Using Near Misses to Enhance Safety Performance in Construction

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Introduction

While the number of fatalities experienced by the construction industry has been declining over the past twenty years, the rate of decrease has been slowing down, almost stagnant in recent years (ILO 2003). As an industry, construction has averaged approximately 1,010 fatalities per year revealing that it is still one of the most dangerous occupations in the United States. (BLS 2013a). Historically, the construction industry has defined safety performance through the measurement and assessment of lagging indicators; injuries, illnesses, and fatalities. These lagging indicator safety measures are used by the Occupational Safety and Health Administration (OSHA) to assess the state of construction safety (BLS 2013b). One major limitation of assessing worker safety performance using lagging indicators is that accidents must occur before hazards or unsafe worker behavior can be identified and mitigated; it’s like looking in the rear view mirror to see where you are going.

An alternative form of safety metric is the leading indicator. These pro-active metrics assess safety performance by gauging processes, activities, and conditions defining safety performance by their adherence to goals future outcomes rather than rely in the past (Hinze et al. 2013). One such indicator is the near miss which is defined as an incident where no property damage and no personal injury occur, but where, given a slight shift in time or position, damage and injury easily could have occurred (BLS 2013b). The major advantage of measuring leading indicators such as near miss reporting is that data can be collected and analyzed without the requirement of a lagging indicator (injury) to occur.

The goals of this research are to identify the most effective methods for assessing non-injury causing events (near misses) through a review of practices. In addition, evidence will be presented through a case analysis that near miss reporting programs can have a positive impact and reduction of injuries on large construction projects.
Literature Review

When compared to other U.S. industrial sectors, the construction industry continues to experience a high number of workplace injuries and fatalities. Much academic research and industry innovation and hard work have been invested into the identification and mitigation of factors related to the increased burden of morbidity and mortality in the construction trades. The following review of literature and theory is intended to briefly skim the major contributions to near miss management program design and the direction of this research.

Construction Accident Statistics

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

The U.S. Bureau of Labor Statistics (BLS) recorded 117 recordable accident cases for every 10,000 workers in the United States in which the injury or illness was nonfatal but required days away from work (BLS 2012). These numbers were almost identical to the previous year. Construction workers experienced 179,100 non-fatal injuries in 2012 (BLS 2013a); a decrease compared to the 184,700 injuries reported by the industry in 2011. Table 1 provides a summation of non-fatal injuries experienced by the construction industry in recent years. Numbers denoted in parentheses represent the percentage of cases when compared to the total non-fatal injuries experienced by the U.S. private industry sector in that year.

Table 1: Non-fatal injuries of the construction industry (BLS 2013a)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>179,100 (6.0%)</td>
</tr>
<tr>
<td>2011</td>
<td>184,700 (8.6%)</td>
</tr>
<tr>
<td>1992- 2010</td>
<td>3,153,701 (10.6%)</td>
</tr>
</tbody>
</table>

Leading Indicators

As previously mentioned, construction companies are required to document work-related accidents (OSHA 2013). These metrics are termed lagging indicators because the measurement and analysis occur after an accident occurs. Lagging indicators are unable to reflect if a hazard has been mitigated, the severity of an event, or the event causation (Lindsay 1992, Flin et al. 2000). Leading indicators are measurements of processes, activities, and conditions that define performance and can predict future results according to Hallowell et al (2013) where leading indicator requirements were developed. Near misses meet the requirements for leading indicators because: 1) near miss data can be quantified, 2) near miss data can be easily understood, 3) the data credible, 4) data must signal the need for action, 5) data must be related to other indicators, and 6) data must not generate unintended consequences (Hallowell et al. 2013,Hinze et al. 2013, UKSHE 2012, Hinze 2006). Examples of safety leading indicators include behavior-based safety (Fang and Huang 2004, Lingard and Rowlinson, 1997, Choudhry et al. 2007, Zohar and Luria 2003), near miss reporting (Hinze et al. 2013, Hinze 2006), jobsite hazard analysis (OSHA 2002, Rozenfield et al. 2010), and safety training (Agnew and Daniels 2011, Jaselskis et al. 1996, Goldenhar et al. 2001, Ho and Dzeng 2010).
One of the primary leading indicators, and the subject of this paper, is that of the near miss. Defined by the U.S. Department of Labor as an incident where no property damage and no personal injury were sustained, but where, given a slight shift in time or position, damage and injury easily could have occurred (BLS 2013a), the near miss has been identified as a leading indicator. Activities such as oil & gas production, chemical manufacturing, nuclear engineering and other high potential for loss but low probability for failure industries have used near miss data for years now (Oktem, 2002). Other industries, including manufacturing, have adopted near miss reporting programs to improve safety on both upstream and downstream processes (Sullivar and Sheffrin 2003). Neither the U.S. Department of Labor, nor OSHA, collect or analyze near miss data (OSHA 2011b).

