1-1-2013

Development And Implementation Of A Proactive Safety Performance Evaluation System For General Contractors

Ahmet Selim Alpmen
Wayne State University,

Recommended Citation

Alpmen, Ahmet Selim, "Development And Implementation Of A Proactive Safety Performance Evaluation System For General Contractors" (2013). *Wayne State University Dissertations.* Paper 629.

DEVELOPMENT AND IMPLEMENTATION OF A PROACTIVE SAFETY PERFORMANCE EVALUATION SYSTEM FOR GENERAL CONTRACTORS

by

AHMET SELİM ALPMEN

DISSERTATION

Submitted to the Graduate School

of Wayne State University,

Detroit, Michigan

in partial fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

2013

MAJOR: CIVIL ENGINEERING

Approved by:

Advisor Date

DEDICATION

To my father (1934-2003) who was my role model and always gave me inspiration to aim higher and taught me how successful one can be and go beyond the expectations if sets his mind to it

and

To my mother (1938-2006) who taught me that patience is a virtue learned by listening to others and made me believe that there is no such thing as impossible.

ACKNOWLEDGMENTS

This dissertation would not have been possible without the guidance and the help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study.

First, my utmost gratitude to my advisor Dr. Mumtaz A. Usmen, PhD, PE whose sincerity, guidance and valuable advice I will never forget. Dr. Usmen has been my inspiration as I experience setbacks and made me believe with his encouragement that I can do better.

I wish to express my sincere appreciation to my PhD committee members: Dr. Ahmed Awad, PhD, PE, Dr. Gongkang Fu, PhD, PE, Professor and Chair of Department of Civil, Architectural and Environmental Engineering at ITT Illinois Institute of Technology, Dr. Carol Miller, PhD, PE, Civil and Environmental Engineering, Dr. Ece Yaprak, Professor in Engineering Technology Department for their vital review and commentary, for their valuable insights and patience and steadfast encouragement to complete this study.

I also would like to acknowledge the safety professionals particularly Roger Thomas who passed away recently, Kenneth McLoud and Phillip A. Gawel who have participated in this study with the information and feedback they have provided to make this research possible.

Lastly, I would like to express my special thanks and gratitude to my family and friends, Emrah Kazan, Sacip Toker, Cem Poyraz and Meliksah Demir for all their support, help and encouragement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION

1.1 Background and Need

Construction safety is an essential aspect of the construction industry which lacks the attention it deserves. It has often been overlooked and neglected to a certain extent since the early days of the evolving construction industry. Because of time and budget constraints, it has rarely become a first priority and has not often considered as a value added product in construction projects. Nonetheless, the importance of construction safety has been realized in the last few decades and it has improved dramatically. Especially high direct cost of accidents, inefficiencies in a project as a consequence of any kind of loss, increasing cost of workers compensation premiums, and medical expenses among other factors have played a significant role in recognizing construction safety's importance. The estimated direct and indirect costs of construction injuries (fatal and non-fatal) totaled $13 billion annually and the medical expenses of non-fatal injuries by itself cost more than $1.36 billion per year of which only 46% were paid by workers' compensation. (The Construction Chart Book, Fourth Edition, 2007)

With the increasing costs of accidents, professionals have realized that even one incident might bankrupt the company due to the lawsuits and claims against the owner. Most importantly, it has been also made clear that no project is worth losing a human life. The other aspect that has been recognized by the professionals is that the projects that are driven by safety are expected to stay on budget and be completed on-time (Cooper, 2001).

Recent reports have proven that a lot has been accomplished in safety improvements. The United States Bureau of Labor Statistics (BLS) releases workplace injury and illness statistics every year. In 2011, the second lowest annual fatality numbers since 1992 were reported since the first census was conducted. It was also reported that the construction fatality and injury and illness rates are declining constantly (Figure 1), however, in spite of all the government, industry and academic efforts, the reality is that nearly 13 workers are killed every day at work places. In addition, although 6% of the US Labor Force is comprised of construction industry workforce, 17% of all work related fatalities are associated with the construction industry (Bureau of Labor Statistics, 2010 Report).

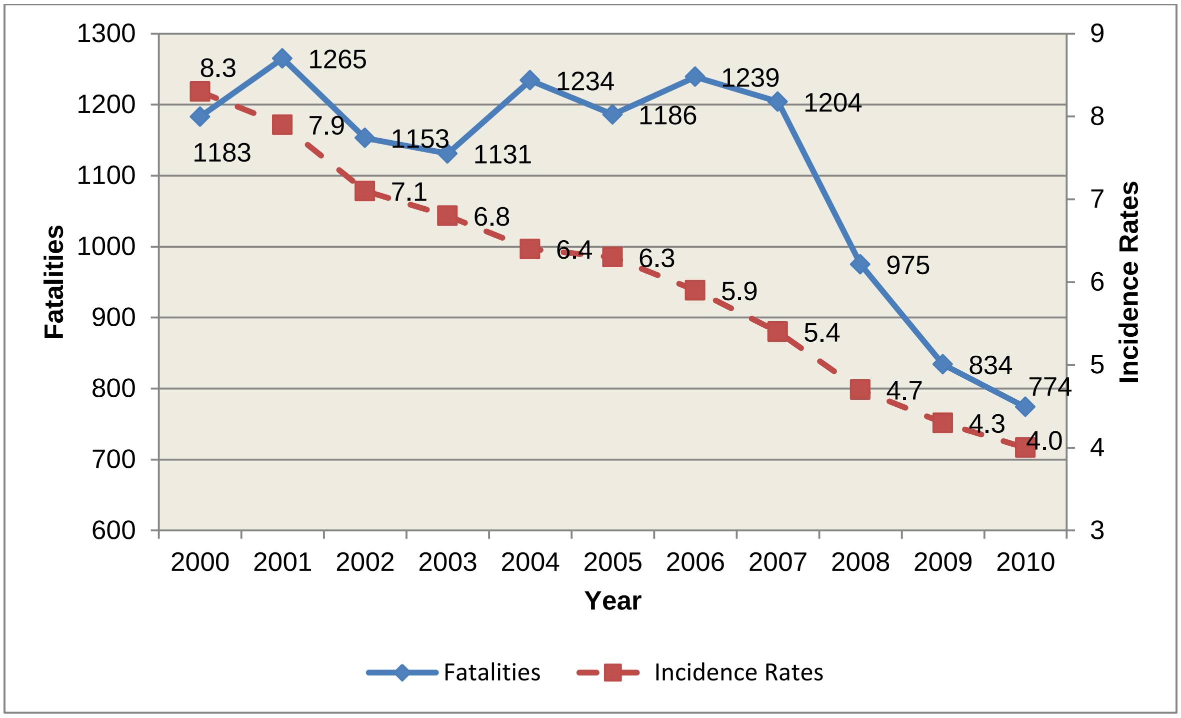


Figure 1: Fatalities and Incidence Rates

Furthermore, the 2010 Occupational Injuries and Illnesses numbers showed that there is a drop in private industry non-fatal incidents, which is 3.5 cases per 100 full time workers, slightly lower than the rates published in 2009 rate of 3.6 cases per 100 workers. However, the same report disclosed that the rate for public sector continues to be higher with 5.7 cases for every 100 workers (BLS Statistics). It is clear that there is a different perception of construction safety between public and private sectors.

Construction industry has its own distinctive characteristics and is prone to accidents as it is labor intensive. The construction operations being so complicated, every job site being unique with its different challenges, adaptation to fast changes in terms of environment as well as structure of the teams involved, difficulties in working in an environment with different contractors, poor definition of roles and responsibilities of the parties that are involved in different phases of design and construction make the construction industry dynamic and exposed to more risk. On top of that, it is a sizeable and diversified industry, which makes it even more difficult to monitor.

Initially, meaning of construction safety needs to be comprehended. It is essential to understand what construction safety is and how it can be measured so it can be improved. Also, challenges with the safety performance measurement systems and what contributes and leads to injuries and illnesses and how they can be identified and eliminated need be grasped. Understanding these elements is the first step to provide a safer place for workers, but this comes with challenges. It is sometimes believed by many professionals that safety is a barrier made up of rules and regulations impeding production and efficiency until someone gets hurt that could have been avoided by following those regulations.

Safety resembles the professional life. We have to invest in it so it can grow into an effective tool. We set goals and in order to achieve them, we plan, organize and work systematically. The same approach applies to safety. Safety culture through training, supervising, inspecting and correcting has to be communicated to the employees, if the ultimate goal of the construction safety, which is defined as “zero fatality and zero injury”, is to be achieved. In his book, Analyzing Safety System Effectiveness, Dan Petersen (1996) defined safety culture as “… unwritten rules of the ballgame that the organization is playing”. He also stated that “The culture of the organization sets the tone for everything in safety”. However, it is not always easy to get people to do things in the safe way. The question that needs to be answered is “what is really important, doing the job safely or quickly?” The truth is workers carry their old habits and behaviors from other experiences and start developing shortcuts and feeling overly confident, which cause unsafe acts, to save time as a trade-off to safety. Hale and Glendon (1987) in their book, Individual Behaviour in the Control of Danger, mentioned that changing the routines that are learned through experience is almost impossible unless they are broken down and reestablished. One may not realize performing a task is wrong until someone advises otherwise.

Heinrich (1931) developed his Domino Theory based on this fact. Injuries are caused by accidents, which are caused by unsafe acts or unsafe conditions, which are actually caused by faults of persons. He estimated that 88% of accidents are either directly caused by unsafe acts or unsafe acts are the main contributor (Heinrich, 1959). Michaud (1995) supported this statement and in his book, Accident Prevention and OSHA Compliance, defined unsafe acts and unsafe conditions and stated that they in fact are interrelated and both are human hazards. In his book, he defined unsafe acts as “a departure from an accepted, normal, or correct procedure or practice which has produced injury or property damage in the past or has the potential for producing such a loss in the future; an unnecessary exposure to a hazard; or conduct that reduces the degree of safety normally present”. Michaud indicated that the majority of the accidents start with the unsafe acts of humans. He also defined in his book unsafe conditions as “any physical state which deviates from that which is acceptable, normal, or correct in terms of its past production or potential future production of personal injury and/or damage to property or things; any physical state which results in a reduction in the degree of safety”. Preziosi (1989) stated unsafe acts one way or other affect accidents and at least 50% of construction accidents are in result of unsafe acts as well as they are conducive to 85% of them. Also, Laitinen (1999) pointed out that unsafe acts and conditions are the two main reasons of accidents. It seems that monitoring unsafe acts and conditions can provide with insights of how safety performance can be improved.

1.2 Problem Statement and Significance

Construction safety is essentially about recognizing the hazards at the job site and eliminating them. As seen from earlier studies, unsafe acts and conditions have significant impacts on accidents and accident causation, which are a representation of poor safety performance. In order to improve construction safety performance, it has to be measured in a certain way. Initially, the meaning of high safety performance needs to be understood. If a company does not have any accidents, can it be considered as a safe company or can one make an assumption that the company with no accidents complies with all rules and regulations? How can one really measure safety performance? It is important to have a useful and reliable safety performance measure that is easy to implement. Hinze and Godfrey (2003) studied the safety performance measures used in the construction industry and evaluated their effectiveness. They outlined the strengths and weaknesses of the project safety measures such as total recordable injuries, lost workday injuries, near misses, inspections, workers behavior, etc. and suggested that recording safety performance at intervals, management involvement and knowing the safety trends can be the most effective ways of performance measurement.

1.3 Proactive and Reactive Safety Performance Measurement Systems

Safety performance measurement techniques have evolved over the years from the measurement of standard injury and illness rates to more refined continuous improvement through on-going monitoring by performing site inspections and implementing lessons learned practices to improve the areas needing more attention. In his book “Safety Metrics: Tools and Techniques for Measuring Safety”, Janicak (2010) pointed out that safety measurement indicators, that are quantitative and qualitative, can be used to control losses, organization assessment and continuous improvement and there are three types of safety indicators; trailing indicators, current indicators and leading indicators.

Trailing indicator is also known as a lagging indicator and measure the past safety performance such as incidence rates and EMR. This method can be considered as a reactive safety performance measurement. Current indicator measures the current safety performance of an on-going project through daily inspections and audits. Leading indicator is the new approach being recognized by the professionals that helps predict future safety performance by identifying employee behaviors through unsafe acts and unsafe conditions and by performing safety sampling. Safety sampling is a technique of performing recurring analysis to observe how safe employees really perform their duties and can be performed by inspections. This method can be considered as a proactive safety performance measurement. There are dissimilarities between these two measurement techniques and Figure 2 illustrates the differences between them.

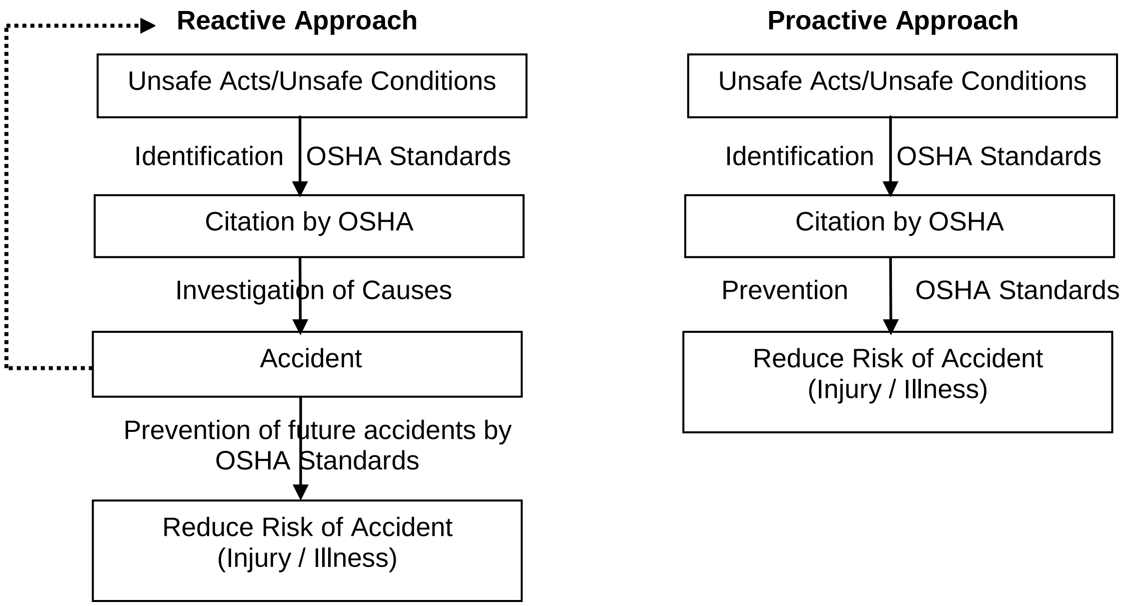


Figure 2: Proactive vs. Reactive Approach

As seen in Figure 2, where the proactive approach is concentrating on accident prevention, the reactive approach is focusing on investigating root causes of an accident or incident. This raises a question that what if there are no accidents or incidents. The general consensus in the industry is that if the company does not have any injuries / illness, it is believed that the company’s safety performance is adequate (Hinze and Godfrey, 2003). What this picture lacks is that the events that lead to incidents do not always cause the incidents. As such, they are really not taken into account as part of the safety measures. The safety measures in the industry are result oriented and disregard the events that contribute to incidents such as unsafe acts or unsafe conditions and are not realized until they result in any kind of loss. This explains the reason why safety measures widely used in the industry are reactive measures and based on post-accident data. The proactive approach based on pre-accident driven data can help in identification of the elements that can lead to future accidents. It can be an essential tool and used as a supplemental measure to lagging performance measures (Mohamed, 1999 and 2003).

Violations can be considered as a proactive approach given the significance that they are not result oriented and employed to caution the contractors and remind them of the safety rules and regulations to furnish a hazard free environment. Recording and analyzing violations can be a preventive measure and an effective instrument. It is believed that violations can lead to accidents but a study of whether violations are associated with safety performance has not been performed. They can be so called outcomes of unsafe acts and unsafe conditions and as demonstrated by earlier studies the main and/or contributing factors to the accidents (Preziosi, 1989; Laitinen, 1999). This is an evolving area for evaluating construction safety performance. This can present new opportunities and needs further development such as analyzing the relationship between the project and company demographics and proactive safety measures and identifying the benefits over the existing system.

In addition to the concerns specified above, the safety measures used in the reactive approach are not site and project specific (representing a microscopic approach), they are only company specific (representing a macroscopic approach). This is illustrated in Figure 3.

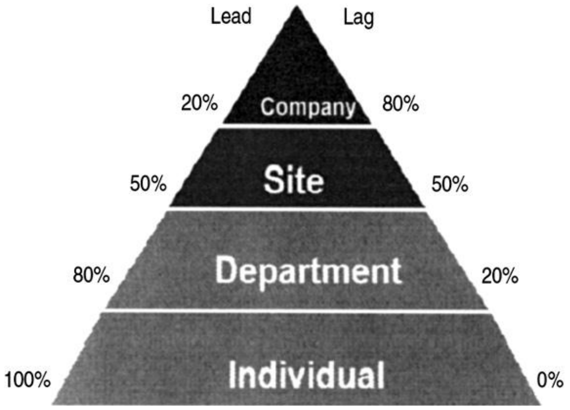


Figure 3: Analysis for Leading (proactive) and Lagging (reactive) Indicators (Bergh, 2003)

Grabowski et al. (2007) explained the differences of leading (proactive) and lagging (reactive) indicators. It was highlighted that leading indicators mainly concentrate on individuals or departments (construction trades) whereas lagging indicators commonly are more concerned about the company measures. Lagging indicators usually lack focus on individuals and do not necessarily reveal the causes of incidents.

Comparison summary of reactive safety measurement system and proactive safety measurement system are shown in Table 1.

Table 1: Reactive Approach and Proactive Approach

Reactive Approach	**Proactive Approach**
Use lagging indicators such as EMR and incidence rates	Use leading indicators such as OSHA Violations caused by unsafe acts and conditions
Macroscopic Approach (Company Specific)	Microscopic Approach (Site / Project Specific)
Post-Accident Driven data	Pre-Accident Driven data
Investigate Causes of Accidents	Accident Prevention

1.5 Rationale of the Study

The reactive safety measures such as EMR and incidence rates are presently employed and widely used to measure safety performance in the construction industry in spite of their shortcomings. The ideology is that they can become more efficient if used in conjunction with a new proactive safety performance evaluation system.

Most of the preceding studies concentrated on EMR and incidence rates to identify the areas of concern that need improvement, and the factors impacting the construction safety performance. They often failed to acknowledge that these measures have shortcomings. Improving safety is one aspect of a research but using a reliable safety measure is as important as conducting a study itself. Using these reactive parameters solely comes with the limitations and need to be well understood while drawing conclusions so as not to mislead an owner while comparing companies' safety performance or making a decision to select a safe contractor, the same holds true for the contractor's own management while self-assessing its safety performance and deficiencies. Few studies examined the limitations and expressed concerns as to how accurate these measures are and whether or not they are used properly (Everett and Thompson, 1995; Hinze, Bren and Piepho, 1995; Hinze and Godfrey, 2003; Hoonaker et al., 2004; Huang and Hinze, 2006). Limitations to these widely used measures are significant given that they may not accurately represent a company's real safety status. Below is a list of some of the disadvantages for both parameters.

1) Disadvantages of EMR;

- Complexity of the formula
- Incomplete reporting

- Injury frequency superseding effects of injury severity
- Dependent on labor wages
- Dependent on company size
- Does not reflect the current safety performance (the most recent year is not used)
- Based on negative aspects of safety performance which in other words means that only injuries / illness are taken into consideration. Safe company is considered as having no incident or as less incidents as possible that would not result in injury or illness. Events that lead to the incident are disregarded or not documented and not accounted for.

2) Disadvantages of Incidence Rates;

- Does not cover the entire construction industry (companies with less than 10 employees are not required to record the accidents)
- Hard to verify what is reported and what is not
- Based on negative aspects of safety performance which in other words means that only injuries / illness are taken into consideration. Safe company is considered as having no incident or as less incidents as possible that would not result in injury or illness. Events that lead to the incident are disregarded or not documented and not accounted for.
- Incidents that do not require medical treatment are not recorded. For instance, workers who are treated in on-site first-aid facilities are not recorded.

These limitations are hard to disregard when the matter is safety. The uncertainties with the highlighted limitations of these measures leave open the question as to whether or not they can be applicable to all construction projects without any restraints. How can one really compare two companies as it relates to construction safety when one is international and the other one is local? How can one really tell whether one’s safety is better than the other one by using these measures while knowing that they have limitations? Or how can one really know just because a company does not have any incidents it is operating in a safe manner? This also raises another concern as to the validity of these measures.

The research suggests that very few studies have measured the safety performance by using proactive approach. Such an approach can provide improvement opportunities in the short-term. In view of the information provided, there is a need for a new and more innovative site specific proactive safety measurement system to fill the gaps of the existing systems in order to identify the areas where there may be opportunities to improve. With the help of this new proactive safety measurement system, a tool also can be developed to better estimate the general contractors’ safety performance for the owners’ use that can contribute to the bid solicitation process and to evaluate general contractors’ safety performance and help improve based on a site specific level.

Additionally, the literature suggests that project level safety performance of specific construction trades has yet to be analyzed. This study can also narrow that gap. In fast changing construction world, comprehending which trades carry the highest risk in terms of safety and impact construction safety performance can lead to development of trade specific safety programs. This may pinpoint hazardous situations and eliminate them before they arise in projects varying different sizes and types. In addition, this can also help safety professionals identify which areas they need to concentrate on to get the most efficient results in terms of improving safety. Baradan and Usmen (2006) investigated the building trades to identify the high risk construction trades from occupational injury and fatality stand point and discovered that roofers and ironworkers are the two trades that are exposed to the most risk. The current study can take it a step further to analyze the construction trades and their ability to affect the overall site safety performance.

