Construction Industry Institute®

Measuring Safety Performance with Active Safety Leading Indicators

Research Summary 284-1
Version 1.1

Construction Industry Institute

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Measuring Safety Performance with Active Safety Leading Indicators

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Executive Summary

Despite reductions in injury rates in the past few decades, many firms with world-class safety records have, in recent years, been frustrated by the inability to make step-change improvements in safety. Efforts to reduce injury rates by simply monitoring classic measures such as the Occupational Safety and Health Administration (OSHA) Total Recordable Injury Rate (TRIR) and the Experience Modification Rate (EMR) have not achieved the desired step-change improvement. Many safety professionals believe that the careful selection, measurement, and response to leading indicators of safety performance will yield significant improvements. CII established Research Team (RT) 284, Leading Indicators for Safety, to investigate the potential of these critical project metrics.

Leading indicators are *measures of attitudes, behaviors, practices, or conditions that influence construction safety performance*. RT 284 divides leading indicators into two groups, namely passive and active. **Passive leading indicators** are the *safety strategies that should be implemented before the construction phase begins to set the project up for success*. Typically, these practices (e.g., contractual language and staffing) are not adjusted once the project begins, but 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, and that can trigger positive responses*. Active leading indicators can be measured and adjusted as the project progresses to dynamically monitor and improve safety performance. RT 284 considers this difference between passive and active leading indicators—a distinction it made during the planning phase of the research process—an important contribution to industry safety. *The research team believes that implementation of active safety leading indicators opens a whole new approach to measuring project safety performance*.

In order to independently examine both passive and active leading indicators, the research team divided the research effort into two phases. In the first phase, the team identified and defined over 100 safety strategies as potential passive leading indicators. To evaluate which of these passive leading indicators best predicted safety performance, the team conducted interviews with management and safety professionals who had familiarity with 57 ongoing or recently completed major projects. Responses to the interview questions related to a project's use of the identified passive leading indicators were statistically compared to the project TRIR. From this comparison, 10 significant passive leading indicators showed a strong negative correlation with injury and illness rates. That is, the injury rates declined as more passive leading indicator practices were implemented. In fact, a statistical analysis of these data indicates that, in general, project recordable injuries were reduced by 0.85 per 200,000 worker hours for every two of the passive leading indicators that were implemented.

The second phase of the research focused on identifying active leading indicators that were extracted from three data sources. First, the research team established three subcommittees to identify, define, and evaluate active leading indicators specific to owners, contractors, and vendors, based on the experience and expertise of the team members. Second, the team conducted detailed case studies at 19 ongoing construction sites in an attempt to identify active leading indicators that were already being employed. These case studies involved data collection through site visits and project management interviews. Finally, the research included a detailed review of the safety performance of 14 award-winning projects identified from CII member organizations. The research activities in the second phase yielded 22 high-potential active leading indicators that have proven to be successful on past projects completed by industry leaders.

To help organizations implement active leading indicators, the research team created Implementation Resource (IR) 284-2, *Implementing Active Leading Indicators*. This resource explains that, when organizations select leading indicators for implementation, they should evaluate

their current safety program, select leading indicators that complement existing strategies, and carefully add new leading indicators that integrate well into the organizational culture. It is important to recognize that leading indicator data collection must be built upon a comprehensive safety management program, which must begin with the full adoption of the CII Zero Accidents Techniques, including aggressive and visible senior management leadership that fosters employee involvement and ownership.

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Introduction

Historically, the frequency and severity of injuries in the construction industry have been greater than in other industries. In addition to worker pain and suffering, the direct costs associated with workplace injuries can significantly reduce project revenues. Furthermore, injuries can have indirect costs in the form of elevated insurance premiums, increased regulatory intervention, project delays, declines in employee morale, increased worker turnover, and other adverse impacts. For decades, researchers have been studying different organizational strategies with the ultimate goal of decreasing injuries, illnesses, and fatalities. The passage of the Occupational Safety and Health Act (OSHA) of 1970 accelerated safety improvement. In fact, the fatality rate in the construction industry decreased by more than 50 percent in the first twenty years after the passage of OSHA. The injury and fatality rates have continued to show improvement, but in recent years, the rate of improvement has slowed. These trends have been documented by the National Safety Council and the Bureau of Labor Statistics.

Construction firms typically rely on safety strategies that were developed and implemented over the past twenty years to form their safety programs. Most firms continue to measure performance on the basis of several commonly used lagging indicators of safety success: the Total Recordable Injury Rate (TRIR); Days Away from Work, Restricted Work or Transfer rates (DART); and the Experience Modification Rates (EMR). In order to advance safety, some industry professionals have started to measure and track leading indicators of safety performance. Leading indicators are measures of the implementation of specific safety processes and may be used as predictors of safety performance.

As mentioned in the executive summary, leading indicators are *measures of attitudes, behaviors, practices, or conditions that influence construction safety performance*. RT 284 has divided leading indicators into two groups: passive and active. **Passive leading indicators** are the

safety strategies that may be implemented before the construction phase begins to set the project up for success. Once project construction begins, these practices (e.g., contractual language, staffing, the designer's role in safety, and training protocols) typically cannot be easily adjusted. They may, however, serve as predictors of construction safety performance. Alternatively, **active leading indicators** are *safety-related practices or observations that can be measured during the construction phase, and that can trigger positive responses*. Active leading indicators are measures of practices that can be easily adjusted as the project progresses to dynamically improve safety performance. This study focused on evaluating the effectiveness of passive leading indicators of construction safety performance through the use of interviews. The research team's further detailed study of active leading indicators included case studies conducted with selected construction projects in the United States.

