Near-Hit
Reporting
Reducing Construction
Industry Injuries

By Eric Marks, Ibukun G. Awolusi and Brian McKay

The construction industry continues to experience a high number of workplace injuries and fatalities as compared to other U.S. industrial sectors. Although this number has been declining over the past 20 years, the rate of decrease has been slowing, and is nearly stagnant in recent years (ILO, 2003). As an industry, construction has averaged 1,010 fatalities per year, indicating that much improvement is still needed to achieve zero injuries, illnesses and fatalities (BLS, 2013a). One such improvement can be found in the collection and measurement of safety data.

Historically, the construction industry has defined safety performance through the measurement and assessment of lagging indicators including injuries, illnesses and fatalities. These lagging indicators are required by OSHA to assess the state of construction safety (BLS, 2013a). One major limitation of assessing safety performance using lagging indicators is that incidents must occur before hazards or unsafe behavior can be identified and mitigated.

Leading indicators are an alternative form of safety metrics that proactively assess safety performance by gauging processes, activities and conditions that define performance and can predict future results (Hinze, Thurman & Wehle, 2013). One such leading indicator is a near-hit, defined as an incident in which no property damage or personal injury occur, but could have occurred given a slight shift in time or position (BLS, 2013a). The major advantage of measuring leading indicators such as near-hits is that data can be collected and analyzed without requiring an injury to occur.

This article presents research products in the development, deployment and effectiveness of using a near-hit management program on construction sites. The authors gathered the information through personal experience, formal research in the Construction Industry Institutes Research Team 301: Using Near Misses to Enhance Safety Performance, and through secondary research and literature review. The goals of this article are to present the near-hit management program and

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demonstrate its quantitative effect and proof of effectiveness when applied to a multibillion dollar construction project, to encourage the use of this methodology in the field.

Construction Incident Statistics

In the U.S., construction companies are required to report all fatalities, injuries and illnesses that occur during or as a result of the work environment (OSHA, 2011). OSHA categorizes reported incidents as 1) occupational fatality, 2) nonfatal injury or 3) nonfatal illness, and further categorizes them as to severity: OSHA recordable injuries and lost time/days away from work cases.

U.S. Bureau of Labor Statistics (BLS) data show 117 recordable incident cases for every 10,000 workers in the U.S. in which the injury or illness was nonfatal but required days away from work (BLS, 2012). Construction workers experienced 179,100 nonfatal injuries in 2012 (6% of cases when compared to the total nonfatal injuries experience by the U.S. private sector that year), a decrease compared to the 184,700 injuries reported by the industry in 2011 (8.6% of cases) and 3,153,701 in 1992 through 2010 (10.6% of cases) (BLS, 2013b).

Leading Indicators

As noted, construction companies are required to document work-related incidents (OSHA, 2013). These metrics, termed *lagging indicators*, cannot reflect whether a hazard, the event severity or causation has been mitigated (Flin, Mearns, O'Connor, et al., 2000; Lindsay, 1992). According

to Hallowell, Hinze, Baud, et al. (2013), leading indicators are measures of processes, activities and conditions that define performance and that can predict future results. Unmitigated high-risk situations, including near-hits, will result in a serious or fatal injury if allowed to continually exist (Krause, Groover & Martin, 2010).

Linear causation models (e.g., domino theory, loss causation models) suggest that incidents are the end result of a sequence of events and provide a sound motivation to collect and analyze near-hit data. Earlier researchers have also found that most serious injuries can be successfully prevented (Hecker, Gambatese & Weinstein, 2005; Hinze, 2002; Hinze & Wilson, 2000; Huang & Hinze, 2006).

Near-Hit Reporting Across Industries

Near-hit reporting has been widely used in various industries throughout the world for some time. A company in the offshore drilling business realized exceptional decreases in lost-time incident

IN BRIEF
- The construction industry continues to rank as one of the most hazardous work environments, experiencing a high number of workplace injuries and fatalities.
- Safety performance improvement is needed to achieve zero injuries, illnesses and fatalities on construction sites. One systematic method of achieving this improvement is through the collection and analysis of safety data such as near-hits.
- This article highlights best practices for collecting and analyzing near-hit information. A near-hit management program for assessing collected data is created so that lessons learned from reported events can be applied to mitigate future hazards on construction sites.
- Results of a construction site case study of the implementation of the created program indicate that near-hit reporting and analysis can improve the safety performance of workers on construction sites.