1.6 Objectives and Scope

The main objective of this study was to develop a new proactive safety performance evaluation system focusing on evaluating construction safety performance through observed safety violations on construction sites. This new evaluation system, site safety performance value (SSPV), relied on the data from internally recorded construction site observations which were obtained from construction sites (safety sampling) before an accident or incident occurred. This can be considered as a proactive safety performance system since it is based on pre-accident driven data. These observations were documented as project safety status reports and discussed further in the following section. The new metric, SSPV, model was based on Occupational Safety and Health's (OSHA) gravity based penalty (GBP) system which was used to determine penalty amounts for cited violations by OSHA.

Next, this new evaluation system was employed to develop a predictive safety performance model to better estimate the general contractors' safety performance for the owners' use in the procurement phase. This could assist owners to examine past safety performances to predict future contractor behaviors in terms of safety. Huang and Hinze (2006) demonstrated that the good safety performance starts with the owner and the projects in which the owner is more involved in construction safety management have better safety performance. It was found that the owner can positively influence safety performance by vigorously participating in safety during all phases of a project including the procurement phase. In addition, this predictive model was used to evaluate general contractors' site safety performance to assist in determining the level of safety and loss control, and identify the areas of concern.

In conclusion, the relationship between the company and project related factors such as company size, company experience, EMR, incidence rates, original contract amount, change order amount, project type, etc. and proactive metric was analyzed to help better devise strategies for improving construction safety.

Site Safety Performance Value (SSPV): f(P1, P2, ….Pn; C1, C2, ….Cm); where

P= Project related factors, and C= Company related factors.

In light of this information, the main objectives of this study were to:

- Develop a proactive safety performance evaluation system by quantifying site safety (from observed OSHA violations).
- Develop a predictive model to estimate site safety performance of a general contractor by using this new proactive safety evaluation system.
- Investigate correlations between project and company related factors and proactive safety performance system and determine the significant parameters that could help identify the areas of concern.

- Identify where safety performance can be improved by recognizing potential hazards. This study can provide an understanding of the potential hazards cited by the violations and may be used to avoid them by being implemented into a safety program.
- Predict future general contractor safety performance for owners use in procurement phase. It needs to be investigated how reliable experience modification rate, or other insurance data, or contractor incidence rate is in measuring safety performance and what alternate objective measures are available.
- Identify those building trades that affect site safety performance the most which can be utilized as a tool for the owners to determine which components of safety program general contractors are required to implement to improve safety performance.

1.7 Research Questions

This study attempted to answer the following questions:

1. What are the demographics of company and project related factors used in this study?
2. How do the company and project related factors combined predict general contractor's future behavior by using OSHA based penalty system in terms of safety performance?
3. How do the company and project related factors combined predict general contractor's future behavior by using number of proposed violations at a project site in terms of safety performance?

4. What, if any, are there similarities and differences between safety performance measures estimated by the OSHA penalty system and the number of observed violations? Which one is “better”?
5. To what extent do the related factors of a project have an effect on site safety performance?
6. How do performing site inspections affect safety performance?
7. How do the construction trades affect predicting overall construction safety performance?
8. Can EMR and Incidence Rates be used as proactive safety measures?

1.8 Research Approach

In order to create a new proactive safety performance evaluation system, information collected from 2002 through 2007 for a Capital Improvement Program (CIP) was used. The Capital Improvement Program (CIP) program supplied all the necessary data, which was employed as the dependent variables (DVs) and independent variables (IVs) to identify the factors influencing the site safety performance measure in this study. An advantage of drawing data from a program is that programs provide one with many resources, many cases and extensive information from a variety of sources. As opposed to one project, they deal with many projects, and consequently different kinds of information can be acquired.

The steps of this study can be outlined as follows:

1. Perform a state of the art (SOA) review to examine construction safety performance measures currently in use and identify important project and company variables pertaining to construction site safety performance.

2. Determine the independent variables (IVs) and dependent variables (DVs).

3. Formulate and calculate companies' proactive safety performance, SSPV, based on captured safety information (observed violations) in project safety status reports. Use OSHA's gravity based penalty system of determining penalties from citations.

4. Conduct correlation and regression analyses using SSPV and project and company related factors.

5. Draw conclusions and provide recommendations for a system that utilizes proactive safety measurement and evaluation which concentrates on the events that may cause the incidents and is not result oriented.

.

CHAPTER 2 STATE – OF –THE – ART– REVIEW

State-of-the-art review (SOA) was conducted to identify the gaps of the existing safety measurement systems and justify why a new safety evaluation system was needed. Similar studies were included in the SOA review to capture the available information and record how they were organized and analyzed by other researchers. Therefore, this section will cover the following topics:

1. Safety performance measurement / evaluation
2. Safety violations and OSHA's penalty system
3. Review of pertinent construction safety research (Use of safety data / info in statistical analyses)
4. Summary

2.1 Safety Performance Measurement / Evaluation

Safety performance has been a great concern of the construction industry. Previous studies concerning implementation of safety performance systems improvement of safety performance were reviewed and summarized in this section. There are two widely industry used safety performance measures: Experience Modification Rate and Incidence rates.

Experience modification rate (EMR) is company specific and used by insurance companies to calculate the insurance premiums. It is calculated by rating bureaus and is based on company's injury claims for the first three years of the last four years. Although, companies with good EMRs pay less money for workers compensation insurance, there are some pitfalls. Levitt and Samelson, (1993) confirmed that "The complexity of these calculations is a major reason why the original purpose of the experience modification rating – motivating employers to improve their safety performance – has been almost completely lost". They also suggested that it does not really present the current safety performance, since it does not go in effect right away. A recent study revealed that (Hoonakker et al., 2004) the lower the injury and illnesses are, the lower the EMR is, and thus claims are not always reported because of the fact that EMR could get higher. Specifically, small incidents and near misses are not being reported so as to prevent higher insurance rates when employer is willing to pay for the cost of the incident. The study advised not to use current EMR, but to use the tendency of the EMR to see whether it is increasing or decreasing.

Further, Hinze, Bren and Piepho (1995) conducted a research with regard to how EMR values were influenced by: 1) injury frequency and injury severity, 2) labor cost, and 3) company size. They highlighted that EMR is essentially an incentive for employers to improve their safety performance; however, variables in the formula makes it really complex and hard to understand. The study confirmed that injury frequency impacts the EMR more than injury severity does. It was also emphasized that when two companies have identical safety performances, it is possible that the one with higher wages might have a lower EMR. Finally, it was also found that the size of the company is an important factor, and when the company size gets larger, the EMR might go lower, thus may not be a proper safety measure when it is used by itself.

Everett and Thompson (1995) examined the workers compensation insurance (WCI) and how EMR plays a key role in the calculation. The study attempted to explain the complexity of the EMR formula and why it is deviated from its intended purpose. It was indicated that incentives provided for having low EMR rates have been lost in the formula and they also attempted to explain why comparing the safety performance by only using EMR might not be sufficient.

Incidence rates are collected by Occupational Safety & Health Administration (OSHA) and reported annually by Bureau of Labor Statistics. An incidence rate “is the number of recordable injuries and illnesses occurring among a given number of full-time workers (usually 100 fulltime workers) over a given period of time (usually one year)” (OSHA 300 Form Instructions).

$$\text{OSHA Recordable Incidence Tate} = \frac{(Number\ of\ Injuries\ and\ Illnesses \times 200{,}000)}{Employee\ Hours\ Worked}$$

In this formula, number of injuries and illnesses represents the total number of recordable injuries and illnesses and injuries and illnesses that involved days away from work. 200,000 figure represent the number of hours 100 employees working 40 hours per week, 50 weeks per year. (OSHA Form 300 Instructions) However, Hoonakker et al., (2004) identified the weakness of the incidence rates due to the fact that they are driven by the number of injuries and illness. Given the companies with less than 10 employees are not required to record the incidents unless they result in a fatality or the hospitalization of three or more employees (OSHA Rules and Regulations, 1904.1(a)(1)), and seventy nine (79%) percent (See Table 2) of the construction companies in the USA have less than 10 employees (The Construction Chart Book, Fourth Edition, 2007), it is not unmerited to mention that incidence rates are not applicable to the entire construction industry.

Table 2: Number and Percentage of Construction Establishments and Employees by Establishment Size (Construction Chart Book, 2007)

Establishment Size (Number of Employees)	**Number of All Establishments**	**% of all of all Establishments**	**Total Number of Employees**	**% of all Employees**
1 to 9	562,457	79.19%	1,756,859	24.42%
10 to 19	78,917	11.11%	1,046,853	14.55%
20 to 99	60,274	8.49%	2,316,454	32.20%
100 to 499	8,074	1.14%	1,465,900	20.38%
500 or more	585	0.08%	607,004	8.44%
Total	710,307	100.00%	7,193,069	100.00%

Even if all the data collected and reported by the employers are accurate, though it is hard to verify whether each incident occurred reported or not, incidence rates may not be a good representation of the industry's general safety performance. It also must be noted that a majority of smaller companies that experience recordable incidents have high incident rates. Also, the incident rates fluctuate significantly from year to year because of the formula established to calculate the rates. Small number of employees means lower number of man-hours which may translate into high incidence rate. Calculations can be more meaningful at larger companies that have higher man-hours.

With the rising number of owners that are involved in construction safety, the restrictions associated with these safety measures have become so evident. Huang and Hinze (2006) in their study about the owner's role in construction safety discovered that the owners are hesitant to rely solely on EMR and incidence rates while selecting contractors and further evaluate the quality of the safety program and qualifications of the safety team involved in the project. Another downside of EMR and incidence rates are that they are reactive approaches and concentrating on the results of undesirable situations such as accidents, injuries, and fatalities.

Since safety performance is a driving factor for comparing companies throughout the industry, many studies were conducted on this topic. Jaselski, Anderson and Russell (1996) studied the safety performance by employing EMR and recordable incidence rates both at the company and the project level and provided quantitative strategies. It was noted that there are limitations to these measures and suggested that combination of safety measures could provide better results. The study also listed the recommendations for lowering EMR and improving recordable incidence rates. It was found that company factors such as management involvement, number of informal safety inspections, quality of company's safety program, providing safety training for new foreman and safety coordinators and safety expenses were significant at the company level in improving recordable incidence rates. At the project level analysis, the results suggested that project manager with more experience, reduced project turnover, increased number of formal and informal safety inspections, reduced penalties and safety incentives for safe employees help improve the project safety performance. Further, company size and years of experience were investigated and company size was not found significant on construction safety performance.

It is agreed that management plays a significant role in safety performance. Sawacha, Naoum and Fong (1999) identified the fact that management commitment towards safety is the driving factor of construction safety performance at the project level. The study examined the impacts of the historical, economical, psychological, technical, procedural, organizational and the environmental issues and how they contributed to site safety performance (employing Pearson's correlation coefficient and factor analysis). For qualitative responses, the Likert scaling method was used to transform the data into quantitative measures. Based on the findings through this study, the most important measures were: 1) management talk on safety, 2) provision of safety booklets, 3) provision of safety equipment, 4) providing safety environment, and 5) appointing a trained safety representative on site. Similar findings were confirmed in a recent study (Abudayyeh et al., 2006). It was found that safety management could improve safety performance and the quality of the work environment. Safety budget, safety management's knowledge and skills, continuous monitoring and support by using feedback, empowerment and workers and employees involvement in policy making are important factors that help improve the performance. Huang and Hinze (2006) investigated the relationship between the owner and the safety performance and came to the conclusion that the owner, through management involvement in safety, selection of the safe contractors and incorporating safety requirements in the contract influence the safety performance. A multiple linear regression model was used in this study.

Most of the research in the construction research has been conducted by relying on the information acquired from general contractors. However, Hinze and Gambatese (2003) emphasized that those specialty contractors; mechanical and roofing contractor, perform most of the construction activities and studied the factors that influence safety performance of specialty contractors. Findings proved that the size of the company is highly correlated with the injury rates and as the company size increased, the safety performance decreased. The study also pointed out that minimizing turnover, implementing drug testing and worker training increases the safety performance of the specialty contractor while using of safety incentives do not necessarily help reduce accidents; in fact in some cases, it backfires.

Thomas, Cheng and Skitmore (2004) discussed the significance of safety performance evaluation systems at organization and project levels and attempted to develop a framework. In this study, project and organizational levels main and sub factors were identified by exploring the previous safety performance evaluation analyses and a safety performance evaluation model was developed which could facilitate identifying potential hazards before they arise. It was revealed through analyzing mean rankings, mean scores and relative importance that the implementation of management safety system in accordance with legislation and compliance with occupational safety and health legislation, codes and standards are the most significant factors at the organizational level. Further, provision of safe working environment was considered to be the most important factor at the project level.

In the United States, especially with the increasing awareness of construction safety and creating a safer environment for employees, safety performance and how to improve safety performance have become a substantial matter and almost mandatory because of OSHA's rules and regulations, fines of violations and direct and indirect costs of accidents. Noura (2002) investigated construction safety performance in the United Arab Emirates (UAE) which in a sense provided different aspects of safety performance in a non-OSHA regulated safety world. The results suggested that even large companies in the UAE did not consider construction safety a high priority and companies often failed to furnish safe conditions for their employees such as not providing sufficient training and orientation and personal protective equipment most likely due to the lack of a safety organization within the UAE. This is indicative of how important an organization such as OSHA is in improving safety by enforcing rules and regulations. The study also suggested that some accidents were caused by the violations of OSHA standards.

Another study about the influence of corporate culture was reported by Molenaar (2009) that examined the relationship between the corporate culture and safety performance. The study initially defined the safety culture and identified the characteristics which explained the safety culture. Then EMR was used as the safety performance measure and structural equation model (SEM) was used to find the relationships between the variables and whether or not they were correlated to safety performance. It was found that safety commitment, safety incentives, safety accountability and disincentives for unsafe performance were positively correlated with the safety performance which represents that the more management is involved with safety and understands the significance and allocates resources and responsibility with an award system in place, the higher safety performance gets. However, the subcontractor involvement was negatively correlated with safety which may indicate that safety performance can be increased by utilizing the same work force over the years.

It was believed that at the project level some safety programs are better defined which lead to better safety performance than others. Aksorn (2008) studied the effectiveness of safety programs and whether or not they were correlated with safety performance. The study attempted to define safety program effectiveness and established relationships between safety elements and associated safety performance by using accident rates, unsafe acts and unsafe conditions which were used as predicted variables. Examples of unsafe acts can be; improper use of tools, equipment, materials or products, failure to wear personal protective equipment, inattention and lack of awareness, failure to warn hazards, improper lifting or loading, use of drugs or alcohol and so forth and examples of unsafe conditions can be; inadequacy of protective systems such as guards and barriers, inadequacy or deficiencies of tools, equipment, material or products, congestion, concerns within the organizational structure such as inadequate training, hazard identification or communication. The study revealed different results for different safety measures through multiple regression analysis. Based on a reactive approach using accident rate as the target variable, it was discovered that accident investigations, safety inspections, control of subcontractors and application of safety incentives influenced the reduction of accident rates. Based on a proactive approach using unsafe acts and unsafe conditions, it was found that safety inspection, accident investigation, job hazard analysis, safety inductions, safety auditing, establishing safety committee and good recordkeeping were associated with safety performance improvement.

Garza, Hancher and Decker (1998) discovered that safety can be improved better on a project level. In their study, four safety measures; EMR, Recordable incidence rate, lost time incidence rate and Workers Compensation Claim Frequency Indicator were included to analyze the effects on construction safety performance. The findings can be summarized in a way that the companies which keep records of individual project incidence rates are far more superior in terms of safety performance than the companies which do not keep records of individual project incidence rates and only keep company incidence rates. Keeping records of project incidence rates separately enables upper management to evaluate the people involved in projects and address specific concerns at a project level. It was also found that EMR and recordable incidence rates can be affected by the company size and referenced safety indicators should be used jointly as a safety measuring tool.

Kartam (1997) approached safety performance from a different perspective and investigated how safety awareness can be increased by using a computerized safety and health system. He developed a system that can be integrated into a schedule which can outline the safety and health activities including the safety standards and recommendations associated with a particular activity which can inform all parties involved in the process including the designers, owners, estimators, project managers of the possible safety hazards and help them address these concerns and take the necessary precautions to eliminate them before said activity starts. He advised that this proactive method can improve the overall safety performance.

Moreover, Tam (1998) studied the effectiveness of safety management strategies and how they influence safety performance. He found significance by using accident rates between the safety performance and the involvement of top management, safety orientation programs for new workers, safety awards or incentives, use of post-accident investigation systems, safety training, safety committees and level of subcontracting. He proved by employing t-test and multiple linear regression that they reduce the number of site accidents to a certain extent. The most effective factors were outlined as post-accident investigation, training, safety award system and subcontractor percentage.

Safety performance was also analyzed by Findley, et al. (2004) in an effort to identify the key safety program elements. EMR value was used to measure the safety performance. The results showed that hiring a full time safety manager with providing continuous education plays an important role in improving safety performance. Presentation of pre-job briefs, implementation of drug prevention programs and attending conferences to be aware of the latest technology also increased safety performance.

The importance of safety performance as a contractor selection tool has been realized in the last decade. A study conducted by Wong, Holt and Cooper (2000), demonstrated that the owners are increasingly using project specific criteria such as ability to completion on time, safety and health, past experience and experience on similar projects, qualifications of management and site personnel, etc. instead of only relying on the lowest price in contractor selection. It was suggested they are more concerned about getting the best value from contractors and realizing the importance of project specific criteria. The study disclosed that the owners believe that highest value can be attained by focusing on contractors' characteristics ant not merely based on the proposed cost during the bidding process. The results also indicated that there is a strong correlation between public and private sector clients, and different types of construction projects such as building and other construction work, and revealed a need for contractor classification indicator, comprised of project specific criteria, built into contractor selection process based on the project specific criteria.

Fong and Choi (2000) also found a similar trend in contractor selection and identified through analytical hierarchy process that safety performance which is measured by safety awareness, safety precautions, and policy, is one of the eight factors that is employed during the bidding process. It was, however, emphasized that the cost still had the most weight in making a decision.

Furthermore, Hatush and Skitmore (1997) researched the factors used for prequalification and contractor selection in the construction industry and recognized five major criteria affecting decision making: financial soundness, technical ability, managerial capability, safety and health performance. From a safety stand point, EMR and incidence rates, safety management accountability and general safety experience such as dealing with dangerous substances, noise issues, company safety policy, safety record and compliance with safety rules and regulations were considered essential factors during the bidding process. Given the limitations of EMR and incidence rates, a question can be raised as to whether a company will comply with the safety rules and regulations when these values are low. Though, reviewing the company safety procedures can be an effective way and a good indication, it is stated that it is a subjective method and not clear for comparison purposes because it is qualitative. This study quantifies company's ability to comply with OSHA safety rules and regulations and transform it into an efficient tool.

2.2 Violations and OSHA Penalty System

Alper and Karsh (2009) defined the violation as "an action that is contrary to a rule". The basis of violations is that per OSHA, each employer or employee has a responsibility to comply with occupation safety and health standards. Any deviation from this main rule can result in safety violations. Understanding and eliminating violations are intended to motivate employers to take safety measures and correct hazardous conditions. When they are first considered, it might not really be thought that they play an important role in the industry, yet the numbers demonstrate that the majority of the incidents take place due to lack of discipline and because of not following the construction safety rules and regulations (Preziosi, 1989; Laitinen, 1999).

As the economy was booming in early 1900s, the safety was not really considered as a high priority which resulted in more than 14,000 worker deaths, nearly 2.5 million worker disabilities and estimation of 300,000 occupational diseases. With the growing number of medical and disability expenses and lost production and earnings, a need to legislate a system appeared that would protect the workers from safety and health hazards.

The OSH Act was signed to address these concerns by President Nixon on December 2, 1970, and the Act took effect on April 29th 1971. It is the most significant legislation and the biggest step taken related to occupational and health safety in the United States and created the Occupational Safety and Health Administration (OSHA) within the Department of Labor. The mission of OSHA is to enforce the Act to prevent work-related injuries, illnesses, and deaths by establishing occupational safety and health standards, performing inspections, and conducting research.

Since the agency was created, occupational fatalities have been cut by more than 65 percent from 38 fatalities per day to 13 fatalities per day, and injury and illness rates have declined by 67 percent from 10.9 incidents to less than 4 in 2010 per one hundred workers (www.osha.gov). The numbers demonstrate how significant the Agency is and how valuable the service it is providing given the fact that the workforce has doubled over the years. The OSH Act created two other agencies besides OSHA:

1. The Occupational Safety and Health Review Commission (OSHRC) – an independent federal agency created to decide contests of citations or penalties resulting

from OSHA inspections. It publishes (http://www.oshrc.gov/) numerous cases reviewed by OSHA with an emphasis on legal aspects.

2. The National Institute for Occupational Safety and Health (NIOSH) – is a research agency established to help assure safe and healthful working conditions for working men and women by providing research, information, education, and training in the field of occupational safety and health (http://www.cdc.gov/niosh). The main goal of this agency is to conduct research to reduce work related injuries and illnesses. As part of its mission, NIOSH operates programs in every state to improve the health and safety of worker such as the Fatality Assessment and Control Evaluation (FACE) Program, which concentrates on investigations of fatal occupational injuries, to prevent occupational fatalities across the nation by identifying and investigating work situations and to supply access to the full text of hundreds of fatality investigation reports.

