the relative effectiveness of subsets of safety strategies in an effort to aid practitioners in the development of optimum safety programs. For example, Jaselskis et al. (1996) studied the impact of safety elements on the experience modification rate (EMR), Tam and Fung (1996) focused on management schemes by investigating their effectiveness and correlating them to company injury rates, Sawacha et al. (1999) conducted a factor analysis to identify and rank the most influential factor driving safety performance, Findley et al. (2004) identified key practices that can reduce fatalities and injuries among 305 construction companies using a 48-item questionnaire, and Aksorn and Hadikusumo (2008) identified 16 critical success factors in order to assess and rank their degree of influence on safety programs that were implemented. The results of these studies indicate that the aforementioned safety strategies are most effective; however, no studies have explicitly quantified the statistical relationship between these safety strategies on the recordable injury rates for a sample of projects. Also, the influence on safety performance of many relatively new strategies (safety knowledge management systems and computer-based training) remains untested.

Safety Roles

All stakeholders involved in a typical construction project, from the owner to the supplier, play an important role in defining the resultant project safety performance. Each of the stakeholders has a different role and, similarly, their roles at influencing safety performance are also different. Designers may play a crucial role as the design evolves, but this role may be minimal once the design has been completed. Owners can play a pivotal role throughout the life of a project, even influencing the design of the project. The general contractor and/or CM firm play key roles in safety, especially during the construction phase. Each subcontractor also plays an important role

in safety, especially as it pertains to their specialized work tasks. These will be described in greater detail.

Owner

According to previous research, the owner plays a critical role in site safety performance. For example, owners, their representatives, and their agents play a pivotal role in the development of contract provisions, have the ability to influence the features of the design, and, in some cases, monitor safety management activities as construction progresses (Gambatese 2000; Huang and Hinze 2006). Owners also may include safety as a selection criterion during procurement. During the construction phase owners can have considerable influence on site safety by actively participating in safety meetings, jobsite audits, accident investigations, safety committees, and other safety activities. Such visible demonstrated commitment to safety sends a clear message to the workforce that safety is a core value on the construction site (Levitt et al. 1981; Hinze 1997).

Designers

Designing for safety is “the incorporation of construction knowledge in the design effort and consideration of safety early on and throughout the project” (Hecker et al. 2005, page 32). Researchers found that 42% of the construction fatalities and 22% of the injuries are linked to decisions made during design. To facilitate designing for safety, Gambatese et al. (1997) created the CII-sponsored ‘Design for Safety Toolbox,’ which packaged hundreds of design suggestions into a software tool that made the design suggestions available to designers during the design phase (Hinze 2001). This CII software was updated in 2009 as a user-friendly software module, entitled Design for Construction Safety Toolbox, Version 2.0 (Hinze and Marini 2008).

Contractor and subcontractors

Unlike owners and designers who must have an altruistic view of their role in safety management to be effective, contractors and subcontractors are the firms that may potentially expose their employees to a litany of construction hazards. General contractors and subcontractors must implement safety programs in order to protect their workers and to comply with the Occupational Safety and Health Act’s General Duty Clause and the Occupational Safety

and Health Administration (OSHA) Construction Industry Regulations. These activities include pre-task planning meetings, safety audits, training, and many other activities described by Hinze (1997). According to Molenaar et al. (2009) the suite of safety program elements implemented serves as the foundation of the site safety culture.

Similar to the owner, the contractor's upper-level managers must show their support and commitment to safety through their participation in safety activities, appropriate behavior-based incentive programs, inclusion of safety as an important measure in evaluations, and the assignment of appropriate resources to meet safety goals (Hinze and Raboud 1988; Tam and Fund 1996; Jaselskis et al. 1996; Vredenburg 2000; Abudayyeh et al. 2006; Rajendran et al. 2006; Hallowell and Gambatese 2009). Additionally, the employees of these firms must be involved in safety planning and policy making because it creates a positive perception of safety strategies among workers (Aksorn and Hadikusumo 2008).

Vendor/supplier

Safety is impacted by all who contribute to the design and construction of the project and who spend time on site. This includes the vendors and suppliers who frequent the site in capacities that range from quick deliveries to those that involve critical components, lengthy crane lifts, and professional installers. According to Zou (2011), vendors and suppliers must comply with all safety rules and activities in connection with their work to prevent disruptions and negative influences on the site safety culture. This is an important issue observed in the aerospace manufacturing industries as well because the safety culture on sites with many vendors is often dictated by the safety attitudes and behaviors of the vendors (Hallowell et al. 2010).

