

# Measures of Effect: Near Miss Reporting on Construction Site Injuries

By

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## Abstract

A large petrochemical construction project implemented a *near miss* management program during a phase of heavy construction. The consequent 966% increase in *near misses* being reported resulted in marginal decreases in reported first aid cases, but also resulted in a significant decrease in OSHA recordable injuries. The correlation statistics between *near miss* rates and first aid cases were  $r(30) = -0.212, p = 0.05$  (exact) and between *near miss* rate and OSHA recordable injuries  $r(30) = -0.342, p < .05$ , revealing a significant but moderate inverse effect between the rate at which *near misses* are reported and OSHA recordable injuries. While construction remains one of the world's most demanding and dangerous occupations, this practicum research has identified an effective counter measure toward decreasing occupational injuries on construction sites. This report includes details about the project, the *near miss* program and reports the use of a modified version of the Eindhoven Error Classification scheme operationalized for use on construction specific error types.

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## Dedication

I dedicate this work to my parents. Each, in their own way, significantly shaped my interests and my life. My dad, Ed Mckay, a workmen's compensation lawyer in Detroit was the first to show me that prevention is not only the best medicine in occupational health, but should be the primary medicine. My mom, Darlene Mckay, showed me the benefits of an inquisitive mind and a thirst for books, experiences and knowledge. I would also like to dedicate this to my wife Margaret whose patience in this process has been a testament to goodwill and my son Aidan for the late nights and missing bedtime stories.

I would also like to dedicate this work to the legacy of Dr. Jimmie Hinze. Dr. Hinze literally wrote the book on construction safety and was a renowned speaker, professor and champion of construction workers safety around the world. He recently passed away of natural causes but was working right up till the end of his life on his own research and the work he was doing for the Construction Industry Institute. I was very fortunate to know him and honored for his direction in this practicum research project.

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## Chapter 1: Introduction

Construction remains a dangerous occupation around the world despite the best intentions of governmental laws, industrial standards, company initiatives and personal efforts. This chapter will describe the current occupational injury characteristics of the construction industry in the U.S. and from around the world. This chapter also describes the research goals, aims and objectives which include: gaining a better understanding about how *near miss* reporting is used in other industries and how the implementation of a new type of *near miss* reporting program affected the rates of occupational injuries during a construction project. The significance of this research is also discussed as *the cost of doing nothing different* in the construction industry is paid for in human injury, illness and suffering.

### 1.1 Public Health Problem in Construction Industry

Occupationally related morbidity and mortality rates remain high within the construction industry compared to other modern industrial endeavors (Bureau of Labor Statistics, 2012; Hinze, 2006). In 2010, nearly 3.1 million workplace injuries were reported by private industry employees of all categories resulting in an occupational injury incidence rate of 3.5 cases per 100 full time equivalent employees in the United States (Bureau of Labor Statistics, 2011). During the same time, the injury rate within the construction industry was higher at 4.0/100 for unskilled laborers and 4.3/100 for specialists (welders, scaffolders, etc) within the



construction trades (Bureau of Labor Statistics, 2011). In 2011, there were 721 (17.5% of total) construction related fatalities in the United States; this is second only to the transportation and warehousing sector with 733 related fatalities respectively (United States Department of Labor, 2013). The occupationally related fatality rate in the United States for the year 2011 was 3.5/100 while construction related fatalities for the same time period were 8.9/100 - approximately 2 ½ times higher than the national average (Bureau of Labor Statistics, 2011). Regarding construction work in other countries, the International Labor Organization (ILO) estimates that as many as 60,000 construction workers are killed on construction sites each year; this is approximately 164 workers a day (International Labor Organization, 2003), while an inestimable number of construction workers are injured seriously enough to never have the opportunity to return to work again because of their disabling injuries. Working on construction, or in the construction industry, is clearly a risk factor in early mortality and morbidity in the United States and around the world.

*Near miss* management systems and *near miss* reporting have been found to be an effective health and safety management tool in many industries including aviation, the railway sector, and oil & gas processing and production among many others (Williamsen, 2012). Historical peer reviewed research related to the efficacy of *near miss* programs has found examples where statistically significant decreases of lost time injury rates were realized in offshore drilling suggesting a 10-fold increase in *near miss* reporting may lead to a 60% reduction in lost time injuries (Phimister J. R., 2003). Other research has found that when onshore oil & gas

programs increase their *near miss* reporting rate to 0.5 *near miss* reports, per person, per year, a 75% reduction in lost time incidents were reported (Phimister J. R., 2003). Research coming from the electrical manufacturing sector observed that after the implementation of a *near miss* program, the annual rate of OSHA recordable incidents decreased 0.84% per annum from 1999 to 2006 in the workplace under investigation (Lander, Eisen, Stentz, Spanjer, Wendland, & Perry, 2011). Additional evidence of the effectiveness includes: using *near miss* reporting to train fire fighters (National Fire Fighter Near Miss, 2008); using *near misses* to enhance patient safety by decreasing medication errors (Myers, Dominici, & Morlock, 2008) and suggestions that modest increases in *near miss* reporting not only affects the incidence of injuries, but also increases the safety satisfaction scores in a cohort of hospital-based radiation oncology personnel (Penn Medicine, 2012). The diversity of occupational venue where these types of programs are being used gives evidence to their adaptability to local work environments and diverse industrial uses; their record gives evidence to their effectiveness.

Until recently, little has been published on the effects of *near miss* programs within the occupational sector of heavy construction, considered to be one of the most dangerous professions. This research project attempts to 'prove the concept' by identifying and measuring the effects of a *near miss* management program on the rates of occupationally related injuries on one large petrochemical construction project.

## 1.2 Research Goals, Aims, and Objectives

The purpose of this research project is to measure the effects of a project specific near *miss* management program implemented during the heavy construction phase of a large petrochemical construction project. In addition, this research will also be one of the first to use a construction specific version of the Eindhoven Classification Model of Human Error related to construction site errors. This tool, developed specifically for this research, and based on the van der Schaaf Model, facilitates the identification of the types of *near misses*, being reported as human error, being reported on the construction site.

The goals of this research were to investigate the effectiveness of a newly designed and implemented *near miss* program on a large construction project; investigate the nature and frequency of *near miss* reporting by craft; categorize the reported *near misses*; and measure the effect of increased *near miss* reporting on the rates of first aid cases and OSHA recordable incidents on the project during the time of the intervention.

This research aimed to assess the effect of *near miss* reporting on a construction project before and after implementation of a *near miss* management program. The formal research objectives were as follows:

1. Calculate the rate of *near miss*, first aid cases and recordable events, as defined by OSHA, prior to and after the intervention of a newly designed *near miss* management program on a large petrochemical construction project.

2. Quantify the relationship between reported *near misses* on the project and reported first aid cases and recordable cases, as defined by OSHA, through the use of measures of univariate and bivariate analysis.

3. Identify the types and frequencies of *near misses* being reported.

Characterize the types and frequencies of *near misses* being reported by error type using the project specific Eindhoven Classification found as Appendix B of this practicum project.

4. Compare the recordable incident rates between the intervention project (Project I) and two non-random control projects (Project C1) and (Project C2) and test for differences in medians.

### **1.3 Significance of this Research**

*Near miss* reporting has been found to be an effective environmental safety and health management tool in many unpredictable industries such as oil & gas production and nuclear energy, aviation and locomotive transportation, chemical processing and transport, and can be found throughout U.S. governmental organization such as the U.S. Navy and the Department of Energy. The apparent success in these industries has led to the adoption of near miss program in other highly specific areas such as fire fighting and health care with similar success stories. The use of *near miss* programs in construction, however, remains sparingly reviewed as there have been very few investigations into the nature of *near misses* within construction, their different types and the relative frequencies of those *near misses* found within the industry (Cambraia, Saurin, & Formoso, 2010).

This research intended to be one of the first to test the effectiveness of a *near miss* management program within a large petrochemical construction project with the goal of using *near miss* reporting to decrease occupational injury on the project.. This research will be one of the first to identify and report the types of human errors associated with the reported *near misses* using a construction specific modified version of the Eindhoven Classification. This type of classification system has been used previously in the dissertation of Tjerk Woutherus van der Schaaf in *Near Miss Reporting in the Chemical Process Industry*(1992), where it was proposed for use and tested within certain elements of the Dutch chemical processing industry. To this author's knowledge, similar applications of the Eindhoven Classification have not been published related to heavy construction work in the field, until now.

This research intends to contribute to the developing body of knowledge of how *near miss* management programs can be used to decrease the rates of occupational injury in the construction industry. This research measured the effect of a *near miss* management program and identified the types of *near misses* being reported. The intent of the research was to prove the efficacy of a newly designed and implemented program for the simple reason of proving what can be done with a managed *near miss* program in construction. It was also intended that this research be a source of further reference on the topic including the Construction Industry's Institute (CII) Research Topic 301: *Using Near Misses to Enhance Safety Performance*. This two year research project was initiated in 2012, and its goals included the identification of *near miss* management systems currently in use within the construction industry, the development of a set of best practices used

throughout the industry related to *near miss* management, the identification of barriers for implementation of *near miss* management programs and the development of a new source of information related to *near misses* in the construction industry.

## Chapter 2: Background & Literature Review

This chapter highlights significant details about the state of the art when it comes to *near miss* reporting from other distinct industries outside of construction. It will be stated that construction is a relatively late adopter of *near miss* reporting, at least according to the literature review conducted for this project. The chapter starts with the problem of defining a *near miss* which is a non-obvious problem in safety and health as it first implies a common knowledge of occupational hazards; something that does not exist across company, cultural or community lines. The background, or the way that *near miss* reporting is used in other industries, is discussed as well as the theoretical basis behind why the industry believes that reporting *near misses* is a good thing after all. The theoretical construct of this program is discussed along with the implications and gap analysis. The construction project, and a detailed presentation of the *near miss* program, is described in the last sub-section.

### 2.1 Definitions

There are many definitions of the *near miss* each dependent on the perceptions of the observer, their tolerance for risk, their experiences and even the way that individual companies may look at *near misses*. The *near miss* event can be described by some as any type of unsafe condition or behavior regardless of its “exposure” to surrounding personnel. Others may see a *near miss* as any combination of unsafe act or behavior connected to some kind of action (actual slip,

dropped tool or release of energy). The point is that there is no standardized definition of a *near miss* found within industry or across industrial sectors. What is found are defining characteristics of a near miss specific to an industrial sector such as those found in firefighting which will be considerably different than near misses related to chemical processing, in theory. In essence, a *near miss* is an event that didn't happen but had the possibility to cause harm. The defining characteristics of the *near miss* will depend on the experiences of the observer and a large part on the industrial sector or working atmosphere of the individual observing the event.

Many authors have struggled to define the *near miss* event across company, industry or even cultural boundaries and the terms *near miss*, close calls, near hits and others are used interchangeably throughout the literature (Williamsen, 2012). Even less agreement on the definition of a *near miss* is found within the construction industry, or any other industry for that matter as the term may take on a negative connotation in some companies, while in others, it is an indicator of a functioning safety management system. The term "*near miss*" is loaded with meaning beyond what can be described here as it takes on both emic and etic values depending on the observer, the company and the author. A select few of these definitions, found in the literature review, are presented below for reference:

- A *near miss* has the potential to, but do not result in harm (Phimister J. R., 2003),
- Incidents in which no injury actually occurred but the potential for an injury existed (Hinze & Godfrey, 2003),



- A *near miss* is an instantaneous event which resulted in the sudden release of energy and had the potential to generate an accident (Cambraia, Saurin, & Formoso, 2010),
- An event that signals system weaknesses that if not remedied, could lead to significant consequences in the future (Phimister J. R., 2000),
- Events that leave no injuries or property damage or evidence that they occurred (Williamsen, 2012),
- An incident or unsafe condition with potential for injury or property damage (Ritwik, 2002),
- An occurrence with potentially important safety related effects which was prevented from developing into actual consequences (van der Schaaf, 1992)
- Any situation that could have resulted in undesirable consequences but did not; ranging from minor breaches in controls to incidents where all the available safeguards were there, but subsequently defeated (U.S. Department of Energy, 2009).

For the purposes of this practicum project, this researcher chose to use the following as the working definition of a *near miss*: a near miss is any combination of unsafe actions or conditions presenting themselves at the site of work that exposes personnel to risk or harm, however remote. This inclusive definition is designed to accept all issues of perceived hazardous conditions, however small, in order to gather information about the conditions on the worksite other than those reports

generated by management personnel or even safety and health professionals on the construction site.

The Occupational Safety and Health Administration (OSHA) defines on the job injuries in three ways; the first aid case, the “OSHA recordable” and a lost time case. The first aid case is an injury of superficial nature treated by first aid only consisting of any combination of: over the counter medications, cleaning, flushing, or soaking a wound, using hot or cold therapy, using temporary immobilization devices while transporting a victim, draining fluid from a blister, removing foreign bodies from the eyes using only irrigation or cotton wisps, use of finger guards, use of massage therapy, and drinking fluids for rehydration therapy. By definition, any treatment going beyond the above mentioned treatments may be classified as an “OSHA” recordable injury.

An OSHA recordable injury is an occupational injury whose treatment goes beyond the first aid case (Asfahl, 2004). This treatment is usually done under the direction of a licensed health care provider and may include over the counter medications given at a prescription dose, any sutures or semi-permanent wound closing devices, the issuance of any type of prescription medication unless it is given for diagnostic purposes or wound prophylaxis (e.g., tetanus), any type of fracture without the resultant immobilization device, or a chipped tooth. An OSHA recordable case is, by definition, required to be reported on the OSHA 300 Log. This company- specific log is maintained by employers who are required to identify and list all recordable events. This log is discoverable by OSHA and must be posted at the site of work for reference by working personnel.