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Background

Over the past 20 years, construction organizations have dedicated significant funding to the development and implementation of safety strategies, with the goal of increasing compliance and reducing injuries, illnesses, and fatalities. Rajendran and Gambatese (2009) found that there are over 300 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 Summary 160-1, *Safety Plus: Making Zero Accidents a Reality*, 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, as well as design for safety, which was investigated by CII RT 101, are only discussed briefly here; the team's assumption is that these CII Zero Accidents techniques have been implemented within organizations and 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 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 (CII RT 160). The time that upper management spends with field safety representatives correlates positively with safety performance. Hallowell and Gambatese (2009) found that experts believe 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 full-time safety staff. As the number of workers on a project increases, it is important to proportionally increase the number of dedicated safety managers. Safety managers should be intimately involved with the development and execution of safety programs on site, including but not limited to the following: pre-task plans, safety audits, safety training, and incident investigations.

Planning: 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, the phase 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. It is essential to ensure that pre-task planning meetings occur at the location at which the work will be conducted. It is also crucial that pre-task planning be incorporated into the daily work routine, and that supervisors be 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 safety risk. 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 aspects 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 of safety policies and because workers adhere more readily 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.

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.

Incident investigations

To identify root causes 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.

Drug and alcohol testing

After pre-employment screening, drug and alcohol testing is a vital aspect of safety management and should be conducted randomly and in response to any OSHA recordable incident. 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.

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 that the general contractor include subcontractors in orientation and training sessions, pre-task planning activities, drug and alcohol testing, and other safety activities.

Safety in design

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). Researchers found that 42 percent of construction fatalities and 22 percent of injuries are linked to decisions made during design. To facilitate designing for safety, Gambatese et al. (1997) created Implementation Resource 101-2, *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. This software was updated in 2009 as a user-friendly software module, Implementation Resource 101-2, *Design for Construction Safety Toolbox*, Version 2.0 (Hinze and Marini 2008).

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Research Methods

This project involved two distinct data collection efforts. The objectives of the first phase were the following:

- 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
- measure the relative effectiveness of these indicators.

The objectives of the second phase were the following:

- identify potential active leading indicators of safety performance
- evaluate their effectiveness based on ease of implementation
- identify metrics
- quantify threshold values
- devise action plans.

Although these were two distinct phases, they were completed concurrently and drew from 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 research objectives, the team divided the data collection process into two distinct phases. After the research team identified and defined passive leading indicators, team members conducted interviews with project representatives from 57 ongoing or recently-completed construction projects throughout the U.S. This gave the team empirical data that it statistically analyzed to determine which of the leading indicators could best serve as predictive measures of safety performance.

Phase 1a: Identifying potential passive leading indicators

The literature review revealed nearly 100 safety strategies that may serve as passive leading indicators of safety performance. The team identified most of these strategies by reviewing the results of prior CII safety research efforts. After having developed an initial list of potential passive leading indicators, the team members took up the task of supplementing and refining it to include additional initiatives currently implemented in their respective organizations. The result was a list of 104 potential passive leading indicators, with associated operational definitions based on a common understanding of the strategies. These were incorporated into a six-page questionnaire that included questions about the following project characteristics and concerns:

- type of contract
- criteria for contract award
- schedule status
- budget status
- hours worked
- 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.

The input provided by the highly qualified members of the research team was important during this phase. The team consisted of 25 professionals who represent safety leaders in the U.S. architecture, engineering, and construction (AEC) community. Collectively, the team totaled 318 years of experience in the construction industry, with 33 years of experience as laborers, 176 years as middle managers, and 109 years as upper-level safety managers in firms with industry-leading recordable injury rates. The presence of such knowledgeable industry experts on the team increased the internal validity of the the research findings and made them widely applicable.

Phase 1b: Interviews with representatives from ongoing and recently completed projects

To achieve the objective of identifying the best predictors of safety performance through statistical data analysis, project data were needed from ongoing or recently-completed projects throughout the United States. Interviews were conducted with representatives of 57 projects, and the interviewees were initially asked 25 project demographic questions (e.g., questions about scope, number of worker-hours accumulated, project delivery method, among others). Subsequently, the interviewees were asked to identify which practices (potential passive leading indicators) were being implemented on the project. The questions were divided into the following categories:

- owner involvement
- safety in contracts and subcontracts
- substance abuse programs
- training and orientation
- design and preconstruction
- equipment and tools
- personal protective equipment (PPE)
- site planning

- worker involvement
- recognition and rewards
- incident investigations
- supervision
- safety staffing.

Interviews were selected as the means of data collection, since this permitted the participants to ask for clarification of questions or to explain their responses. This ensured consistency and more detailed responses. For example, it was important to ensure that policies (e.g., a 100-percent hard-hat policy) were written, communicated, and consistently enforced.

Interviews were limited to projects in the United States, with contacts supplied by the Construction Industry Institute (CII) and the Associated General Contractors of America (AGC). Some additional interviewees were identified by research team members. The interviews (conducted in-person and over the telephone) were conducted primarily with safety managers and project managers. It was essential that the interviews be conducted with individuals who had responsible project positions and who were intimately familiar with the project under investigation. Because of the number of questions asked in each interview (over 140), some phone interviews were conducted in multiple sessions to accommodate the schedule constraints of the interviewees. Projects ranged in size from 800 to 20,000,000 worker hours expended and a scope between $51,000 and $3,600,000,000. The following project types were represented: commercial buildings (20 percent), industrial facilities (30 percent), infrastructure (13 percent), energy facilities (23 percent), institutional (four percent), heavy civil (three percent) healthcare (four percent), and marine projects (three percent). On average, those projects were 55 percent complete when the interviews were conducted.

Phase 2: Active Leading Indicators

The objectives of the second phase of the research were the following

- identify and clearly define effective active leading indicators of safety success that can be measured and monitored during a project
- describe typical resource requirements for implementation
- establish accurate metrics and acceptable threshold values
- describe appropriate positive actions when leading indicator measures fall outside tolerance limits.

One source of active leading indicators was the research team's collective experience. Additionally, the team conducted case studies by making site visits and performing interviews on 19 ongoing projects located in various regions of the U.S. Empirical data were also collected from safety reports of 14 award-winning projects in the research team members' respective organizations. Ultimately, the data from these three sources were combined to achieve the objectives and to ensure reliable results. The relationships among these data sources are shown in Figure 1.