Measuring safety

Lagging indicators

Abudayyeh et al. (2006) found that continuous monitoring of safety programs was part of the improvement of safety performance. Safety evaluation involves the regular measurement of safety performance indicators that help to trigger positive safety responses. Zhong et al. (2003) identified four different methods of safety evaluation: (1) recording the adoption of safety

technology; (2) examining qualitative risk factors and their relationships to existing safety processes; (3) measuring lagging indicators as a project commences; and (4) and conducting perception surveys. Unfortunately, typical evaluation programs focus on lagging indicators of safety performance, including but not limited to OSHA TRIRs, DART rates, and EMRs, which do not provide structured, continuous response metrics tied to preventative measures (Aksorn and Hadikusumo 2008).

Construction organizations often strive to create and maintain a culture of safety. Unfortunately, there is no consistent definition of construction safety culture in the literature (James and Jones 1974; Schneider 1975, 1990; Schein 1984; Glick 1985; Cooke and Rousseau 1988; Van Hoewijk 1988; Schein 1992). Nevertheless, the safety literature does support several common characteristics of safety culture such as the molar perceptions that employees have of their environment (Zohar 1980); the predominant safety-related beliefs, values, and behaviors (Molenaar et al. 2009); demonstrated upper management support and commitment to safety (Jaselskis et al. 1996); and employee involvement in safety management and planning (Rajendran et al. 2009). Establishing, measuring, monitoring, and continuously improving a suite of highly effective on-site safety management strategies is a vital foundation for a strong culture of safety.

Leading indicators

Although there has yet to be a comprehensive study of construction safety leading indicators, some literature resources exist that provide insight on activities that may be measured, monitored, and controlled in a leading indicator program. First, Chao and Henshaw (2002) discuss a practical method of measuring the participation in and quality of job hazard analyses (JHAs). Typically, firms measure JHA's through the paperwork that is completed. Second, a large body of literature discusses the use of safety perception surveys of the workforce as a method of measuring the overall safety climate during project execution (Choudhry et al. 2009). Climate surveys can be an efficient method of obtaining and aggregating a large volume of feedback from a representative sample of the workforce. Typically, perception surveys provide feedback on subjective issues such as management commitment or involvement or the level of communication between workers and supervisors; practical issues such as the use of tools and their quality; and the effectiveness of safety strategies and how they may be improved. Third,

safety audits (safety inspections) may be implemented to assess compliance with OSHA safety regulations and internal company safety policies (Meridan 1994). It is critical to include both managers and workers to establish buy-in from the workforce. Although audits typically focus on hazards in the workplace, Cameron and Duff (2007, page 879) discuss how behavioral audits are a “valid and reliable measure of management safety performance in the construction industry.” Behavioral audits may extend beyond superficial observations such as compliance with personal protective equipment (PPE) policies to include work sequencing, communication, and human error.

4. RESEARCH METHODS

This project involved two distinct data collection efforts. The objectives of the first phase were to: identify potential *passive* leading indicators of construction safety performance, reduce the dataset to those indicators that differentiate strong safety performance from average or poor performance, and measure the relative effectiveness of these indicators. The objective of the second phase was to identify potential *active* leading indicators of safety performance, evaluate their effectiveness based on ease of implementation, identify metrics, quantify threshold values, and devise action plans. Although these were two distinct phases, they were completed concurrently and relied on similar data sources. The following discussion provides details on the data sources and collection procedures.

Phase 1: Passive Leading Indicators

In order to achieve the aforementioned objectives, the data collection process was divided into two distinct phases. After the research team identified and defined passive leading indicators, the team conducted interviews with project representatives from 57 ongoing or recently-completed construction projects throughout the US. This resulted in the collection of qualitative data that could be statistically analyzed to identify the leading indicators that could best serve as predictive measures of safety performance.