A lost time or days away from work case are those injuries that result in the incapability of the worker to return to assigned duties on their next scheduled shift (Asfahl, 2004). The nature of these injuries is usually the result of significant trauma where extensive recuperative time is needed in order to return to work. Lost time cases were not included in this investigation. They are relatively rare events within mature construction companies and as such, were not experienced during the time of the *near miss* management program intervention.

## **2.2 Background**

*Near miss* reporting has been recognized as a best practice in many high tech industries such as aviation, aircraft carrier operations, nuclear submarine operations, air traffic control, nuclear power operations, oil and gas production and the chemical processing industries (van der Schaaf, 1992;Oktem, 2002;Barach & Small, 2000). These industries, while enjoying a relatively low frequency of catastrophic events (Reason, Human error, 1990), are called High Reliability Organizations (HROs) by the US Department of Energy (2009). Common characteristics of these organizations include operations that may occur under stressful conditions, experiencing a low frequency of catastrophic events in their industry, having a high potential impact to their operations, environment or human health under catastrophic events, and a low tolerance for mistakes or error (U.S. Department of Energy, 2009). These industries are also highly self regulated and are closely monitored by legislative regulations and committees such as the Federal Aviation Administration, OSHA, Nuclear Regulatory Agency, and the National

Transportation Safety Board depending on their industry. These industries have strong internal controls and an emphasis on regulations and governmental oversight that makes the occurrence of catastrophes an improbable and infrequent event, as designed. Therefore, in many cases, *near miss* management programs, in these industries, were designed to capture human errors as they occurred in the field as real events (injuries) became uncommon under such rigid working conditions. In other words, for lack of any substantial catastrophic events, *near misses* and errors were now being investigated thoroughly in order to gain an understanding of what mistakes are being made at work which did not lead to injury.

While these industries have implemented various elements of *near miss* management programs for years now, the construction industry has been slower to adopt *near miss* reporting (Cambraia, Saurin, & Formoso, 2010). Hinze (2002) reported that on average, only 22 total *near misses* were reported during the entire duration of large construction projects under an investigation he conducted into construction related safety research. This research considered measurable conditions such as type of contract, management systems, venue and the implementation of various health and safety management strategies including the implementation of a *near miss* management programs. He found that companies who had implemented *near miss* management programs experienced lower rates of occupationally related injuries (Hinze J., 2006) while concurrent research in the offshore oil fields found that a 10-fold increase in near miss reporting resulted in a 60% decrease in injuries serious enough to require time away from work; in other

reports, a 75% reduction in lost time injuries was realized when personnel reported *near misses* at a rate of only 0.5 near misses per person, per year (Phimister J. R., 2003).

It is generally accepted that for every serious incident, a large number of smaller more frequent “*near misses*”, “near hits”, or “close calls” were experienced under the same conditions that would later result in tragedy (van der Schaaf, 1992) and were found to have common causes (Gnoni, 2012). If it were not for the resilience of a few key personnel, heroic actions, defenses in place, management barriers or a certain degree of luck, these incidents could have had led to far different, more severe consequences. The basic function of a near miss program is then to learn from these numerous but unsubstantial events before occur relying on the “free lesson” before defenses are defeated and an incident is realized.

For example, investigators discovered that numerous warnings were ignored by NASA Administration just prior to space shuttle Challenger disaster where “O” rings failed in the solid rocket boosters (Phimister J. R., 2003); leaking pipes and maintenance requests were ignored leading to the toxic chemical release in Bhopal (Kletz, 2009) and runaway reactor reactions in Chernobyl and Three Mile Island were the result of human errors and confusing data inputs/outputs built into the system where near misses were reported, but never acted on (Reason, Human error, 1990). Many lessons were learned as a result of these catastrophes including the realization that following up on a few accident pre-cursors or *near misses* on the front end of these incidents may have prevented the occurrence of the incident in the first place (Reason, Managing the risks of organizational accidents, 1997). For

this reason, these highly reliable organizations have taken the position that *near misses* and non-catastrophic events need to be taken seriously, analyzed, and acted upon before they become true events in the future. Because of this realization, the reporting of *near misses* in low incident/ high severity industries such as aviation, nuclear, chemical processing, oil & gas, and the military has become quite common (Cambraia, Saurin, & Formoso, 2010) and useful for the development of information related to the functionality and effectiveness of Environmental Safety and Health (ES&H) programs. It is these non-serious incidents that were of interest in this research.

Non-serious *near misses* or human errors occur quite frequently on construction sites but may remain only a localized source of inspiration, usually known only to the person committing the error or experiencing the *near miss*. These incidents, historically in this researcher's experience, are rarely reported beyond the confines of the local work area, which is basically only a "lesson" to those immediately involved in the event itself. The intention of the *near miss* management program was to facilitate the identification and reporting of these incidents so that all personnel, not just those immediately involved in the incident, have the opportunity to share in the experience and learn something about the job site through communication and vicarious experience leading to increased awareness about conditions on the construction site.

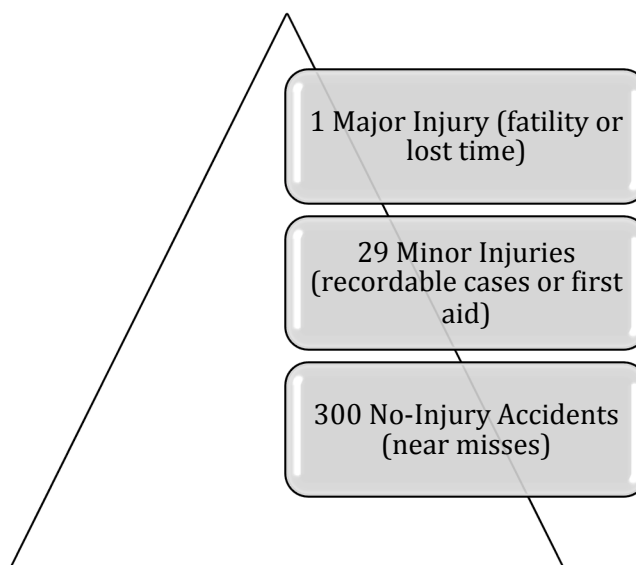
### 2.3 Theory and Models

Arguably, one of the earliest and most influential contributors in the field of occupational safety theory was H. W. Heinrich and his work in the text *Industrial Accident Prevention: A Scientific Approach* (1931). Heinrich was working as an Assistant Superintendent at the Travelers Insurance Company when he started the analysis of occupationally related insurance claims. He found that for every accident that causes a major injury, there are 29 incidents of lesser severity and approximately 300 “accidents” that cause no injuries whatsoever. This finding would become known as Heinrich’s Law which he refined further into Heinrich’s Domino Theory.

The Heinrich Domino Theory suggests that there are five sequential factors, barriers, or protective measures that need to be overcome leading to incidents (Toft, Dell, Klockner, & Hutton, 2012) with the assumption that if one domino falls, the rest will follow linking a series of events, errors or mistakes to their final outcome, an injury-causing accident. Heinrich identified (named) five causal links in his chain of dominoes which included the (1) social environment, (2) fault of the person, (3) unsafe acts, conditions, mechanical or physical hazards, (4) accident itself, (5) the final injury (Heinrich, 1931). In this model, each domino represents one of the causal links, and if one domino falls, all the distal dominoes fall in successive order resulting, ultimately, in an accident. Conversely, removing or strengthening the resilience of one of the dominoes through management action breaks the causal chain and subsequently stops the occurrence of the pending incident. Based on this

theory, since accidents are the result of failures of management actions in a series of events, finding out where errors occur, or *near misses* happen in the chain of events, will help the practitioner identify areas where effort is needed, barriers need to be reinforced or other interventions need to be strengthened in order to prevent incidents.

The Heinrich Triangle, or accident pyramid, is one of the most pervasive graphics found in occupational injury theory. Although the exact breakdown of how many of each type of event occurs in each band differs between theorists, it is generally accepted that there are more *near misses* at the base of the pyramid, reported or not, than there are first aid cases, recordable injuries or more serious events that form the top of the pyramid. Heinrich's triangle is reproduced below;



**Figure 1 Heinrich's Triangle (reproduced)**

Building upon Heinrich's earlier work, Bird and Germain (1996) analyzed over 1.7 million accidents reported by 297 companies representing 21 different industrial groups in order to test the earlier claims of Heinrich. Over three billion



work hours were represented in this research with the following findings: for every one major injury (e.g., fatality, disability), there were 9.8 reported injuries of less severity usually requiring nothing more than first aid (Bird & Germain, 1996). Further analysis, and in depth interview of respondents, expanded inclusion criteria to include accidents that resulted in property damage in the model. With the inclusion of property damage, this ratio found that for every one serious incident, thirty incidents or lesser severity were reported and over six hundred *near misses* were calculated to have happened in their findings. These revelations led to the Bird Safety Pyramid, much like Heinrich's but with different ratios, which led to the development of Bird's Loss Causation Model / Theory (Dyck, 2011). Now, with the inclusion of property damage incidents, a more detailed analysis of incident precursors started to emerge.

The Domino Theory and the Loss Causation Models are known as linear causation models by safety theorists (Toft, Dell, Klockner, & Hutton, 2012). Models of this type suggest that accidents are the results of a sequence or chain of events with the end result being that of an unplanned incident possibly leading to an occupational injury. Incidents, in these models, are prevented through the application of engineering controls to lessen the severity of the exposure to the human by taking away the hazard or by the introduction of engineering controls into the system that mitigate the hazard; use of management procedures designed to facilitate a safe working environment through policies, procedures and training; and the consistent use of barriers, guards and personal protective equipment as the last line of defense.

Critics of the linear models react to the simplicity of the model itself suggesting, rightly so, that incidents are not merely the result of a sequence of events in a never changing cycle, but are complex events stemming from interrelated management decisions, equipment failures, training, and human conditions (Decker, 2006). In addition, it has been theorized that although these models lend themselves well to non-complex system where causes naturally lead to effects, in today's highly complex systems, their explanatory power in incident investigations is lacking (Qureshi, 2007). Additionally, it is thought by some that too much emphasis is given through these models to the human side of error whereas contemporary safety related causal models emphasize the role of the system in which people work or otherwise hidden latent management errors (Reason, Managing the risks of organizational accidents, 1997). After all, there are forces at work that are beyond the control of the construction worker in the field such as the types of working conditions, expectations, condition of the tools and the acts and actions of project management that influence the ultimate outcome of occupational injury statistics on the worksite (Cullen, 2000). Finally, questions have been raised about the authenticity of the data coming from Heinrich's original study as a data set has never been reproduced (Manuele, 2011) and, in admission, much of the data was taken from the files of insurance claims submitted by plant owners in the 1920's who probably had incentive to "blame the victim". While questions remain as to the exact ratios of *near miss* events to those of a more serious nature endure, the basis of these claims remains one of the most influential constructs in all of the field of safety and health management (Manuele, 2011). Despite the

theoretical shortcomings of the linear models, these theories remain popular in the safety and health management literature, as well as in practice and are still being vigorously defended (Pardy, 2013).

Practical applications of this model are found within the hierarchy of controls, a system that prioritizes the mitigating actions available to management personnel when hazards have been identified in the workplace (Dyck, 2011). The controls, in order of the most effective to the least effective, include eliminating hazards from the system, substituting hazardous materials or processes from the system with the use of less hazardous materials, isolating the hazards so there is no human contact, redesigning the task through engineering, using administrative controls such as training and procedures and lastly, the use of personal protective equipment at the point of work. While there were similarities in the use of the hierarchy of controls with Heinrich's "dominoes", it was imagined that a break in any of this hierarchy would expose workers to hazardous conditions through lapses in hazard identification or control. Subsequent accident causation models built upon the concepts of the linear models while acknowledging the complexity of the dynamic forces that take place in the work scape.

Models based on the epidemiological triad of host, environment and agent emerged and matured within the accident causation research. One such model popularized by James Reason is called the "Swiss Cheese" Model of Accident Causation (Reason, *Managing the risks of organizational accidents*, 1997). Using the natural history of disease metaphor, Reason reinforced and added to the linear causation models the idea of the "resident pathogen" effect (Toft, Dell, Klockner, &

Hutton, 2012) of which there are two types, active and latent errors. Active errors are those unsafe acts committed by people who have direct contact with the work or the system under question (Weststat, 2001). Latent errors lie dormant in the system until such a time as defenses are defeated, barriers removed or chance occurrences allow for activation in the system or are the remnants of decisions made by management or the designers of the system in question (Reason, Human error, 1990). These latent errors could be the result of decisions made within organization where decisions about materials, location, expense and design are made. Latent errors may be hidden within the system until a time that their presence is realized through a culmination of events often leading to an incident; these latent errors are often found to be the root causes of many complex and catastrophic events (Vincoli, 1994) and may have unintended consequences impacting safety goals in the future (Weststat, 2001).

Active errors are those committed by a human usually at the point of the work and may involve anything from muscular-skeletal slips to lapses in judgment or memory (Reason, Human error, 1990). An excellent source for identifying human error types is presented by Rasmussen and his skills, rules, knowledge (SRK) Model of Human Error (van der Schaaf & Habraken, 2005) where three initial types of errors are defined; skills-based errors, rules-based errors and knowledge-based errors.

Skills (S) based errors are those directly related to the physical actions of the human and can include errors of body movement, mechanics, loss of grip, loss of balance or other sudden whole body movements. They are the errors that occur

when one is on “auto pilot” doing activities with very little conscious thought or attention to details. Using tools, swinging a hammer, using a saw, or climbing ladders are functions that would come under automatic control and requires very little conscious effort to perform after initially learning the behaviors (Rasmussen, 1983). There are two types of skill based error types identified by Rasmussen and further refined by Reason called slips and trips (Reason, Human error, 1990);

- Slips are failures in highly developed motor skills where lapses in attention result in mistaken body movements such as controlling the path of a hammer and hitting one’s thumb;
- Trips are failures in whole body movements such as the movement of the legs and placement of feet upon the ground when one “slips” but catches themselves before falling.