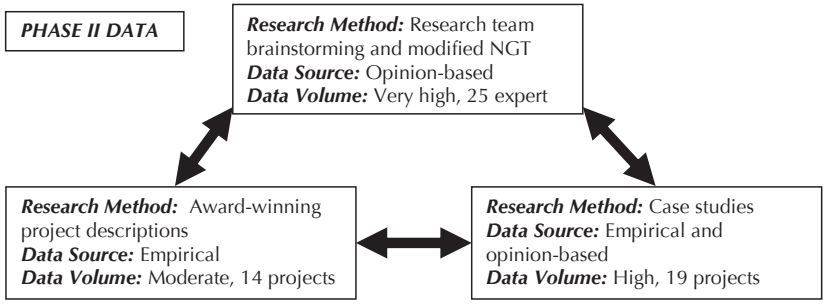

Figure 1. Phase 2 data triangulation approach

Phase 2a: Research team brainstorming and prioritization using a modified nominal group technique (NGT)

The research team was organized into three expert subcommittees that investigated active leading indicators; these subcommittees focused on owners, contractors (including subcontractors), and vendors, respectively. Over the course of four face-to-face meetings and several teleconferences, the subcommittees performed the following tasks:

- identified, described, and prioritized potential active leading indicators
- established metrics
- quantified threshold values
- devised action plans
- documented expected resource requirements.

To ensure consistency in their findings, the subcommittees reported regularly to the entire team. Because this process was initially opinion-based, empirical data collected from active and completed projects were required to validate the findings.

Phase 2b: Case studies on active projects

The first empirical data source involved conducting case studies on active projects in the U.S. In total, the team conducted 19 case study visits in 12 different states. 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. 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?" If injury rates were not measured, the interviewer asked this question: "How do you know if your project safety performance is good without measuring the number or rate of

injuries?" Asking these questions clearly was important, because of significant misconceptions and imprecise definitions of leading indicators that currently exist in the industry.

Phase 2c: Empirical data from award-winning projects

The third data source involved collecting fourteen detailed and specific reports from award-winning projects from two companies represented by research team members. Most reports included a brief description of the project, the safety strategies implemented on the project, the lagging indicators of safety performance (e.g., TRIR), a description of the leading indicators collected, and their scores on the project. A detailed content analysis was manually conducted on these reports to identify which leading indicators were used, which were the best predictors of performance, and the outcomes of the projects. The content of the injury reports were analyzed in three steps: 1) manual coding; 2) text recognition; and 3) the testing and measument of the reliability of the output by comparing it to alternative data sources (e.g., the results from Phases 2a and 2b). The reader should note that these award-winning project descriptions were only available from three very large companies, each with annual revenues exceeding $9 billion, more than 10,000 workers, and overall TRIR rates of less than 1.0. Thus, these data have only been tested on very large, relatively safe construction projects.

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Findings

Phase 1

The interview process for collecting information on passive leading indicators was conducted with representatives of 57 projects in the United States. Appendix A shows the proportion of leading indicators implemented on these projects. A sample of the data from Appendix A is provided in Table 1 below. To ensure a valid dataset for statistical analyses, only projects that had accumulated at least 50,000 worker-hours at the time of the interview were analyzed. There were 28 projects that had accumulated at least 50,000 worker hours, so these became the basis of analysis for the passive leading indicators. This worker-hour constraint was imposed to ensure that the projects had sufficient exposure time and incident reporting; these thresholds enabled the statistical analyses to differentiate the effective from the less effective leading indicators. The resulting dataset was mostly binary because the questionnaire generally solicited "yes" or "no" responses for each leading indicator. Several continuous variables were included (e.g., frequency of toolbox talks) but these values were later dichotomized for analysis. The data in Table 1 and Appendix A include a brief description of each passive leading indicator and the proportion of the 28 projects on which the practice was implemented. Indicators used on 80 percent or more of the projects were considered "requisite" indicators (e.g., basic indicators that should be used on all projects).

Table 1. Sample passive leading indicators

Leading Indicator	% of projects
Specific safety prequalification	100%
Cost Plus type of project (as opposed to Lump Sum)	85%
Early project completion reward	29%
Participation of all contractors and major subs in safety meetings	93%
Minimum ratio of number of safety personnel to workers	62%
Mandatory substance abuse program	90%
Work hour restrictions	36%

To statistically analyze the data, a series of two-sample tests were conducted. Specifically, the response metrics (e.g., the OSHA TRIR) for those projects that did not implement a particular practice were compared to the TRIR of those projects that did implement the practice. Because the TRIRs did not follow a normal distribution, a one-sided Wilcoxon Rank Sum test was used to compare the sample means and compute a *p*-value. This statistical test was utilized to ensure that the TRIR value of each respondent carried equal weight. The analysis showed strong statistical evidence (p-value < 0.05) for 10 potential passive leading indicators. One should note that many effective strategies did not emerge as differentiators because they were implemented on nearly every project (e.g., a written safety plan). The results of the passive leading indicator statistics are provided in Table 2.

Table 2. Ten significant passive leading indicators

Leading Indicator Description	Diff in mean TRIR	*p*-value
1. Owner review and approval of CM's and GC's project safety plan	5.37	0.045
2. Participation of all contractors and subcontractors in safety meetings	0.92	0.053
3. Site-specific safety orientation for all managers	1.18	0.004
4. 100-percent steel-toed boots policy	1.59	0.048
5. Medical facilities on site	1.44	0.030
6. First aid log maintained	3.09	0.043
7. Minimum ratio of safety professionals to workers	1.21	0.041
8. Worker-to-worker observation program	1.16	0.039
9. Worker involvement in perception surveys	1.17	0.048
10. Foremen involved in policy creation and implementation	0.71	0.030

To further analyze the data, the team gave a score to each project, based upon how many of the 10 statistically significant passive leading indicators were implemented. The team computed the score for each project by adding ten percentage points for each significant passive leading indicator that was implemented. Project scores ranged from a low of 30 percent to a high of 100 percent. The projects were then grouped into four sets based on their scores: 30 or 40 percent; 50 or 60 percent; 70 or 80 percent; and 90 or 100 percent. As Figure 2 clearly shows, higher passive leading indicator scores were associated with lower TRIR values.