Theory & Model
The Safety Pyramid, shown in Figure 1, illustrates the concept that there are a lot more minor incidents, unsafe conditions and behaviors than there are actual injurious outcomes. More generally, a large number of safety leading indicators must occur (e.g. near misses) before a lagging indicator (i.e. worker injury) occurs, according to this model.

![Figure 1: Heinrich’s Safety Pyramid (OSG 2009)](image)

Linear causation models suggest that accidents are the end result of a sequence of events and (e.g. the Domino Theory and the Loss Causation Models) are derived from the Safety Pyramid (Toft et al. 2012). The unsafe conditions and behaviors represented in the model suggest that strengthening barriers and / or limiting the frequency of these unplanned events should lessen the frequency of injury causing outcomes. Several researchers have modified and augmented the existing pyramid to include “incidents without damage or loss” and “unsafe hazards and conditions” (Phimister et al. 2003) to be more inclusive. Concepts of the Safety Pyramid support previous research findings that all serious injury to workers can be successfully prevented (Hinze 2002, Huang and Hinze 2006, Hecker et al. 2005, Hinze and Wilson 2000).

Near Miss Reporting in Industry
Near miss reporting has been widely used in a variety of industries throughout the US and the world for some time now. A company in the offshore drilling business realized exceptional decreases in lost time accident rates when they implemented a near miss program; they found that a near miss reporting rate of
0.5 near misses reported per person / per year correlated with a 75% reduction in lost time injury rates (Phimister et al. 2003).

The process of collecting and analyzing near miss data has been studied in the chemical process industry (Schaaf and Kanse 2004). Seven stages outline the reporting of a near miss: 1) identification, 2) disclosure, 3) distribution, 4) direct and root-cause analysis, 5) solution determination, 6) dissemination, and 7) resolution. The study also investigated human behavior associated with reporting near misses and the associated barriers. Within the chemical processing industry, the U.S. Nuclear Regulatory Commission (NRC) collects and reviews near miss reports for nuclear reactors (Donovan 2011). Most negative incidents identified at nuclear plants are low risk, but some higher severity instances are further reviewed and mitigated by regulation from the NRC. A similar regulatory commission exists in Ireland in which the industry is experiencing exponential increases in near miss reporting (Clancy et al. 2011).

The aviation industry also benefits from practices of near miss reporting. Aircraft Proximity Hazard (Airprox) is an aviation industry term for a near miss (CAA 2013). The primary objective of Airprox is to improve flight safety with regards to identified hazards and lessons learned from near miss occurrences. An Airprox is a situation where 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 were focused at limiting the risk of recurrence of a specific Airprox event.

The Fire Fighter near miss reporting system is another distinct industry adopting near misses as an opportunity to learn. The near miss database is managed by the International Association of Fire Chiefs and funded by the Federal Emergency Management Agency’s (FEMA) Assistance to Firefighters grant (International Association of Fire Chiefs, 2015). This anonymous reporting database is designed to accept near miss reports from fire departments from around the country. The database is open for review and the lessons learned and experiences from the community of fire fighting is shared for any interested parties. Another study on near miss reporting in the medical field concerning transfusion medicine (Callum et al. 2001) collected data on human errors and near misses at the blood bank. Of the 819 near miss events recorded, 61 were potentially life threatening. 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 on nursing home environments as well (Wagner et al. 2006).