It is evident that establishing an agency as known as OSHA has increased safety awareness and promoted safety which resulted in reduction of injuries and illnesses. However, there is still room for improvement as it relates to finding new and innovative ways to establish safer work places.

Since the Act was put in place, 26 states established their own safety agencies and they operate their own plans which were approved by OSHA. To establish a plan, the standards must be at least as effective as the comparable federal standards. In other words, state programs are stricter than federal standards.

The OSH Act also introduced a gravity based penalty system for violations of the OSHA standards announced under authority of OSHA to increase safety awareness and promote safety at site. In this study, OSHA's gravity based penalty system was employed to calculate the values of the dependent variables. OSHA evaluates penalties on the basis of gravity of the violation, size of the company, employer’s history and good faith. Janicak (2010) in his book articulates that Gravity Based Penalty system reflects a better sense of real site conditions because it gives more significance to hazards that are expected to result in injury/illness and those expected to cause serious injury/illness.

OSHA established the gravity based penalty system to encourage the employers to furnish a hazard free work place and not to punish them. In theory, OSHA inspections do not need a reason to happen. Any organization can be visited at any time by an inspector who need not have any reason to appear except the fact that the workplace is covered by federal safety regulations. However, OSHA has only a limited number of compliance officers to conduct site inspections for specific reasons. Therefore, not every site in the United States is evaluated. In contrast to having over 700,000 construction establishments in the United States, the number of inspections is relatively small. Therefore, OSHA has a system in place to efficiently inspect work places by sorting them based on importance and needs assessment. Factors that trigger a site inspection are prioritized as follows: 1) top priority is imminent danger, 2) catastrophes/fatalities or accidents serious enough to hospitalize three or more people, 3) employee complaints, 4) referrals form government agencies 5) Special inspection programs and random inspection programs, 6) Follow-up inspections. As seen in Table 3, the number of OSHA’s inspections has been slightly reduced around 1.2% from 2003 to 2007 (www.osha.gov).

Table 3: OSHA Inspection Statistics from 2003 to 2007 (www.osha.gov)

OSHA Inspection Statistics	FY2003	FY2004	FY2005	FY2006	FY2007	% Change 2003-2007
Total Inspections	39,817	39,167	38,714	38,579	39,324	-1.2%
Total Programmed Inspections	22,436	21,576	21,404	21,506	23,035	2.7%
Total Unprogrammed Inspections	17,381	17,590	17,310	17,073	16,288	-6.3%
Fatality Investigations	1,021	1,060	1,114	1,081	1,043	2.2%
Complaints	7,969	8,062	7,716	7,376	7,055	-11.5%
Referrals	4,472	4,585	4,787	5,019	5,007	12.0%
Other	3,880	3,829	4,807	3,555	3,183	-18.0%

OSHA Field Operations Manual (2009) is a tool providing direction to the compliance officers to make sure all safety and health requirements are met and OSHA safety procedures are followed. Chapter IV of the OSHA Field Operations Manual focuses on the following five types of violations:

Serious: This type of violation has to be proposed when there is a risk that a serious harm or even death could result, and the employer was aware of or should have known of the hazard. The penalty can range up to $7,000 per serious violation.

Other-than-serious (OTS): This type of violation is proposed when the violation has a direct relationship with job safety, but would most probably not cause death or serious injury. Penalties are discretionary, but may range up to $7,000 at Area Director’s discretion.

Willful: This is type of violation is committed when there is a deliberate disregard of the requirements of the Occupational Safety and Health Act and regulations. These violations could carry penalties of $5,000 to $70,000.

Repeat: This type of violation is proposed if an employer has been cited before, and a substantially similar condition is found again upon a following visit. Repeated violation penalties can be up to $70,000. The citations don’t have to be issued at the same worksite. If the violation recurred at any site within the states, OSHA may use two different sites to set up a repeat violation on a single employer.

Failure to Abate: This type of violation is proposed if a prior violation is failed to be corrected. If a prior violation has never been corrected to comply with the regulations, penalties of up to $7,000 per day for each day the violation continues beyond the agreed abatement date.

Chapter VI of OSHA Field Operations Manual (2009) examines the penalties. It explains how the penalty system works, and how violations are assessed and penalties are proposed. It helps to understand how violations are defined and how citation on different types of violations are determined.

A study was conducted by Gleason and Barnum (1978) on the effectiveness of OSHA violations, several years after the passing of the Occupational and Health Act. It examined whether or not they were encouraging employers to take necessary actions to prevent incidents. It was found that there were uncertainties with standards, how employers were cited and how the violations would be classified. Finally, it was suggested that, penalty amounts should be increased, and more inspections should be made in order to make the system more effective. United States Department of Labor issued a memo on April 22, 2010 to make several changes to the penalty system in effect and made some adjustments to the reduction factors and how they were calculated. These enhancements were intended to improve the penalty system and provide a greater deterrent. Before these revision, an average serious violation cost around $1,000 and with the revision in place this amount increased dramatically and expected to go up to average of $3,000 - $4,000 (A memo from United States Department of Labor issued on April 22 2010).

All penalty amounts are proposed amounts along with the citations. The Area Director makes the determination as to what citations, if any will be issued, and what penalties, if any, will be proposed based on OSHA Standards - 29 CFR, Part 1903 Inspections, Citations, and Proposed Penalties. Upon receipt of the cited violations, the employer may contest the penalty amount as well as the citation within 15 days after it is issued. After that, the Occupational Safety and Health Review Commission may negotiate to settle for a reduced penalty amount. In this study, proposed penalties will be considered as the settled penalty amount.

OSHA reveals the 10 most violated standards every fiscal year. Table 4 represents the ten most violated OSHA standards from 2009 through 2012.

Table 4: Number and Ranking of Most Violated OSHA Standards

OSHA Standards		**2009**	**2010**	**2011**	**2012**
Scaffolding	1926.451	9093 (1)	9056 (1)	7069 (2)	3814 (3)
Hazard Communication	1910.1200	6378 (3)	7179 (3)	6538 (3)	4696(2)
Fall Protection	1926.501	6771 (2)	8224 (2)	7139 (1)	7250 (1)
Lockout/Tagout	1910.147	3321 (5)	3756 (6)	3639 (5)	1572 (9)
Respiratory Protection	1910.134	3803 (4)	4224 (4)	3944 (4)	2371 (4)
Machine Guarding	1910.212	2364 (10)	2712 (10)	2728 (10)	2097 (6)
Electrical - Wiring	1910.305	3079 (6)	3628 (7)	3584 (6)	1744 (8)
Power Industrial Trucks	1910.147	2993 (8)	3453 (8)	3432 (7)	1993 (7)
Ladders	1926.1053	3072 (7)	4132(5)	3244 (8)	2310 (5)
Electrical - General	1910.303	2556 (9)	2977 (9)	2863 (9)	1332 (10)

As seen in Table 4, scaffolding, hazard communication, fall protection, lockout / tagout, respiratory protection and ladder standards consistently rank in the top five. This indicates the trend of the violations for the general industry OSHA standards. Moreover, Michigan Occupational Safety and Health Administration (MIOSHA) publishes a similar report every fiscal year to assist in preventing the incidents, and it appears that fall protection-sides and edges, guardrails, head protection, excavation and electrical installation are the most violated standards.

In order to be proactive in accident prevention, OSHA performs site inspections and cites violations and proposes penalties. The citations issued by the compliance officers are usually contested, and the Occupational Safety and Health Review Commission (OSHRC) analyzes and decides whether or not they are valid. In a study conducted by Mohan and Niles (2002), an attempt was made to evaluate the effectiveness of these citations as a deterrent tool in improving safety performance. Considering the fact that each inspected site was found to be given three citations is sufficient evidence to demonstrate how really important this process is. The study also identified that because of the lack of clarity in the OSHA language, the employer might interpret the standards differently than the compliance officer, which can cause problems in the application of the regulations at the job site. As a result, it was discovered the language can be improved and standards can be made easier to follow.

2.3 Review of Pertinent Construction Safety Research

Use of the safety data and how they are utilized in statistical analyses are vital in recognizing the hazards at the sites and understanding the root causes of construction accidents. This helps improve all aspects of construction safety.

Huang and Hinze (2003) investigated the construction worker fall accidents by analyzing a total of 7543 OSHA investigated accidents (data from January 1990 through October 2001). Among these accidents, 2741 were falls, with 2687 falls from an elevation and 54 falls from the same level. The study revealed the trends on the time of fall occurrence, height of falls, injuries resulting from falls, causes of falls and relations between OSHA inspections and falls (using Pearson Correlation and mostly frequency distribution). It was found that two-thirds of the workers involved in falls were killed and July is when the occurrence of the accidents reach peak. Main causes of the accidents were identified as the human errors and inadequate and inappropriate use of fall protection equipment. It was also shown that falls occurred more frequently on certain types of projects, highest with new construction, then renovation, maintenance, and demolition, respectively. As a result, it was suggested that fall prevention must be implemented at all elevations above 6ft.

A more recent study conducted by Hinze, Devenport and Giang (2006) analyzed the construction worker injuries that do not result in lost time. The data were retrieved from a health service provider, which provided a full service occupational medicine system and sustains demographics and injury data of nearly 136,000 injured workers. Data were categorized into sixteen different injury groups and frequency distribution was used. The study documented that lacerations were the most frequent types of injuries followed by lumbar spine, which was also among the most costly. It was indicated that even though lacerations were not really pricey, they still cost a lot of money because of their frequency. As a result, it was concluded that injuries cost money and affect human life whether or not they are serious. It was recommended these injuries can be reduced by implementing specific programs.

Hinze and Russell (1995) conducted a research study and analyzed fatalities recorded by OSHA. Years 1980, 1985, and 1990 were selected with the intention to observe the trend. The study focused on the areas where the number of fatalities and the number of violations were the greatest. It was emphasized that falls were one of the main causes of the fatalities and the reasons of these falls and fatalities were identified. It was proved that special fall protection systems should be put into practice in order to improve the safety performance. As a result, it was recommended that OSHA should use an improved coding system to benefit more from the acquired data associated with injuries and illnesses.

Poon (2000) also analyzed the effectiveness of 14 safety elements in a safety management system and whether or not they can reduce the construction site accident rate in Hong Kong. The study revealed through multiple linear regression method that accident/incident investigation programs, safety inspection programs, accident/incident reporting programs and safety orientation programs combined were significant and explained the accident frequency rate up to 84%.

A different study aimed to analyze the relationship between the observed safety aspects and accident rates was conducted by Laitinen (1999). The safety aspects were considered as employee’s working habits, use of scaffolding and ladders, use of machines and equipment, use protection against falling, lighting and electricity, and housekeeping. The results found a significant relationship between the observed safety index and accident rates. It was observed that the sites with higher safety index had experienced lower accident rates and the sites with lower safety index had experienced higher accident rates. In instances, observation index provided better results than the accident rates. The limitation of this study was that the index was compared to only accident rates which can cause misinterpretation of the data in a way that if the site did not have any accidents, it could be considered as safe.

2.4 Summary

It appears that most of these studies focus on the existing safety measurement systems, identify the shortcomings, and recommend strategies on how to make them more effective. However, they do not study innovative methods and techniques of using proactive approach as opposed to reactive approach safety performance. They also focus on management's point of view and overlook worker's perspective. Information is obtained either through surveys or questionnaires, which might not be reliable because of the fact that they do not have legal obligations. The difficulty with analyzing the data collected from management personnel rather than on-site personnel who would have the first-hand experience is that it does not reflect the current safety state of a construction site and reflect more of management concerns. Therefore, most of these studies represent a macroscopic approach (company related) as opposed to microscopic approach (project related). Another concern with the safety measures mentioned in above research is that they all have limitations and should be used in a controlled environment where advantages and disadvantages can be analyzed together.

In light of the above discussion, this study aims to develop a new proactive safety performance system by using internally recorded observed violations caused by unsafe acts and unsafe conditions prior to injuries and illnesses occur. This proactive safety performance system can be used to assist in building a predictive model to predict contractors’ future safety performance. It also can be used to identify where safety performance can be improved by recognizing potential hazards.

CHAPTER 3 METHODOLOGY

3.1 Data Source and Data Acquisition

The Detroit Public School Program Manager Team (DPSPMT) was selected by DPS in 2000 to act as an extension of the DPS staff, as Owner's representative, so as to plan, oversee and control all aspects of the $1.5 Billion Capital Improvement Program (CIP). The DPSPMT was comprised of six companies that were 56 percent minority owned and 80 percent Detroit based.

The goal of this team was to provide Detroit children a better environment to receive the highest quality education. At the beginning of the program, many problems were encountered. The $1.5 billion bond was not sufficient to meet all the District's needs. Therefore, CIP projects to enhance the learning environment were prioritized by the District with the help of public input and the DPSPMT. However, this triggered another problem for the team. When the program started, most of the projects had yet to be determined, thus some projects, to ensure the on-time completion, were fast-tracked by shortening the duration of the projects by overlapping the design and construction phases. This brought new challenges and was thought that this could increase the risk of possible injuries and accidents at the job sites. Moreover, DPSPMT, not only had built new schools and additions, but also had renovated the existing buildings, which made it more complex to deal with because of different exposures. In an ordinary construction site, only the workers would be the main concern in terms of safety. However, in this program, from Pre-K through 12 grade students, school personnel, visitors, as well as parents had to be considered to create a hazard free environment. To overcome all these obstacles, DPSPMT established a safety and risk management department through an insurance company and implemented a safety policy to ensure all construction sites were hazard free. Three safety professionals with over 20 years of construction safety experience and similar backgrounds were appointed to carry out the inspections which provided uniformity with the way site safety reports were generated. It must be noted that there was no fatality during this program which can be an indication of how successful the safety and risk management department was in terms of providing a safer workplace for all parties involved.

All of the construction sites, where DPSPMT worked on, were inspected randomly on a regular basis in an attempt to identify the liability issues and to make necessary adjustments and to provide a safer environment for all the parties involved. Other objectives of these inspections were to underline unsafe conditions and equipment, focus on unsafe work practices or behavior trends before they lead to injuries, to reveal the need for new safeguards and to promote safety across the capital improvement program. Aksron and Hadikusumo (2002) investigated the effectiveness of safety programs in the construction industry and discovered that safety inspections are the main factor on lowering unsafe acts and unsafe conditions on jobsites which result in safer workplace and a proactive approach to control and prevent hazards.

As a result of these inspections, project status reports were created to capture the safety concerns, to recognize the hazards and to point out the problems encountered at the sites in terms of safety. There are 591 site safety reports in this study, and were used as a basis for this study and employed to compute the values of the selected dependent variables.

Project status safety reports were essentially “snapshots” of the general contractor’s (GC) safety performance for the specified site from the safety and risk management department’s perspective and they were in a narrative form. Each one of them was treated as one single case. Every time a site was inspected, one project status report was created. When the same site was visited again, another project status report was created which resulted in some of the sites having more than one project status report. This was because some of the projects were much larger in terms of size and cost than the other ones.

Throughout the six years of the Capital Improvement Program (CIP), detailed construction documentation such as contracts, construction reports, solicitation documents such as bid packages, bid proposals, pre-bid meeting minutes, etc., submittals, closeout documents, financial reports, schedules and so forth pertaining to all aspects of construction were obtained. Two main characteristics were selected as the variable groups: project related factors and company related factors.

First, variables pertaining to these factors were identified. Many studies were reviewed and analyzed to identify the variables that would contribute to this study. For instance, many researchers (Everett and Thompson, 1995; Hinze, Bren, Piepho, 1995; Molenar, Washington, Park, 2009; Jaselski, Anderson, Russell, 1996; Garza, Hancher, Decker, 1998; Hoonaker, 2004) studied the EMR and incidence rates (employee hours worked previous year, number of lost workday non-fatal cases, number of no lost workday cases or total recordable incidence rates and lost time incidence rate) both separately and together as construction safety measures or to discover whether or not they are reliable measures or to compare the companies’ safety performance and identify the factors improving them. What earlier studies lack though was whether these measures were associated with proactive safety performance measure and influence company’s safety performance at a project level. Therefore, they were incorporated into this study as independent variables. Additionally, company size, firm’s years of experience and peak craft size were analyzed by Jaselski, Anderson, Russel (1996) and yielded significant results in the investigation of safety performance. Many other researchers studied other factors that potentially can influence safety performance, how they are associated with it and made suggestions as to how to improve performance with these parameters. State of the art review shed light on the development of methodology in this study and guided through categorization of the variables utilized in the study. Accordingly, the following variables were listed as the company related factors: size of the company, years of experience in the business, total number of site employees, past incidence records, Experience Modification Rate (EMR) and gender (female to male ratio) and the following variables were listed as the project related factors: duration of the project, number of site employees at site during inspection, contract award amount, change order amount, final contract amount, change factor, type of project and SOC building trades. In this study, 121 projects and 56 companies were used.

These parameters were obtained from a variety of sources. Size of the company, years of experience in the business, total number of site employees, gender ratio, EMR and incidence rates were acquired from bid proposal forms and personnel survey reports. Contract award amount, change order amount, final contract amount, change factor, type of project were located in Program Management Information System (PMIS) database. This was a program management tool used by the Detroit Public Schools Program Manager Team which managed all vendors, properties and related data, controlled budgets and contracts, tracked contracts and change orders by category of work, broke work down into work types, tracked processes, and managed the purchase order and payment process and special cases such as insurance and bond monitoring. Durations of the projects were acquired through scheduling software Primavera Project Planner used by the program. Finally, building trades engaged in the projects were procured from site safety status reports and M.U.S.T (Management and Unions Strive Together) Testing and Drug Alcohol Program documentation, which provided drug and alcohol testing and safety awareness training to the site personnel. Site safety status reports and M.U.S.T reports were also employed to find out crew size and trades at each site visit. Some of these variables were qualitative as opposed to quantitative and they were categorized such as project types and quantified for incorporation in the statistical analyses.

3.2 Data Organization

As mentioned earlier, even though there was one project status report for each site visit, in some cases there was more than one status report for one construction site. This brought new challenges to the examination of the available data. Another issue was that some companies were awarded larger numbers of projects than others within the program. These concerns raised questions as to whether or not the data would be biased due to the fact that some companies experienced more site visits than others which resulted in generation of more site safety reports for some companies. In order to address this issue, prior studies that encountered similar problems (e.g., Laitinen, 1999) were analyzed and the weight factoring method was selected by the analyst to be implemented in the current study. The weighting of variables was made necessary by random sampling.

It is essential to understand the main reasons and principles of weighting method. Sharot (1986) defines weighting as “a multiplying factor applied to some or all of the respondents in a survey”. He also mentioned that it is used to change the relative importance of respondents in analysis. To explain the method better, an example of grading system can be used. For instance, let’s assume in a school system that there are different courses where some grades come from short one-week courses while others represent full-semester courses involving much more study work and more credits. Multiplying each grade by some measure of the course's length and importance such as credits may give a more adequate grade average than simply averaging all grades.

The same approach applies to this study. Project and company related factors where some companies and projects were visited more frequently should be given more weight due to their relative importance within the model. The regression analysis was based on the site safety reports generated by visiting a site and some sites were visited more than once. Therefore, the number of site visits was used as a weighting factor and the project and company related factors were multiplied by the number of site visits. This enabled maintaining integrity of the data and prevented skewness and thus corrected the proportion.

While the site inspections in particular focused on the liability exposure standpoint of the safety issues, they also concentrated on site safety violations.

However, when these violations were documented and recorded, they were completed on a narrative form which did not list the OSHA standard numbers or subparts and they were not sorted by OSHA's Safety and Health Regulations for Construction (Standards – 29 CFR). The safety reports included a general checklist on the first page of each safety report to make it easy to document the violations for the safety professionals. Soon after starting and reviewing the reports, this checklist was found to be not reliable and adequate for the purpose of this study as not all the comments in the narrative section were marked on the checklist. In addition, some important information related to specific conditions was only found in the content of the narrative report. Therefore, the first step was to translate all narrative project status information into a spreadsheet and tabulate observed violations in terms of relevant OSHA standards. Table 5 summarizes OSHA's Safety and Health Regulations for Construction subparts (Standards 29 – CFR). For instance, if there were a hardhat violation at the site, it would fall under Subpart E, Head Protection – 1926.100 and marked on the spreadsheet as such. This task was meticulously performed for every one of the 591 site safety reports. Each safety report form was individually read, analyzed and summarized into an Excel spreadsheet. Columns for all construction subparts were created in the spreadsheet and each observed violation was noted under its relative subpart and OSHA standard based on OSHA Regulations (Standards - 29 CFR). Subsequently, all remarks noted by the safety professionals on these safety reports explaining the special conditions such as any restrictions to the site or the number of people exposed to a specific hazard or if similar hazard was encountered at any other location on site or even short discussions with the employees were also entered into the spreadsheet with Insert Comment command and under a separate column.

The second and most important step was to estimate the possible penalty amounts based on OSHA's gravity based penalty system. Before commencing with the calculations of observed violations, the procedures were required to be well understood. Therefore, it was determined that the best source would be to communicate with the local authorities and in this sense several people from MIOSHA's Lansing office were consulted to understand the penalty process and procedures set out in OSHA Field Operations Manual (2009) better. MIOSHA staff explained how severity and probability assessments are made and important factors taken into account making these assessments. They emphasized the importance of grouping and combining violations and gave real life examples of when violations can be grouped and combined. It must be advised that Chapter 6 of OSHA Field Operations Manual (2009) was used as the main source and guideline when estimating the penalty amounts. In addition, an OSHA violation guideline matrix, which will be discussed in detail later, was generated with the help of safety professionals from industry to determine the classifications of violations and make severity and probability assessments to establish the gravity of the violations.

The third step was to define the reduction factors; size, good faith, history set out in the OSHA's Field Operations Manual and to apply them to the estimated penalty amounts. These parameters were also reviewed and entered into the spreadsheet along with other company and project related information from other previously mentioned sources.