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rates when it implemented a near-hit program; the company found that a reporting rate of 0.5 near-hits/person/year correlated with a 75% reduction in lost-time injury rates (Phimister, Oktem, Kleindorfer, et al., 2003).

The process of collecting and analyzing near-hit data has been studied in the chemical process industry (van der Schaaf & Kanse, 2004). The study also investigated barriers to and human behavior associated with reporting near-hits. Within the chemical processing industry, the U.S. Nuclear Regulatory Commission has collected and reviewed near-hit reports for nuclear reactors since 2000 (Donovan, 2011).

The aviation industry also benefits from near-hit reporting practices. *Aircraft proximity hazard* (*airprox*) is an aviation industry term for a near-hit. An airprox is a situation in which the distance between aircraft, as well as their relative positions and speed, have been such that the safety of the aircraft involved was compromised (CAA, 2013). Safety recommendations are focused at limiting the risk of recurrence of a specific airprox event. The primary objective is to improve flight safety with regard to identified hazards and lessons learned from near-hit occurrences.

The firefighter near-hit reporting system is another distinct industry adopting near-hits as an opportunity to learn. The near-hit database (**http://fire.nationalnearmiss.org/reports**) is managed by the International Association of Fire Chiefs (IAFC) and funded by Federal Emergency Management Agency's Assistance to Firefighters grant. This anonymous reporting database is designed to accept near-hit reports from fire departments throughout the U.S. The database is open for review, and shares lessons learned and experiences from the firefighting community. A similar database is also available for law enforcement officials (**http://leo.nationalnearmiss.org/browse-reports**).

A study by Callum, Kaplan, Merkley, et al. (2001), on near-hit reporting in the medical field concerning transfusion medicine collected data on human errors and near-hits at a blood bank. Three of the most concerning events were 1) samples collected from the wrong patient; 2) mislabeled samples; and 3) requests for blood for the wrong patient (Callum, et al., 2001). Similar studies were conducted in nursing home environments (Wagner, Capezuti & Ouslander, 2006).

The construction industry has been slower to adopt near-hit reporting when compared to other industries in the U.S. private sector (Cambraia, Saurin & Formoso, 2010), with some notable exceptions. For example, a large U.S. manufacturing company uses a system called ARTTS-NMA: Autonomous Real-Time Tracking System of Near Miss Accidents on construction sites (Caterpillar, 2013). This system uses ultrasonic technology for outdoor and indoor real-time location tracking, sensors for environmental surveillance, radio frequency identification for access control and worker information, and wireless sensor networks for data transmission (Wu, Huanjia, Chew, et al., 2010). The goal is to automatically identify a specific type of hazard as a near-hit event and alert safety personnel before a similar situation occurs.
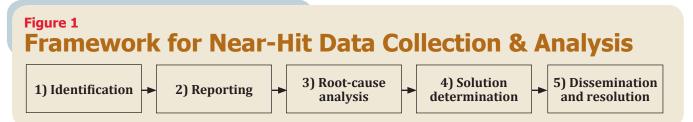
In summary, BLS maintains a database for lagging indicator data including workplace fatalities, injuries and illnesses, but does not require near-hit reporting. Several industrial sectors collect and analyze near-hit data for potential safety improvement. Many of these industries maintain an industry-wide near-hit reporting database so that other industry personnel can learn from each other's near-hit information. The construction industry has been slower to adopt near-hit reporting for reasons such as fear of retaliation, anticipated barriers, and miscommunication that the more near-hits that are reported, the poorer safety performance can be expected on a project.