The construction industry has been slower to adopt near miss reporting when compared to other industries in the U.S. private sector (Cambraia et al. 2010) but there are some notable exceptions. A large manufacturing company in the United States uses an Autonomous Real-Time Tracking System of Near Miss Accidents (ARTTS-NMA) 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 (RFID) for access control and worker information, and wireless sensor networks for data transmission (Wu et al. 2010). The goal is to automatically identify a specific type of hazard as a near miss event and alert safety personnel before the same situation occurs in the future.

And, according to research done by the Construction Industry Institute in Research Team 301: Using Near Misses to Enhance Safety Performance; a fair number of construction companies are now realizing the benefit of a robust near miss management program in their health, safety and environmental management programs. According to the research and the information from review of 47 construction projects, near miss programs were identified as essential elements in many mature HSE programs, some companies were in development of their own near miss programs and a select few were adopting programs under recommendations from their clients or insurance brokers.
Summary

In summary, the BLS maintains a database for lagging indicator data including workplace fatalities, injuries and illnesses, but does not require near miss reporting. Several other industrial sectors collect and analyze near miss data for potential safety improvement. Many of these industries maintain an industry-wide near miss reporting database so that all industry personnel can learn from one another’s near miss information. The construction industry has been slower to adopt near misses for a variety of reasons related to anticipated barriers, miscommunication that the more near misses are being reported, the poorer safety performance can be expected on the project, fear of retaliation and the possible loss of a trusting environment according research done by the Construction Industry Institute on the same subject.

Objective

The objective of this paper is to present the products of research in the development, deployment and effectiveness of using a near miss management program on construction sites. The information has been gathered through the personal experience of the authors, formal research in the Construction Industry Institutes Research Team 301: Using Near Misses to Enhance Safety Performance and through the products of secondary research and literature review.

The intended goals of this paper are to, first, present the near miss management program through its various components: identification, reporting, root causal analysis, solution determination and dissemination of the information. Each of the topics are covered very briefly and are presented in order emphasizing only the best practices observed during the primary research with RT 301 and further discussions with subject matter experts. Secondly, we will present the quantitative effect of the implementation of near miss management program applied to a multi-billion dollar construction project and its proof of effectiveness thus encouraging the use of this methodology in the field.

Near Miss Data Collection and Analysis Framework

This high level model for a near miss management program is presented as the basic methodology for site safety managers and construction management personnel to collect, analyze and use safety data in an effective environment. This framework implements a management system for near miss data and can be a vital component in the data flow within a near miss reporting program. Stages for this framework of transitioning near miss data to information and ultimately knowledge for dissemination are presented in Figure 2 and further described below.

Figure 2. Stages for near miss data collection and analysis framework

Step 1 Identification: This 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 misses and how they differ from lagging indicators (e.g. injuries and illnesses). If the near miss is of high severity or danger is immediate, the worker should execute the stop work authority and mitigate any hazards immediately.

Hazard identification is a skill set that can be improved over time. Work done by the Construction Industry’s Institute Research Team 293 Strategies for Improving Hazard Recognition outlined a variety of tested hazard recognition techniques proving the point that this skill set can be rehearsed and improved with the right mix of education and experience. Hazards identification in the
field is essential for the development of the near miss definition and for the functioning of the program. The success of a near miss reporting program largely depends on the ability and motivation of individuals to identify and report near misses on construction sites.

**Step 2 Reporting**: The next stage within the near miss data collection and analysis framework is reporting. Construction site personnel that identifies a near miss must report the event to their immediate supervisor through a near miss reporting system. This reporting system can either use electronic or paper-based reporting depending on the construction site constraints. Both systems should allow for anonymity of employees if they so choose. Both system options must be accompanied with database capabilities to house the collected near miss data. This database should have the following capabilities:

- Store, retrieve and display raw and analyzed data
- Perform statistically analysis of incidents reported
- Navigate through incident forms, reports and other record applications
- Provide various categories of information to the user
- Enable customization capabilities
- Support commonly used programming languages (e.g. SQL)