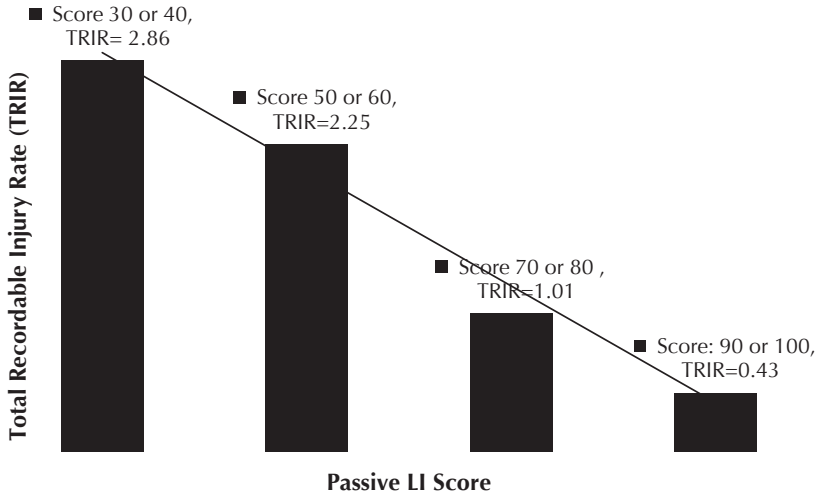

Figure 2. Passive leading indicator scores versus TRIRs

Though the findings are consistent with previous research, the study has some limitations. First, the team used a convenience sample with project contacts obtained from CII and the AGC. Second, the fact that the projects were located in the United States limits the external validity of the results. Third, most of the representatives interviewed were employed by large companies. Half of these companies had annual volumes of business exceeding $1 billion. Finally, the research team members were employed by large companies that also provided project data through the interviews. Consequently, the results specifically represent large contractor projects in the United States and projects that have accumulated at least 50,000 worker hours. In spite of these limitations, there is strong theoretical evidence from the large volume of literature reviewed that these results should extend to other populations.

Phase 2

The data collection procedure in the second phase involved data triangulation from three sources. As shown in Figure 1, these data sources varied in their type (i.e., empirical and opinion-based) and quantity. The research team members served as the primary data source, since, as a very experienced panel of experts, they provided the most

complete database of active leading indicators. The team used the case study and award-winning project description data to confirm the results it generated. The detailed results are shown in Research Report 284-11, *Implementing Active Safety Leading Indicators*; they include the opinion-based results that the team validated and refined using the empirical data it obtained from current or recently completed projects. Sample data for one of the 50 reported active leading indicators are provided in Tables 3a and 3b. Additionally, the data provided in these tables represent only the practices that the team found to have an extremely high potential as active leading indicators. Although the team initially identified more than one hundred active leading indicators, only the most important and best-validated active leading indicators are reported.

The research team made several interesting observations during the case study visits. First, on some projects, the team observed that the role of the safety manager was critical, since people in this position were able to use feedback from jobsite employees as leading indicators, they had established positive personal connections and open lines of communication with these employees. On some very large projects that the team visited, the safety managers were not able to establish personal connections with the workers, nor did they receive daily employee feedback. Second, there is a great misunderstanding of the meaning of leading indicators within some organizations. A common theme was to use past safety events as predictors of future performance, which is not the goal or intent of leading indicators. Changing this mindset will be important to driving a culture of leading indicators. Finally, world-class companies that have adopted leading indicators have done so carefully. Once they have established a protocol for measurement, provided training, and devoted resources, they continuously monitor and improve their processes. An important lesson that one firm learned was that, when a leading indicator does not lead to positive improvement, it should be removed from the program.

Table 3a. Sample active leading indicator description, metrics, and threshold

Active Leading Indicator	Description	How It Is Measured	Minimum Threshold
Owner discussion with foremen	Owner's project manager meets with foremen to discuss issues, ask questions, and give feedback (positive and negative) about what is happening on site. Monthly meetings are hosted by the owner's PM and attended by all site foremen. Action items with timelines are captured by the owner and assigned to the responsible owner team members.	% action items closed on or before the target completion date	100% of action items are addressed in the time allotted

Table 3b. Sample active leading indicator action plans, resource requirements, and notes

Active Leading Indicator	Action Plan	Resource Requirement	Notes
Owner discussions with foremen	Hold regular meetings between the owner's PM and the contractor's foremen as a feedback process and/or mechanism. Monitor the attendance of the foremen and the feedback by observing who is in attendance (sign-in sheet) and what is being discussed in the meetings (meeting minutes). At the meetings, report on feedback pertaining to the actions initiated at the owner's previous PM meeting. The owner's PM will assign action items to the appropriate owner project team member and a system will be established to monitor action item due dates and communicate back to the PM prior to the set deadline. If an action item is not met by a given timeline, the owner's PM should investigate and establish a plan for closing out the action item. The owner's PM will establish firm expectations of the owner's team members to close out action items in order to address the foremen's concerns.	A standing agenda will be maintained. Meeting minutes will be kept. Action items will be enumerated, and the close-out of these action items will be tracked.	These meetings should be set up early in the project to establish foreman buy-in and to send the message that management cares about their HSE concerns. The feedback process needs to be a no blame- or no consequence-type process that is without fear of reprimand.

The active leading indicators are categorized by responsible firm, including contractors and subcontractors, vendors and suppliers, and owners. Each leading indicator has a name, description, metric, threshold value, action plan, and resource requirement. (Please consult the glossary for common terms.) The reader should note that the research team does not advocate the use of all active leading indicators on all projects. Rather, users should evaluate their current practices and the characteristics of the project, then select the leading indicators that would best integrate with the project environment. The focus of integration should be on identifying, measuring, monitoring, and responding to process weaknesses to continuously improve safety performance—basing the program on the philosophy that what gets measured gets managed. Additionally, for firms that are building their initial leading indicator program, implementation of all leading indicators is likely to cause confusion and frustration. The research team recommends selecting one or two active leading indicators to implement initially, with a focus on continuous improvement of the program thereafter. More mature organizations may wish to use the results to supplement their programs or to improve the execution, measurement, or response to existing indicators. Regardless of the level of implementation, the use of active leading indicators should focus on proactive safety techniques, continuous and accurate measurement, sustained tracking, and positive responses.