Rules (R) based errors are those related to the accidental or intentional breaking of the rules, regulations or policies in the management system (Reason, Human error, 1990). Rule breaking behaviors can be deliberate or unintentional, depending on the circumstances and whether personnel were aware of the rules. Many rules that govern the behavior of personnel, related to safety, on a construction site have been developed by the National Institute of Occupational Safety and Health (NIOSH) through research and are enforced by the Occupational Safety & Health Administration (OSHA). These are the minimum regulations by which companies are supposed to work and cover activities such as the safe use of electricity, access to ladders and fall protection, confined space work, welding and just about any other activity found within activities on a construction site.

The specific regulations related to construction are found in the 29 Code of Federal Regulations (CFR) part 1926; Safety and Health Regulations for Construction and are the basis for occupational health requirements when working in the United States (United States Department of Labor, 2013). These regulations set the minimum standards about the safety and health programs required on a construction site and each construction contractor is required to have a safety and health management program and site specific planning that meets these standards at each of their respective construction sites. These site-specific plans outline the educational, personnel, and management requirements for each site and form the basis of the rules for expected construction site related behaviors.

There are six identified rule based error types in the construction specific Eindhoven Classification developed by this researcher;

- Qualification errors are those found to be with the wrong combination of a person's experience and the task at hand;
- Coordination errors are those that occur when two competing work crews impede access or control of an area without consideration of the other work crew's activities;
- Verification errors are those committed when there is an incomplete assessment of conditions on the worksite such as using equipment that has not been inspected;
- Identification errors are those related to not properly identifying hazards;

- Monitoring errors are those where personnel are inappropriately monitoring a situation;
- Procedure not followed errors are those that occur when personnel deviate from desired course of actions or behaviors other than those directed by the company.

Knowledge (K) based errors are those related to the function or the application, retention or use of knowledge or what the person knew at the time of the commission of the error (Reason, Human error, 1990). Personnel committing a knowledge based error are either applying what they have learned previously inappropriately to the current problem; they are not identifying the problem appropriately or don't know the proper solution or the option of solutions available to solve the problem in the field or at the desk (Rasmussen, 1983).

Latent errors are divided into two groups; technical and organizational. Technical errors are those related to machinery, parts or mechanized systems and the errors may not be evident until an incident occurs. These error types are usually beyond the span of control of the usual construction worker at the point of work or construction. There are three identified technical error types identified in this model;

- External – these types of errors are beyond the control of the construction workers on the site where material is delivered on the site broken or inoperable and cannot be installed.
- Construction - these errors occur when items are installed incorrectly or tolerances have not been identified and controlled. Examples of these

types of errors would be, for example, when not enough torque is applied to a pump and the vibration applies premature wear to the machine.

- Mechanical – errors that occur when machines or parts wear out or break such as a broken hydraulic line or metal fatigue due to use.

Organizational errors are those related to a company's operating procedures and internal culture. Organizational errors are often the target of root cause analysis investigations where the focus is to find the underlying reason behind an incident that goes beyond those directly at the point of work (Vincoli, 1994). There are two types of organization errors in this model:

- Transfer of knowledge errors are those where incomplete instructions or training were involved in inadequate preparedness of the construction crew
- Standard operating procedure (SOP) errors are those where the SOPs were either too ambiguous for use or were confusing in the field.

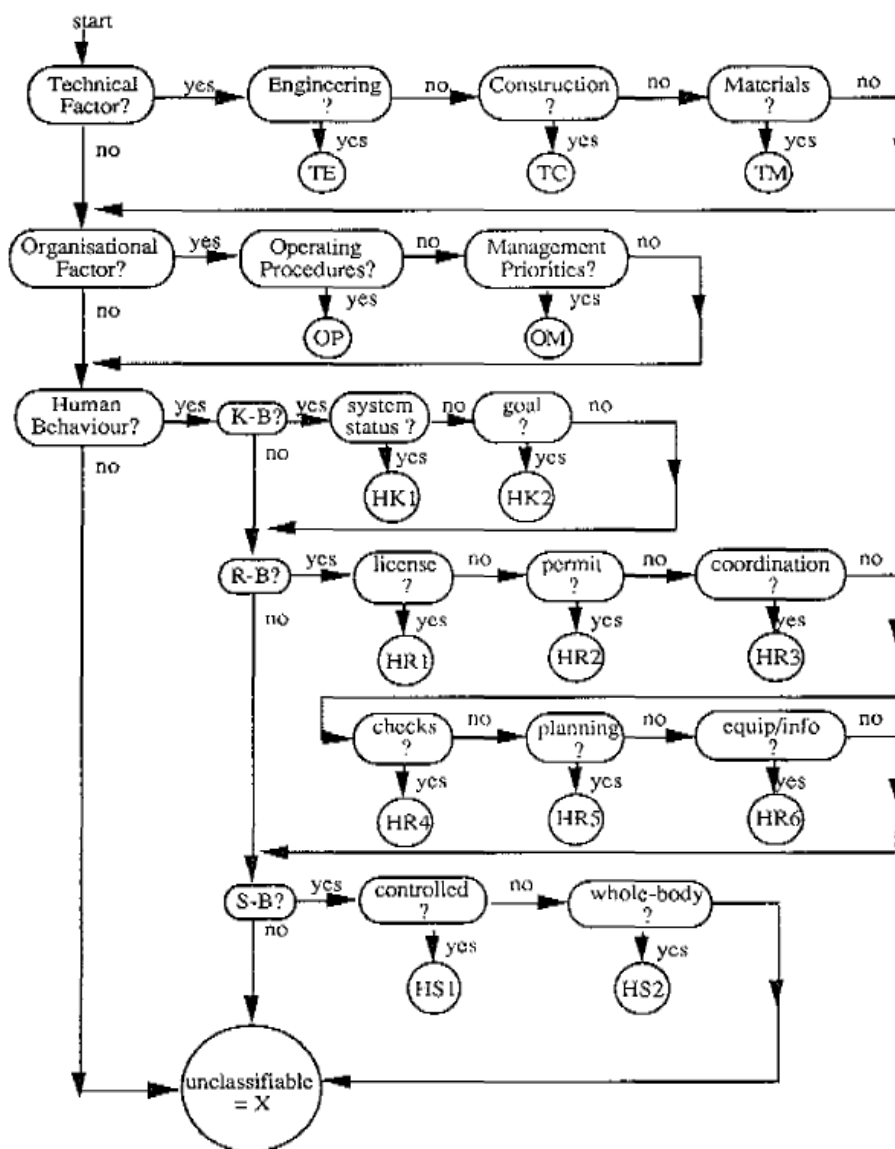
These types of errors were first codified by Rasmussen and Jenson doing research on human error in the systems analysis community (Rasmussen, 1983). They were initially working on a verbal protocol in electronic troubleshooting in 1974 and used these three error types in their work designing systems (Reason, Human error, 1990). Their work in this field led to the development of what was later called the SRK Model whereas Reason (1990), using this model, further estimated the relative frequency of human error types at approximately 61% skills based, 28% rule based, and 11% are knowledge based according to secondary



calculations by Garcia-Chico (Garcia-Chico, 2006). The identification and understanding of these error type frequencies across industrial groups, and specifically construction, are an important component of this research project.

## The Eindhoven Classification

Rasmussen's SRK Model contributed to the development of the Eindhoven Classification Model of System Failure and was used in the van der Schaaf thesis *Near Miss Reporting in the Chemical Process Industry* (van der Schaaf, 1992). This initial error classification is reproduced in Figure 2.



**Figure 2 Eindhoven Classification Scheme, Reproduced in whole (van der Schaaf, 1992)**

Based on Rasmussen's influential paper, *Skills, Rules, Knowledge; Signals, Signs, and Symbols, and other Distinctions in Human Performance Models (1983)*, Reason operationalized the SRK model in the development of his Generic Error Modeling System (GEMS) (Reason, Human error, 1990). This initial classification (GEMS) identifies 15 distinct error types categorized by active error types consisting of the skills, rules, and knowledge based categories and the set of latent error types which include technical and organizational factors. These error types have been codified and used by *van der Schaff* not only in his research into near miss reporting and the chemical processing industry (van der Schaaf, 1992) but again in the development of the Prevention and Recovery Information System for Monitoring and Analysis (PRISMA) (van der schAAF & Habraken, 2005) designed to investigate medical errors related to transfusion medicine.

This research has modified the initial Eindhoven Classification making it specific to construction and construction type errors. This revised classification scheme was operationalized during this project and is included as appending A.

## **2.4 Theoretical Orientation for this Research**

The theoretical orientation for this research depends on the theory first developed by Heinrich, his accident triangle and his Domino Theory of accident causation. Despite the simplicity of his initial models it has to be believed that there are more *near misses* than there are OSHA recordable injuries than there are more serious events. This has been proven by Bird and Germaine as well as experienced by this researcher through his own career.

However, because Heinrich's linear model loses explanatory power in today's highly complex occupational infrastructure (Toft, Dell, Klockner, & Hutton, 2012), Reason's epidemiological approach has been incorporated. In addition, Rasmussen's work on the skills, rules, knowledge based error types (Rasmussen, 1983) contributed to the construction of Reason's Generic Error Modeling System (GEMS) which forms the foundation of this project's error identification component.

While acknowledging the previous work in the field of Heinrich and Bird, and also the contribution of Rasmussen, Reason and van der Schaff, this research relies heavily on the principles of Reason's "Swiss Cheese Model" as this is found to be a strong model with an impressive set of tools to work with in the development of a *near miss* management program and further safety related construction management.

Conceptually, Reason's Model is similar to the Heinrich's Domino concept whereas, previously, each domino represented one of the five factors the (1) social environment, (2) fault of the person, (3) unsafe acts, conditions, mechanical or physical hazards, (4) accident itself, and (5) the final injury (Heinrich, 1931); Reason's model using the concept of Swiss Cheese slices represents protective barriers in the system but allows an avenue for "accident trajectory" emphasizing that barriers are in a constant flux in complex systems. Reason's building upon the concepts of Heinrich, the inclusion of active and latent errors in his model and the inclusion of the epidemiological triad makes the Swiss Cheese Model an excellent framework used in both the development of the near miss program and the lens under which it is being judged.

## 2.5 Research Gaps & Significance of this Research

An Ebsco-Host query using eleven databases including Academic Search Premiere, CINAHL, Pubmed, Medline and Eric along with six others resulted in 2,961 results from the term *near miss*. Refinements in the Boolean parameters to include the terms *near miss* and *safety* resulted in 938 results; the terms *near miss* and *patient* resulted in 709 results; the terms *near miss* and *management* resulted in 696 results; the terms *near miss* and *industry* 310 results; and finally the terms *near miss* and *construction* identified forty-two results. Of those 42 *near miss* and *construction* results, thirteen inspired the direction of this research project whereas *near miss* management systems in the construction industry appear to be a relatively new practice (Cambraia, Saurin, & Formoso, 2010). And there is a lack of research about the effect that *near miss* management programs have on the rates of OSHA recordable events (Lander, Eisen, Stentz, Spanjer, Wendlend, & Perry, 2011), let alone those that occur in the construction industry. This research project attempted to validate and quantify the effects of *near miss* management programs on the rates of occupationally related injuries during the heavy construction phase of a petrochemical facility.

The public health implications of this research are far reaching as mentioned previously; the construction industry in the United States has an occupational fatality rate that is 2 ½ times the national average (United States Department of Labor, 2013). The International Labor Organization estimates that there are, on average, 164 construction workers killed on the job every day around the world (International Labor Organization, 2003). The social and economic cost of this

epidemic of injury alone is compelling evidence that more needs to be done in providing safer work environments on construction sites. It is time to try these best practices in a venue where heavily mechanized activities meets labor intense human activities in the field, on the construction site.

## **2.6 The Construction Project and Near Miss Management Program**

The construction project undergoing the *near miss* intervention consists of the engineering, procurement and construction of a large petrochemical Liquid Natural Gas (LNG) Plant. This LNG plant will capture residual LNG from offshore oil drilling and production rigs off the coast, liquefy it and process associated petrochemicals. The LNG will supply the energy needed to power one of the region's first gas turbine electric power plants designed to meet the needs of the local population. The remainder of the LNG will be condensed and sold on the world market monetizing a resource that would have otherwise been wasted in offshore flaring activities.

The construction phase of the project began in the first quarter of 2008 beginning with the civil construction activities of rough grading, soil stabilization, and setting piles. The development of the life support services began almost immediately as space became available and included the building of the accommodation units designed to accommodate approximately 6500 resident workers, the infrastructure needed to support them such as water treatment facilities and a kitchen capable of producing approximately 21,000 meals per day at peak manpower. The projected cost of the project was estimated to be around 8

billion dollars with a total estimated man-hour expenditure of 42 million man-hours over four years.

The peak of construction activities occurred during the last quarter of 2010 with approximately 7500 workers approximating 450,000 man-hours per week consisting of construction, catering and contractor personnel. During the intervention time frame (n=30 weeks), there were approximately 6100 workers working approximately 365,000 man-hours per week. Of those, approximately 3000 personnel were under the direction of the company providing the *near miss* intervention otherwise known as the prime contractor. The remaining personnel were associated with other sub-contractors or catering and not necessarily under the direction or control of the primary contractor. Therefore, while the *near miss* intervention was known project wide, the hours, injury rates, and *near misses* submitted by the subcontractors were not included in this research project for reasons related to access to the data and the possibility of dissimilar construction activities (catering, housekeeping) or safety and health related management procedures (different companies).

It is also important to note that *near miss* reporting within the intervention project existed prior to the development of the new *near miss* management program. However, in its former practice, *near misses*, while being encouraged, were never emphasized to the extent that this novel *near miss* management program did so. In addition, in the intervention program, the definition of what is included in a *near miss* report was changed; the methods for collection were

enhanced; the *near misses*, once collected, were analyzed differently; and the dissemination of the *near miss* reports were significantly increased.