Near-Hit Data Collection & Analysis Framework

This article presents a high-level model for a near-hit management program as the basic methodology for site safety managers and construction management personnel to collect, analyze and use safety data effectively. This framework implements a management system for near-hit data and can be a vital component in the data flow within a near-hit reporting program. Figure 1 presents the five steps for this framework of transitioning near-hit data to information and ultimately knowledge for dissemination. The five steps are further described here.

Step 1: Identification

The first step occurs when construction site personnel recognize an unsafe event or set of conditions on a construction site. Employees should be trained to identify near-hits and how they differ from lag-

Figure 1

Framework for Near-Hit Data Collection & Analysis

| 1) Identification | → | 2) Reporting | → | 3) Root-cause analysis | → | 4) Solution determination | → | 5) Dissemination and resolution |

ging indicators (e.g., injuries, illnesses). If the near-hit is of high severity or danger is imminent, the worker should execute the stop work authority and mitigate any hazards immediately. Similarly to hazard identification, construction workers should be trained as an extension of existing safety training programs to identify and report near-hit events. For example, when workers are educated about proper PPE for working at heights, they should also be instructed on how to identify and report cases in which coworkers are not wearing PPE while working at heights. The success of a near-hit reporting program largely depends on the ability and motivation of individuals to identify and report near-hits on construction sites.

Step 2: Reporting

Construction site personnel who identify near-hits must report those events to their immediate supervisor through a near-hit reporting system. Depending on the site constraints, this reporting system can use either electronic- or paper-based reporting. Both systems should maintain employee anonymity, and both options must have the database capability to house the collected data.

Although required near-hit report criteria may vary between companies, a set of standard criteria is essential for each report (e.g., company name, event date, time, location, description). Automated near-hit reporting programs allow for photos with the report. Additional information might include record supervisor name, job/craft, possible consequences, corrective measures taken, whether further action is required, and whether the event was reported to the observer's supervisor.

Step 3: Root-Cause Analysis

Determining the factors that contributed to the near-hit occurrence is the next step. When a near-hit is reported, use a consistent measure of categorization so that similar events are categorized accordingly, regardless of who is taking in the report. Van der Schaaf (1992) used one such categorization scheme in his doctoral thesis work.
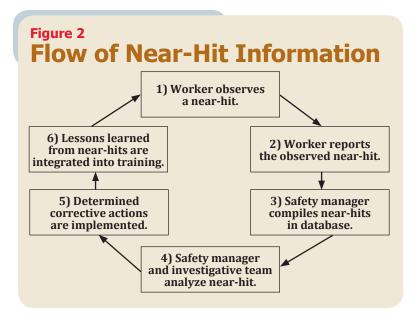
Table 1

ECM for Human Errors in Construction

Factor	Category	Definition
Skill-based	Slips	Failure in highly developed motor skills such as using a hammer but missing the nail.
	Tripping	Failure in whole-body movements such as climbing a ladder, tripping on even ground, swinging arm or kicking something.
Rule-based	Qualifications	Asking someone to do something in which s/he has limited experience or knowledge.
	Coordination	A lack of coordination between two construction groups such as walking into a barricaded area or groups not coordinating with each other on work assignments.
	Verification	The incomplete assessment of something on the worksite such as using equipment which hasn't been inspected or using the wrong materials at the wrong time
	Identification	Failures that result from faulty task planning such as hazards not identified on the job safety analysis or hazardous conditions that remain unrecognized.
	Monitoring	Improper identification controls such as checks or calibration.
	Compliance	Procedures that are not followed, off task or shortcuts.
	Construction	Correct design that was not constructed properly or was set up in inaccessible areas and not constructed to plan.
	Protocol	Failures relating to the quality and availability of department protocols (e.g., too complicated, inaccurate, absent or poorly presented).
Knowledge-based	Knowledge	Inability of a person to apply his/her existing knowledge to a new situation (e.g., the worker was unaware of a rule).
Other	External	Technical failures beyond the control and responsibility of the investigating organization.
	Mechanical	Failures involved with mechanical issues beyond the control of field personnel.
	Culture	Failures resulting from collective approach and its attendant modes of behavior to risks in the investigating organization.