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Implementation Resource

Incorporating active safety leading indicators into construction project management requires commitment, planning, education, execution, and periodic evaluation. If implemented correctly with active senior management support, an active leading indicator program will yield reductions in the incidence and severity of injuries. IR 284-2 identifies and describes, in detail, the following nine elements required to implement a successful active safety leading indicator program:

1. Select appropriate active leading indicators of safety that consider the work types, corporate maturity and resource levels.
2. Define appropriate actionable leading metrics.
3. Develop the process for accurately measuring the selected leading indicators.
4. Engage responsible parties at all levels of the organization.
5. Implement the leading indicator measurement process.
6. Analyze the leading indicator data.
7. Publicize by communicating and interpreting leading indicator data results to management, workers, staff and business affiliates such as owners, subcontractors and vendors.
8. Evaluate the effectiveness of the selected leading indicators and adjust safety leading indicators as project/corporate structures change or mature to incorporate key learnings.
9. Celebrate successes with the leading indicator program and step change improvements in safety performance.

IR 284-2 also provides implementation examples for each of the elements in this process. (See Figure 3 for a diagram of the nine-step process.)

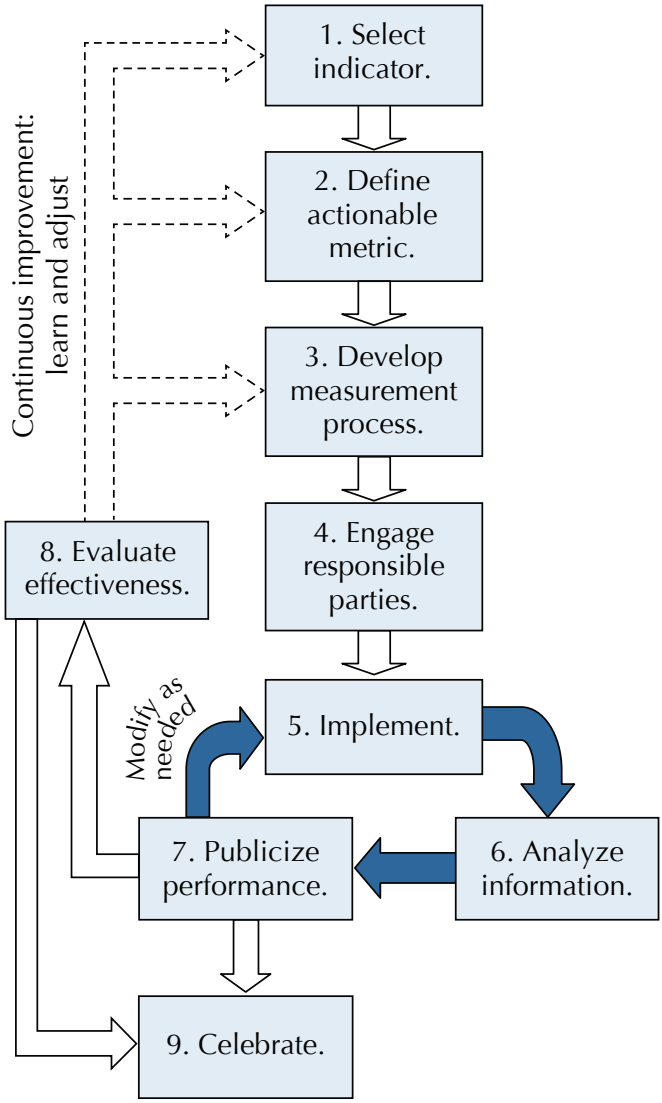

Figure 3. Flow chart for implementing an active leading indicator program

6

Conclusions and Recommendations

RT 284 recognizes that, in order to foster a zero-injury culture, both contractors and owners must be deeply committed to properly measuring active safety leading indicators. The team further recognizes that this commitment requires an understanding of the difference between and importance of **passive** and **active** leading indicators. The intent of this research was to provide meaningful measures that can help both contractors and owners attain and sustain a zero-injury construction culture on their jobsites. None of these recommendations should be viewed as replacements to existing practices; but rather, they should be understood as metrics that can help safety implementers determine whether current practices, procedures, and policies are sufficiently robust to continue to improve safety. In addition, in making these recommendations, the research team assumes that contractors or owners who jointly or independently endeavor to utilize these measures already have mature safety programs in place. Further, the team assumes that these programs strive not only to attain zero injuries, but also that they reflect a safety culture that is only satisfied with *continuous improvement*. Each organization's desire in implementing these metrics should be to perform an honest assessment that generates *positive actions* that, in turn, lead to new behaviors and employee beliefs that further strengthen the existing safety culture.

Although the research shows that companies that implement and track a majority of these metrics have better safety performance, each company or partnership must evaluate its current culture, climate, and values to determine how best to implement additional measures. Rather than attempting to make radical changes, the research team suggests evaluating the organizational safety culture, selecting strategies and metrics that integrate well with the existing culture, and striving for continuous improvement in safety performance. Not every leading indicator will be effective for every project or organization. The team also recommends that organizations consider adding new metrics by

phasing in one or more at a time and then adding more metrics as the climate allows. This research shows that companies that implement more than six of the differentiator passive leading indicators have a marked improvement in contractor safety performance. As new metrics are implemented, the team suggests first determining why particular results are obtained and then making implementation adjustments as necessary.

This was largely an exploratory study because, during the study period, leading indicators were rarely fully implemented in practice. As more projects implement leading indicators, the team recommends that CII support future research that 1) measures and tracks the success of implementing leading indicators, 2) investigates the integration of safety leading indicators with other project health measurement tools, and 3) refines the leading indicators with actual safety performance realized on construction projects. Such efforts would help CII companies to "zero in on zero" as these metrics are refined.