Upon completion of the spreadsheet, the information was refined and reorganized until it was ready to be analyzed and to perform statistical analyses to develop a predictive model to measure site safety performance by using site observations. Figure 4 presents a graphical representation of the formulation of the variables.

Table 5: OSHA's Safety and Health Regulations for Construction

Subpart Name	**Content**	**Standards**
1926 Subpart A.	General	1926.1 to 1926.5.
1926 Subpart B	General Interpretations	1926.10 to 1926.16
1926 Subpart C	General Safety and Health Provisions	1926.20 to 1926.35
1926 Subpart D	Occupational Health and Environmental Controls	1926.50 to 1926.66
1926 Subpart E	Personal Protective and Life Saving Equipment	1926.95 to 1926.107
1926 Subpart F	Fire Protection and Prevention	1926.150 to 1926.159
1926 Subpart G	Signs, Signals, and Barricades	1926.200 to 1926.203
1926 Subpart H	Materials Handling, Storage, Use, and Disposal	1926.250 to 1926.252
1926 Subpart I	Tools to Hand and Power	1926.300 to 1926.307
1926 Subpart J	Welding and Cutting	1926.350 to 1926.35
1926 Subpart K	Electrical	1926.400 to 1926.449
1926 Subpart L	Scaffolds	1926.450 to 1926.454
1926 Subpart M	Fall Protection	1926.500 to 1926.503
1926 Subpart N	Helicopters, Hoists, Elevators, and Conveyors	1926.550 to 1926.556
1926 Subpart O	Motor Vehicles, Mechanized Equipment, and Marine Operations	1926.600 to 1926.606
1926 Subpart P	Excavations	1926.650 to 1926.652
1926 Subpart Q	Concrete and Masonry Construction	1926.700 to1926.706
1926 Subpart R	Steel Erection	1926.750 to 1926.761
1926 Subpart S	Underground Construction, Caissons, Cofferdams, and Compressed Air	1926.800 to 1926.804
1926 Subpart T	Demolition	1926.850 to1926.860
1926 Subpart U	Blasting and the Use of Explosives	1926.900 to 1926.914
1926 Subpart V	Power Transmission and Distribution	1926.950 to 1926.960
1926 Subpart W	Rollover Protective Structures; Overhead Protection	1926.1000 to 1926.1003

1926 Subpart X	Ladders	1926.1050 to 1926.1060
1926 Subpart Y	Commercial Diving Operations	1926.1071 to 1926.1091
1926 Subpart Z	Toxic and Hazardous Substances	1926.1100 to 1926.1152
1926 Subpart CC	Cranes & Derricks in Construction	1926.1400 to 1926.1501

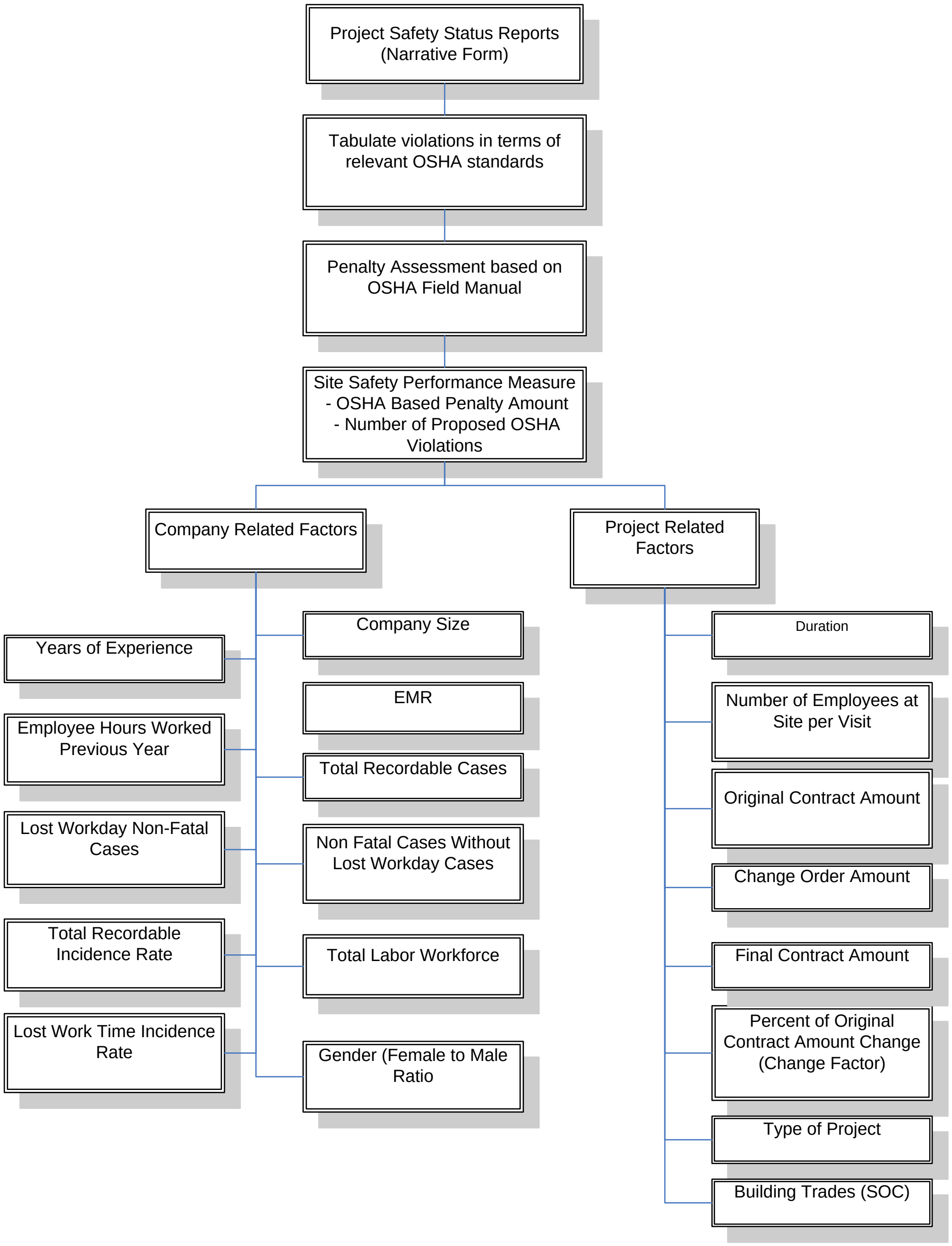


Figure 4: Formulation of Variables

3.2.1 Definition of Variables

This study included several variables that have been used in many studies for decades as reviewed earlier.

3.2.1.1 Dependent Variables (DVs)

1. Site Safety Performance Value by OSHA penalty amounts: This variable is based on the adjusted proposed Penalty dollar amounts through internally recorded site observations. OSHA's Gravity Based Penalty System (GBP) was employed to quantify and assign dollar amounts to the observed violations.
2. Site Safety Performance Value by the number of observed OSHA violations: The number of violations at each site was calculated by counting internally recorded site observations. Each violation, regardless of type, was counted as one.

3.2.1.2 Independent Variables (IVs)

Project Related Factors

1. Duration of the Project (Days): The time between the Notice to Proceed issued by the Owner and issuance of a Substantial Completion of a project. Substantial completion is also known as ready for Occupancy by the Owner.
2. Number of Employees at Site per Visit: Number of Workers performing duties during a site visit.
3. Original Contract Amount: The value of the contract awarded to the general contractor.

4. Change Order Amount: In this study, this variable represents how much change in terms of cost has occurred in between contract award date and substantial completion date. The changes occurred between the substantial completion and final completion (It is the final step of a construction project prior to closing it. All issues are addressed such as punchlist and closeout documents before final completion is issued) were not included as this research concentrated on the construction duration.
5. Final Contract Amount: The value of the contract at final completion of the project.
6. Percent of Original Contract Amount Change (Change Factor): This variable indicates the percentage of changes occurred through change orders. It is calculated by deducting final contract amount from original contract amount divided by original contract amount.
7. Type of Project (Renovation / New / Addition / Demolition): It illustrates the type of construction. It is categorized as renovation, new construction, addition to an existing building and demolition.
8. Building Trades: In this study building trades were categorized by the 2010 Standard Occupational Classifications system (SOC). This system provides uniformity amongst all Federal agencies publishing statistical data, and help classify occupations. The system has advanced over the years and the main purpose is to examine the statistics of each occupation so they can be used for evaluation and enhancement. Construction industry is covered under

Classification Code 47-0000, Construction and Extraction Occupations and Table 6 demonstrates the occupation codes that are associated with construction trades.

Table 6: Construction Trades with SOC Codes

Construction Trades	**Standard Occupational Classification Codes (SOC)**
Boilermakers	47-2010
Brickmasons, blockmasons stonemasons	47-2020
Carpenters	47-2030
Carpet, Floor, and Tile Installers and Finishers	47-2040
Cement Masons, Concrete Finishers, and Terrazzo Workers	47-2050
Construction laborers	47-2060
Construction equipment operators	47-2070
Drywall Installers, Ceiling Tile Installers, and Tapers	47-2080
Electricians	47-2110
Glaziers	47-2120
Insulation workers	47-2130
Painters and Paperhangers	47-2140
Pipelayers, Plumbers, Pipefitters, and Steamfitters	47-2150
Plasterers and Stucco Masons	47-2160
Reinforcing Iron and Rebar Workers	47-2170
Roofers	47-2180
Sheetmetal Workers	47-2210
Structural Iron and Steel Workers	47-2220
Solar Photovoltaic Installers	47-2230

Not all these trades were applicable to this study because of the trades noted on the site safety status reports. Trades that were mentioned in the MUST sheets and safety reports were as follows:

1. Brickmasons, blockmasons and stonemasons
2. Tilesetters and marble setters
3. Carpet, floor, and tile installers and finishers
4. Carpenters
5. Cement masons, concrete finishers, and terrazzo workers
6. Construction equipment operators
7. Drywall installers, ceiling tile installers, and tapers
8. Electricians
9. Insulation workers
10. Glaziers
11. Painters and paperhangers
12. Pipelayers, plumbers, pipefitters, and steamfitters
13. Plasterers and stucco masons
14. Roofers
15. Sheet metal workers
16. Ironworkers (Structural and reinforcing iron and metal workers)

Company Related Factors

1. Company Size: The dollar value of company’s revenue for the previous year. It is company’s annual revenue reported at the end of its fiscal year.
2. Years of Experience in Business: The time between the establishment of a company and the year of the project the company is awarded.

3. EMR: Experience Modification Rate: It is a widely used in construction industry a safety measure and used by insurance companies to calculate the insurance premiums.
4. Employee Hours Worked Previous Year: It is the total number of hours including overtime of company’s full-time employees and number of regular hours worked by non-full-time employees worked previous year. Part time, seasonal and temporary workers are considered as non-full time. It excludes any type of non work time such as holiday, vacation and sick leave (United States Bureau of Labor Statistics).
5. Lost Workday Non-Fatal Cases: Cases resulting in days away from work, or a combination of days away from work and days of restricted work activity (United States Bureau of Labor Statistics Glossary).
6. Non-Fatal Cases Without Lost Workday Cases: Cases resulting in no lost days away from work.
7. Total Recordable Cases: The total of Lost Workday Non-Fatal Cases and Non-Fatal Cases without Lost Workday Cases.
8. Company Labor Workforce: The total Labor Workforce Employed by the Company.
9. Total Recordable Incidence Rate: It is a rate calculated based on the total number of recordable injuries and illnesses occurring for 100 full time workers per year.

10. Lost Work Time Incidence Rate: It is a rate calculated based on the total number of lost work time injuries and illnesses occurring for 100 full time workers per year.
11. Gender (Female to Male Ratio): It is the number and proportion of males for each female in a company. It is calculated by dividing the number of males to number of females.

3.3 Data Preparation

3.3.1 Development of Site Safety Performance Value (SSPV)

3.3.1.1 OSHA Penalty System

OSHA has established a safety system as an incentive for the companies to ensure safety rules and regulations are followed. The purpose of the OSHA penalty system is in fact not to punish companies but more like to bring them up to required safety standards to comply with the OSHA’s rules and regulations and provide a safer work place.

The maximum penalty amount established by OSHA is $70,000 for each willful or repeated violation and $7,000 for each serious or other-than-serious violation as well as $7,000 for each day after a stated abatement date for not addressing a violation. To enforce the regulations and set deterrent effect, a minimum penalty of $5,000 for a willful violation has been implemented. When the adjusted proposed penalty is less than $100 for an other-than-serious violation, no penalty is given. The minimum penalty amount for serious violations was established as $500. If the adjusted proposed penalty amount is less than $500, the $500 penalty is proposed. Also, the proposed penalty for posting violation is $1,000 and the minimum cannot be less than $250.

Penalties are assessed based on the gravity (combining the severity assessment and the probability assessment) of the violation, and the size, good faith and history of the employer. Essentially, gravity controls the base amount, and the other factors determine the reductions. To determine the gravity of a violation, two factors are taken into account: 1) The severity of the injury or illness as a result of a violation, 2) The probability that an injury or illness can happen due to a violation.

A severity assessment is assigned to a hazard and is significant while determining the gravity. It can be categorized as follows: a) High Severity: death from injury or illness; injuries involving permanent disability; or chronic, irreversible illness; b) Medium Severity: Injuries or temporary illnesses resulting in hospitalization, but limited period of disability; and c) Low Severity: Injuries or temporary illnesses not resulting in hospitalization.

The probability has no impact on determining the classification of a violation but affects the amount of the penalty to be proposed. There are two types. 1) Greater probability: when a chance of an injury or illness will occur is high. 2) Lesser probability: when a chance of an injury or illness will occur is relatively low. It should be noted that the number of workers exposed, frequency and duration of employee exposure to the hazard, and working conditions are some of the aspects taken into account to determine the likelihood of the violation:

In light of the given information, gravity based penalties (GBP) for serious violations are assessed based on Table 7.

Table 7: Serious Violation Penalty Table

Severity	**Probability**	**GBP**	**Gravity**
High	Greater	$7,000	High
Medium	Greater	$6,000	Moderate
Low	Greater	$5,000	Moderate
High	Lesser	$5,000	Moderate
Medium	Lesser	$4,000	Moderate
Low	Lesser	$3,000	Low

There is no severity assessment taken into consideration for other-than-serious (OTS) violations. Table 8 represents the penalty amounts for these violations.

Table 8: Other-Than-Serious (OTS) Penalty Table

Probability	**Severity**	**GBP**
Greater	Minimal	$1,000 - $7,000
Lesser	Minimal	$0

If an OTS violation is proposed which has a low probability of resulting in an injury or illness, there is no penalty proposed. (For instance, scaffold with improper planking in an area where nobody works. Employees not normally exposed, but may come in close proximity to the hazard on an infrequent basis). On the other hand, if the violation has a greater probability of resulting in an injury or illness, then a base penalty of $1,000 is applied (Example: Continuous noise exposure; employees exposed daily on a continuous basis; no hearing conservation program; no personal protective equipment). Combined or grouped violations are considered as one violation and assessed as one GBP. The severity and the probability assessments for combined violations are based on the case with the highest gravity.

Penalty Reduction Factors

OSHA has established a penalty reduction system to provide companies with an incentive in order to evaluate all companies fairly, regardless of their experience or size, and in the same level depending on the number of employees, good faith and previous violations. A memo from United States Department of Labor issued on April 22 2010 made several changes to the reduction amounts in effect and how they were calculated. These enhancements were intended to improve the penalty system and to provide a greater deterrent. There are evidently certain limitations to the reduction factors; penalties considered to be repeated can only be reduced for size, penalties considered to be willful and serious high gravity (high severity and high probability) can only be reduced for size and history.

Once gravity based penalties are proposed for the violations, penalty adjustment factors which are size, good faith, history could be applied. Size reduction is based on the number employees and demonstrated in Table 9.

Table 9: Size Reduction Table (based on April 22, 2010 Memo)

Employees	**Percent reduction**
1-25	40
26-100	30
101-250	10
251 or more	None

Good faith reduction is based on the employer’s safety and health management system and whether it is written and how well it is implemented and used to be as much as 35%. The memo issued on April 22, 2010 also made some changes to the good faith reduction and reduced it down to 15% and eliminated partnership program. Additional 15% for quick fix was also retained.

In this study, each company was given a 15% reduction because all contractors that participated in the capital improvement program were mandated to have a written safety program approved by the Safety and Risk Management Department.

The last reduction, which might adjust the proposed penalty, is history reduction and 10% is given to employers who have not been cited for any serious, willful, or repeat violations within the past five years (changed from three years after the issuance of the 2010 memo). OSHA’s web site was used to research whether or not companies involved in the program had prior violations and 10% reduction was applied to those with no prior violations. The memo added a new element of 10% history increase into the penalty structure for companies which have been given any high gravity serious, willful, repeat, or failure to abate violations within the past five years. As a result, the companies with prior violations were given 10% increase in their penalty amounts.

Gravity based penalty used to be reduced by as much as 95% depending on size, good faith, and history of the employer. Before, reduction percentages were summed up and applied to the proposed penalty amounts at once. With the issuance of the 2010 memo, reduction percentages were changed to be serially applied as follows: History, Good Faith, and size. There are certain limitations applicable to these reductions.

1. High gravity penalties are only adjusted for size and history.
2. Penalties that are considered as repeated are only adjusted for size and good faith.

3. Penalties that considered as willful are only adjusted for size and history. (If one violation is willful, then none of the violations found during the same inspection can be adjusted for good faith)

In present study, only serious and other than serious violations were recorded in the safety report as the safety professionals who inspected the sites did not report any willful violations. Besides, repeat and failure to abate violations were not applicable to this study. The purpose of inspections made during the program was to point out the exposures that the program management team could have been held liable for. Therefore, project status reports recorded during these site visits were utilized for internal purposes and they were not reported to official agencies.

3.3.1.2 OSHA Violation Guideline Matrix

As mentioned earlier, any deviation from OSHA's safety and health standards can set basis for safety violations. Based on the understanding of the OSHA Gravity Based Penalty System, all construction site specific safety reports, which were in narrative format, were reviewed, studied, and translated into all pertinent project information into a spreadsheet and observed violations were tabulated based on OSHA standards.

Subsequently, an OSHA violation guideline matrix was generated based on this approach with the help of experienced safety professionals (See Table 10). A total 11 safety professionals from the industry who have had over 15 years of construction safety experience, were contacted. They were individually consulted on how to best interpret the raw data so it can be transformed in decisions regarding probability and severity. They were selected because of their industry experience as well as their experience with OSHA standards and violations. 3 of these 11 safety professionals generated all the site safety reports used in this study. All professionals included have been involved in all aspects of construction and have worked in variety of construction projects such as hospitals, schools, airports, highways, detention facilities and so forth. Assuming different responsibilities such as Owner's Representative, Construction Manager, General Contractors and so forth, were beneficial to understand their perception of risk assessment.

They were provided with the 116 observed safety violations that were identified based on OSHA standards and inquired to answer several questions as it relates to determining the classification of violations and make severity and probability assessments to establish the gravity of the violations. Definitions of severity and probability as it is explained in the OSHA Field Manual were provided to the safety professionals. Severity was used to determine if death or serious harm could result from an accident and probability was used to calculate the likelihood that an injury or illness could occur due to the proposed violation. Probability was not used if a violation was serious, but used to determine the gravity. Based on the consistency of the answers provided, it was verified that the safety professionals had strong insights and a complete understanding of how OSHA's gravity based penalty system worked.

The first step was to agree on the classification of the proposed violation as serious or other than serious based on the severity assessment. The safety professionals were asked whether or not death or serious physical harm could result from an accident/incident which may be caused by the observed violation. Classification was made based on the type of hazardous exposures, type of injury or illness, potential death or serious harm, (Amputations, concussion, crushing, fractures, burns, cuts, sprains, etc.) and employer's knowledge of hazardous condition. Serious category was selected when there was substantial probability that death or serious physical harm could result from the potential injury or illness. In contrast, other than serious category was selected when potential injury or illness was not believed to cause death or serious physical harm, but would have a direct relationship to safety.

Upon selection of the classification, if an observed violation was considered to be serious, severity class was defined. Safety professionals were asked to answer what kind of an injury or illness could result from an accident / incident which may be caused by the alleged violations. It was categorized as high severity, when death from injury or illness; injuries involving permanent disability; or chronic irreversible illness could occur due to the observed violation. It was categorized as medium severity, when injuries or temporary reversible illness resulting in hospitalization or a variable but a limited period of disability was believed to occur due to the proposed violation. Last, it was categorized as low severity, when injuries or temporary reversible illness not resulting in hospitalization and requiring only minor supportive treatment could occur due to observed violation.

Finally, the safety professionals were asked to provide their assessment of the likelihood of injury/illness. Probability assessment was completed whether the classification of an observed violation was serious or other than serious based on the number of employees exposed, frequency of exposure or duration of employee over exposure, employee proximity and use of personal protective equipment. It was categorized as greater or lesser depending on the likelihood of an injury or illness occurring. Greater probability was selected when the likelihood of an injury or illness occurring was deemed to be high, and lesser probability was chosen when the likelihood of an injury or illness occurring was deemed to be low.

All answers were reviewed and used to generate the OSHA violation matrix table. This table was used as a general guideline in order to determine the types of violations and severity and probability for the observed violations noted on the site safety status reports. However, each report and violation was reviewed case by case and final decision was made based on the comments noted on each site safety report. In other words, a violation which could have been considered as a serious violation could have been logged in as other than serious based on the circumstances indicated on the site safety status report.