The *near miss* management program was designed to incorporate the identified elements of *near miss* programs identified by Tjerk van der Schaaf in his doctoral dissertation (1992) on *Near Miss Reporting in the Chemical Process Industry*. The *near miss* intervention was based on these elements and operationalized for use on this project and include; the definition of what is a *near miss*, the rollout of the program, the collection of *near misses*, the analysis of the types and frequencies of *near misses* being reported and the positive reinforcement mechanisms for feedback and sustainability of the *near miss* program. The essential elements are further defined in the following paragraphs.

### **Definition**

Upon implementation of the *near miss* management program, the defining characteristics of the *near miss* were discussed and a new definition was proposed. Instead of relying on the determination of whether something was an unsafe condition, unsafe behavior or a combination of both, it was decided that the new definition would incorporate the concept of an outcome as a lesson learned or “free lesson”. In other words, if something could be learned from the event, or the reporting of the event, then it was called a *near miss* and reported as such and included in the *near miss* management program.

There were 28 “*near miss* types” in use or defined and each of the *near misses* being reported were subsequently codified under one of these categories. A brief explanation of each type follows below:



**Table 1, Types of Near Misses**

Near Miss Type	Description
Aerial lift or Manbasket use	The inappropriate use of mechanical platforms such as improper set up or use
Barricades	The crossing of barricades without permission or need. The removal or accidental destruction of barricades.
Body positioning	The improper lifting techniques, pinch points or awkward positions required for work
Electrical	The improper grounding, wiring or faults in an electrical system
Environmental	Destroyed habitat, spills, drips, and water way disturbance
Excavation	Improper excavation slopes, techniques, permits or procedures
Fall Protection & Prevention	Improper fall protection procedures or requirements. Lack of inspected PPE
Falling / Flying Objects	Dropped objects and flying particles from welding slag or grinding
Fire Protection	Improper identification and storage of combustible materials. Missing fire extinguishers
Handling Materials	Improper storage of bulk materials exposing personnel to tip overs.
Heavy Equipment	The operation of heavy machinery and its impact on personnel in the area
Hoisting	Lifting materials over the heads of personnel in the work area
Improper PPE	Lack of PPE or missing PPE. Could include incorrect choice of PPE
Ladders	Misuse of ladders including inspection, set up and use.
Lock out Tag out	Misuse of energy isolation devices including procedural paperwork
Material Loading	The movement of materials on front loaders and skids
Material Storage	The inappropriate positioning and movement of materials in storage. Too much, too heavy or tipping moments expose personnel to unsafe conditions
Off Task	Personnel on tasks not assigned by the company
Operational Maintenance	Maintenance on equipment due to wear and tear
Pinch Point	Personnel coming in between equipment and the super structure
Rigging & Lifting	The misuse of rigging equipment designed to lift material by crane. Could include procedural issues such as paperwork and inspection tags.
Scaffold	The misuse of scaffolding or its components. Could include personnel using untagged uninspected scaffold members.
Tools (Hand powered)	The use of hand tools such as hammers and powered tools such as grinders
Tools (Malfunction)	Malfunction due to wear and tear
Tools (Selection)	Inappropriate use of a tool for a required task
Trips & Slips	Full body movements or tipping moments under pace
Vehicle operations	The improper use of a personal vehicle such as speeding or parking
Welding & Hot work	Improper set up of welding and hot work areas including fire blankets and equipment inspection.

## Roll Out

The program was announced at the foreman / general foreman luncheon held in March of 2011. These weekly lunch meetings, held on Saturdays, are dedicated to the topic of safety, quality, schedule and other concerns of the construction project. Topics usually consisted of information from the site, the changing scope of work and path of construction on the site, any future activities and significant events affecting the construction project or construction camp. The information is then disseminated to the rest of the workforce through the approximately 80 attendees in the form of interpersonal meetings held back at the construction site.

The *near miss* initiative was kicked off in this meeting as buy in from the middle managers and foreman from the field was essential in the success and motivation in keeping the initiative alive. The goal of the *near miss* program was to stop the next first aid case, as explained to the attendees, and the basic construct of the program was explained. The new *near miss* reporting forms, the collection points, and the collection methods were explained and identified.

Barriers to the successful execution of near miss management programs were identified through the work of Phimister et al. (2003), in their work on *Near Miss Management Systems in the Chemical Process Industry*. These barriers included the potential for recrimination, motivation on the part of the *near miss* reporters, management commitment and confusion (Phimister J. R., 2003). These issues were addressed during the kick off of the program as well as throughout the intervention period. The potential for recrimination was addressed by the no name/no blame

policy whereas the reporter either had the choice of anonymity when making a report or they had our guarantee that they would not face any negative consequences, regardless of what was being reported unless the item that was being reported was of intentional nature. Motivational issues were addressed by challenging all personnel to turn in at least three to five near misses, per person, per year while employed on this project. It was agreed that since personnel in the field are in direct contact with the workplace hazards, their participation was essential for the success of the program (Cambraia, Saurin, & Formoso, 2010) and that reporting between 3-5 near misses, per person, per year is reasonable and achievable. The issue of construction management commitment and motivation in sustaining the program was never an issue on this project. Resources and time needed for the implementation of this program were both easily attained as well as the assistance in the design, building and placing of the new *near miss* collection boxes. In order to lessen any potential confusion as this program was being implemented, this researcher first gained “buy in” from the foremen and general foreman who then communicated the components of the program to personnel in under their authority.

### **Collection**

The *near misses*, if written in the field, were collected in “*near miss*” drop boxes placed in convenient locations around the site. The *near miss* collection forms were available in different and pertinent languages (Portuguese, Tagalog, English, Hindi) and the reporter could choose the language in which they were fluent. The *near miss* forms included entry points for date, time, location of the

event, types of craft reporting, types of craft involved, types of near misses and what was done to correct the situation in the field (see Figure 2). Once collected, the near misses were brought into the safety management facility where they were evaluated.

<b>Near Miss Reporting</b> <small>Fill out the form in your own words.</small> <small>The near miss you report today, may save somebody tomorrow!</small>		
Discovery Date: Time: _____	Report Date: _____	General Foreman Name: _____ Your Name (Optional): _____
<b>Discoverers Job Description:</b> <input type="checkbox"/> Field Non Manual <input type="checkbox"/> General Foreman <input type="checkbox"/> Foreman <input type="checkbox"/> ES&H <input type="checkbox"/> Insulation <input type="checkbox"/> Piping / pipefitter <input type="checkbox"/> Welder <input type="checkbox"/> Indirects <input type="checkbox"/> Rigger <input type="checkbox"/> Mechanical <input type="checkbox"/> Heavy Equipment Operator <input type="checkbox"/> Other: _____		
<b>Where Discovered :</b> <input type="checkbox"/> ISBL : _____ <input type="checkbox"/> OSBL: _____ <input type="checkbox"/> Tanks: _____ <input type="checkbox"/> Camp: _____		
<b>Near Miss Type:</b> <input type="checkbox"/> Dropped Object <input type="checkbox"/> Fall Protection <input type="checkbox"/> PPE <input type="checkbox"/> Electrical <input type="checkbox"/> LOTO <input type="checkbox"/> Confined Space <input type="checkbox"/> Scaffolds <input type="checkbox"/> Ladders <input type="checkbox"/> Barricades <input type="checkbox"/> Fire <input type="checkbox"/> Heavy Equipment Operation <input type="checkbox"/> Other: _____		
<b>Description of Near Miss/ Hazard/ Unsafe Condition:</b> _____ _____ _____		
Any Immediate Actions Taken? _____		

**Figure 2 Near Miss Reporting Form**

Another approach to reporting near misses was through the use of an electronic reporting form created by using Adobe Acrobat Professional and selecting for the forms function. The electronic forms greatly raised the awareness of the *near miss* program for those personnel bound to a desk on the construction project. It allowed them to participate in the program and allowed them to participate to a level never realized previously. The immediate effect was the increase of *near misses* being reported by this group as well gaining a perspective about safety issues not usually associated with the construction site. Information related to office

safety were now being recognized project wide and new information was gained about exposures in the work offices and the housing units.

### **Analysis**

The *near miss* collection boxes and electronic forms were emptied and collected daily and the documents brought in at the end of the regularly scheduled day shift. The initial analysis of *near misses* were simply a function of categorization of craft type and the types of *near misses* that were being reported on the construction site. The function of this simple categorization was to calculate frequencies and types of *near misses* being reported by the construction craft on the project. The data collected included the area where the *near miss* occurred, the type, the craft reporting the *near miss*, the craft exposed to the *near miss*, and time information.

### **Feedback**

The products of the *near miss* collection were used to populate the next morning's Plan of the Day (POD) brief. A POD meeting is held daily, before the commencement of work on site by all project management staff. The POD brief is a collection of information pertinent to the day's activities such as road closures, radiological testing areas and any other interruption to the daily workflow. They now included information about the types and frequencies of *near misses* being reported on the construction site from the previous days activities. These POD briefs were brought out to the work site and discussed, in groups, before the commencement of construction activities as part of each foreman's tailgate or tool box meeting.

The tailgate or toolbox meeting is a familiar term for those involved in safety management within construction industry. It is a meeting, held at the beginning of a shift and point of work, between a foreman and his crew. It is usually held at the bed of their truck (tailgate) or at the tool crib where the day's construction activities are discussed. In addition, this is also where certain elements of the hazard identification process are usually conducted. One such item is the job hazard analysis (JHA) or job safety analysis (JSA) which is a written document or a series of narrative entries and checkboxes designed to help the work crew identify the steps needed to work their task, identify the hazardous exposures and then check that they have the proper personal protective equipment, training, and tools needed to perform the job correctly and safely. The ideal job hazard analysis is conducted by the employees doing the work (Occupational Safety and Health Organization, 2002) at the point of the work and just prior to commencement of the activity. The workers involved in the activity should be able to list the steps needed to complete their job, identify the hazards and assure that they have the skills, temperament, training, and supplies needed to do the work in a safe manner. An important consideration here is that the workers are fluent in their tasks and have an appropriate regard for the risks encountered on the job. Now, with the inclusion of the POD notes which have included the *near misses* (unsafe conditions, unsafe behaviors) from the previous day, the crew developing the job hazard analysis can identify hazardous conditions that they may have previously forgotten about or misidentified in the first place. If nothing else changed, the crew now has the

opportunity to hear about other's errors on the worksite and now have the chance to learn something through the vicarious experiences of others.

### **Weekly**

The *near misses* turned in for each week during the intervention were collated as to types and frequencies. These data were then used to produce a weekly *near miss* summary primarily for the benefit of the foreman and general foreman on the job. These personnel met on a weekly basis at the "Foreman / General Foreman" luncheon held on Saturdays. The primary function of this interaction was to discuss safety on the job site and included members of the construction management team including the Site Construction Manager. The inclusion of *near miss* data in this venue allowed all participants in the meeting to hear about and understand the health and safety related exposures being reported by their own crews. In this venue, not only were the *near misses* identified, but there were enough management on site (decision makers) that could address the issues at the point of discussion. For example, when an increased frequency of *near misses* related to crossing barricades into another work crews area were being reported, the two managers of the adjacent areas discovered an ambiguous work zone and responsibility about who is responsible for barricade maintenance. These errors were identified through personnel in the field, analyzed, and corrected in the Foreman/General Foreman meeting where these types of *near miss* reports were subsequently extinguished through a correction of the circumstances.

## Encouragement

Positive reinforcement in the form of simple peer group recognition, gift cards to the commissary or early quits (personnel allowed to leave the worksite earlier than actual quit time) were used to encourage participation in the program. For example, crews may have been rewarded for turning in the most *near misses* in a week regardless what types of *near misses* were being reported, who reported them, or who were involved in committing the *near misses*. Other weeks, the reward would go to the crew who reported the most *near misses* within their own work group or maybe a single award would be given to the person, if identifiable, who turned the most potentially hazardous *near miss* report of that week.

The *near miss* management program, in total, comprised of these parts was found to be a self feeding, self maturing broadcast of the latest and current events on the construction project. As issues were identified and discussed, members of the construction crews were able to learn from others' mistakes. In addition, the activity itself became a source to measure an elusive concept within the company – that of engagement. Engagement is the perceived measure of the workers' commitment to the construction team and the philosophy of the project which is that of a zero accident culture. Until now, engagement was not clearly defined or measurable while this new program delivered the “stats” on who, what, how and when *near misses* were being reported in the field becoming a proxy measure of engagement.



## Chapter 3: Methods and Analysis

This chapter describes the research methods and analysis chosen to test the effectiveness of the *near miss* program on this construction project. A series of specific statistical tests were chosen because of their “exactness” characteristics and were applied to the secondary data analysis in this research. The following subsections provide details about the specific testing procedures needed to answer each of the research questions presented in this practicum project.

### 3.1 Research Questions and Hypotheses

This research examined the effects of a *near miss* program on the lagging indicators (rates) of occupational injury on a heavy petrochemical construction project. There were three primary research questions;

1. What is the effect of the *near miss* management program on the rates of first aid cases and recordable injury events on a heavy petrochemical construction project?

***Hypothesis 1:*** Increasing the rates of which *near misses* are being reported will decrease the rates of occupationally related first aid cases and recordable incidents on the construction project.

***Hypothesis 2:*** Increasing the rates of reported *near misses* will be inversely correlated with the rates of first aid cases and recordable incidents on the construction project.

2. What types are *near misses* are being reported by the personnel during the near miss management program intervention?

**Hypothesis 3:** The relative frequency of the types of near misses reported prior to the intervention will remain unchanged post intervention.

3. What is the effect of the *near miss* management program on the rates of occupational injury within the intervention project compared to other similar construction projects?

**Hypothesis 4:** Compared to two non-random control construction projects, the project implementing the *near miss* management program will have decreased occupational injury and therefore, lower rates of first aid cases and OSHA recordable injury.