References

Gambatese, J. A., Hinze, J. W., and Haas, C. T. (1997). "A tool to design for construction worker safety." *Journal of Architectural Engineering*, 31(1): 32-41.

Hallowell, M. R. and Gambatese J. A. (2009). "Construction safety risk mitigation." *Journal of Construction Engineering and Management*, ASCE, 135(12): 1316-1323.

Hecker, S., Gambatese, J., and Weinstein, M. (2005). "Designing for Worker Safety: Moving the Construction Safety Process Upstream." *Professional Safety*, 32-44.

Hinze, J. (2001). *Safety Plus: Making Zero Accidents A Reality*. Research Summary 160-1, Construction Industry Institute.

Hinze, J. (2002). *Making Zero Accidents A Reality: Focus on Shutdowns, Turnarounds, and Outages*. Research Summary 160A-1, Construction Industry Institute.

Hinze, J. and Marini, J. (2008). "Software to Select Design for Safety Suggestions," CIB W99 2008 International Conference on Evolution of and Directions in Construction Safety and Health, Gainesville, Florida, March 9-11.

Hinze, J., Thurman, S. and Wehle, A. (2012). "Leading indicators of construction safety performance." *Safety Science*. http://dx.doi.org/10.1016/j.ssci.2012.05.016.

Rajendran, S., and Gambatese, J. (2009). "Development and initial validation of sustainable construction safety and health rating system." *Journal of Construction Engineering and Management*, 135(10), 1067-1075.

Glossary

Days Away/Restricted or Transfer (DART) Rate: A calculation of the number of recordable injuries and illnesses per 200,000 worker hours that resulted in days away from work, restricted work activity, and/or job transfer that a company or project experiences in any given time frame, e.g., a project life cycle.

Experience Modification Rate (EMR): A measurement developed by the insurance industry to adjust workers' compensation insurance premiums on the basis of work type, loss history, and payroll amount

Leading Indicators: Measures of attitudes, behaviors, practices, or conditions that influence construction safety performance.

Leading Indicators, Active: Safety-related practices or observations that can be measured during the construction phase to trigger positive responses. As a project progresses, work practices can be adjusted in response to dynamic monitoring, to improve safety performance.

Leading Indicators, Passive: Safety strategies that are implemented before the construction phase begins to set a project up for success; these are typically not adjusted once the project begins.

Recordable Injuries: All work-related deaths, illnesses, and injuries that are caused by or significantly aggravated by the work place and that result in a loss of consciousness, restriction of work or motion, permanent transfer to another job within the company, or require some type of medical treatment beyond first-aid treatment.

Severity Rate: Calculation of the number of lost days experienced per 200,000 worker hours in any given time frame.

Total Recordable Injury Rate (TRIR): Calculation of the number of recordable injuries that a company or project experiences per 200,000 worker hours in any given time frame.

Appendix A

Passive Leading Indicators Implemented on at Least 80 Percent of the Projects

The following table presents a list of passive leading indicators of safety performance, organized by frequency of implementation observed. Passive leading indicators implemented on more than 80 percent of projects should be considered foundational elements.

Leading Indicator	% of projects
Health and safety (H&S) manual	100%
Specific safety prequalification	100%
Subs' participation in general contractor (GC) orientation and training	100%
Subs' safety standards compared to GC	100%
Safety leadership training for foremen	100%
Management review of craft worker training	100%
Safety during constructability reviews	100%
Safety in scheduling	100%
Written site safety plan	100%
Heavy equipment inspection and approval program	100%
Lock-out tag-out policy	100%
100-percent hard hat policy	100%
Stop work policy	100%
Emergency response plan for the project	100%
Job hazard analyses	100%
Worker involvement in hazard assessment	100%
Safety goals development and communication	100%
Safe behavior reward and recognition	100%
Near misses investigation	100%
Foremen are involved in accident investigation	100%
Foremen are involved in hazard assessment	100%

Leading Indicator	% of projects
Regularly scheduled meetings for safety personnel	100%
Owner review and approval of construction management and GC's project safety plan*	97%
GC involvement in the investigation of subs' injuries	97%
Subs prequalification on safety	97%
Site-specific safety orientation for all employees	97%
Site-specific safety orientation for all managers*	97%
Computer-based safety training	97%
Company-specific orientation for all new hires	97%
PPE inspection and maintenance policy	97%
100-percent safety glasses policy	97%
Worker involvement in pre-task safety planning	97%
Injury reporting and analysis program	97%
Root cause analysis program	97%
Foremen are involved in jobsite safety inspections and audits	97%
Formal interviews for safety personnel	97%
Safety during design phase	96%
Foremen are involved in lessons learned/knowledge management	96%
Participation of all contractors and major subs in safety meetings*	93%
100-percent fall protection	93%
Full time safety manager on the project	93%
Quality requirements of restroom facilities	93%
First aid log*	93%
Established disciplinary program	93%
Review of H&S manual by owner/CEO	90%
Owner visibility in safety planning	90%
Mandatory substance abuse program	90%

* Significant passive leading indicator (see Figure 3)

Leading Indicator	% of projects
Safety instructor for the project	90%
Onsite testing and skill evaluation of mobile equipment for craft workers	90%
Regular inspection and maintenance of all tools	90%
Zero-tolerance policy	90%
Early-return-to-work policy	90%
Foremen evaluation in safety performance	90%
Safety training history for all personnel	87%
Regularly scheduled equipment inspections	87%
100-percent gloves policy	87%
Formal lessons learned/knowledge management program	87%
Worker hydration program	87%
Heat and cold stress program	87%
Worker involvement in safety committees	87%
Worker involvement in accident investigations	87%
Employees' skills	86%
Leadership development program	86%
Lump Sum or Cost Plus contract	85%
Maintenance program for all equipment	83%
Noise measurement and mitigation policy	83%
Project health and wellness reviews	83%
Worker involvement in inspections and audits	83%
Past safety performance for foremen selection	83%
Foremen are involved in safety committees	83%
Owner review of key contract H&S professionals	80%
Unannounced random drug and alcohol program	80%
100-percent reflective vest policy	80%
Fit for duty	80%