**Step 3 Root-Cause Analysis**: Determining the factors that contributed to the near miss occurrence and the assignment of a root cause is the next step in the evaluation process. When the near misses are being reported, it is important that a consistent measure of categorization is used so that similar near misses are categorized similarly, regardless of who is taking in the report. One such categorization scheme was initially used by van der Schaaf (1992) in his doctoral thesis work; *Near Miss Reporting in the Chemical Process Industry*. His classification scheme, named after his University, became known as the Eindhoven Classification Model of System Error (ECM). Initially used exclusively in the classifications in the chemical industry, van der Schaaf applied the system in the medical field going after near misses in not only the transfusion medicine domain but also in the administration of medications with great success.

A construction specific ECM was later developed by Mckay in his thesis work entitled *Measures of Effect: Near miss reporting on Construction Site Injuries* (2013) and used in the categorization of over 3000 near misses. Table 2 presents the classification categories for this construction specific ECM. The types of categories are classified as either a skill based, rule based, or knowledge based factor (see Table 2). Definitions of each category and example events are provided.

<table>
<thead>
<tr>
<th>Table 2: Eindhoven Classification Model for Human Errors in Construction</th>
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<tbody>
<tr>
<td><strong>Factor</strong></td>
</tr>
<tr>
<td>Skill Based</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Rule Based</td>
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</tbody>
</table>
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 JSA or hazardous conditions that remain unrecognized.

Monitoring: Improper identification controls such as checks or calibration.

Compliance: Procedure which are not followed, off task, or shortcuts.

Construction: Correct design which 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 the protocols within the department (too complicated, inaccurate, absent or poorly presented).

Knowledge Based: Inability of a person to apply their existing knowledge to a new situation, for example they were unaware of a rule.

Knowledge Other: Technical failures beyond the control and responsibility of the investigating organization.

External: Failures involved with mechanical issues beyond the control of the personnel in the field.

Mechanical: Failures resulting from collective approach and its attendant modes of behavior to risks in the investigating organization.

Culture: Failures resulting from collective approach and its attendant modes of behavior to risks in the investigating organization.

Step 4 Solution Determination: Once near misses have been categorized, solutions are presented taking into account the severity and consequences of the preceding near miss events. Simple, non-complex or life threatening events are treated as an exchange of information (e.g., near misses involving ppe are offered sources of ppe retrieval, etc.). 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. A simple human error determination using the ECM, in many cases, will direct the type of remedial actions needed in the field to prevent recurrence of the unsafe condition or behaviors.

Step 5 Dissemination and Resolution: The corrective actions, ideally, will have been employed in the field following the near miss events and the work area will have been left in a safe state. In many cases, the reported near miss may not have required a “stop work” or other lifesaving measures. The incident may have happened, corrected and workers in the area will have continued their jobs. If a near miss happens, 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 miss and corrective actions taken and should be communicated as soon as possible (i.e., the next days tool box talks if possible). Safety managers will integrate learned lessons from the reported near miss into existing safety training. This step allows for the worker who reported the near miss to receive feedback on how the situation was corrected. By educating construction site personnel from other projects on lessons
learned from near misses, safety performance of workers can be enhanced. Figure 3 presents the flow of information for a single reported near miss.

![Figure 3: Flow of Near Miss Information](image)

**Case Study**

A novel near miss data collection and analysis system was implemented on a large-scale Liquefied Natural Gas (LNG) construction project located outside of the U.S. The multi-billion dollar Engineer-Procure-Construct (EPC) project had a sophisticated and mature safety program and recordable and lost time rates that were stable and low (compared to other construction projects in their NAICS) but nonetheless stagnant.