### 3.2 Data Collection

This research used secondary data from a large petrochemical construction project whose management had developed and implemented a new *near miss* management program to be used on the construction project. The *near miss* management program was developed in January and February of 2011 and fully implemented on the project on the 8<sup>th</sup> of March, 2011. While the construction company had a procedure for reporting *near misses* prior to the implementation of the *near miss* management program, the new program significantly enhanced the process in that: (a) the definition of a *near miss* had changed, (b) there were enhanced collection points and procedures, (c) there were daily reports that went to all personnel related to the quantity, type and severity of near misses being

reported, (d) there were weekly report outs to foreman and general foreman about what types of *near misses* were being reported within their realms of responsibility and (e) the *near misses* were now being characterized, for the first time, using an project specific model based on the Eindhoven Classification Model (Appendix A)

This research project relied on existing data and secondary data analysis to test the research hypotheses. The primary sources of the data came from the Project Controls department both at the project level and the business unit level, and an administrative near miss database. In calculating rates for occupational injuries and exposure, the project “hours” were collected from the Project Controls Department. Project Controls are largely responsible for many administrative activities on construction projects such as keeping a record of hours worked, payroll, scheduling, and project cost estimations. They have reporting obligations internally to the company as well as administratively to governmental organizations such as those monitoring wages and hours worked per week. In addition, they have an obligation to report out occupational health statistics to OSHA, in the United States, once a year as part of their recordkeeping requirements. As such, these data are collected from each project on a monthly basis in order to update a central database kept at the corporate headquarters of the construction company. This data has shared access with administrators in the company, this researcher being one of them, and is controlled by the database manager. Permission to use hours in the calculation for this research was given with the understanding that the names of the construction project under the intervention, and the two projects used as controls, would not be identified as hours worked per unit of construction becomes a

commercial and competitive matter. The validity of this data should be considered high as there are many internal controls in place to assure accuracy in both reimbursement schemes and reporting guidelines.

The data related to the number, frequency and types of *near misses* being reported during the intervention were collected from the project specific “incident tracker” or *near miss* database. This Microsoft Access based tracker was designed to collect data on safety related incidents including *near misses*, first aid cases, recordable incidents, fire alarms, fire drills, environmental incidents and any other safety and health related information deemed pertinent to the reporting needs of the project. Two administrative personnel, and this researcher, control access to this database and were responsible for the data entry into the system and in keeping it up to date. Entries into this database required information about: the nature of the incident, time and date of incident, location, craft type involved, foreman involved, a short narrative of the event and what, if any, measures were done to correct the situation.

Prior to the implementation, and as part of the *near miss* management program, the database was enhanced to include the new units of analysis required of the program. These included specific definitions of the *near miss* types, the type of craft reporting the *near miss*, the type of *near miss* (electrical, rigging, etc), and the simplified estimation of the error type. This updated and simplified error type designation was used by the administrators of the database to supply information for the plan of the day meetings and weekly products for use within the project.

For the purposes of this research, the week was chosen as the time-based unit of analysis as it followed the normal project reporting requirements at the time of the intervention. Thirty weeks were chosen to be included in this research: fifteen weeks prior to the intervention and fifteen weeks during the intervention considering over a half year of heavy construction experience equaling 5,478, 777 worker exposed hours. Thirty weeks were considered sufficient time to evaluate the effects of this research and retain a statistically significant ( $n=30$ ) for use in the calculation of test statistics. Additionally, thirty weeks roughly corresponded to similar construction activities on the project considering as the project is being built, certain percentages of craft personnel will be mobilized or demobilized depending on their needed skills. For example, the front end of heavy construction activities will rely heavily upon civil work such as foundations and dirt work while future activities will rely heavily upon welding and scaffolding activities. This research, in considering the scope change of the work being done on the project, was able to address this by bracketing off significant changes in the path of construction as well as minimizing the impact of a changing character of personnel on the project through the intervention period defined in the research scope.

### **3.3 Research Design**

This study used two types of study design. For answering the first primary research question and in testing **Hypothesis 1** and **Hypothesis 2**, a pre-and-post study design was used, where a construction project was evaluated before, during and after the introduction of a *near miss* management program for a period of thirty weeks (The first fifteen weeks were the project working without the *near miss*

management system in place; the second fifteen weeks monitored during the implementation). **Hypothesis 3**, related to the types of *near misses* being reported, used descriptive statistics and comparison to determine if the intervention had an impact on the types of near misses being reported between the pre-intervention group and the post intervention group. In testing **Hypothesis 4**, a quasi-experimental study design was used, whereby two non-random control groups (a large petrochemical construction project and a large civil engineering construction project) were compared using the same descriptive measures as the intervention project, but without the benefit of the *near miss* management program in place. Having non-random control groups should help lessen threats to internal validity of the program to the project under investigation (Shannon, Robson, & Guastello, 1999), specifically in controlling the effect of any corporate-wide influences that may have otherwise confounded the results of this research. These influences may have included any corporate wide directives such as a change in vendors, scope of work changes, changes in reporting procedures or even the application of other construction safety and health related messages or programs designed to identify and eliminate hazards at work.

Control project #1 was a large project in terms of manpower and scope coming from the same business unit (Oil & Gas) as the intervention project. In the corporate structure, these projects both report to the same functional managers. Any new safety or health related initiatives would be rolled out equally amongst all projects in this business unit as well as any new procedures, processes or programs.

The only difference between this control project and the *near miss* intervention project is the *near miss* program itself.

Control project #2 was from a different business unit but was similar in size and manpower to be useful as a comparison. While this project belonged to the Civil Business Unit, any corporate wide performance programs or initiatives, as described above, would be employed on this project as well. These projects all are accountable to the processes and procedures put in place by the corporation and all are equally accountable for their own performance related to safety and health on the construction site.

### **3.4 Data Analysis Methods**

The overall analysis strategy used in this research project was that of a pre- and post-test approach, which accomplished two goals: the examination of before and after data in the construction project undergoing the *near miss* intervention and the comparison of this data, and any changes, with a non-randomized control construction project that did not implement the *near miss* intervention. An assumption in this methodology is that the intervention project and control projects are similar enough in work hours, scope and construction type to remain valuable in comparison. Specific investigation strategies are outlined below.

#### **3.4.1 Measuring the Effect of the Near Miss Management Program**

*Sample.* Non-randomized data were collected from the projects incident database including hours worked, the number of *near misses* reported, the number of first aid cases and the number of recordable injuries incurred for fifteen weeks

prior to the intervention (Group 1) and for fifteen weeks during the *near miss* intervention (Group 2) for a total ( $n=30$ ) weeks. The data resided in a Microsoft Access database which was then exported to an Excel spreadsheet. This Excel spreadsheet was then imported to IBM's Statistics (SPSS) v.21.0.

*Variables.* The variables used in this analysis were the rates of *near miss* reporting, first aid cases, and OSHA recordable cases between measured in the population before (pre) and after (post) deployment of the *near miss* management program. The independent variable for this study is the rate of *near miss* reporting, while the dependent variables are the rates of first aid cases and OSHA recordable injuries recorded in the database on the construction project.

*Procedure.* A non-parametric comparison of medians between the population data prior to and post the application of the *near miss* management program was calculated using the Mann-Whitney *U* Test statistic. The Mann-Whitney test was chosen because of the non-Gaussian distribution of the data using the following formula:

$$U = N_1N_2 + \frac{N_1(N_1 + 1)}{2} - R_1$$

The calculation was the product of the Mann-Whitney test for independent samples function in IBM's SPSS Statistics, v. 21 and considered statistically significant at  $P < .05$ .

Descriptive and probability statistics were then calculated to identify the types and frequencies of error types being reported between the pre-intervention and post intervention time frame including a Poisson table used to identify the change in probabilities of a first aid case or OSHA recordable incident occurring in the pre and



post intervention time frame. Poisson probability calculations are useful in determining the probability of rare events (Janicak, 2010) and has the formula

$$P(x) = \frac{e^{(-m)}(M^x)}{x!}.$$

### 3.4.2 Measuring the Correlation Between Near Misses and Incidents

*Sample.* The sample used in this evaluation is identical to the sample used in 3.4.1.

*Variables.* The independent variable remained the rate of *near miss* reporting within the same data set (intervention project). The dependent variables remain the rates of first aid cases and OSHA recordable injuries within the intervention projects data set.

*Procedure to test hypothesis 1 and 2.* A Kendall's Correlation Coefficient, (Kendall's tau) was chosen to test the relationship between variables because it is the preferred test statistic used when; a) data is not normally distributed, b) when there are large numbers of tied ranks are used in the calculation; and c) there are limited number of cases. Additionally, the Kendall's tau was a more accurate representation of what the population correlation would be (Field, 2009) as it is a more exact test than Spearman's non-parametric test statistics.

### 3.4.3 Identifying the Types and Frequencies of Near Misses being Reported

*Sample.* There were 1196 *near misses* turned in during the scope of this research and all were used in the identification of near miss types being turned in by construction craft.

*Variables.* The variables under consideration were the rates of *near misses*, first aid cases and OSHA recordable incident as reported.

*Procedure to test hypothesis 3.* There were 1196 near misses being turned in by construction site personnel during this intervention. Each near miss had previously been assigned a near miss type (e.g., electrical, scaffolding, etc...) as part of the initial program. Each *near miss* was then coded into one of sixteen distinct error types using an operationalized construction specific Eindhoven Classification designed by this researcher and found in Appendix A.

#### **3.4.4 Comparing Medians Between Intervention Project and Two Non-Random Controls**

*Sample.* The recordable injury rates were analyzed between the intervention project and two non-random controls chosen because of their similarity in size and scope to the project undergoing the intervention.

*Procedure to test hypothesis 4.* This analysis used a non-parametric comparison of medians between the construction project undergoing the *near miss* intervention and two non-random controls from the same construction company. The calculation was the product of the Kruskal-Wallis test for independent group function in IBM's SPSS Statistics, v. 21. This test statistic identified whether there were differences in the medians of the sample projects during the time of the intervention and considered statistically significant at  $p < .05$ .

### **3.5 Protection of Human Subjects**

The primary source of data for this research resides in a pre-existing anonymous database. This database includes references to areas on a construction site, types of near misses, incidents, and first aid cases but is not linked in any way to information about the person, injury or any other searchable or identifiable information. This type of research was judged to be exempt from Full IRB Review pursuant to 45 CFR 46.101 in that Research “involving the collection or study of existing data, documents or records, pathological specimens or diagnostic specimens, if these sources are publicly available or if the information is recorded in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects” are exempt from full IRB Review Criteria. The University of Alaska Anchorage’s IRB Panel granted this research an exempt status in April of 2013.

## Chapter 4: Results

The results of the statistical testing are presented in order of performance. Tests were considered statistically relevant at  $P < .05$  using IBM's Statistics (SPSS) v.21.0 and presented in tabular format. The layout of this chapter is presented in the order of the statistical tests completed for the research questions discussed in Chapter 3.

### 4.1 Measuring the Effect of the Near Miss Management Program – Results

Table 2 summarizes the data of calculated *near miss*, first aid and recordable case rates for during the time from of the pre-intervention and post-intervention of the *near miss* reporting program.

**Table 2. Pre-Intervention and Post-Intervention Rate Comparison**

Group 1 - Pre Intervention				Group 2 - Post Intervention			
Week #	Near Miss Rate	First Aid Rate	Recordable Rate	Week #	Near Miss Rate	First aid Rate	Recordable Rate
1	5.4	1.8	0.0	1	10.1	6.7	1.1
2	5.4	9.9	0.9	2	48.1	5.9	0.0
3	1.8	7.3	0.9	3	36.7	8.9	0.0
4	2.9	6.7	1.0	4	76.0	9.0	0.0
5	5.6	3.7	0.0	5	49.8	1.1	0.0
6	7.3	2.1	2.1	6	61.0	5.1	0.0
7	1.3	5.0	0.0	7	72.7	8.2	0.0
8	19.9	6.2	0.0	8	185.5	6.1	0.0
9	16.6	4.9	1.0	9	138.2	3.5	0.0
10	12.7	4.9	1.0	10	78.0	0.0	0.0
11	2.9	7.8	0.0	11	86.4	0.0	0.0
12	9.7	1.1	1.1	12	87.8	2.4	0.0
13	5.4	5.4	0.0	13	77.3	4.8	0.0
14	5.2	2.1	1.0	14	184.8	0.0	0.0
15	6.4	6.4	0.0	15	105.3	2.5	0.0
<b>Total (N)</b>	<b>15.0</b>	<b>15.0</b>	<b>15.0</b>	<b>Total (N)</b>	<b>15.0</b>	<b>15.0</b>	<b>15.0</b>
<b>Median</b>	<b>5.43</b>	<b>5.04</b>	<b>0.9</b>	<b>Median</b>	<b>77.34</b>	<b>4.83</b>	<b>0.07</b>

Mann-Whitney U-Tests were calculated using data from Table 1 with the following results:

- The rates of *near miss* reporting pre-intervention (median 5.43) differed significantly after the intervention of the *near miss* program (median 77.34), reporting a *Mann-Whitney U* = 222.0,  $z = 4.542$ ,  $p < .001$ , and represented a substantial effect at ( $r = 0.827$ ).
- The rates of first aid cases during the pre-intervention time frame (median 5.04) did not significantly differ from the first aid rates during the time frame of the intervention (median 4.83) reporting a *Mann-Whitney U* = 98.0,  $z = -0.602$ ,  $p > 0.05$ .
- The rates of recordable injuries in during the pre-intervention time frame (median 0.90) differed significantly during the time frame of the intervention (median 0.07) reporting a *Mann-Whitney U* = 63.0,  $z = -2.532$ ,  $p < .05$  and represented a modest effect at ( $r = -.462$ ).

Table 3 signifies the calculated Poisson probabilities for having a first aid case or an OSHA recordable injury pre and post intervention. For example, the probability of having zero first aid cases prior to the *near miss* program intervention was 0.8% but rose to 3.5% after the intervention, a difference of over 339%.