Phase 1a: Identifying potential passive leading indicators and interview questionnaire development

Passive leading indicators are simply programs or practices that have been shown to be effective in enhancing construction safety performance. To identify these programs/practices, a thorough review was conducted of past CII safety research that had been conducted since 1999. This resulted in a review of the findings of five prior safety studies. These findings were consolidated to develop the core of the passive leading indicator questionnaire that was later used in interviews. This resulted in nearly 100 questions. The questionnaire was then reviewed by Research Team 284, which resulted in the addition of several more questions. The final questionnaire contained 104 questions specific to passive leading indicators (see Appendix A). After including questions about the project description and company demographics, the final questionnaire contained over 140 questions.

The final questionnaire consisted of six-pages of questions. This included questions about the type of contract, criteria for contract award, schedule status, budget status, hours worked, existence of work-hour restrictions, owner involvement in safety, orientation and training, subcontractor management, drug testing, addressing safety during the design phase, heavy equipment practices, personal protective equipment (PPE) policies, programs to involve workers in safety, worker recognition, incident investigations, and other related questions.

As the questionnaire was developed, it was decided that the questions should be able to be answered in a simple manner, preferably by a “yes” or “no” response. This was done as it was felt that the questionnaire interviews that were to be conducted, primarily by telephone, would be unduly long if detailed responses were sought. It was recognized that detailed information would be helpful, but the cost would be an overly-long interview. Also, because the team desired to make two-sample comparisons of mean recordable injury rates between project that used a particular indicator and those that did not, the ‘yes/no’ approach allowed for direct assignment to sample groups. Detailed information about leading indicator implementation was gathered during later phases that involved case studies, content analysis, and team brainstorming.

After careful review of the questionnaire, which had gone through several iterations of changes, it was concluded that the questionnaire was ready for data collection. It was noted that the research team was highly qualified to assist in the questionnaire development. Research Team 284 consisted of 25 professionals who were recognized as safety leaders in the US architecture, engineering, and construction (AEC) community. Collectively, the team had amassed 318 years of experience in the construction industry, with 33 years of experience as field workers, 176 years as middle managers, and 109 years as upper-level safety managers in firms with industry-leading recordable injury rates. The input from this elite group helped to instill confidence about the relative completeness of the final questionnaire.

Phase 1b: Phone interviews

While most interviews were conducted via the telephone, some were conducted on-site. The on-site interviews were generally conducted with site safety managers. These tended to take about

one and a half hours to conduct. The interviews conducted over the telephone were generally shorter in length, ranging from about 20 minutes to slightly over an hour. The length of time varied to a large extent on the interviewee, as some preferred to elaborate on their responses. The interviewees were instructed that the research was being conducted to identify those programs/practices being implemented to enhance safety performance. They were asked to simply answer with a “yes” or “no” to most questions, without elaboration. It was explained that the questionnaire was lengthy and that the “rapid fire” mode of responses would facilitate the completion of the interview in a reasonable time.

There were some questions that could not be answered with a “yes” or “no” response. Most notably, it was desired to obtain information on the number of hours worked on the project and the number of Occupational Safety and Health Administration (OSHA) recordable injuries that had been sustained by the workforce. This information was sought in order to compute the OSHA recordable injury rate (TRIR), the number of recordable injuries sustained per 200,000 hours of worker exposure. Interviews were conducted with the top safety representatives responsible for the project. Unfortunately, some interviewees could not (or would not) provide this information.

A total of 57 interviews were conducted. This constituted the database on which conclusions were to be drawn about the effectiveness of specific safety programs/practices. It should be noted that while some interviewees did not provide the needed safety performance information, some also were unable to answer specific questions in the interviews. While follow-up calls were made in some instances to obtain the missing information, many of these questions remained unanswered. Projects ranged in size from 70,000 to 20,000,000 worker-hours expended and a scope of work between \$51,000 and \$3,600,000,000. The project types included commercial buildings (20%), industrial facilities (30%), infrastructure (13%), energy facilities (23%), institutional (4%), heavy civil (3%), healthcare (4%), and marine projects (3%). On average, those projects were 55% complete when the interviews were conducted. All of the projects were located in the United States.

Phase 2: Active Leading Indicators

To achieve the research objectives a mixed-methods research approach was implemented. Because active leading indicators is a new concept that has not seen widespread use in the construction industry the efforts were exploratory in nature. Three concurrent activities were conducted in an effort to cross validate the findings from each of the methods (see Figure 2). Case studies on 19 projects were conducted to identify and describe any active leading indicators already in use. A review of detailed reports of 14 award-winning projects in industry-leading organizations was conducted to observe the role that active leading indicators played in the achievement of safety success. Finally, an expert panel made up of research team members used an iterative process of brainstorming and refining a suite of active leading indicators based on their experience. The specific research activities associated with these three data collection strategies are discussed in detail.