Table 10: OSHA Violation Guideline Matrix

OSHA VIOLATIONS		**SERIOUS**					**OTHER THAN SERIOUS**	
		Severity			**Probability**		**Probability**	
		High	**Medium**	**Low**	**Greater**	**Lesser**	**Greater**	**Lesser**
Posting Requirements 1903.2								
1	OSHA and safety posters are not being displayed. 1903.2						x	
Occupational Health and Environmental Controls 1926.50								
1	Emergency medical numbers are not posted and First-Aid Kit is not available. 1926.50			x	x			
General Safety and Health Provisions 1926.21								
1	Safety training or orientation is not provided. 1926.21(b)(2)		x		x			
2	There is not enough ventilation, lighting, or monitoring. Air sampling is not done. 1926.21(b)(6)	x			x			
Housekeeping – 1926.25								
1	Worksite is not clean or free of construction debris. 1926.25(a)			x	x			

OSHA VIOLATIONS		SERIOUS					OTHER THAN SERIOUS	
		Severity			Probability		Probability	
		High	Medium	Low	Greater	Lesser	Greater	Lesser
2	Scrap materials are not removed or stacked in orderly fashion. 1926.25(b)						x	
3	Refuse containers are not adequate or in use. 1926.25 (c)						x	
Illumination – 1926.56								
1	Lighting is not adequate in work areas. 1926.56			X	x			
Fire Protection – 1926.150-154								
1	Fire extinguishers are not in place or adequately charged. 1926.150 (a) (3 and 4)			x	X			
2	Fire fighting equipment is not accessible or clear at all times.1926.150 (a)(2)		X		x			
3	“No Smoking” or “Flammable” signs are not posted at storage and fueling locations. (They are not clearly identified.) 1926.151(a)(3)							x
4	Portable heaters are not being used in accordance with specs. (Direct fire) and/or ventilation is not adequate. 1926.154(a) and (b)		x			x		
5	Portable tanks are nearer than 20ft from any building. 1926.152 (c)(4)			x		x		
6	Fuel tanks and propane tanks are not protected from damage. (from vehicular traffic). 1926.153 (a)		x			x		
7	Flammable or combustible liquids are stored in areas used for exits on stairways. 1926.152(a)(2)			x	x			
Means of Egress – 1926.34								
1	Exits are not clearly marked and/or evacuation plans are not posted. 1926.34(b)			x	x			
2	Egress is not continually maintained free of all obstructions. 1926.34 (c)		x		x			
Electrical – 1926.400-407, 416, 417								
1	Live parts of electric equipment operating at 50 volts or more are not guarded against accidental contact by cabinets or other forms of enclosures. 1926.403(i)(2)(i) or 1910.303(g)(2)(i)		x		x			

OSHA VIOLATIONS		SERIOUS					OTHER THAN SERIOUS	
		Severity			Probability		Probability	
		High	Medium	Low	Greater	Lesser	Greater	Lesser
2	Electrical equipment (distribution boxes, electric panels and devices) are not marked. 1926.403(g)			x		x		
3	Improper grounding of equipment and circuitry. 1926.404(b)(1)		x		x			
4	Electrical circuits are not properly identified. 1926.417(b)						x	
5	Flexible cords are not connected to devices and fittings so that strain relief is provided which will prevent pull from being directly transmitted to joints or terminal screws. 1926.405(g)(2)(ii)			x	x			
6	Sufficient access and working space are not provided and maintained about all electric equipment.1926.403(i)(1)			x		x		
7	Corded and plugged equipment used in wet locations.1926.404(f)(7)	x				x		
8	Work areas are not kept clear of cords.1926.416(b)(2)						x	
9	Inadequate or improper temporary wiring. 1926.405(a)(2)(ii)			x	x			
Hand and Power Tools – 1926.300-307								
1	Hand tools are not maintained and damaged/or broken. 1926.301(a)			x	x			
2	Electric power tools are not double insulated or grounded. 1926.302(a)		x			x		
3	Hand held powered tools are not equipped with constant pressure switch where appropriate. 1926.300(d)(3)			x		x		
4	Tools are not maintained in secure and safe condition. 1926.300(a)						x	
5	Air compressors are not equipped with functioning pressure gages.1926.306(b)(3)		x			x		
6	Power tools designed to accommodate guards are not equipped with guards and guards are not adequate.1926.300(b)(2)		x			x		
Fall Protection – 1926.500, 501, 502								

OSHA VIOLATIONS		SERIOUS					OTHER THAN SERIOUS	
		Severity			Probability		Probability	
		High	Medium	Low	Greater	Lesser	Greater	Lesser
1	Employees working above 6 feet (1.8 m) or more with an unprotected side or edge or leading edge or on roof are not protected from falling by guardrail systems, safety net systems, or personal fall arrest systems. 1926.501(b)(1), (2), (10).	x			x			
2	Floor openings, holes are not covered, secured or guarded. 1926.501(b)(4)	x			x			
3	Wall openings less than 39 inches off the floor and greater than six feet from any lower surface are not protected by a guardrail or safety net system. 1926.501(b)(14).	x			x			
4	Employees working down below other employees are not protected. (Toeboards, canopies, etc.) Toe boards are not properly installed. (Should be min 3.5 inches) 1926.502(j)(1,2 and 3)		x			x		
5	Guardrail is not properly installed. (Should be 42” high -/+ 3” high) 1926.502(b)(1) and/or is not capable of withstanding a force of at least 200 pounds. 1926.502(b)(3)	x			x			
6	Personal fall arrest systems are not in good condition and/or the anchorages used do not capable of supporting at least 5,000 pounds per employee. 1926.502(d)	x			x			
7	Midrails, screens, mesh are not installed between the top edge of the guardrail system or the walking/working surface when there is no wall at least 21 inches high. 1926.502(b)(2)	x				x		
Scaffolding and Lifts – 1926.450 - 453								
1	Scaffold components are not visibly free of any physical damage. 1926.451(f)(3).		x		x			
2	Supported scaffold is not properly erected on a firm surface with all pins and braces in place and locked. 1926.451 (c)(1,2)	x			x			

OSHA VIOLATIONS		SERIOUS					OTHER THAN SERIOUS	
		Severity			Probability		Probability	
		High	Medium	Low	Greater	Lesser	Greater	Lesser
3	Wheels are not locked when scaffold is in use. 1926.451(d)(16)		x			x		
4	Standard guard railing is not installed on scaffolds over 10 ft including ends, work platforms & walkways. 1926.451(g)(1)	x			x			
5	Footing and anchors are not sound and capable of carrying 4 times the max intended load without settling. 1926.451(a)(1)	x				x		
6	Working surface is not fully planked and secured. 1926.451(b)(1)		x		x			
7	Planks are not overlapping minimum 6” and maximum 12”. 1926.451(b)(4a and 5)			x		x		
8	There is no means of access to the scaffold. 1926.451 (e)(1)			x	x			
9	Toe boards are not installed or not installed properly. 1926.451(h)(4)		x		x			
10	Top and mid rails are not properly installed. 1926.451(g)(4)(ii and iii)		x		x			
11	Scaffold is not free of debris. 1926.451(f)(13)			x	x			
12	Person in lift basket is not wearing fall prevention or protection equipment. 1926.453(b)(2)(v)		x			x		
13	Lift is not positioned on solid and level ground.1926.453(b)(2)(vii)		x			x		
Ladders & Stairways – 1926.1053 (Ladders), 1926.1052 (Stairways)								
1	Ladders are not in good condition or right ladders are not being used. (Missing rungs, etc.) 1926.1053(b)(16) and/or not used for elevation changes of 19 inches or more.1926.1051(a)		x		x			
2	Ladders are not properly constructed 1926.1053(a)(2).			x		x		
3	Side rails of ladders do not extend 3 feet above landing and/or not secured at top.1926.1053(b)(1)		x		x			
4	Fixed and portable ladder rungs are not uniformly spaced 10” – 14” apart. 1926.1053(a)(3)(i)							x

OSHA VIOLATIONS		SERIOUS					OTHER THAN SERIOUS	
		Severity			Probability		Probability	
		High	Medium	Low	Greater	Lesser	Greater	Lesser
5	Non-conductive ladders are not being used around live wiring. 1926.1053(b)(12)		x		x			
6	Ladders and stairwells are not free of slipping hazards. 1926.1053(b)(2)			x	x			
7	Stairs that have 4 or more steps or rising more than 30” do not have handrails. Stair treads do not comply with the standards. 1926.1052 (c)(1)		x			x		
8	Stairrails are not at least 36 inches (91.5 cm) tall from the upper surface of the stairrail system to the surface of the tread. 1926.1052 (c)(3)(i)			x		x		
9	Ladder is not resting on a firm or substantial surface. 1926.1053(b)(6)			x	x			
Welding & Cutting – 1926.350-354								
1	Gauges, valves, torches & lines are not in good condition. They are not free of oil or grease. 1926.350(i)			x		x		
2	Compressed cylinders are not stored secured upright at all times except transportation. 1926.350(a)(9) Cylinders are damaged or defective. 1926.350(c)(3)		x			x		
3	Oxygen is not stored separate from acetylene and all flammables by 20’. 1926.350(a)(10)		x		x			
4	There are no fire extinguishers near welding and cutting areas. 1926.352(d)			x		x		
5	Ventilation is not adequate. 1926.353(c)(1)		x		x			
6	Arc welding is not properly grounded. 1926.351 (c)		x			x		
7	Parts of arc welding outfits are not properly insulated. 1926.351(b)(1)			x		x		
Personal Protective Equipment – 1926.95, 100-107								
1	Hard hats are not worn at all times. 1926.100(a)		x		x			
2	Eye and face protection is not in place when required. 1926.102(a)	x			x			

OSHA VIOLATIONS		SERIOUS					OTHER THAN SERIOUS	
		Severity			Probability		Probability	
		High	Medium	Low	Greater	Lesser	Greater	Lesser
3	Hearing protection is not used in areas of moderate, extreme or long term noise. 1926.101(a)		x		x			
4	Respiratory protection is not used when condition requires. 1926.103 same as 1910.134		x		x			
5	Employees are not using gloves when handling sharp objects. 1926.28(a)		x		x			
6	Safety harness, lifelines or shock absorbing lanyards are not available or do not meet the requirements. 1926.104	x			x			
Signs, Signals, and Barricades – 1926.200-203								
1	Direction signs are not used to inform the public. Danger and caution signs are not in place. 1926.200 (b and c)						x	
2	Traffic signs are not posted at points of hazard. 1925.200 (g)(1)		x			x		
5	Open excavation, road drop offs, manholes, uneven surfaces are not barricaded. 1926.200 and 202		x		x			
6	There are no exits signs over doors in buildings. 1926.200(d)			x	x			
Materials Handling, Storage, Use, and Disposal – 1926.250-251								
1	Material inside buildings under construction is not stored properly. (Should be at least 6 feet away from any hoistway or inside floor openings and 10 feet away from an unfinished exterior wall.) 1926.250(b)(1)			x	x			
2	Brick stacks are more than 7 feet in height. 1926.250(b)(6)		x			x		
3	Rigging equipment for material handling is not inspected prior to each use. 1926.251(a)(1)		x		x			
4	Rigging equipment is loaded in excess of its recommended safe working load. 1926.251(a)(2)(ii)		x		x			
Excavations – 1926.651								
1	Underground utilities are not located or marked. 1926.651 (b)		x		x			
2	Trenches 5' or more depth are not shored, shielded or have sides sloped. 1926.652(a)(1)(ii)	x			x			

OSHA VIOLATIONS		SERIOUS					OTHER THAN SERIOUS	
		Severity			Probability		Probability	
		High	Medium	Low	Greater	Lesser	Greater	Lesser
3	Trenches 4’ and greater are not provided with stairways, ladders or other means of egress. 1926.651(c)(2)		x		x			
4	Excavated material or spoils is not placed at least 2’ from the edge. 1926.651(j)(2)			x	x			
5	Employees are not protected from falling material. 1926.621(j)		x		x			
6	Ventilation is not adequate. 1926. 651(g)(1)	x				x		
7	Daily inspection of excavation and adjacent areas by a competent person is not done. 1926.651(k)		x			x		
Cranes and Derricks - 1926.1501 (New Standard Number issued on Aug 9, 2010)								
1	Power lines distance from machines is less than 10’. 1926.1501(a)(15)	x			x			
2	Competent person is not making daily inspections or tests.1926.1501(a)(5)		x		x			
3	Workers are not clear of crane swinging loads. 1926.1501(a)(9)		x			x		
Hoists, Elevators, and Conveyors 1926.550								
1	Inspection and test of all functions and safety devices are not made. 1926.552(c)(15)			x		x		
2	Employees are riding on material hoists except for the purposes of inspection and maintenance. 1926.552(b)(1)(ii)			x	x			
Motor Vehicles – 1926.601								
1	Haul road is not adequate or maintained. 1926.602(a)(3)(i)							x
2	Horns or backup alarms are not functioning. Vehicles with an obstructed rear view are not equipped with an operable back-up alarm or used only with an observer. 1926.602(a)(9)		x		x			
3	Operators are not trained or authorized to operate. (1910.178)	x				x		
4	Parked or unattended equipment's blade, forks or bucket are not lowered to ground or blocked. 1926.600(a)(3)(i)			x		x		

OSHA VIOLATIONS		SERIOUS					OTHER THAN SERIOUS	
		Severity			Probability		Probability	
		High	Medium	Low	Greater	Lesser	Greater	Lesser
5	Forklift truck does not have overhead guard. 1926.602(a)(6) also Subpart W		x			x		
6	Vehicles do not have seat belts or they are not used. 1926.602(a)(2)		x		x			
Toxic and Hazardous Substances – 1926.1100-1152								
1	MSDS are not on hand or recorded. 1910.1200(g)(8) and (1)			x	x			
2	Containers are not properly labeled or insufficient labeling. 1900.1200(b)(3) and for asbestos 1926.1101(k)(8)			x	x			
3	Employees are not properly trained or the training is inadequate. 1910.1200(h)(1) and for asbestos 1926.1101(k)(9)		x		x			
4	Hazcom signs are not in place. Lack of identification. 1910.1200(f) and for asbestos 1926.1101(k)(7)		x			x		
5	Asbestos waste, containers and equipment are not properly disposed of. 1926.1101(l)(2)		x		x			
6	There are chemical spills that might cause an accident.1910.1200(b)(4)		x		x			
Concrete & Masonry – 1926.701-706								
1	Masonry walls over 8' in height adequately are not braced to prevent overturning and to prevent collapse. 1926.706(b)	x				x		
2	Formwork designed, fabricated, erected do not support vertical or lateral loads. 1926.703(a)(1)	x			x			
3	Limited Access Zone is not established. 1926.706(a)		x			x		
4	Protruding reinforcing steel, onto and into which employees could fall, is not guarded to eliminate the hazard of impalement. 1926.701(b)		x			x		
Steel Erection - 1926.752, 760								
1	Employees engaged in a steel erection activity on a walking/working surface with an unprotected side or edge more than 15' are not protected.	x			x			

OSHA VIOLATIONS		SERIOUS					OTHER THAN SERIOUS	
		Severity			Probability		Probability	
		High	Medium	Low	Greater	Lesser	Greater	Lesser
	1926.760(a)(1)							
2	Employees are not protected from fall hazards of more than two stories or 30’. 1926.760(b)(1)	x			x			
3	Perimeter safety cable is not properly installed. 1926.760(a)(2)	x				x		
Demolition – 1926.850								
1	Electric, gas, water, steam, sewer, or other service lines are not shut off or capped. 1926.850(d)	x				x		
2	Chutes are not constructed properly. 1926.852(b)			x		x		
Lockout / Tagout – 1910.147								
1	Material and equipment are not properly tagged or locked.	x				x		

Combining Violations

Per the OSHA’s Field Operations Manual, different violations of a single standard should be combined. Consequently, in this study, when different violations were observed that were associated with the same standard or if the same violation was encountered multiple times during the same visit, they were combined into one citation.

Grouping Violations

OSHA advises that if one hazard is associated with interconnected violations of different standards, they should be grouped into a single violation. Construction Safety: Engineering and Management Principles, Designing and Managing Safer Job Sites book outlines physical and health hazards at construction sites and was employed as a guideline to identify potential hazards (Table 11).

Table 11: Physical and Health Hazards at Construction Sites

Potential Hazard	Contributing Equipment / Condition	Potential Cause
Falls	Scaffolding	Under construction, lack of fall protection
	Ladders	Positioning, poor equipment maintenance
	Roofs, floors	Unprotected openings in roofs and floors
Struck by / crushed	Excavations	Shoring/ trenching deficiencies, unprotected edges, unmarked areas
	Buildings	Under construction/demolition, poor barrier protection
	Falling objects	No toe boards on scaffolding; poor housekeeping; lack of storage facilities; improper hoisting and rigging
	Vehicles	Automobiles at general construction sites or road construction sites, by construction vehicles or passing traffic
	Machinery	Inadequate barriers; improper repairs; inadequate or no lockout
Caught in / pinched	Equipment	Inadequate or no lockout; inadequate training; inadequate maintenance; improper guarding; improper fit of personal protective equipment; personal protective equipment being drawn into equipment
	Tools	Improper use; poor fit; improper body position; poor tool maintenance
Electrocution		Inadequate or no lockout; contact with energized equipment/lines; damaged or no insulation
Eye injuries	Foreign objects, dust, projectiles	Lack of personal protective equipment; poorly maintained personal protective equipment; lack of guards; not wetting down work
Temperature	Hot / cold	Inadequate or poorly fitting personal protective equipment; inadequate work/rest regimen for weather conditions; lack of water/cool, shaded break area or warm area
Noise	Equipment	Lack of hearing protection; lack of training; engineering controls not possible or not used

Potential Hazard	Contributing Equipment / Condition	Potential Cause
Vibration	Equipment	Pneumatic tools; inadequate or no personal protective equipment; no insulation
Musculo – skeletal disorders	Sprains/strains	Lifting technique; unbalanced loads; too much weight; Awkward positioning; repetitive motion; lack of training in proper technique; not using aids such as carts, levers, stools
	Carpal Tunnel	Hand position; tools; lack of assistive equipment
	Bursitis	Kneeling; concrete work; floor or carpet laying
	Other repetitive motion injuries	Tools; overwork; lack of training; lack of assistive equipment
Cancer, respiratory disease	Particulate from cement, lead, asbestos, wood, fiber board	Inhalation while welding, sanding, sandblasting, pouring, demolition, removal; dry work; inadequate local or area ventilation; inadequate respiratory protection and clothing; lack of proper washing facilities
Neurological difficulties, sensitizers, dermatitis, reproductive difficulties	Solvents, nickel; hexavalent chromium	Inhalation of or skin contact with paints, varnishes, lacquers, adhesives; grinding; welding; cutting
	Pesticides Fire retardants	Lawn or wood treatments
Biological hazards	Bacteria	Inadequate hygiene facilities, contaminated water; inadequate hazard control in healthcare facilities

When the OSHA violation matrix was created, this was taken into consideration and the observed violations were broken down by the safety and health regulations for construction standards to assist with the calculations and grouping. Subsequently, hazards were identified for each observed violation based on Table 11 and interrelated ones were grouped into one violation.

Grouping violations is a vital step in the calculations. OSHA has drawn a road map as to how violations are grouped and how the calculations should be made. Based on these factors, severity and probability assessments are made separately when observed violations are grouped.

Grouped severity assessment is calculated based on the two main rules. First, the severity suggested for the grouped violation cannot be less than the severity of the most serious single alleged violation. Second, when single violations are grouped, severity of grouped violations is believed to be more serious than any single violation, then severity is calculated based on the grouped violations.

Grouped probability assessment is also made based on two factors. First, the probability suggested for the grouped violation cannot be less than the probability of the most serious single alleged violation. Second, when single violations are grouped, probability of injury or illness resulting from grouped violations is believed to be greater than the probability of any single violation, then probability is calculated based on the grouped violations.

3.3.1.3 Site Safety Performance Value (SSPV) Calculation

Upon creation of the OSHA violation matrix, it was used as a tool to formulate observed violations in a spreadsheet to calculate the penalty amounts for each site specific safety report. The Gravity Based Penalty system established the penalty amounts, which are between $3,000 and $7,000 for serious violations (Table 7), and between $0 and $7,000 (Only the Area Director may propose $7,000) for other than serious violations (Table 8).

It must be noted that when more than one violation was combined and grouped into one violation, gravity based penalty was proposed based on this violation. After calculating the proposed penalty amount for each safety report, reduction factors were applied to calculate the final proposed penalty amounts.

3.4 Data Analysis

This investigation relied on univariate analysis, zero-order correlations (Pearson) and hierarchical multiple regressions to examine the relationships between the variables. The data was organized using Microsoft Excel and analyzed by using the Statistical Package for Social Sciences (SPSS) software. It is essential to provide some background information about the purpose of univariate analysis and multiple regressions and highlight some of the key issues relevant to these analyses.

To start with, the major goal of univariate analysis is to describe the individual variables in a given data set. Ho (2006) argued that this analysis is the first step in analyzing one's data set. It is important to highlight that one is not testing any hypothesis but rather simply describing the individual variables in the data set. This can be achieved by looking at the frequency of the responses, central tendency (e.g., mean) and range of the values for every variable in the data set (Fielding and Gilbert, 2001). This makes the data more presentable and easier to understand. In the study, correlations were relied on examining the relationships among the variables.

Finally, multiple regressions analyses were performed to understand the contribution of company and project related factors in predicting the site safety performance measure and trades affecting the safety performance the most. In this study, the dependent variables were selected as the observed violation penalty amounts and number of proposed violations and the independent variables were selected as company and project related factors.