**Table 3, Poisson Probability Calculations**

First Aid Count	Pre Intervention	Post Intervention	% Change	Recordable Count	Pre Intervention	Post Intervention	% Change
0	0.8	3.5	339.3	0	0.68	0.80	16
1	3.9	11.8	204.4	1	0.26	0.18	-50
2	9.4	19.8	110.9	2	0.05	0.02	-165
3	15.1	22.0	46.2	3	0.01	0.00	-370
4	18.1	18.4	1.3	4	0.00	0.00	-733
5	17.5	12.3	-29.8	5	0.00	0.00	-1377
6	14.0	6.8	-51.4	6	0.00	0.00	-2518
7	9.7	3.3	-66.3	7	0.00	0.00	-4542
8	5.8	1.4	-76.6	8	0.00	0.00	-8128
9	3.1	0.5	-83.8	9	0.00	0.00	-14486
10	1.5	0.2	-88.8	10	0.00	0.00	-25758

#### 4.2 Measuring the Correlation Between Near Miss Rates and Incidents

Table 4 presents the results of the Kendall's tau Correlation Statistics where the rate of *near miss* reporting was found to have no statistically significant correlation between the rates of first aid cases being reported prior to, or during, the intervention of the *near miss* program. However, the *near miss* reporting rates have a negative correlation with the rates of OSHA recordable injuries at ( $p < 0.05$ ). The data are summarized below:

- The correlation between *near miss* reporting rate and first aid rate was not statistically significant at  $r(30) = -0.212$ , ( $p = 0.05$ ) (exact).

- There was a statistically significant inverse correlation between *near miss* rate and recordable injury rate, with  $r(30) = -0.342, p < .05$ .

**Table 4, Correlation Statistics (First Aid and Recordable)**

			Correlations		
			Near Miss Rate	First Aid Rate	Recordable Rate
Kendall's tau_b	Near Miss Rate	Correlation Coefficient	1.000	-.212	-.342**
		Sig. (1-tailed)	.	.050	.009
		N	30	30	30
	First Aid Rate	Correlation Coefficient	-.212	1.000	-.003
		Sig. (1-tailed)	.050	.	.491
		N	30	30	30
	Recordable Rate	Correlation Coefficient	-.342**	-.003	1.000
		Sig. (1-tailed)	.009	.491	.
		N	30	30	30

\*\* . Correlation is significant at the 0.01 level (1-tailed).

### 4.3 Identifying the Types and Frequencies of Near Misses being Reported

Table 5 summarizes the types of *near misses* being reported prior to and during the *near miss* management intervention. The comparison between relative percentages is presented, indicating a change in the frequency of reporting and the types of near misses highlighted during the campaign.

**Table 5, Comparison of Near Miss Characterization Pre and Post Intervention**

Near Miss Type	Pre- Intervention Count	Post - Intervention Count	Pre- Intervention Percentage	Post - Intervention Percentage	Percent Difference
Aerial Lift/Manbasket	1	9	1	1	-11.7%
Barricade	2	111	2	10	444.5%
Body Positioning	4	41	4	4	0.6%
Electrical	9	12	9	1	-86.9%
Environmental	0	5	0	0	-
Excavation	0	1	0	0	-
Fall Protection & Prevention	18	129	17	12	-29.7%
Falling / Flying Objects	22	123	21	12	-45.1%
Fire Protection	4	19	4	2	-53.4%
Handling Materials	4	17	4	2	-58.3%
Heavy Equipment Operation	5	63	5	6	23.6%
Hoisting Operation	0	16	0	2	-
Improper PPE	9	298	9	28	224.9%
Ladders	0	26	0	2	-
Lock Out Tag Out	1	6	1	1	-41.1%
Material Loading / Unloading	1	2	1	0	-80.4%
Material Storage	0	4	0	0	-
Off Task	2	20	2	2	-1.9%
Operational (Maintenance & Equipment Opt.)	2	12	2	1	-41.1%
Pinch Point	0	2	0	0	-
Rigging & Lifting	1	15	1	1	47.2%
Scaffold	2	16	2	2	-21.5%
Tool/Equipment (Hand/Powered)	0	6	0	1	-
Tool/Equipment (Malfunction)	1	2	1	0	-80.4%
Tool/Equipment Selection	2	7	2	1	-65.7%
Trip/Slip/Fall from Same Level	5	28	5	3	-45.1%
Vehicle Operation	7	40	7	4	-43.9%
Welding/Hotwork	0	10	0	1	-

Table 6 summarizes 1164 near misses by error type (Eindhoven Classification) using the construction specific Eindhoven Classification (Appendix A)



modified for use in this research project. A little more than 44% of the error types recorded during this project were related to compliance issues on the site which are infractions of known company policies. Identification errors, where hazards existed but were not recognized by the crew, were responsible for another 24% and the work between crews, or coordination errors at approximately 10% were, identified as issues in the field. These three error types, it turns out, were responsible for over 75% of the reported *near misses* on the construction site during the time of the research project.

**Table 6. Error Types Reported**

	Frequency	Percent	Valid Percent	Cumulative Percent
	50	4.3	4.3	4.3
Compliance	515	44.2	44.2	48.5
Construction	11	.9	.9	49.5
Coordination	123	10.6	10.6	60.1
Culture	1	.1	.1	60.1
External	3	.3	.3	60.4
Identification	285	24.5	24.5	84.9
Knowledge	11	.9	.9	85.8
Mechanical	20	1.7	1.7	87.5
Monitoring	4	.3	.3	87.9
Protocol	1	.1	.1	88.0
Slips	50	4.3	4.3	92.3
Trips	24	2.1	2.1	94.3
Verification	66	5.7	5.7	100.0
Total	1164	100.0	100.0	

Table 7 represents the category of construction worker versus the types of errors being reported on the construction site. The purpose of this table was to

identify the types of crew who were either responsible for the error, responsible for the identification of the error or who were impacted by the error while on the construction site. Compliance, identification and coordination remained the three top error types responsible for over 75% of the reported *near misses* which now includes the craft types involved in the errors.

Table 8 summarizes the types of *near misses* being turned in during this research project and their subsequent coding using the modified Eindhoven Error types developed for this research. The top five error types, in descending order, were as follows: (1) compliance errors, (2) identification, (3) slips, (4) trips, and (5) verification errors. The types of *near misses* being reported came from the turning in of near misses by the construction craft. This table is a product of secondary analysis using the modified Eindhoven Classification developed for this research.

**Table 7. Craft Type vs. Error Type (Eindhoven Classification)**

Craft Type / Discipline	Eindhoven Error Classification												
	Compliance	Construction	Coordination	Culture	External	Identification	Knowledge	Mechanical	Monitoring	Protocol	Slips	Trips	Verification
Bus Driver	3	0	0	0	0	1	0	0	0	0	0	0	0
Camp Services	0	0	0	0	0	3	0	1	0	0	1	1	0
Carpenter	1	0	0	0	0	0	0	0	0	0	0	0	0
Cement Masons	1	0	1	0	0	0	0	0	0	0	0	0	0
Civil	21	0	1	0	0	9	0	1	1	0	0	1	0
CUS	0	0	1	0	0	0	0	0	0	0	0	0	1
Electrical Equipment Operation	138	1	15	0	0	51	0	0	0	0	4	2	8
ESH	26	0	3	0	0	10	2	2	0	0	0	1	2
Indirects	1	0	0	1	0	0	0	0	0	0	0	0	1
Instrumentation	5	0	1	0	0	1	1	0	0	0	0	0	0
Insulation	15	0	7	0	0	4	1	1	0	0	4	1	0
Mechanic	59	2	14	0	0	22	0	1	0	0	6	3	8
Millwrights	12	0	3	0	0	11	1	3	0	0	0	1	0
Non-Manual	2	0	1	0	0	1	0	0	0	0	1	0	1
Painting	11	0	1	0	0	1	0	0	0	0	0	0	0
Pipefitters	28	0	14	0	0	15	2	1	0	0	0	0	2
Plant Operation	66	1	26	0	1	42	2	5	2	0	6	2	17
Rigging	1	0	0	0	0	1	0	0	0	0	0	0	0
Scaffolding	6	0	1	0	0	6	0	1	0	0	0	0	1
Security	21	2	10	0	0	27	1	1	0	0	18	3	7
Structural	0	0	0	0	0	0	0	0	0	0	0	0	2
Testing	8	2	3	0	0	7	0	1	0	0	2	2	3
Tool Crib	0	1	1	0	0	1	0	0	0	0	0	0	0
Unknown	0	1	1	0	0	1	0	0	0	0	0	0	0
Warehouse Management	66	1	13	0	2	56	1	0	1	1	6	7	10
Welder	1	0	0	0	0	0	0	1	0	0	0	0	0
	2	0	0	0	0	1	0	0	0	0	0	0	0
Total	10	0	4	0	0	11	0	0	0	0	1	0	3
	504	11	121	1	3	282	11	19	4	1	49	24	66

Table 8. Near Miss Type vs Error Classification

Near Miss Type	Eindhoven Error Classification												
	Compliance	Construction	Coordination	Culture	External	Identification	Knowledge	Mechanical	Monitoring	Protocol	Slips	Trips	Verification
Lift/Manbasket	7	0	1	0	0	2	0	0	0	0	0	0	0
Barricade	7	0	82	0	0	11	0	0	0	0	1	0	1
Body Positioning	8	0	1	0	0	28	1	1	0	0	3	2	0
Electrical	5	2	0	0	0	6	1	2	1	0	1	0	1
Environmental	0	0	2	0	0	1	0	1	1	0	0	0	0
Excavation	0	0	0	0	0	1	0	0	0	0	0	0	0
Fall Protection & Prevention	79	0	1	0	0	37	2	0	0	0	2	1	18
Falling / Flying Objects	9	5	11	0	1	67	0	3	0	0	34	5	3
Fire Protection	8	1	1	0	1	5	0	1	0	0	0	0	5
Handling Materials	3	1	2	0	0	9	0	1	1	0	3	1	0
Heavy Equipment Operation	39	0	5	0	0	14	3	3	0	0	1	0	2
Hoisting Operation	1	0	0	0	1	8	0	0	0	0	2	0	4
Improper PPE	282	0	2	0	0	14	0	0	1	0	0	0	1
Ladders	5	1	1	0	0	15	0	0	0	0	0	1	2
Lock Out Tag Out	0	0	1	0	0	1	0	0	0	0	0	0	4
Material Loading / Unloading	1	0	0	0	0	1	0	0	0	0	0	0	0
Material Storage	0	0	1	0	0	3	0	0	0	0	0	0	0
Off Task	6	1	4	0	0	6	0	0	0	0	0	0	3
Operational (Maintenance & Equipment Opt.)	1	0	1	0	0	4	2	4	0	1	0	0	1
Pinch Point	0	0	0	0	0	0	0	0	0	0	0	1	0
Rigging & Lifting	1	0	2	0	0	3	0	2	0	0	0	0	8
Scaffold	3	0	0	0	0	7	0	0	0	0	3	0	4
Tool/Equipment (Hand/Powered)	0	0	0	0	0	4	0	0	0	0	0	0	1
Tool/Equipment (Malfunction)	0	0	1	0	0	0	0	2	0	0	0	0	0
Tool/Equipment Selection	2	0	0	0	0	3	0	0	0	0	0	0	4
Trip/Slip/Fall from Same Level	7	0	0	1	0	13	0	0	0	0	0	10	0
Vehicle Operation	31	0	2	0	0	10	1	0	0	0	0	2	0
Welding/Hotwork	2	0	1	0	0	5	0	0	0	0	0	0	1
<b>Total</b>	<b>507</b>	<b>11</b>	<b>122</b>	<b>1</b>	<b>3</b>	<b>278</b>	<b>10</b>	<b>20</b>	<b>4</b>	<b>1</b>	<b>50</b>	<b>23</b>	<b>63</b>

#### 4.4 Comparing Medians Between Intervention Project and Two Non-Random Controls

A Kruskal-Wallis test was conducted to evaluate the differences in median rates of OSHA recordable injuries between the intervention project (*near miss* project) and two non-random controls. The test revealed a test statistic of  $\chi^2(2) = 16.061, (p < .05)$ . This test statistic indicates that the median rates of OSHA recordable injuries are not the same between the three projects nor are they linked in any way which may suggest a company-wide or business line-wide change in management which would effect the rates of injuries across the company. Each construction site, the intervention and two controls, had different medians for OSHA recordable injuries, different ranges, and were not linked in any correlated reduction in injury rates. The reduction in OSHA recordable rates, during the intervention period, were isolated to the intervention project and not necessarily impacted by corollary events outside of the project, at least according to this test statistic.

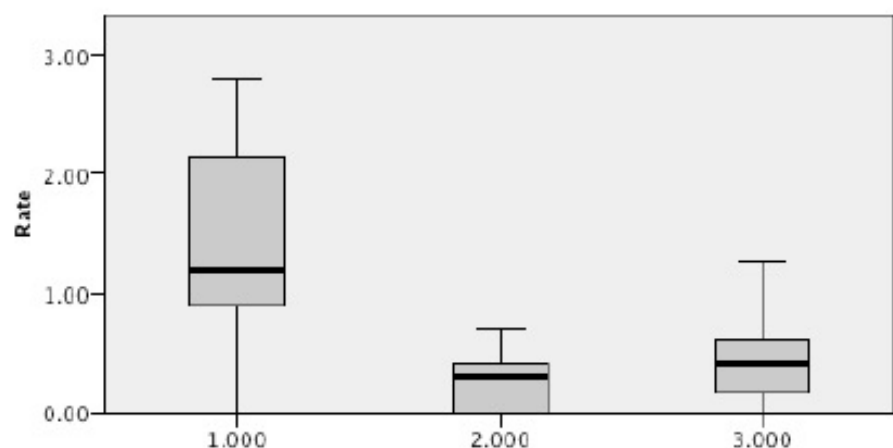


Figure 3. KW - Comparison of Medians Between Projects

## Chapter 5: Discussion

This chapter presents a discussion for each of the preceding research questions and hypotheses. It follows in the order of the previous two chapters and simply restates each hypothesis before a detailed discussion of the findings.