McKay (2013) later developed a construction-specific Eindhoven Classification Model (ECM); he used it to categorize more than 3,000 near-hits. The categories, defined in Table 1, are classified as either a skill-based, rule-based or knowledge-based factor.

Step 4: Solution Determination

Once near-hits have been categorized, the next step is to present solutions, taking into account the severity and consequences of the preceding near-hit events. Simple, noncomplex or life-threatening events are treated as an exchange of information. More significant events are treated differently, but only after threats to life safety are removed and the site is rendered safe. These more complex events may involve changes in strategy on site and may involve the use of systematic root-cause analysis methods or work groups in order to find resolution. In many cases, a simple human error determination using the ECM will direct the type of remedial actions needed in the field to prevent recurrence of the unsafe condition or behaviors.

Figure 2
Flow of Near-Hit Information

1) Worker observes a near-hit.

2) Worker reports the observed near-hit.

3) Safety manager compiles near-hits in database.

4) Safety manager and investigative team analyze near-hit.

5) Determined corrective actions are implemented.

6) Lessons learned from near-hits are integrated into training.

Step 5: Dissemination & Resolution

Ideally, corrective actions will have been employed in the field following the near-hit events and the work area will have been left in a safe state. In many cases, the reported near-hit may not have required a stop-work or other lifesaving measure. The incident may have occurred, been corrected and workers in the area will have continued their jobs. If a near-hit occurs but is not reported, then the lesson learned is only of consequence for those in the immediate area. The broader audience (including all other site personnel) should be informed of the reported near-hit and corrective actions taken, and should be communicated as soon as possible (e.g., the next day's toolbox talks).

Safety managers will integrate learned lessons from the reported near-hit into existing safety training. This step allows for the worker who reported the near-hit to receive feedback on how the situation was corrected. By educating construction site personnel from other projects on lessons learned from near-hits, safety performance of workers can be enhanced. Figure 2 depicts the flow of information for a single reported near-hit.

Case Study

A novel near-hit data collection and analysis system was implemented on a large-scale liquefied natural gas construction project located outside the U.S. The multibillion-dollar engineer-procure-construct project had a sophisticated, mature safety program, and recordable and lost-time rates that were stable and low compared to other construction projects in the same NAICS, but nonetheless stagnant.

The rates of near-hit reporting, first-aid cases and other recordable injuries as defined by OSHA were tracked for 15 weeks before and after implementation of the near-hit data collection and anal-

ysis system. Researchers found the rates of near-hit reporting increased significantly after implementation of the system (McKay, 2013). No statistically significant change was experienced between the values of first aids experienced before and after implementation. However, the number of OSHA-recordable injuries differed after the implementation of the near-hit collection and analysis system ($p = 0.026$). A correlation study using Kendall rank correlation coefficient (Sen, 1968) identified the connection between the number of near-hits reported and OSHA-defined recordable injuries after the system was implemented (Table 2).

The ECM adopted for construction safety was used to categorize near-hits reported. Types and frequencies of near-hits reported after implementation of the near-hit data collection and analysis system are shown in Table 3. Table 3 also presents the number of incidents per category of preimplementation and postimplementation of the near-hit data collection and analysis system.

Significant differences were identified between the number of first-aid reportable cases before and after implementation of the system. The significance of the increase in near-hits reported allowed for a favorable testing situation in which researchers theorized that an increase in near-hit reporting would affect the rates of first-aid cases and recordable injuries in an inverse relationship. Significant differences were also identified between the measures of near-hit reporting, with an overall increase of 966% reported after system implementation on the construction site. The project experienced a 100% decrease in OSHA recordable cases during the time of the near-hit intervention.

The increased reporting of near-hits was attributed to management investment and ownership of the implemented program, as well as a significant effort to educate employees about the near-hit program, including training on identifying near-hits, the reporting process and benefits of reporting. No incentives were provided to employees for quantity or quality of near-hit reports.