* Significant passive leading indicator (see Figure 3)

Appendix B

Passive Leading Indicators Implemented on Less than 80 Percent of the Projects

Leading Indicator	% of projects
Safety mentoring program for workers	77%
Monthly H&S training for supervisors	73%
10-hour OSHA training for company employees	73%
Worker involvement in perception surveys*	73%
Union workers on site	70%
Vendor safety orientation	70%
Safety perception surveys completion by foremen	70%
Background check for every new employee	69%
100-percent earplugs policy	67%
Jobsite superintendent participation in new-hire orientation	67%
Foremen are involved in policy creation and implementation*	67%
Quality requirements of lunchroom facilities	63%
Worker-to-worker observation program*	63%
Stretch-and-flex program for workers	63%
Minimum ratio of number of safety supervisors to workers	62%
Worker involvement in policy creation and implementation	60%
Safety orientation test	57%
Minimum ratio of safety professionals to workers*	57%
In-person training and certification	55%
Minimum ratio of craft workers to supervisors	53%
Percentage of daily toolbox safety meetings	52%
Quality requirements of parking lot	52%
Fatigue management program	52%
100-percent steel-toed boots policy*	50%

* Significant passive leading indicator (see Figure 3)

Leading Indicator	% of projects
No-injuries reward or incentives	48%
Medical facilities on site*	43%
Productivity incentive program	43%
Work hour restrictions	36%
Early project completion reward	29%

* Significant passive leading indicator (see Figure 3)

Appendix C

Examples of Active Leading Indicators

The following pages contain five selected descriptions of active leading indicators. These are designed to provide a general view of active leading indicators, whether they pertain to contractors, subcontractors, owners, or vendors.

1. Auditing Program

Contractor/Subcontractor

Description

One way that safety performance on a construction project can be assessed is through periodic (daily or weekly) jobsite safety inspections or audits. These audits should focus on jobsite conditions and worker behaviors, and are commonly performed with a standard form that has been customized for specific types of projects. The audits should ideally monitor the level of compliance with all facets of the project, including personal protective equipment, scaffolding, ladders, trenching, fall protection, fire protection, electrical safety, cranes, and equipment. The audit should record any conditions that warrant correction. Photographs may be taken to help document deficient areas in need of attention. These areas include the following: housekeeping assessments (office and field); periodic corporate representative audits/inspections; weekly scheduled project management team audits/inspections; periodic third-party consultant audits/inspections; and photographs taken to provide feedback to field supervisors/employees on hazards observed during audits/inspections. Audit information provides ongoing feedback on the safety conditions and behaviors on site.

Measurement

Audits are commonly conducted so that a score can be computed for each tour of the project site, typically represented as a percentage score. A score of 100 percent would represent full compliance for all observed conditions and worker behaviors.

Threshold

An audit score of 95 percent or above would be acceptable on many projects. For life-critical items, there must be 100-percent compliance, or some form of immediate intervention is required.

Resources

An audit form or checklist that ensures a consistent means of scoring must be maintained. Data must be regularly documented for the tracking, trending, and closing of corrective actions. Personnel are required to input/track data.

Action Plan

Audits are utilized to identify areas of non-compliance. Once these areas have been identified, responsible parties must then devise a plan to address the causal factors. Expectations should be communicated to field personnel, and progress should be measured regularly (daily or weekly). To demonstrate its leadership in the audit/inspection program, the project management team should have a visible field presence. Audit results should be communicated to project employees at least weekly.

Notes

Results of audits can be skewed, depending on the objective(s) (training) of the auditors. Audits are best when consistently conducted by the same individuals; however, audits/inspections should be validated by third parties as deemed appropriate.

2. Pre-task Planning

Contractor/Subcontractor

Description

A pre-task plan is prepared at the crew level prior to the performance of every task. Pre-task plans are prepared with input from all members of the crew that will perform the task, and this is done just before the task is performed. In addition, pre-task plans are updated when changes occur in the work environment or to the work scope. A post-work evaluation of the pre-task plan process should also be performed. The pre-task plan is the primary tool for workers to plan safety into the job. Other planning tools may be used, but the pre-task plan ensures worker engagement and participation in the identification of hazards, establishing controls, and outlining safe steps to do the job. Pre-task plans are documented on forms that help to minimize tedious paperwork.

Measurement

The ideal measurement of pre-task plans should be focused on their quality, which is determined by how carefully each plan is prepared. Quantitative measures, which can also be utilized, include the following: the number of pre-task plans prepared per day versus the number of work orders/tasks; the number of pre-task plans prepared per day; or the number of pre-task planning meetings conducted each day. Qualitative measures may be ideal for pre-task plans, since they ensure that the plan is specific to the task, that the plan is thorough, and that all crew members participate in the planning session.

Threshold

Regarding the number of pre-task plans versus the number of tasks performed, the ratio should be 100 percent, since no tasks should be undertaken without an initial pre-task planning meeting.

Resources

Pre-task planning forms that are tailored to the type of project undertaken should be prepared and readily available to all field crews. Personnel must be assigned to evaluate and score the pre-task plans, as well as to input/track the data.

Action Plan

A responsible party should actively audit pre-task planning sessions every day for compliance with expectations. Feedback should be provided to the supervisors and crews, especially when expectations are not being met. When pre-task plans fall below expected targets, supervisors and their respective crews are to receive additional training, which may be in the form of short refreshers/remedial training in the field, or as more extensive training, depending on the nature of the failure to follow protocol. The crew foremen are responsible for ensuring that each of their crew members is actively involved in the pre-task planning meetings.

Notes

Pre-task planning meetings should be conducted where the work is taking place—not in the tool room, employee lunchroom, or other locations away from the workface. These meetings should take place immediately before the work is to be performed. Scores based on the quality of the pre-task planning form are to be maintained separately for each supervisor.