As for multiple regression, the aim is to understand the association of multiple independent variables (IVs) with a dependent variable (DV) (Pedhazur, 1997). Specifically, the goal is to understand the predictive ability of the IVs for a given DV (Tabachnick and Fidell, 2007). In doing so, one can not only understand the total variance accounted for by the set of IVs but also investigate the most important IV in predicting the outcome. This is considered especially useful in exploratory studies where there are not any clear sets of theoretical arguments regarding the importance of one variable over the other (Tabachnick and Fidell, 2007). Two key issues to consider in multiple regression analyses are multicollinearity and singularity (Pedhazur, 1997; Tabachnick and Fidell, 2007). If they are present, one either can't run the analyses or obtain unreliable estimates. Considering the fact that the variables within each parameter represent that specific dimension, moderate to high correlations might be observed among the variables. In order to address these issues, the Tolerance and Variance Inflation Factor (VIF) values, which measure the impact of collinearity among the variables in a regression model, are investigated for multicollinearity analysis. Field (2009) suggests that if correlation analyses show that, r, is more than 0.9 (r>0/9) between two variables, it may be an indication of multicollinearity and suggests dropping one of the variables from the analyses. As a rule of thumb, if the tolerance is less than .20, a problem with multicollinearity is indicated. As for VIF, values above 4 suggest a multicollinerarity problem (Menard, 1995, Myers, 1990). If a variable is found to indicate multicollinerarity, that specific variable is dropped from the analyses. The values for all predictors were examined to ensure they were within the acceptable ranges before running the analyses. Considering the number of variables that were investigated, seven regression analyses were performed as seen in Figure 5.

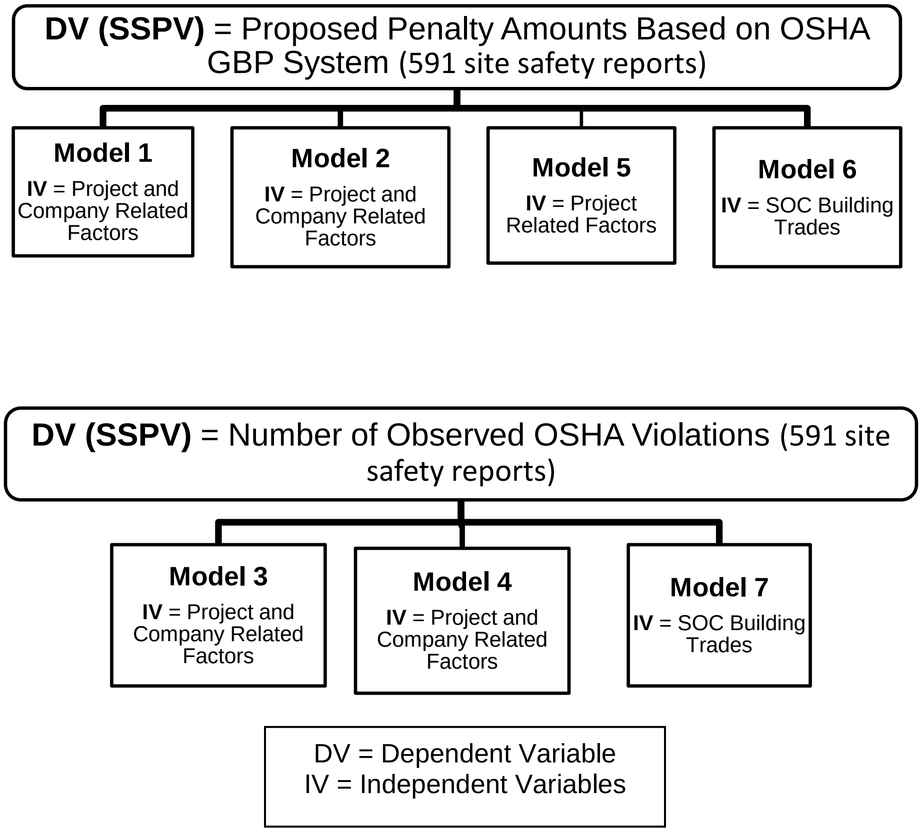


Figure 5: Multiple Linear Regression Models

CHAPTER 4 RESULTS

4.1 Univariate/Frequency Analysis Results

This section summarizes the variables used in the study and how they were distributed in the data set. Each variable was examined separately and the range of values was examined to gain insights to their meaning and significance. Univariate analysis results are presented below under in 3 main headings.

4.1.1 Violation and Site Characteristics

The study identified 116 different types violations based on the OSHA standards. As indicated earlier, gravity of these violations were determined based on the severity and probability assessments. As a result, 106 out of 116 of these violations were classified as serious violations and 10 as other than serious violations. As discussed, no willful violation was observed. In addition, since repeat violations and failure to abate violations only apply to violations that were previously cited by OSHA, they were disregarded in this study. As it can be seen from the OSHA violation statistics table, Table 12, willful violations are not even 1% of the total number of violations and repeat violations are around only 3% of the total number of violations. In other words, serious and other than serious violations account for around 95% of the total number of violations cited by OSHA.

Table 12: OSHA Violations Statistics 2003 through 2007 for Construction Industry

OSHA Violation Statistics	FY2003	FY2004	FY2005	FY2006	FY2007	% Change 2003-2007
Total Violations	83,539	86,708	85,307	83,913	88,846	6.4%
Total Serious Violations	59,861	61,666	61,018	61,337	67,176	12.2%
Total Willful Violations	404	462	747	479	415	2.7
Total Repeat Violations	2,147	2,360	2,350	2,551	2,714	26.4%
Total Other-than-Serious	20,552	21,705	20,819	19,246	18,331	-10.8%

There were a total of 591 site visits performed by the safety department which resulted in a total of 1764 observed violations. Out of these 591 site visits, there were 178 sites, which represents around 30.1% of the total number of site visits, no violations were observed. In 413 site visits, violations were observed and noted in the site safety status reports (Figure 6). The OSHA's 2009 report indicated that 75% of all the sites inspected by OSHA citations were given for non-compliance of the safety standards. In 2010, OSHA's citation rate went up to 82%. As seen in Figure 6, this study's citation rate being lower than OSHA's rate can be a result of a controlled safety environment. We can make an assumption that if a company is made aware that its' construction site will be inspected at least one time before construction is completed than its safety performance increases. Since OSHA has only limited number of compliance officers, (only around 2% of all on-going construction sites based on www.osha.gov), they cannot inspect every site in the United States, and knowing that their project will most likely not be inspected seems to give companies ease of mind and relaxation which might cause them to take chances with their safety requirements.

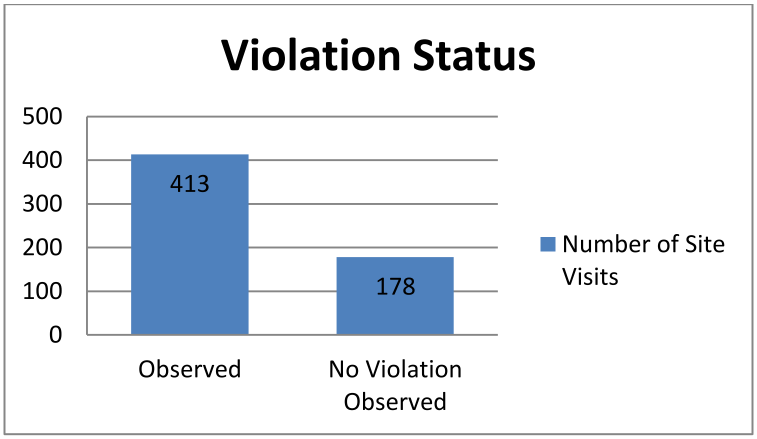


Figure 6: Frequency Distribution of Violation Observation

The descriptive statistics of 591 site visits are presented in Table 13. As seen in the table, penalty amounts before reductions range from $0 to $52,000 with a mean of $12,479. Penalty amounts after reductions are relatively smaller and range from $0 and $36,495 with a mean of $8,589 which translates into a 30% reduction. The number of violations observed in each site visit ranges from 0 to 14 with an average of 3 violations. This number is consistent with the findings of the Mohan and Niles (2002) study. In their study, they discovered that each site inspected by the OSHA Compliance Officers was given an average of three citations which is the same as the findings of this study. One can argue that citing violations can be a subjective process because one violation noted by an inspector may not be noted by another one. However, the results disprove this hypothesis and suggest that OSHA compliance officers interpret the standards in a similar fashion and share the same perspective as it relates to safety rules and regulations while citing violations. It appears that OSHA's strong presence and successful history as well as success in implementing safety rules and regulations got everybody "on the same page" and streamlined the process in terms of the procedures followed during the inspections.

Table 13: Descriptive Statistics of Site Characteristics

	Minimum	**Maximum**	**Mean**
Penalty Amount before Reductions per Site	$.00	$52,000.00	$12,478.85
Penalty Amount after Reductions per Site	$.00	$36,495.00	$8,589.08
No of Violations Observed per Site	0	14	2.98
No of Employees per Site	0	210	38.97
No of Trades per Site	0	12	4.30

Moreover, the number of employees observed on each site visit ranges from 0 to 210 with an average of 39 employees per site. As stated earlier the sites visits were random and performed without giving any notices to the companies. In 12 instances, the safety professionals visited the site, when there was no one working and performed their walkthrough regardless, inspected the job site and OSHA requirements, and documented the unsafe conditions. In addition, the number of trades noted for each site ranges from 0 to 12 with an average of 4 trades per site.

4.1.1.1 Types of Violations

<u>Types of Violations</u>

OSHA suggests that serious violations can be categorized into 3 groups based on gravity: High, medium, low. In this data set, frequency of the type of violations and number of violations are presented in Table 14.

Table 14: Types of Violations and Number of Violations

Types of Violations	**Gravity**	**Violation Types**	**%**		**No of Violations**	**%**	**%**
Serious	High	15	12.93%	91.38%	468	26.53%	91.33%
	Moderate	78	67.24%		1087	61.62%	
	Low	13	11.21%		56	3.17%	
OTS	OTS	10	8.62%	8.62%	153	8.67%	8.67%
	Total	116	100.00%	100.00%	1764	100.00%	100.00%

As illustrated in Figure 7, the most frequent type of violation observed in this study was Moderate violation. Around 67% of the violations observed were moderate level violations. In Figure 8, the number of violations based on the types of violations was demonstrated.

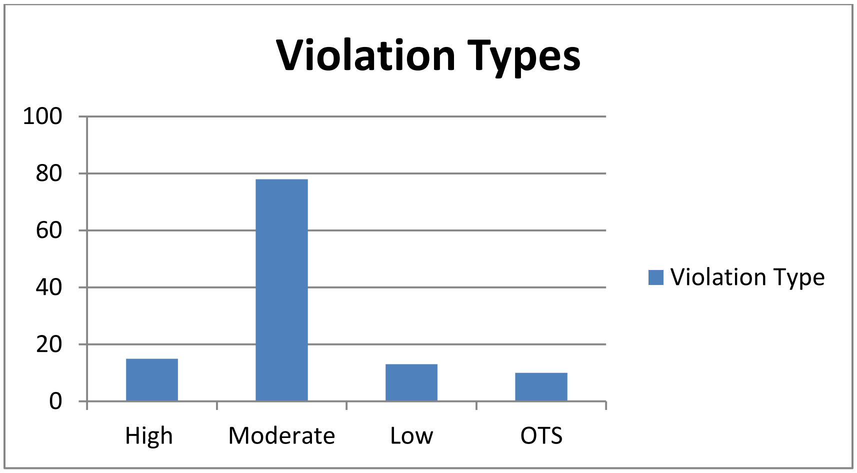


Figure 7: Violation Types

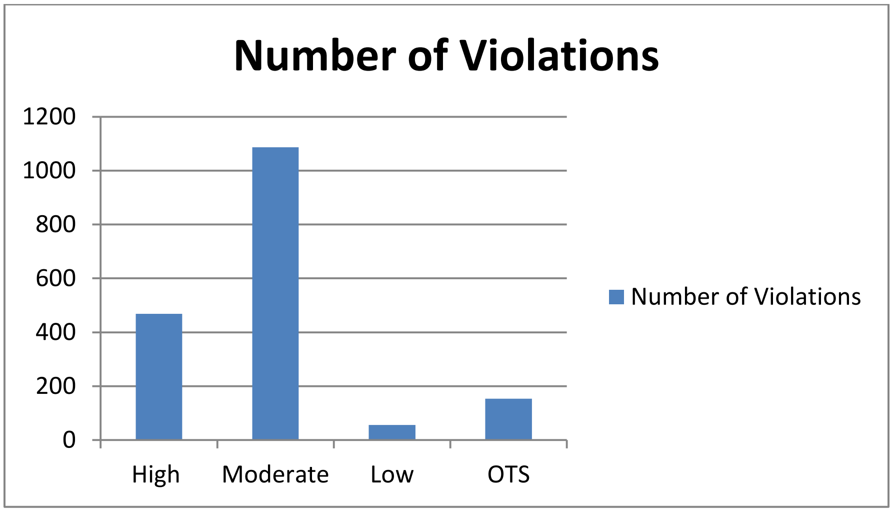


Figure 8: Frequency Distribution of Number of Violations

As shown in Table 14, 1087 out of 1764 violations that were observed during the site inspections appeared to be moderate violations.

Types of Violations Based on Gravity Based Penalty System

As indicated earlier, OSHA's penalties are based on the combination of severity and probability assessments of a violation. Severity can be categorized into 3 groups: High severity which is when death or permanent disability can result from an injury or illness, medium severity which is a limited period of disability can result from an injury or illness and low severity which injuries or temporary illnesses not resulting in hospitalization. The probability, on the other hand, has two types; greater and lesser which show the likelihood of an injury or illness occurrence. Table 15 shows frequency of the type of violations and number of violations based on OSHA's Gravity Based Penalty System.

Table 15: Types of Violations Based on Gravity Based Penalty System

Types of Violations	Gravity	Severity	Probability	Violation Types	%	No of Violations	%
Serious	High	High	Greater	15	12.93%	468	26.53%
	Moderate	Medium	Greater	30	25.86%	559	31.69%
	Moderate	Low	Greater	19	16.38%	302	17.12%
	Moderate	High	Lesser	9	7.76%	62	3.51%
	Moderate	Medium	Lesser	20	17.24%	164	9.30%
	Low	Low	Lesser	13	11.21%	56	3.17%
OTS	OTS	OTS	OTS	10	8.62%	153	8.67%
			Total	116	100.00%	1764	100.00%

As illustrated in Figure 9, the most frequent type of violation observed in this study is medium severity and greater probability type of violation. Around 25% of the violations observed were this type of a violation. Figure 10 presents the number of violations based on gravity type of violations.

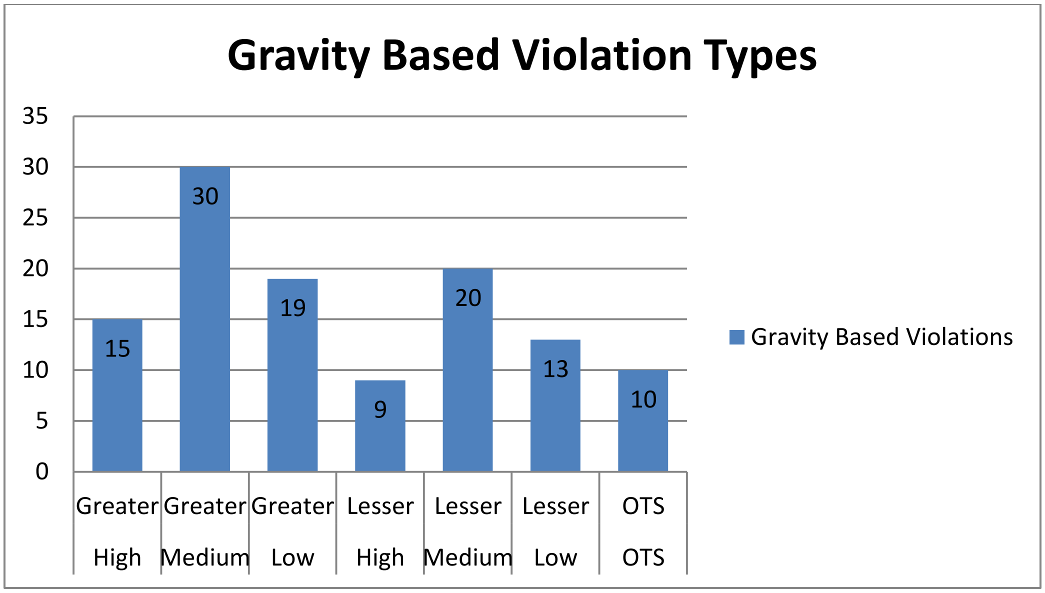


Figure 9: Gravity Based Violation Types

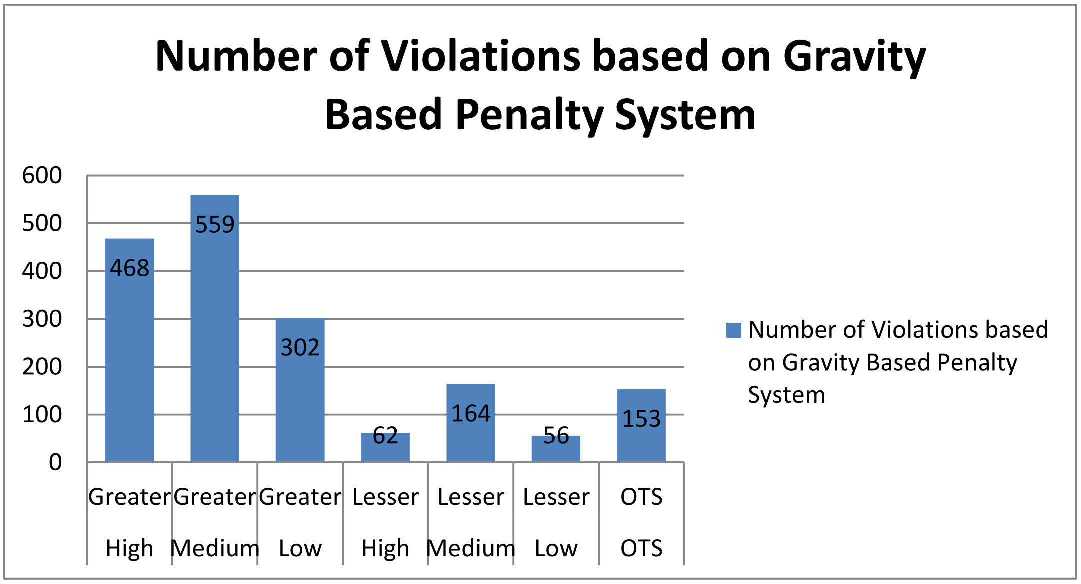


Figure 10: Frequency Distribution of Number of Gravity Based Violations

As shown in Figure 10, 559 out of 1764 violations that were observed during the site inspections appeared to be medium severity and greater probability violations. It also can be seen from Table 15 that 1329 out of 1764 violations, which represents 75%

of the sample population, that were observed in this study appeared to expose the workers to high probability of injury or illness. This can be interpreted in a way that the safety professionals who performed the inspections could have focused more towards high risk areas on sites where workers are more susceptible to injury or illness and paid more attention to these areas to avoid larger incidents.

Most Violated OSHA Standards

OSHA publishes most violated standards every year applicable to all industries including general industry, construction, maritime and agriculture. Even though scaffolding, fall protection and ladder violations consistently rank in the top ten every year in the construction industry, it is difficult to compare the findings of this study against OSHA's most cited violations list, given that it contains other industries. However, more refined comparison can be made by employing MIOSHA's list of top 25 construction safety violations against the results of this study and identify the similarities and differences. As presented in Table 16, MIOSHA's top 25 list (Top 25 MIOSHA Violations report, only 20 violations are listed) includes personal protective equipment, fall protection, scaffolding, excavations, ladders, electrical, signs, signals and barricades, tools and fire prevention.

Table 16: Top 25 MIOSHA Safety Violations Fiscal Year 2009-2010

Rank	Description	Rule Number
1	Personal Protective Equipment – Head Protection	408.40622(1)
2	Personal Protective Equipment – Face and Eye Protection	408.40624(1)
3	Fall Protection – Unprotected Sides and Edges	1926.501(b)(1)
4	Scaffolds – Guardrails	408.41213(1)
5	Fall Protection – Residential Fall Protection	1926.501(b)(13

Rank	Description	Rule Number
6	Fall Protection – Hole Covers	1926.501(b)(4)(
7	Electrical – GFCI	408.41725(11)
8	Excavations – Slope, Bench, Shield or Shore	408.40941(1)
9	Ladders – Ladders 3’ Above Landing	408.41124(5)
10	Electrical – Protect Against Accidental Contact	408.41723(2)
11	Fall Protection – Training	1926.503(a)(1)
12	Aerial Work Platforms – Tie-off	408.43214(1)
13	Ladders – Standing on Top Step or Cap	408.41126(2)
14	Scaffolds – Platforms and Planking	408.41217(1)
15	Excavations – Egress	408.40933(5)
16	Scaffolds – Sound, Rigid Support at Base	408.41210(11)
17	Signs, Signals & Barricades – Traffic Control	408.42322(1)
18	Fall Protection – Roofing on Low-Slope Roofs	1926.501(b)(10
19	Tools – Powered Nailers and Staplers	408.41937(4)
20	Fire Prevention – Fire Extinguishers	408.41851(6)

The findings of this study revealed similar trends, as shown in Table 17, and correspond to MIOSHA’s top 25 violations. Personal protective equipment (Subpart E), fall protection (Subpart M), scaffolding (Subpart L), ladders (Subpart X), housekeeping and training, (Subpart C), Signs, Signals and Barricades, (Subpart G) and electrical (Subpart K) appeared to be the areas where most violations were observed. Providing that the top four causes of death in construction sites per OSHA are falls, electrocutions, struck by objects, and caught-in between, it is not unexpected that the observed violations are somewhat related to these causes which are likely to lead to accidents.