The Mann-Whitney statistics (Ruxton, 2006) were used to correlate collected safety data. The rates of near-hits reported were inversely correlated with the number of recordable first-aid cases [$r(30) = -0.281$; $p < 0.05$] and the counts of recordable injury cases [$r(30) = -0.373$; $p < 0.01$]. The near-hit data collection and analysis system was found to be less correlated with recordable first-aid cases than with recordable injury cases.

One possible explanation for this is that first-aid cases seem to have a more random distribution. A first-aid case could include dust blown into the eye, treatment for an insect sting, heat rash or other conceivable event that could befall a person while at work. Recordable injuries are more action-oriented events that are typically the result of a larger release of energy such as a slip and fall, hitting one's thumb

with a hammer or suffering a laceration while at work. This could be further investigated by research stemming from this initial attempt.

The top five near-hit categories were identical across the preintervention and postintervention samples, and are reported in order from highest to lowest: compliance, identification, slips, trips and verification (Mc-Kay, 2013). In view of this, an OSH management program would have a target-rich environment when considering where to apply limited resources given that the top five near-hit types are related to human error and are active errors, but this should be tested on other projects.

Near-Hit Reporting for Other Industries

Many industrial sectors have benefitted from the collection and analysis of near-hits, including energy production (Fabiano & Curro, 2012), medicine (Callum, Kaplan, Merkley, et al., 2001) and manufacturing (Lander, Eisen, Stentz, et al., 2011). The chemical processing industry has experienced many benefits and improved safety from implementing near-hit reporting programs (Phimister, Oktem, Kleindorfer, et al., 2003). When interviewing more than 100 chemical processing and management personnel from 20 chemical and pharmaceutical facilities, researchers identified a decrease in traditional mistakes that can contribute to injuries or illnesses. Furthermore, the study identified a qualitative improvement in the proactive approach of interviewees in terms of safety and mitigating unsafe situations (Phimister, et al., 2003). Consequently, an overall improvement in safety management among most interviewees was identified after implementing a near-hit reporting program. The benefits of near-hit reporting can be realized through industries.

Conclusion

The strength of the near-hit reporting data collection and analysis system lies in its ability to generate useful safety information for a given construction site. During the evaluation period, near-

Table 2
Correlation Coefficient Analysis

		Near-hits reported	First-aid count	OSHA injury recordable count	First-aid rate	OSHA injury recordable rate
Near-hits reported	Correlation coefficient	1.000	*-0.281*	**-0.373**	-0.207	*-0.320*
	Significance (1-tailed)		0.019	0.008	0.056	0.014

Note. *Values marked in italics denote a correlation value that is statistically significant at the 0.05 level (1-tailed test). Numbers marked in bold show a correlation value that is statistically significant at the 0.01 level (1-tailed test).*

Table 3
Near-Hit Categorization Using ECM

	Frequency		Total frequency	Percent	Cumulative percent
	Pre-implementation	*Post-implementation*			
Slips	9	41	50	4.5	4.5
Tripping	7	17	24	2.2	6.6
Coordination	5	118	123	11.0	17.7
Verification	10	56	66	5.9	23.6
Identification	21	264	285	25.6	49.2
Monitoring	0	4	4	0.4	49.6
Compliance	37	478	515	46.2	95.8
Construction	5	6	11	1.0	96.8
Protocol	0	1	1	0.1	96.9
Knowledge	3	8	11	1.0	97.8
External	2	1	3	0.3	98.1
Mechanical	5	15	20	1.8	99.9
Culture	0	1	1	0.1	100.0
Total			**1,114**	**100.0**	

hit information was consistently presented to the entire workforce in the form of plan-of-the-day meetings, toolbox talks or similar pre-work task planning sessions. The ability to collect, analyze and disseminate safety information allows employers to mitigate hazardous events and conditions before an incident occurs.

The primary contribution of this research is the correlated link between the number of near-hits collected and the decreased number of first-aid cases and recordable injuries on a construction site. The ECM was modified to categorize near-hit events specific to construction sites for the first time, at least at the time of this publication. This initial research step provides a foundation for future research in near-hit reporting on construction site injuries. Future research could include correlating near-hit reporting to expected severity and risk

exposure and the generation of predicted variables or outcomes. **PS**

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