### 5.1 Measuring the Effect of the Near Miss Management Program

The study's first hypothesis was that increasing the rates at which near misses are being reported will decrease the rates of occupationally related first aid cases and recordable incidents on the construction project. When tested, this hypothesis produced mixed results in that the increase in *near miss* reporting had no statistically significant effect on first aid cases but produced a significant effect on OSHA recordable cases.

#### Near Miss

During the thirty-week time interval for this research project, *near miss* reporting increased by 966% (see Table 1). The initial challenge to the construction site personnel was to turn in between three to five *near misses*, per person, per year for the remainder of their time on the project. At the time of the intervention, there were approximately 3000 personnel exposed to the *near miss* intervention theoretically producing between 9000 (173 per week) to 15,000 (288 per week) near misses per year on the project. There were approximately 1182 near misses turned in during the thirty-week assessment with a majority of those being turned in during the post intervention period; 105 turned in pre-intervention, 1077 turned in post intervention, which were responsible for 91% of

the *near misses* being reported resulting in a statistically significant increase in *near misses* reported after the development and implementation of the *near miss* management program on this construction project.

### **First Aid**

While there was a significant increase in the number of *near misses* being reported during the intervention, the subsequent increase did not reveal a statistically significant decrease in the number, or the rate, of first aid cases being reported on the construction project. First aid cases can involve anything from dust in the eye, to heat rash evaluation, to clinical rechecks to athlete's foot experienced while on the job and many other complaints. These types of events, while still considered first aid cases, are not necessarily easily attributable to any one type of construction activity and may be considered random events happening to personnel regardless of their construction activity. Further analysis of this subject was beyond this research but could be a topic of interest in later work on the subject. The relationship between first aid cases and recordable events were not analyzed in this research but one possibility remains; first aid cases and OSHA recordable injuries come from a different set of root causes not easily attributable to the human error paradigm presented in this work.

Although there was no statistically significant decrease in first aid rates between the pre and post intervention time frame, there were still interesting outcomes detected. The probabilities of having at least one or more first aid cases and having one or more OSHA recordable cases were calculated using a Poisson Probability distribution and were presented in Table 2. The probability of having

zero first aid cases in any given week on the construction project prior to the *near miss* management intervention was calculated to be 0.8% and then recalculated for the time frame after the initiation of the *near miss* management intervention and found to be 3.5%, an increase of over 339%. While the rates of first aid cases did not significantly change during the intervention, the overall probability of having zero first aid cases in any given week during the intervention rose by 339%. Not only is that an improvement in the calculated odds of having an injury free workplace, this may set the initial benchmark for other programs initiating their own *near miss* management program in the future.

### **OSHA Recordable**

The effects of increased *near miss* reporting on the rates of OSHA recordable injuries were found to have a moderate, inversely related, relationship and was found to be highly significant at the 99% significance level. As the rates of *near misses* being reported increased, the rates of OSHA recordable injuries decreased in a statistically significant and predictable way.

OSHA recordable injuries are those serious enough to need professional medical attention such as the application of sutures or prescription medications to control pain or infection. Compared to first aid cases, OSHA recordable injuries are the result of an acute exposure to exaggerated forces such as physical and chemical agents, mechanical and electrical energy, falls through openings and contact with objects carrying significant force energies (Castillo, Pizatella, & Stout, 2011). Whether or not exposure to one of these energies resulted in a first aid case or an OSHA recordable is largely a matter of personal factors of those workers involved,



such as their ability to regain control of the situation, their use of personal protective equipment as a mitigating factor, their personal health and even a certain degree of luck in the circumstances of their exposure.

One of the main overarching goals in the development of the *near miss* management program was to facilitate a decrease in occupational injury on the construction project. The results reported here indicate that as *near miss* reporting rates increase, a moderate, but highly significant, effect takes place on the construction project at least related to OSHA recordable injuries. As mentioned previously, the OSHA recordable injury is one that is categorized as “more serious” than the first aid case; it occupies one level above first aid cases Heinrich’s Triangle; and, in many cases, requires professionally licensed medical personnel to diagnose and treat the injury.

## **5.2 Measuring the Association Between Near Miss Rates and Incidents**

The second hypothesis suggested that increasing the rates of reported *near misses* would be inversely correlated with the rates of first aid cases and OSHA recordable injuries on the construction project. When tested, this hypothesis produced similar results as found in 5.1; there was little or no significant effect on first aid cases but an effect was identified when compared to OSHA recordable cases.

### **First Aid**

The rates of *near misses* were tested for correlation with the rates of first aid cases within the intervention project. As reported in section 5.1, there were no

statistically valid correlations found between the rates of *near miss* reporting and the rates of first aid cases on the construction project. For similar reasoning, it is possible that because of the random nature of many first aid cases (dust in the eye, heat rash, etc...) the statistically valid effect, at the 95% confidence interval tested for, is beyond this research study.

### **OSHA Recordable**

The rates of *near misses* were tested for correlation with the rates of OSHA recordable injuries within the intervention project. The results indicated that there is a modest effect, but strongly significant at the 99% confidence interval; as *near miss* rates increase, the rates of OSHA recordable injuries decrease.

As stated earlier in section 5.1, Measuring the Effect of the Near Miss Management Program, the effect of increased *near miss* reporting was more evident in association between OSHA recordable cases than it was in the first aid cases. Again, the first aid cases reported were for relatively minor events such as scrapes and abrasions, dust in the eye, sunburn or any one of hundreds of minor bodily complaints that befall personnel, regardless of their job or status on the construction site. Further research would have to be done to truly call these random events, but in any case, finding a truly causal factor on the construction site would be a time consuming research effort with little or no true benefit to the researcher or the personnel on the construction project. OSHA recordable events, however, are more serious and require, theoretically, more energy to induce an injury and more specialized medical effort in the resultant treatment of that injury. The OSHA recordable events are not necessarily random in nature as described in

the following example; a random first aid type injury may involve some dust or dirt in the eye of one of the workers that is easily washed out by simple irrigation. This type of event may happen on the bus on the way to the worksite, on the scaffolding in the pipe rack, in the lunch room or any one of hundreds of construction controlled areas on the worksite and if reported, would be logged as a first aid case in the incident tracker. In a similar situation, if this same worker were hit with flying debris in the eye from an angle grinder when walking through the pipe rack, this event has changed as the velocity of the particle hitting the eye is higher (more energy) and the resultant injury is more severe. A metal particle in the eye may not simply be removed by simple irrigation and may involve something more invasive such as specialist removal with an eye magnet. This type of foreign debris removal would be considered an OSHA recordable injury.

A *near miss* report would probably not be generated regarding the examples in the first aid case. The act of getting unknown debris while walking through the construction site is different than getting a high velocity metal particle in the eye when working / walking / visiting a work area where grinders are being used. The former activity is a random activity and results in low energy injuries. The latter activity, getting close to a grinder, is non-random. In this case, to properly work with grinders, personnel need to have specialized training, safety glasses and a protective secondary face shield and a designated work area to work at a safer state. If any of these protective conditions were not being met on the work site, this may generate the reporting of a *near miss*. For example, someone working with a grinder without the face shield or the proper work set up may inspire

someone to write up a *near miss* report. Once this report is generated, the cycle begins as the event is analyzed, the work crew identified, and the *near miss*, in the form of information is shared the next day with the entire work site. The sharing of this information will, hopefully, reinforce the message that face shields are required when grinding and may answer questions as to where to get face shields on the site, what types are required, and will facilitate their use in the future through enforcement.

### **5.3 Identifying the Types and Frequencies of Near Misses Being Reported**

The third hypothesis suggested that the relative frequency of the types of *near misses* reported prior to the intervention would remain unchanged post intervention. This hypothesis was tested using descriptive statistics and produced mixed results; the relative frequency of some near miss types remained unchanged but there were significant differences found in other types as discussed below.

The near misses collected during the time frame of the intervention were categorized using the Modified Eindhoven Classification as secondary data analysis. Table 3, Comparison of Near Miss Characterization Pre and Post Intervention, identifies the relative percentage of *near miss* types being reported prior to the *near miss* intervention and after on the intervention project. As a reminder, *near misses* were being reported prior to the implementation of the new *near miss* program but the programs was restructured enough during the intervention as to posit that there were two distinct systems at work, one pre intervention, one post.

## Near Misses

Interestingly, prior to the intervention, the most frequently reported *near miss* on the construction project was falling and flying object responsible for 21% of the total *near misses*. In the experience of this researcher, the most common, and classic, definition of a *near miss* on a construction site used the scenario of falling objects from scaffolds or pipe racks as the prime example of a *near miss*. After all, a tool falling from a scaffold and hitting someone is an incident; the same tool falling to the ground and narrowly missing someone is a *near miss* and can be easily imagined to have substantially different consequences if the tool had actually hit personnel. The next most frequently reported *near miss* was that of an unsafe condition related to fall protection responsible for 17% of the *near miss* reports prior to the implementation of the intervention. Again, unsafe conditions related to fall protection are relatively easy to identify by seasoned construction personnel and are of a serious nature as falls remain the number one killer in construction (Bureau of Labor Statistics, 2011). Between these two unsafe conditions, falling objects and fall protection, 38% of the *near misses* are represented prior to the intervention, a period of fifteen weeks.

There were two substantial increases in the types of near misses being reported after the implementation of the program: barricades and the use of personal protective equipment (PPE). Barricades are essential components of a construction site as they demarcate areas where heavy equipment is being used or they help identify unsafe areas where only specialized crew can enter. The crossing of barricades, the accidental removal or destruction of them, and

maintenance are the types of unsafe conditions that would be reported as a near miss on this program. The fact that these types of *near miss* reports increased by over 444% during the intervention can be looked at in two ways. Either there was increased awareness on the site and personnel had increased their vigilance in the identification and reporting of these conditions, or the site was out of control and there were more unsafe conditions out there to be reported. Considering these two options, it is unlikely that the site experienced any conditions that would allow it to degrade its safety performance so rapidly. Instead, this researcher suggests that the increased reporting is a function of the *near miss* program which increased awareness of the condition on site and fostered this culture of reporting.

The other significant increase in *near miss* reports was that of personal protective equipment, or lack of it, coming in from the construction site personnel. Again, the 224% increase in reports can be looked at as improved awareness of the unsafe conditions or it can be looked at as a site out of control, as mentioned previously. The preferred outlook is that of increased awareness of the issues and an increased frequency of the reporting remembering that reporting the issue is only the first step in the program and that the follow up in the corrective actions and management wide attention is where this program works.

### **Craft Type**

Table 5 represents the craft types, or disciplines, and the types of *near misses*, classified by Eindhoven Error Type. This data is included in this paper as a reference to what kinds of errors are being committed by each specific type of craft, as reported through the *near miss* program. This is an important component of the

*near miss* management program and has roots in the public health domain of surveillance. Historically, worksite interventions or awareness campaigns were not specific to any one issue or to any one work crew. Now, with the benefit of added information, these work site interventions or campaigns may be targeted to certain craft types making the message more specific and meaningful.

### **Error Types**

The error types presented in this section are the results of secondary analysis conducted by this researcher supported by the modification to the Eindhoven Classification, in this case, modified for construction and presented in Table 6. Van der Schaaf found that the identification of the types of errors present in near miss cases or actual events has been found to be useful material in the chemical processing industry (van der Schaaf, 1992) as well as in his work with transfusion medicine (van der Schaaf & Habraken, 2005). By analyzing the types of *near misses* being reported, who is reporting them, who they are affecting and their respective error types, a rich source of data is available for the health and safety professional to target and design craft and error specific interventions. The five most common error types are reported below with a brief discussion about their occurrence and what it meant on the construction site at the time of reporting.

*Compliance.* The most commonly reported compliance issues reported through the program were related to personal protective equipment; 282 reports of missing PPE (safety glasses, vest, etc) and 79 reports of missing or inadequate fall protection harnesses. Compliance issues are simply a matter of personnel doing (wearing) the company provided PPE at the right times during hazardous

work operations. Non-compliant personnel will either remove their PPE periodically because of fogging or maintenance issues or they may have simply forgotten to apply the PPE in certain situations. Other personnel may take the opportunity to remove their PPE when they think they can get away with it. PPE isn't always the most comfortable choice on the construction site and PPE compliance is, in the experience of this researcher, usually an ever present issue.

*Identification.* Identification errors are those where personnel are exposed to an unsafe condition or behavior and simply did not realize the potential for harm. Interestingly, hazards not identified are one of the most commonly used root causes identified in incident investigations after the occurrence of recordable injuries on this project (Markle, 2011). The top two near miss types related to this error type were falling objects and fall protection. Falling objects from pipe racks are a major concern in construction. In 2011, there were 192 construction workers killed by falling objects in the United States (Bureau of Labor Statistics, 2013), many of them being hit by falling objects from height. In this case, according to the Eindhoven Classification designed for use in this research, these potential falling objects were identified, mitigated and stopped from falling through the use of this program. In other words, these types of errors were related to equipment or tools left in the scaffolding or the pipe rack either hanging on a rail or close to the edge of at risk of falling. These were not true dropped items but, rather, items that were inappropriately stored or contained up in the rack. The reporting of these types of near misses, and their subsequent errors, identified the problem to a specific



location, personnel and item so that it can be discussed and taken care of before there is a true incident.

The other most frequently reported identification error was related to fall protection issues and personnel exposing themselves to fall risks either without taking the proper precautions, or exposing themselves to fall risks without realizing the issue (e.g., walking on a scaffold under construction).