Table 17: Frequency of Observed OSHA Violations

Rank	Standard Number	Standard Violated	Frequency	Cumulative %
1	1926.102(a)	Eye and face protection is not in place when required.	107	6.07%
2	1926.25(a)	Worksite is not clean or free of construction debris.	105	12.02%
3	1926.100(a)	Hard hats are not worn at all times.	102	17.80%
4	1926.202	Open excavation, road drop offs, manholes, uneven surfaces are not barricaded.	102	23.58%
5	1926.501(b)(1,2,10)	Employees working above 6 feet (1.8 m) or more with an unprotected side or edge or leading edge or on roof are not protected from falling by guardrail systems, safety net systems, or personal fall arrest systems.	95	28.97%
6	1926.501(b)(4)	Floor openings, holes are not covered, secured or guarded.	82	33.62%
7	1926.21(b)(2)	Safety training or orientation is not provided.	79	38.10%
8	1926.451(g)(1)	Standard guard railing is not installed on scaffolds over 10 ft including ends, work platforms & walkways.	60	41.50%
9	1926.1053(b)(1)	Side rails of ladders do not extend 3 feet above landing and/or not secured at top.	59	44.84%
10	1926.25(b)	Scrap materials are not removed or stacked in orderly fashion.	56	48.02%
11	1926.200 (b,c,f)	Direction signs are not used to inform the public. Danger and caution signs are not in place.	45	50.57%
12	1926.501(b)(14)	Wall openings less than 39 inches off the floor and greater than six feet from any lower surface are not protected by a guardrail or safety net system.	42	52.95%
13	1926.56	Lighting is not adequate in work areas.	30	54.65%
14	1926.404(b)(1)	Improper grounding of equipment and circuitry.	30	56.35%
15	1926.451(c)(1,2)	Supported scaffold is not properly erected on a firm surface with all pins and braces in place and locked.	26	57.82%
16	1926.451(e)(1)	There is no means of access to the scaffold.	26	59.30%

Rank	Standard Number	Standard Violated	Frequency	Cumulative %
17	1926.453(b)(2)(v)	Person in lift basket is not wearing fall prevention or protection equipment.	25	60.71%
18	1926.502(j)(1,2,3)	Employees working down below other employees are not protected. (Toeboards, canopies, etc.) Toe boards are not properly installed. (Should be min 3.5 inches)	24	62.07%
19	1926.701(b)	Protruding reinforcing steel, onto and into which employees could fall, is not guarded to eliminate the hazard of impalement.	23	63.38%
20	1926.760(a)(2)	Perimeter safety cable is not properly installed.	21	64.57%
21	1926.403(g)	Electrical equipment (distribution boxes, electric panels and devices) are not marked.	20	65.70%
22	1926.153(a)	Fuel tanks and propane tanks are not protected from damage. (from vehicular traffic).	19	66.78%
23	1926.403(i)(2)(i)	Live parts of electric equipment operating at 50 volts or more are not guarded against accidental contact by cabinets or other forms of enclosures.	19	67.86%
24	1926.405(a)(2)(ii)	Inadequate or improper temporary wiring.	19	68.93%
25	1926.651(c)(2)	Trenches 4’ and greater are not provided with stairways, ladders or other means of egress.	18	69.95%
26	1903.2	OSHA and safety posters are not being displayed.	17	70.92%
27	1926.150(a)(3,4)	Fire extinguishers are not in place or adequately charged.	16	71.83%
28	1926.652(a)(1)(ii)	Trenches 5’ or more depth are not shored, shielded or have sides sloped.	16	72.73%
29	1926.353(c)(1)	Ventilation is not adequate.	14	73.53%
30	1926.502(b)(3)	Guardrail is not properly installed. (Should be 42” high -/+ 3” high) 1926.502(b)(1) and/or is not capable of withstanding a force of at least 200 pounds.	13	74.26%
31	1926.451(f)(3)	Scaffold components are not visibly free of any physical damage.	13	75.00%
32	1926.451(b)(1)	Working surface is not fully planked and secured.	13	75.74%

Rank	Standard Number	Standard Violated	Frequency	Cumulative %
33	1926.1051(a)	Ladders are not in good condition or right ladders are not being used. (Missing rungs, etc.) 1926.1053(b)(16) and/or not used for elevation changes of 19 inches or more.1926.1051(a)	13	76.47%
34	1926.25(c)	Refuse containers are not adequate or in use.	12	77.15%
35	1926.502(b)(2)	Midrails, screens, mesh are not installed between the top edge of the guardrail system or the walking/working surface when there is no wall at least 21 inches high.	12	77.83%
36	1925.200 (g)(1)	Traffic signs are not posted at points of hazard.	12	78.51%
37	1910.147	Material and equipment are not properly tagged or locked.	12	79.20%
38	1926.651(j)(2)	Excavated material or spoils is not placed at least 2' from the edge.	11	79.82%
39	1926.5	Emergency medical numbers are not posted and First-Aid Kit is not available.	10	80.39%
40	1926.1053(b)(2)	Ladders and stairwells are not free of slipping hazards.	10	80.95%
41	1926.1053(b)(6)	Ladder is not resting on a firm or substantial surface.	10	81.52%
42	1926.103	Respiratory protection is not used when condition requires.	10	82.09%
43	1926.250(b)(1)	Material inside buildings under construction is not stored properly. (Should be at least 6 feet away from any hoistway or inside floor openings and 10 feet away from an unfinished exterior wall.)	10	82.65%
44	1926.152(a)(2)	Flammable or combustible liquids are stored in areas used for exits on stairways.	9	83.16%
45	1926.1052 (c)(1)	Stairs that have 4 or more steps or rising more than 30" do not have handrails. Stair treads do not comply with the standards.	9	83.67%
46	1926.602(a)(2)	Vehicles do not have seat belts or they are not used.	9	84.18%
47	1910.1200(b)(4)	There are chemical spills that might cause an accident.	9	84.69%
48	1926.706(a)	Limited Access Zone is not established.	9	85.20%

Rank	Standard Number	Standard Violated	Frequency	Cumulative %
49	1926.34(b)	Exits are not clearly marked and/or evacuation plans are not posted.	8	85.66%
50	1926.301(a)	Hand tools are not maintained and damaged/or broken.	8	86.11%
51	1926.453(b)(2)(vii)	Lift is not positioned on solid and level ground.	8	86.56%
52	1926.28(a)	Employees are not using gloves when handling sharp objects.	8	87.02%
53	1926.1501(a)(15)	Competent person is not making daily inspections or tests.	8	87.47%
54	1926.151(a)(3)	"No Smoking" or "Flammable" signs are not posted at storage and fueling locations. (They are not clearly identified.)	7	87.87%
55	1926.405(g)(2)(ii)	Flexible cords are not connected to devices and fittings so that strain relief is provided which will prevent pull from being directly transmitted to joints or terminal screws.	7	88.27%
56	1926.451(h)(4)	Toe boards are not installed or not installed properly.	7	88.66%
57	1926.451(g)(4)(ii and iii)	Top and mid rails are not properly installed.	7	89.06%
58	1926.350(c)(3)	Compressed cylinders are not stored secured upright at all times except transportation. 1926.350(a)(9) Cylinders are damaged or defective. 1926.350(c)(3)	7	89.46%
59	1926.251(a)(1)	Rigging equipment for material handling is not inspected prior to each use.	7	89.85%
60	1926.651 (b)	Underground utilities are not located or marked.	7	90.25%
61	1926. 651(g)(1)	Ventilation is not adequate.	7	90.65%
62	1926.760(b)(1)	Employees are not protected from fall hazards of more than two stories or 30'.	7	91.04%
63	1926.451(f)(13)	Scaffold is not free of debris.	6	91.38%
64	1926.352(d)	There are no fire extinguishers near welding and cutting areas.	6	91.72%
65	1926.251(a)(2)(ii)	Rigging equipment is loaded in excess of its recommended safe working load.	6	92.06%
66	1926.1501(a)(9)	Workers are not clear of crane swinging loads.	6	92.40%
67	1926.552(b)(1)(ii)	Employees are riding on material hoists except for the purposes of inspection and maintenance.	6	92.74%

Rank	Standard Number	Standard Violated	Frequency	Cumulative %
68	1926.403(i)(1)	Sufficient access and working space are not provided and maintained about all electric equipment.	5	93.03%
69	1926.416(b)(2)	Work areas are not kept clear of cords.	5	93.31%
70	1926.300(d)(3)	Hand held powered tools are not equipped with constant pressure switch where appropriate.	5	93.59%
71	1926.502(d)	Personal fall arrest systems are not in good condition and/or the anchorages used do not capable of supporting at least 5,000 pounds per employee.	5	93.88%
72	1926.1053(a)(3)(i)	Fixed and portable ladder rungs are not uniformly spaced 10” – 14” apart.	5	94.16%
73	1926.200(d)	There are no exits signs over doors in buildings.	5	94.44%
74	1926.1501(a)(15)	Power lines distance from machines is less than 10’.	5	94.73%
75	1926.552(c)(15)	Inspection and test of all functions and safety devices are not made.	5	95.01%
76	1926.602(a)(9)	Horns or backup alarms are not functioning. Vehicles with an obstructed rear view are not equipped with an operable back-up alarm or used only with an observer.	5	95.29%
77	1926.760(a)(1)	Employees engaged in a steel erection activity on a walking/working surface with an unprotected side or edge more than 15’ are not protected.	5	95.58%
78	1926.150(a)(2)	Firefighting equipment is not accessible or clear at all times.	4	95.80%
79	1926.300(a)	Tools are not maintained in secure and safe condition.	4	96.03%
80	1926.451(d)(16)	Wheels are not locked when scaffold is in use.	4	96.26%
81	1910.1200(g)(8) and (1)	MSDS are not on hand or recorded.	4	96.49%
82	1926.706(b)	Masonry walls over 8’ in height adequately are not braced to prevent overturning and to prevent collapse.	4	96.71%
83	1926.21(b)(6)	There is not enough ventilation, lighting, or monitoring. Air sampling is not done.	3	96.88%
84	1926.302(a)	Electric power tools are not double insulated or grounded.	3	97.05%

Rank	Standard Number	Standard Violated	Frequency	Cumulative %
85	1926.306(b)(3)	Air compressors are not equipped with functioning pressure gages.	3	97.22%
86	1926.451(a)(1)	Footing and anchors are not sound and capable of carrying 4 times the max intended load without settling.	3	97.39%
87	1926.451(b)(4a and 5)	Planks are not overlapping minimum 6" and maximum 12".	3	97.56%
88	1926.350(a)(10)	Oxygen is not stored separate from acetylene and all flammables by 20'.	3	97.73%
89	1926.250(b)(6)	Brick stacks are more than 7 feet in height.	3	97.90%
90	1926.852(b)	Chutes are not constructed properly.	3	98.07%
91	1926.154(a,b)	Portable heaters are not being used in accordance with specs. (Direct fire) and/or ventilation is not adequate.	2	98.19%
92	1926.152(c)(4)	Portable tanks are nearer than 20ft from any building.	2	98.30%
93	1926.1053(a)(2	Ladders are not properly constructed.	2	98.41%
94	1926.351 (c)	Arc welding is not properly grounded.	2	98.53%
95	1926.351(b)(1)	Parts of arc welding outfits are not properly insulated.	2	98.64%
96	1926.101(a)	Hearing protection is not used in areas of moderate, extreme or long term noise.	2	98.75%
97	1926.651(k)	Daily inspection of excavation and adjacent areas by a competent person is not done.	2	98.87%
98	1926.1101(k)(8)	Containers are not properly labeled or insufficient labeling. 1900.1200(b)(3) and for asbestos 1926.1101(k)(8)	2	98.98%
99	1926.34(c)	Egress is not continually maintained free of all obstructions.	1	99.04%
100	1926.417(b)	Electrical circuits are not properly identified.	1	99.09%
101	1926.404(f)(7)	Corded and plugged equipment used in wet locations.	1	99.15%
102	1926.300(b)(2)	Power tools designed to accommodate guards are not equipped with guards and/or guards are not adequate.)	1	99.21%
103	1926.1053(b)(12)	Non-conductive ladders are not being used around live wiring.	1	99.26%

Rank	Standard Number	Standard Violated	Frequency	Cumulative %
104	1926.1052 (c)(3)(i)	Stairrails are not at least 36 inches (91.5 cm) tall from the upper surface of the stairrail system to the surface of the tread.	1	99.32%
105	1926.350(i)	Gauges, valves, torches & lines are not in good condition. They are not free of oil or grease.	1	99.38%
106	1926.104	Safety harness, lifelines or shock absorbing lanyards are not available or do not meet the requirements.	1	99.43%
107	1926.621(j)	Employees are not protected from falling material.	1	99.49%
108	1926.602(a)(3)(i)	Haul road is not adequate or maintained.	1	99.55%
109	1910.178	Operators are not trained or authorized to operate.	1	99.60%
110	1926.600(a)(3)(i)	Parked or unattended equipment's blade, forks or bucket are not lowered to ground or blocked.	1	99.66%
111	1926.602(a)(6) also Subpart W	Forklift truck does not have overhead guard.	1	99.72%
112	1926.1101(k)(9)	Employees are not properly trained or the training is inadequate. 1910.1200(h)(1) and for asbestos 1926.1101(k)(9)	1	99.77%
113	1926.1101(k)(7)	Hazcom signs are not in place. Lack of identification. 1910.1200(f) and for asbestos 1926.1101(k)(7)	1	99.83%
114	1926.1101(l)(2)	Asbestos waste, containers and equipment are not properly disposed of.	1	99.89%
115	1926.703(a)(1)	Formwork designed, fabricated, erected do not support vertical or lateral loads.	1	99.94%
116	1926.850(d)	Electric, gas, water, steam, sewer, or other service lines are not shut off or capped.	1	100.00%

It is evident from the results that there is a trend between top cited violations published every year by MIOSHA and OSHA, and the leading causes of worker deaths in construction published by OSHA. This signifies that OSHA violations are a good indication of potential accidents but have not been given sufficient consideration to be utilized as a proactive accident prevention tool. Table 17 clearly demonstrates that the

25 top observed violations make up 70%, 1234 out of the 1764 violations, of observed violations in this study. Since these violations represent focal points, these findings could assist in providing guidance to establish special safety training programs to reduce the number of accidents or violations and increase safety performance

Observed Violations Based on OSHA Subparts

There are different construction activities such as excavations, steel erection, concrete, tunneling, or different safety exposures such electrical safety. OSHA has established subparts based on the different safety exposures such as fall protection, electrical, fire protection, etc and separated safety and health regulations as shown in Table 5. Based on the observed violations and penalty dollar amounts assigned to these violations, the penalty amount associated with each subpart was estimated and listed in Table 18.

Table 18: Penalty Amounts Ranked by OSHA Subparts

OSHA Standards	No of Violations	Total Before Reductions	History Reduction / Increase	Good Faith Reduction	Size Reduction	Total After Reductions	Average Violation Amount
Subpart M - Fall Protection	273	$1,256,000	($48,200)	($6,105)	($235,683)	$966,013	$3,539
Subpart C - General Safety and Health Provisions	264	$1,115,000	($41,100)	($156,240)	($204,701)	$712,959	$2,701
Subpart E - Personal Protective and Life Saving Equipment	230	$912,000	($40,000)	($23,280)	($227,933)	$620,787	$2,699
Subpart L - Scaffolds	201	$725,000	($23,200)	($27,675)	($132,259)	$541,866	$2,696

OSHA Standards	No of Violations	Total Before Reductions	History Reduction / Increase	Good Faith Reduction	Size Reduction	Total After Reductions	Average Violation Amount
Subpart G - Signs, Signals, and Barricades	164	$685,000	($29,100)	($78,750)	($128,546)	$448,605	$2,735
Subpart X - Ladders	110	$505,000	($17,100)	($73,185)	($73,712)	$341,003	$3,100
Subpart K - Electrical	107	$445,000	($19,600)	($59,925)	($80,564)	$284,912	$2,663
Subpart P - Excavations	62	$254,000	($12,900)	($15,480)	($39,179)	$186,441	$3,007
Subpart F - Fire Protection and Prevention	59	$211,000	($4,300)	($31,005)	($28,314)	$147,382	$2,498
Subpart D - Occupational Health and Environmental Controls	40	$194,000	($10,100)	($26,535)	($40,965)	$116,401	$2,910
Subpart Q - Concrete and Masonry Construction	37	$151,000	($3,100)	($21,135)	($24,645)	$102,121	$2,760
Subpart J - Welding and Cutting	35	$142,000	($5,900)	($20,415)	($28,271)	$87,414	$2,498
Subpart R - Steel Erection	33	$137,000	($5,600)	($9,225)	($21,615)	$100,560	$3,047
Subpart H - Materials Handling, Storage, Use, and Disposal	26	$127,000	($3,900)	($18,465)	($23,902)	$80,733	$3,105
Subpart CC - Cranes and Derricks Used in Construction	19	$107,000	($3,100)	($10,440)	($17,113)	$76,347	$4,018

OSHA Standards	No of Violations	Total Before Reductions	History Reduction / Increase	Good Faith Reduction	Size Reduction	Total After Reductions	Average Violation Amount
Subpart O - Motor Vehicles, Mechanized Equipment, and Marine Operations	18	$96,000	($3,400)	($13,890)	($17,595)	$61,115	$3,395
Subpart Z - Toxic and Hazardous Substances	18	$96,000	($4,100)	($13,485)	($17,308)	$61,107	$3,395
Subpart I - Tools - Hand and Power	24	$81,000	($4,300)	($10,560)	($18,687)	$47,453	$1,977
1910 Subpart J - General Environmental Controls	12	$60,000	($1,500)	($8,775)	($8,458)	$41,268	$3,439
Subpart N - Helicopters, Hoists, Elevators, and Conveyors	11	$45,000	($2,600)	$0	($9,350)	$33,050	$3,005
1903.2 - Posting of notice; availability of the Act, regulations and applicable standards.	17	$17,000	($700)	($2,445)	($3,222)	$10,634	$626
Subpart T - Demolition	4	$14,000	($800)	($1,980)	($3,239)	$7,982	$1,995
Total	1,764	$7,375,000	($284,600)	($628,995)	($1,385,257)	$5,076,149	$2,878

As reported in Table 18, penalty amounts ranked by OSHA subparts, coincides with the MIOSHA most observed violations list (Table 16). As seen also in Figure 11, fall protection, general safety and health provisions, personal protective equipment, scaffolds, signs, signals, barricades, ladders, electrical and excavations subparts incurred the most penalties which also are the main causes of construction fatalities and comprised of around 80% (Table 18) of the overall penalty amounts in this study. In other words, penalties estimated by the observed violations can predict the accidents to a certain degree. This can be construed that violations in fact are good representation of safety performance and can be used to predict the contractor behavior since the observed violations seem to contain the main causes for fatalities in the construction industry which are falls, electrocutions, struck by objects, and caught-in between. Reducing number and dollar amount of citations can be considered as loss of control. It also can lead to accident prevention in specific areas.

Table 18 presents that had these inspections were conducted by the OSHA compliance officers, the proposed penalty amount for the entire program would have been $7,375,000. After applying reduction factors; history average 4%, good faith average 9%, size average 19%, the total penalty amount would have been $5,076,149. These penalty amounts prove that safety is really an incentive and can motivate the contractors by displaying the penalty amounts they may be exposed to in the long run if they do not desire to invest in construction safety at the beginning of a project. According to the professionals in the construction industry, the incidence rates can be great indicators of safety performance but they sure fall short in explaining how safety really can save money to a project and all parties involved in the process. Penalty amounts can certainly fill this void. This can be an area where Return of Investment (ROI) technique can be researched and provide insights for future studies. It needs to be understood that maintaining a safe work place costs money and it is better to expend it before anyone gets hurt. Supporting the importance of this practice, Findley, et al. (2004) has shown that investment in worker protection programs pays off and reduces the costs associated with construction injuries and fatalities.

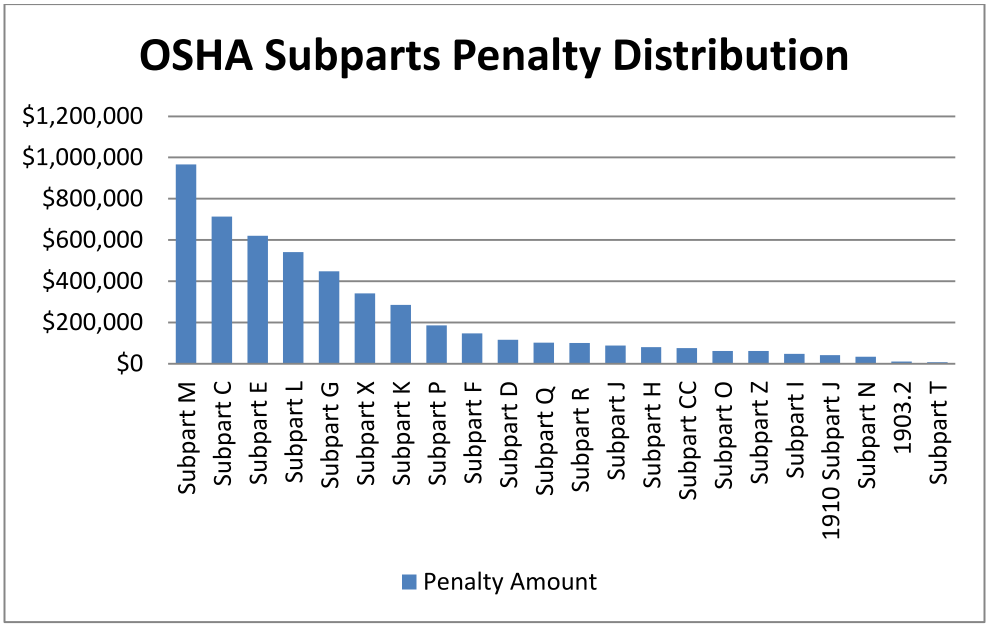


Figure 11: OSHA Subparts Penalty Distribution

As also shown in Table 18, the average violation amount was calculated as to be $2,878 in this study. As mentioned earlier, United States Department of Labor issued a memo in April 2010 to make enhancements to OSHA'S penalty policies. Per OSHA’s statistics, prior to the revision, the average serious penalty amount was around $1,000 and OSHA advised that they expect this amount to increase up to $3,000 (US Bureau of Labor Memo dated April 22, 2010). Comparison of what OSHA’s expectancy is from the new penalty system in place and findings of this study provide an additional validity for the methodology of this study.