3. Owner's Project Manager Participates in the Worker Orientation Sessions

Owner

Description

All workers new to a project are to receive orientation training. This training will acquaint each participant with the project site (e.g., site logistics, storage areas, tool storage, and toilets) and project rules (e.g., vehicle speeds on site, organized or personal breaks, and the site smoking policy). Of course, many safety rules will be stressed (e.g., no running on site, 100-percent tie-off when working at elevation, and 100-percent safety eyewear). The orientation session should be scheduled early on in order to give workers a comprehensive first impression of the project. This is the ideal time to stress safety. The owner of the project can reinforce the safety agenda for the project by having the owner's project manager participate in each orientation session. At this face-to-face meeting, the owner's project manager can stress safety and, through his or her impassioned commitment, can help to establish the project's safety expectations. A 15-20-minute presentation at the orientation session can be effective. An effective means should be devised to ensure that the owner's project manager is informed about the scheduling of all orientation sessions.

Measurement

Percentage of orientation sessions in which the owner's project manager is an active participant.

Threshold

The threshold is to be 100-percent participation of the owner's project manager in orientation sessions. Anything less would warrant adjustment on the part of the owner's project manager.

Resources

The owner's project manager should prepare an outline or script to ensure that specific points are made and that consistent expectations are shared at the orientation sessions. Upper-level personnel should verify that the owner's project manager is an active participant at each orientation session.

Action Plan

The owner's project manager must be committed to sincerely addressing each group of workers at orientation sessions. The owner's project manager should promptly use a standardized form to document participation in these orientation sessions. The owner's upper-level personnel will intervene when the owner's project manager fails to meet the orientation session participation goals.

Notes

It is important that this responsibility not be diluted through its assignment to someone below the owner's project management level. It is only in rare instances in which the owner's project manager cannot attend a session that the responsibility should be assigned to another party on the owner's site staff. This leading indicator sets the tone for site safety. This is to reinforce the safety agenda of the prime contractor.

4. Foremen Conduct Discussions and Feedback Meetings with the Owner's PM

Owner

Description

Effective communications are vital to the successful execution of construction projects. The project owner can play a key role in establishing communication through which problems can be more easily solved. One such approach is for the owner's project manager (PM) to maintain regular meetings with the contractor's foremen. At these meetings, the foremen can raise issues, ask questions, and give feedback (positive and negative) about what is happening on the project site. A monthly meeting is hosted by the owner's PM and attended by all site foremen; meetings may be held more frequently.

Measurement

Total number of meetings held versus the number of meetings scheduled.

Total number of foremen attending the meetings versus the number of foremen on the project site.

Percentage of action items that are closed on or before the target dates set for them.

Threshold

The threshold for the number of meetings scheduled versus those held should not be less than 100 percent.

The threshold for the number of foremen attending the meetings versus the number of foremen on the project site should not be less than 90 percent. (Circumstances may prevent some foremen from participating at all meetings.)

The threshold for the number of action items that are closed versus the number of action items enumerated at the meetings should be 100 percent, provided that appropriate time is allotted to address each.

Resources

A standing agenda should be maintained. Meeting minutes should be kept, action items should be enumerated, and the close-out of these action items should be tracked.

Action Plan

Hold regular meetings between the owner's PM and the contractor's foremen as a feedback process and/or mechanism. Monitor the attendance of the foremen and the feedback by tracking attendance (sign-in sheet) and recording the meeting discussions (meeting minutes). At the meetings, report on feedback pertaining to the actions initiated by the owner's previous PM meeting. The owner's PM will assign action items to the appropriate owner project team member, and a system will be established to monitor action-item due dates and to communicate back to the PM prior to the set deadlines. If an action item is not accomplished by a given due date, the owner's PM should investigate and establish a plan for closing out the action item. The owner's PM should establish firm expectations of the owner's team members on closing out action items in order to address the foremen's concerns.

Notes

These meetings should be set up especially early on in the project to establish the foremen's buy-in and to send the message that management cares about their HSE concerns. The feedback process must be conducted such that none of the foremen fears reprimand. On lump sum contracts, there should be an inclusion stipulating compulsory participation in these meetings.

5. Vendor Safety Audits

Vendor

Description

Vendors are frequent visitors on construction sites. Whether delivering concrete or plumbing fixtures, the time that vendors spend on site may vary from a few minutes to several hours. Some vendors will make many subsequent visits, as well. It is imperative that all vendors comply with all safety rules and regulations that have been developed for their safety. The procedures may include the following: mandatory check-in at the job gate; attendance at an orientation session prepared for vendors; accompaniment by a site representative while on site; restriction to the vendor vehicle unless escorted on site; and wearing of all required personal protective equipment when on site. While the vendor safety procedures may be clear and concise, it is imperative that full compliance is ensured. A regular audit of vendors should be conducted, following procedures that are similar to jobsite safety audits. All compliance infractions must be addressed. Audits of vendor site visits should have a particular focus on high-risk deliveries.

Measurement

The measure of compliance is the percentage of vendors following policies.

Threshold

Compliance is to be 100 percent. Any observed infractions of the safety procedures by vendors should be addressed with the non-compliant vendors. When more than five percent of the vendors are found to be in non-compliance, a more aggressive response is needed.

Resources

Staff time will be required to prepare and conduct audits, and management time will be needed to review and respond to audit results. The response will consist of stressing compliance with the non-compliant vendors. Special meetings may be required if a particular vendor is consistently in non-compliance.

Action Plan

The frequency of vendor audits will be dictated by the percentage of non-complying vendors. Ideally, all (100 percent) of the vendors will be found to be in full compliance. When more than five percent of the vendors are found to be in non-compliance, a broad-scale communication should be made with all vendors to describe the appropriate vendor procedures on site and to stress adherence to them. More non-compliance will result in increased audits.

Notes

The purchase orders and purchase agreements must include provisions whereby vendors are contractually bound to comply with company safety procedures when on site. The organization that controls access to the construction site is ultimately responsible for measuring and tracking this indicator.

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