*Coordination.* Errors in coordination are most commonly related to the activities of multiple work crews in congested areas on the construction site. The most common associated error in coordination was the impact on barricades in the work area. The errors, in this example, are those where personnel find themselves on the other side of a barricade either unintentionally or through non-compliance. Finding one's self in a barricaded area without proper authorization or training is a serious concern. Many times, barricades are being put up because of an unsafe condition such as radiological testing of pipe welds or pneumatic testing is going on in the area. However, barricades are commonly moved without authorization on a busy construction sites or they simply fall down and are not replaced. In this situation, many of these near misses were reported and management were able to, again, identify the areas of major concern, correct the problem and strengthen the barricade program. At the very least, the issue was highlighted in the mornings' plan of the day meeting and any barricade issues reported from the day before were identified by management and mitigated.

*Verification.* Verification errors are those unsafe conditions, usually, where a tool or a piece of equipment is being used inappropriately or is being used

without having gone through its quarterly inspection. For example, all electrical hand tools are required to be inspected on a quarterly basis by a competent person; a person is deemed competent when they have the experience and training necessary to identify hazardous conditions and have the ability to stop work in the area for safety related work conditions. When these tools are inspected, they are color coded to identify that they have met the requirements of the inspection program. Using a tool that has not been inspected is a verification error usually only found after an incident or malfunction occurs. However, in this case, the unverified or inspected tools were found by the construction craft personnel before any management intervention and taken out of service, a safer condition.

*Slips.* Slips are human errors related to full body movements such as swinging one's arm out to hit something, a trip on a flat or uneven surface, or any other unintentional release of body movements that could have, or did, result in pain. These happen all the time and are usually beyond control of a safety and health management system. However, if they are related to conditions in the workplace such as congested areas or trip hazards, they can be identified and controlled through management actions.

As mentioned previously, falling objects are a concern in the construction industry and they are implicated two times in this research through Eindhoven Error Classification; through identification errors such as leaving tools on the edge of a scaffold at height and now through slips where a tool actually slips from the hand of a worker during use. A slip, in this case, was reported 50 times with 34 subsequent falling objects through the *near miss* program according to Table 6.

While this probably isn't the total number of fallen objects during this time period, it certainly allows safety and health personnel the opportunity to investigate the occurrence through who is reporting the incidents, where they are occurring and what are the consequences of the event.

#### **5.4 Comparing Medians Between Intervention Project and Two Non-Random Controls**

The fourth hypothesis compared two non-random control construction projects with the project undergoing the *near miss* management program under the assumption that the project under the *near miss* program will have decreased rates of occupational injury rates during the intervention time frame. This hypothesis was confirmed using the testing procedure identified in the methods section and described below.

The construction project exposed to the *near miss* intervention was compared with two other similarly sized and scoped construction projects, one from the same business related to oil and gas and the other similarly sized but originating from a majority of civil based activities (road work and tracks). Results of the statistical testing indicated that the median rates of OSHA recordable incidents were different between all three projects. This suggests that while all three projects are under similar management procedures, there are factors individual to each project that influence the rates of occupational injury. In other words, the control and occurrence of occupational injuries are not random and safety and health management programs have effects on the system. The implementation of this *near miss* management program, as statistically suggested, reduced the rates of the occupational injuries in the intervention project without a corresponding decrease in the rates of occupational injury in the other two projects which may have suggested global influences such as broad management changes

from within the company or perhaps economic variable such as a downturn in the construction industry

### **5.5 Implications for Environmental, Safety and Health in Construction**

Evidence suggests that the *near miss* management program developed and implemented on this construction project led to statistically significant increases in the number and rate of *near misses* being reported and that these *near misses*, and the subsequent mitigation measures, led to statistically significant decreases in OSHA recordable injuries. This evidence is corroborated with the experience of similar *near miss* management programs initially developed by aviation, nuclear, oil and gas, and even medical programs as reported earlier in this report.

The construction industry remains a dangerous place to work with a fatality rate more than twice the U.S. national average (Bureau of Labor Statistics, 2011). Findings of this research suggests that the implementation of a *near miss* management program on a large petrochemical construction site can help decrease occupational injuries experienced by construction personnel. The initial evidence of the effectiveness of the near miss program should inspire more direct work and the adoption of similar programs within the construction industry.

## 5.6 Strengths and Limitations

One of the primary strengths of this research is that the *near miss* intervention was applied to a significantly large sized construction project over a thirty-week pre and post intervention study period. The results of this project incorporate approximately 5.5 million man hours of construction effort, and 1182 *near misses* turned in for evaluation resulting in a measurable decrease in occupational injury morbidity. One of the first to do so, this research has evaluated a *near miss* program, found useful in other industrial endeavors in decreasing occupational injury, within the construction occupation. However, this strength in the size and scope of this project may also be a weakness. Although resources were not considerably stressed during the design or implementation of this *near miss* program, there still remains the logistics of designing the implementation, identifying collection points and materials, the analysis of the incoming *near miss* reports, and the reporting of the analytics in the field requiring manpower resources which may not be available to smaller or resource stressed projects.

This research has identified and measured the effects of a *near miss* management program on one large petrochemical construction project. While the results indicated that the *near miss* program had significant effect, this remains the product of a single construction project. It is not known at this time whether these results are transferable to other projects or what the essential contributing factors necessary for such an achievement might be. Variables that may have positively influenced the success of the intervention on this project probably include the attitudes of management, the enthusiasm of the principal investigator, client

influences, location, the use of rewards and many others. The impact of these variables requires further investigation in order to generalize these results to other modes of construction.

This research introduces a conceptual modified model of the Eindhoven Classification for the first time in a *near miss* management program related to construction safety. It was a construct of this researcher relying heavily on the work of van der Schaaff and his work in the chemical processing industry as well as the medical error modeling. This remains a relatively untested mechanism in the world of construction safety so further testing is needed for both internal and external validity.

This research does not include the case of the lost time injury. In these events, personnel are not able to return to work from anywhere from a day to weeks to even months after their injuries with some never making it back to work. These events were not included in this research because none occurred during the intervention in order to study; they are considered as rare events.

## Chapter 6: Conclusion and Recommendations

### Summary

The original premise behind this research was that *near miss* management programs are used by highly complex organizations as part of their safety and health management systems and that this use has contributed to decreasing rates of occupational injury in their respective industries. These industries, described as high reliability organizations (U.S. Department of Energy, 2009), have implemented and refined these programs to an extent that they are now being used by a diverse variety of occupational activities including the fire services, healthcare and nursing. The research into the role of *near miss* reporting in construction has been less enthusiastic up to this point, until now. This research provided evidence that *near miss* management programs, used during the construction of a petrochemical plant, effectively produced a viable program and decreased the occupational injury burden on the project and to its personnel.

The implications for the construction industry should be clear; construction remains one of the most dangerous occupations in the world with a staggering toll on the lives of the injured and devastating impacts on the families of those killed on the job. A *near miss* management program designed for use and implemented on the construction of a heavy industrial petrochemical plant resulted in a decreased count and rate of occupational injuries during the time of the *near miss* program.

In addition to providing proof of effectiveness of *near miss* programs in construction, this research project also assigned human error categories to the



types of *near misses* being reported by the personnel. This initial investigation into the types of errors being reported can help lead to a better understanding of not only what exposures are being identified out in the field, but may lead to a better understanding of many facets of the safety and health management system. For example, collection of error types may lead to:

- Increased awareness and hazard recognition in the workforce,
- Error types and mitigation measures (skills based errors require skills based solutions),
- Educational programs designed to help eliminate hazardous conditions as they are realized and experienced out in the field.

This research was an important first step in the wider application of these near miss programs and techniques and will hopefully gain a wider acceptance in the construction industry. The results found in this research project will be used by the Research Team 301(RT 301) from the Construction Industry Institute in their development of Using Near Misses to Enhance Safety Performance. This group's research project will produce a suite of available best practices related to *near miss* programs found in other, but similar, industries to construction.

Finally, a *near miss* management program has to be understood as an entity that is more than the sum of its constituent parts. The simple collection of *near misses* from the field is not, in this researcher's opinion, enough to facilitate change on the construction site. Each component of the *near miss* program needs to be carefully considered within the context of the project, the resources and the logistics of getting the message out. Of the six identified components necessary for

the *near miss* management program studied in this research, each is equally important in their own right. Efforts should be made to make each component a “best practice” standing on its own merits. For example, in order to have an effective *near miss* program, the personnel have to be fluent in the company’s definition of a *near miss* and what constitutes an unsafe condition or behavior. Hazard identification is a skill and can be taught through experience and training through formal or informal means. The reporting of *near misses*, and the full application of this program, are just one of the ways that hazard identification can be “taught” in that the experiences of a few on the construction site are shared by all through the mechanisms described in this research. A clearer understanding on this could be tested in future work through the analysis of hazard identification “skills challenge” on the personnel on projects with a *near miss* program, and those without one.

This *near miss* management program is more than the sum of its constituent parts lending itself to a theory of strong emergence; that is the program, as a whole, is irreducible. The simple reporting of a *near miss* without analysis or feedback is just an operational obligation. The reporting of the same *near miss* where it is analyzed and shared is a vicarious experience shared by all personnel on the construction site.

### **Recommendations**

This preliminary research into the effect of a *near miss* program on the rates of occupational injury remains the product of one intervention on one construction project. The observed decrease in OSHA recordable injuries and the outcome of

the correlation analysis suggests that increased use of *near misses* have a statistically significant effect in decreasing occupational injury on the intervention project. Given these findings, *near miss* programs need to be validated under different construction project management systems including those doing self performing work, those under subcontractor performed work, construction management (only), lump sum, time and materials, or vendor only contracted conditions, amongst many variations thereof. Of particular interest would be those projects under union control of the trades or highly specialized subcontracted work considering the internal management culture of the union or specialized trades.

The management of the program itself, while not overly taxing, does take time to do effectively. The role of management in this process is essential because they will set the pace of the work schedule as well as allocating the required resources in order to manage the program. The incorporation of the *near miss* management programs into the construction industry should be analyzed using an organizational change theory model to further understand the dynamics, after incorporation of the program is adopted and maintained throughout the organization. An analysis of this nature may illuminate any structural or procedural barriers into the implementation of *near miss* programs and benefit future organizations wishing to take on the initiative.

The types of *near misses* being reported, only briefly discussed in this research paper, need to be better understood. These *near miss* reports are related in some way to the actual frequency of incidents, occupational injuries or other unplanned events but this relationship remained concealed during this research. A

better understanding could be developed by cataloging not only *near miss* events with the construction specific Eindhoven Classification, but could include first aid cases, OSHA recordable injuries, lost time cases and even fatalities. That kind of analysis would not only determine the relative frequencies of *near miss* event versus the actual injuries, but could be used as a prediction model for future injuries which includes an update of the “accident pyramids” mentioned previously in this report.

It was suggested earlier in this work that *near misses* provide a vicarious learning experience as it is possible to learn from the errors of others on the construction site. If that is true, it could lead to a testable hypothesis for future work in that the hazard identification skills testing scores should be higher in construction personnel exposed to *near miss* management programs than those that are not.

Also, as mentioned previously, *near miss* management programs are more than just the sum of their parts. It is important to understand each of the essential elements in isolation outside of the near miss management program if for no other reason than to identify the best practices related to each component. For example, further work needs to be conducted related to the operationalization of the “*near miss*” concept within construction, as many researchers have struggled to find an inclusive definition of the term. Additional work should be done in order to identify the best practices, procedures and processes used to write and collect *near misses* in the field. Once collected, near misses need to be categorized according to *near miss* types, error types, or combinations of company specific programs and the

above mentioned in order to standardize the data. A third party database, if available, could be used to collect construction industry specific *near misses*, much like what is done with the Fire Fighter Near Miss Database (National Fire Fighter Near Miss, 2008). Construction companies that choose to participate in this database would be able to learn from their peers in the industry as well as identify real time trends in comparison to what they are seeing within their own companies.

*Near miss* management programs need to become a component of the safety and health management systems being used within the construction industry right now. The case has been made and presented; *near miss* management programs, reporting and follow up is an effective tool in the prevention of construction related occupational injuries. It is a relatively low cost program that benefits not only the company's bottom line, but prevents occupational injury burden within the workplace.

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## Appendix A – Eindhoven Classification

Type	Identification	Category	Code	Definition
Active Errors  (Human Errors)	Skill Based 1	Slips	HES	Failure in highly developed motor skills such as using a hammer, using powered and non powered hand tools
		Tripping	HET	Failure in whole body movements such as climbing a ladder, tripping on even ground, swinging arm out and hitting something, kicking something.
	Rule Based 2	Qualifications	HEQ	The wrong combination of a persons education and experience vs the task at hand. Asking someone to do something in which they have limited experience or knowledge.
		Coordination	HEC	A lack of coordination between two construction groups such as walking into a barricaded area or area under pressure testing. Groups not coordinating with each other.
		Verification	HEV	The incomplete assessment of something on the worksite such as using equipment which hasn't been inspected, not color coded, not the right tools for the job.
		Identification	HEI	Failures that result from faulty task planning such as hazards not identified on the JHA or STARRT cards. Did not know that XXXXX was a hazard.
		Monitoring	HEM	Monitoring a situation inappropriately – not realizing hazardous situations because of incorrect gas monitoring.
		Compliance	HEI	Procedure which are not followed, off task, shortcut
	Knowledge Based 3	Knowledge	HEK	Inability of a person to apply their existing knowledge to new situation. They simply didn't know it was a rule.
	Latent	Technical 4	External	TEX
Construction			TEC	Correct design, but not constructed properly allowing for premature wear and tear.
Mechanical			TEM	Near misses based on something breaking because of mechanical reasons such as hydraulic lines breaking, machinery breaks down, tires go flat, etc.
Organizational 5		Transfer of Knowledge	OEK	Failures resulting in the incomplete transfer of knowledge to personnel either during specific training such how to operate machinery properly or how to shut down machinery in an emergency.
		SOP / Core Process/ SWPP/ Protocol	OEP	Failures relating to the availability and quality of existing protocols related to the task at hand. Common error types include confusing, conflicting, complicated,