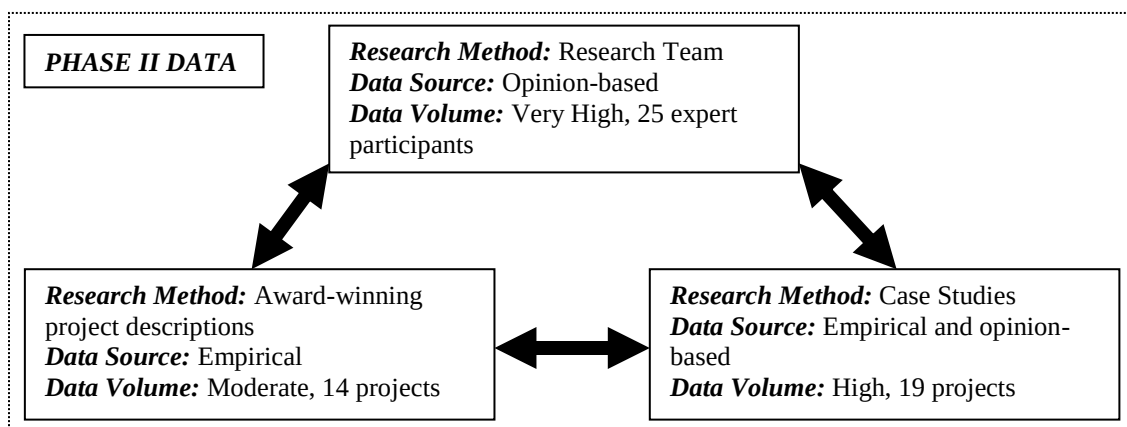


Figure 2. Phase II data triangulation approach

Case studies on active projects

Projects were initially selected through contacts with Construction Industry Institute (CII) member companies, primarily through research team members. Additional projects were identified through the cooperative efforts of the Associated General Contractors (AGC). Since this was an exploratory study, the comparative case studies goal was to conduct studies of relatively high-performing large or signature projects, which have the highest potential for implementing innovative safety methods. Having data from multiple projects allowed the team to look for patterns in the resulting data (Eisenhardt 1989). When selecting the number of projects, the literature suggests a minimum of four to ten cases when investigating complex contextual

relationships (Eisenhardt 1989; Yin 2003). The specific number required to obtain valid and reliable results depends on the quality of the duplication of findings among cases and the level of replication in the results. The projects for the case studies included industrial/energy facilities (4), highway/heavy projects (7), building projects (7), and marine projects (1). The average Occupational Safety and Health total recordable injury rate (OSHA TRIR) on these projects was 2.56, with five projects reporting TRIR values in the inclusive range of 0 and 1. The summary of the case study demographics is provided in Table 1.

Without exception, these case studies involved a site visit, interviews with project management, and the collection of supporting documentation. In several cases, the researchers conducted a site tour, interviewed owner representatives and workers, and conducted observations of work practices and safety meetings. The hosts were upper-level safety managers and project managers who directly managed the project. A protocol set by Yin (2003) was followed. In all cases, the following question was the central theme of all discussions and data collection: “Other than injury rates, how do you measure and monitor safety performance on your project?” Alternatively, “How do you know if your project safety process is in good condition without measuring the number or rate of injuries?” Stating these questions clearly was important due to the vast misconception and equivocal definitions of leading indicators that currently exist in the industry. This primary question served as a starting point for discussions and subsequent data collection.

Case study research must be carefully designed to ensure internal validity, external validity, construct validity and reliability to promote confidence in the results (Taylor et al. 2009). Internal validity was pursued by minimizing the potential influence of bias from the research team, by asking for methods of measuring and monitoring safety management processes rather than requesting examples of leading indicators, and having multiple researchers independently conduct the case studies. External validity was preserved by examining a variety of project types with a wide geographical spread, triangulating multiple data obtained from each case, and following a pre-defined protocol. Finally, reliability was enhanced by validating against other data sources, e.g., results of expert group brainstorming and findings from award-winning project reports.