The rates of near miss reporting, first aid cases, and recordable injuries as defined by OSHA were tracked fifteen weeks before and after the implementation of the near miss data collection and analysis system. Researchers found the rates of near miss reporting increased significantly after the data collection and analysis system were implemented (Mckay, 2013). A statistically significant change between the values of first aids experienced before and after implementation was not experienced. However, the number of OSHA recordable injuries were found to be statistically significantly different after the implementation of the near miss collection and analysis system (p-value = 0.026). A correlation study using Kendall tau rank correlation coefficient (Pranab 1968) identified the connection between the number of near misses reported and the first aid cases and OSHA defined recordable injuries after the near miss data collection and analysis system was implemented (see Table 3). Values marked in italicized font denote a correlation value that is statistically significant at the 0.05 level (1-tailed test). The numbers marked in bold show a correlation value that is statistically significant at the 0.01 level (1-tailed test).

<table>
<thead>
<tr>
<th>Near Misses Reported</th>
<th>First Aid Count</th>
<th>OSHA Injury Recordable Count</th>
<th>First Aid Rate</th>
<th>OSHA Injury Recordable Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation Coefficient</td>
<td>1.000</td>
<td>-0.281</td>
<td>-0.373</td>
<td>-0.207</td>
</tr>
</tbody>
</table>
The Eindhoven Classification adopted for construction safety was used to categorize near misses reported. Types and frequencies of near misses reported after the near miss data collection and analysis system implementation are shown in Table 4. Figure 4 shows the number of incidents per category of pre-implementation and post implementation of the near miss data collection and analysis system. The number of near misses for each category fifteen weeks before and after the implementation of the system are shown.

| Slips    | 50  | 4.5 | 4.5 |
| Tripping | 24  | 2.1 | 6.6 |
| Coordination | 123 | 11.0 | 17.6 |
| Verification | 66  | 5.92 | 23.5 |
| Identification | 285 | 25.6 | 49.1 |
| Monitoring | 4   | 0.36 | 49.5 |
| Compliance | 515 | 46.2 | 95.7 |
| Construction | 11  | 1.0 | 96.7 |
| Protocol | 1   | 0.1 | 96.7 |
| Knowledge | 11  | 1.0 | 97.8 |
| External | 3   | 0.3 | 98.1 |
| Mechanical | 20  | 1.8 | 99.9 |
| Culture | 1   | 0.1 | 100.0 |
| Total | 1114 | 100.0 |
Significant differences were identified between the number of first aid reportable cases before and after the implementation of the near miss data collection and analysis system. The significance of the increase in near miss reported allowed for a favorable testing situation where it was theorized that an increase in near miss reporting would impact the rates of first aid cases and recordable injuries in an inverse relationship. Significant differences were also identified between the measures of near miss reporting with an overall increase of 966% reported once implementation of the system on the construction site. The project experienced a 100% decrease in OSHA recordable cases during the time of the near miss intervention.

The Mann-Whitney statistics (Ruxton 2006) were used to correlate collected safety data. The rates of near misses reported were found to be 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 miss data collection and analysis system was found to be less correlated with recordable first aid cases than on recordable injury cases. One possible explanation for this could be that first aid cases seem to have a more random distribution. A first aid case could include dust blown into the eye, treatment for a bug sting, a heat rash or any other conceivable event that could befall a person while at work. Recordable injuries, are events that are more action oriented and usually are the result of a larger release of energy such as a slip and fall, hitting ones 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 miss categories were identical across the pre-intervention and post intervention samples and are reported in order from highest to lowest: compliance, identification, slips, trips, and verification (Mckay, 2013). Considering this, a safety and health management program would have a target rich environment in considering where to apply limited resources considering the top five near miss types are related to human error and are active errors but this needs to be tested on other projects.

**Conclusion**

The strength of the near miss reporting data collection and analysis system lies in its ability to generate useful safety information for a given construction site. During this evaluation period, near miss information was consistently presented to the entire workforce in the form of a plan of the day meeting, toolbox talks or other similar pre-work task planning sessions. The ability to collect, analyze and disseminate safety information allows for hazardous events and conditions to be mitigated before a lagging indicator occurs.
The primary strength of this research is the correlated link between the number of near misses collected and the decreased incidents of first aid cases and recordable injuries on a construction site. The Eindhoven Classification was modified to categorize near miss 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 miss reporting on construction site injuries. Future research could include correlating near miss reporting to expected severity and risk exposure and the generation of predicted variables or outcomes.

References