4.1.1.2 Proposed Penalty Amounts before Reductions are applied per Site

It was explained that OSHA has reduction factors applicable to proposed penalty amounts based on size, history and good faith. As presented in Table 19 and Figure 12, proposed penalty amounts prior to these factors were applied. It can be seen that most sites, around 78.2%, were proposed penalty amounts less than $20,000.

Table 19: Penalty Amounts before Reductions per Site

	Frequency	Percent (%)	Cumulative Percent (%)
0	178	30.1	30.1
$1 - $10,000	79	13.4	43.5
$10,001 - $20,000	205	34.7	78.2
$20,001 - $30,000	97	16.4	94.6
>$30,000	32	5.4	100.0
Total	591	100.0	

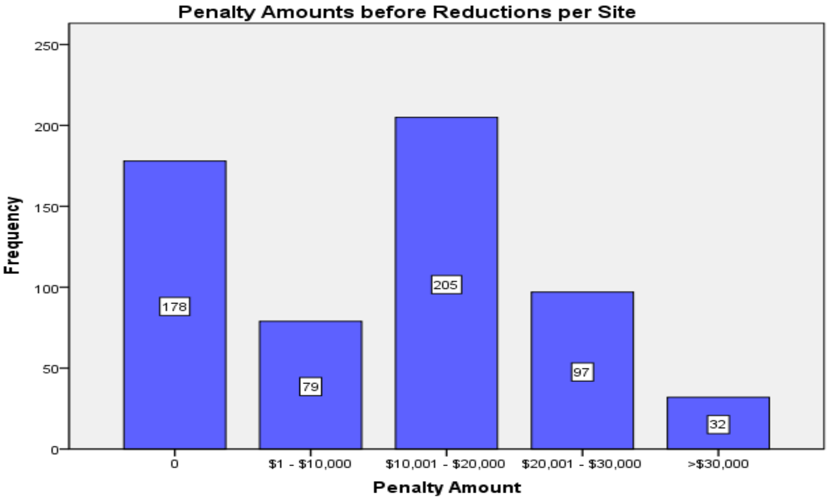


Figure 12: Frequency Distribution of Penalty Amounts before Reductions per Site

4.1.1.3 Proposed Penalty Amount After Reductions are applied per Site

As seen in Table 19 and Figure 13, proposed penalty amounts are relatively smaller after reduction factors are applied. 30.1% of the sites were not proposed any penalties and more than 68% of the sites were proposed penalty amounts between

$535 and $30,000. These values were used in the regression analyses as the dependent variable.

Table 20: Penalty Amounts after Reductions per Site

	Frequency	Percent (%)	Cumulative Percent (%)
0	178	30.1	30.1
$1 - $10,000	182	30.8	60.9
$10,001 - $20,000	170	28.8	89.7
$20,001 - $30,000	52	8.8	98.5
>$30,000	9	1.5	100.0
Total	591	100.0	

Figure 13: Frequency Distribution of Penalty Amounts after Reductions per Site

4.1.1.4 Number of Violations Observed per Site

Out of the 591 site visits, there were 178 sites, which represent around 30.1% of the total number of site visits, where no violations were observed. Table 21 and Figure 14 show the frequency of violations across sites.

Table 21: Number of Observed Violations per Site

	Frequency	Percent (%)	Cumulative Percent (%)
No Violation	178	30.1	30.1
1 Violation	32	5.4	35.5
2 Violations	63	10.7	46.2
3 Violations	65	11.0	57.2
4 Violations	99	16.8	73.9
More Than 4 Violations	154	26.1	100.0
Total	591	100.0	

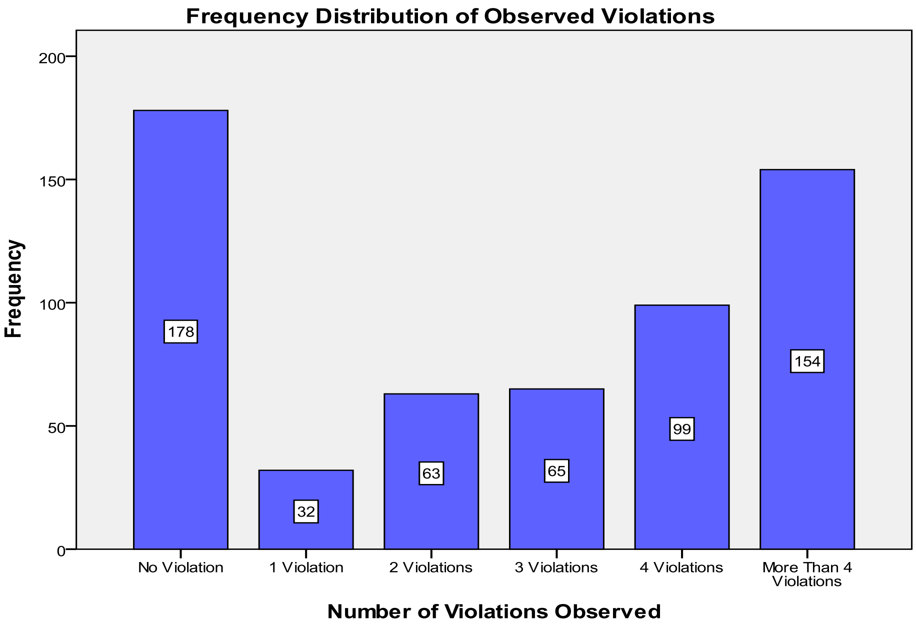


Figure 14: Frequency Distribution of Observed Violations at each Site

4.1.1.5 Number of Employees at Site during Each Site Visit

There were 12 instances when a site was visited during which there were no employees were present. Even in those cases, the site was inspected and violations (only unsafe conditions) were noted and safety reports were generated. Most construction sites visited contained less than 100 employees working during inspection (Table 22 and Figure 15).

Table 22: Number of Employees during Each Site Visit Site

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
0	12	2.0	2.0
1-10	183	31.0	33.0
11-25	118	20.0	53.0
26-50	97	16.4	69.4
51-100	135	22.8	92.2
>100	46	7.8	100.0
Total	591	100.0	

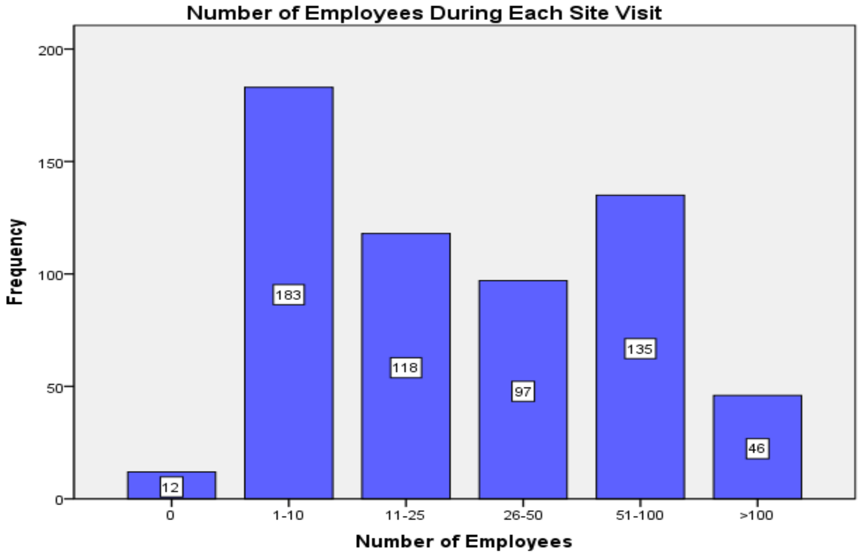


Figure 15: Frequency Distribution of Number of Employees during Each Site Visit

4.1.1.6 Number of Trades at Site during Each Site Visit

When construction sites were visited, the number of trades was also noted in the safety reports. This information was used to in the regression model where building trades were researched to find out whether or not they affect site safety performance (Table 23 and Figure 16).

Table 23: Number of Trades per Site

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
0	12	2.0	2.0
1-2	175	29.6	31.6
3-4	146	24.7	56.3
5-6	136	23.0	79.4
=>7	122	20.6	100.0
Total	591	100.0	

Figure 16: Frequency Distribution of Number of Trades per Site

4.1.1.7 Types of Construction Trades at Site during Each Site Visit

Building trades were categorized by the 2010 Standard Occupational Classifications system (SOC). As illustrated in Figure 17, the construction trade that was observed the most in this study was electricians followed by the plumbers and block, brick and stone masons, carpenters and sheet metal workers.

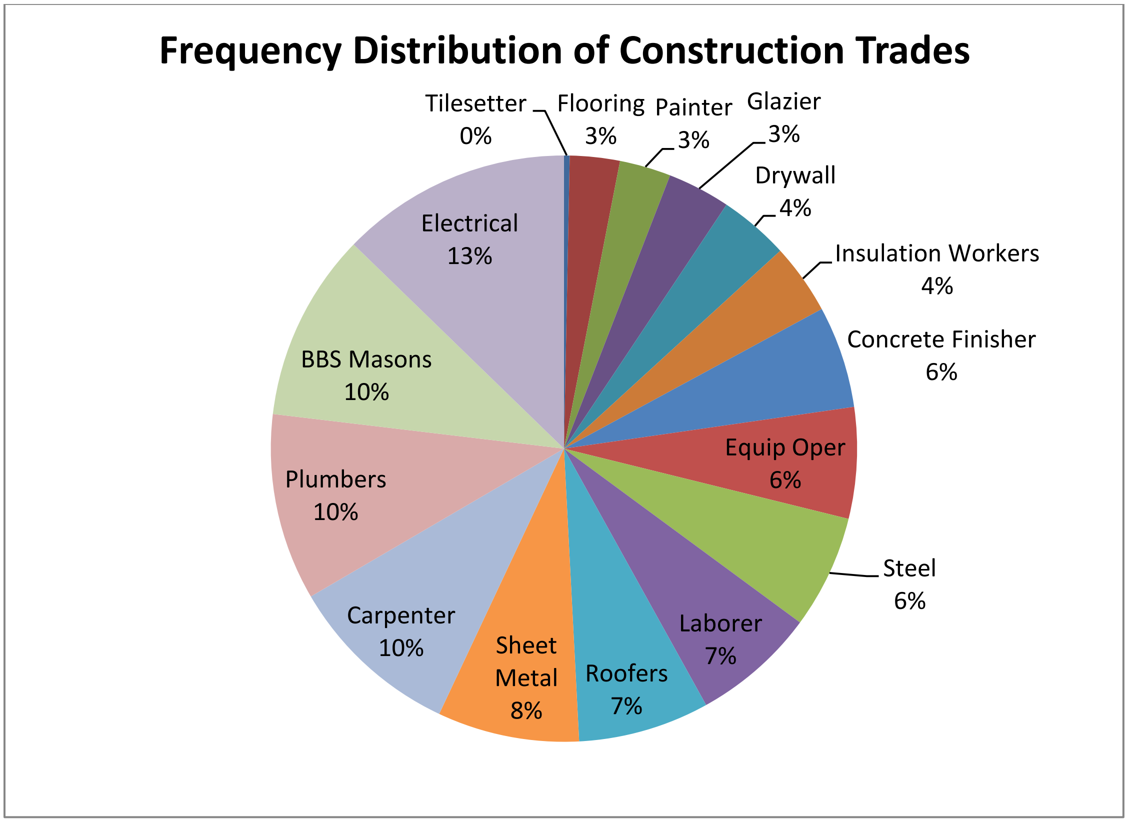


Figure 17: Frequency Distribution of Construction Trades Observed on Sites

4.1.2 Project Related Factors

A total of 121 projects were visited and inspected during this study. As discussed earlier, some of these sites were visited more than once. Thus, penalty amounts associated with each site needed to be reorganized to estimate the penalty amounts for each project.

Table 24: Descriptive Statistics for Project Related Factors

	Minimum	**Maximum**	**Mean**
Project Duration	12	807	158.51
Original Contract Amount per Project	$8,000.00	$ 83,005,016	$ 4,173,611
Change Order Amount per Project	-$232,758.53	$ 2,120,599	$ 1,087,478
Final Contract Amount per Project	$8,000.00	$104,211,003	$ 5,261,089
Number of Site Visits per Project	1	38	4.88
Number of Violations per Project	0	168	14.58
Penalty Amount per Project before Deductions	$.00	$641,000	$60,950
Penalty Amount per Project after Deductions	$.00	$530,055	$41,951

4.1.2.1 Types of Projects

The projects included in this study were categorized into four groups; new, addition, renovation and demolition. As seen in Table 25 and Figure 18, renovation projects comprised of 73.6% of the projects included in this study.

Table 25: Project Type

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
New	11	9.1	9.1
Addition	15	12.4	21.5
Renovation	89	73.6	95.0
Demolition	6	5.0	100.0
Total	121	100.0	

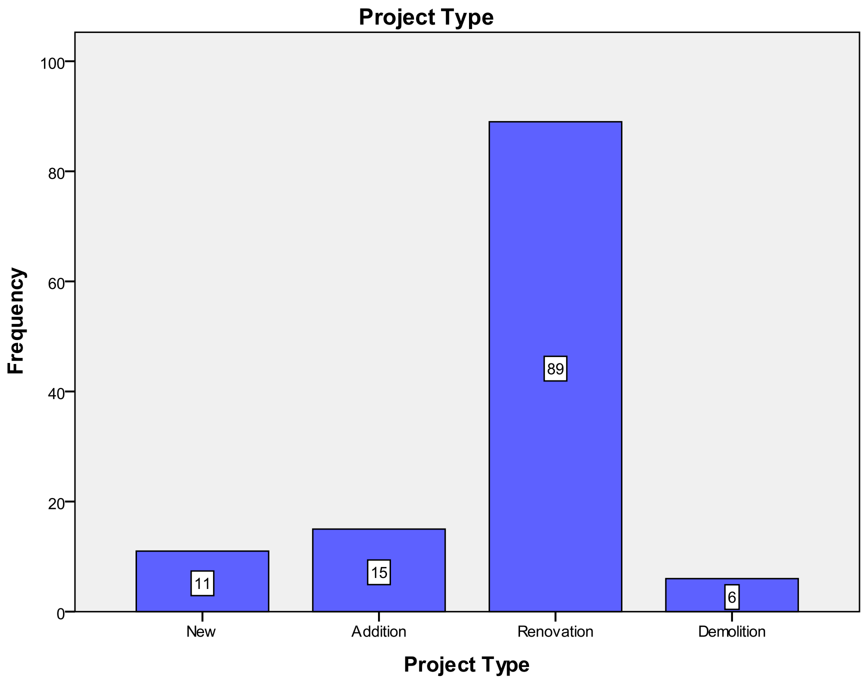


Figure 18: Frequency Distribution of Project Types

4.1.2.2 Number of Site Visits per Project

Some sites were visited more frequently than other sites. Therefore, number of site visits was used as a weight factor. As seen in Table 26: Number of Site Visit per Project and Figure 19, 43% of the projects were only visited once, whereas 43% of the sites were visited between 2 to 8 times.

Table 26: Number of Site Visit per Project

	Frequency	Percent (%)	Cumulative Percent (%)
1	52	43.0	43.0
2	21	17.4	60.3
3	12	9.9	70.2
4	2	1.7	71.9
5	6	5.0	76.9
6	3	2.5	79.3

7	2	1.7	81.0
8	6	5.0	86.0
>8	17	14.0	100.0
Total	121	100.0	

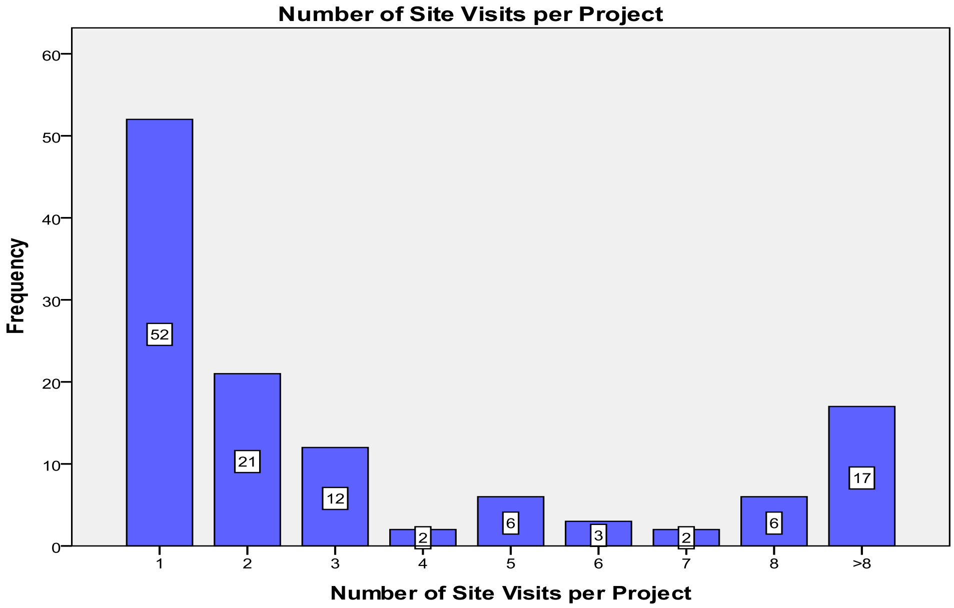


Figure 19: Frequency Distribution of Number of Site Visits per Project

4.1.2.3 Observed Violation Penalty Amounts before Reductions are applied per Project

OSHA has reduction factors applicable to proposed penalty amounts based on size, history and good faith. Shown in Table 27 and Figure 20, proposed penalty amounts prior to these factors were applied. It can be seen that most projects, around 86%, were proposed penalty amounts less than $100,000.

Table 27: Penalty Amount before Reductions per Site

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
0	16	13.2	13.2
$1 - $10,000	11	9.1	22.3
$10,001 - $20,000	37	30.6	52.9
$20,001 - $30,000	12	9.9	62.8
$30,001 - $50,000	12	9.9	72.7
$50,001 - $100,000	16	13.2	86.0
>$100,000	17	14.0	100.0
Total	121	100.0	

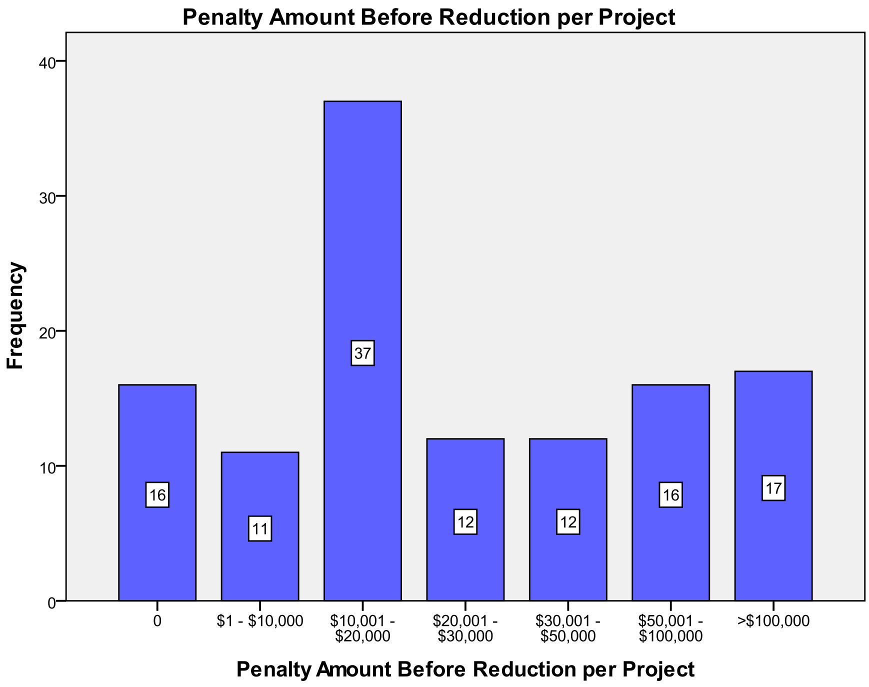


Figure 20: Frequency Distribution of Penalty Amounts before Reductions per Project

4.1.2.4 Observed Violation Penalty Amounts after Reductions are applied per Project

As seen in Table 28 and Figure 21, proposed penalty amounts are relatively smaller after reduction factors are applied. 13.2% of the projects were not proposed any penalties and more than 69% of the projects were proposed penalty amounts between $1,800 and $100,000. These values were used in the regression analyses as the dependent variable.

Table 28: Penalty Amount after Reductions per Project

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
0	16	13.2	13.2
$1 - $10,000	40	33.1	46.3
$10,001 - $20,000	22	18.2	64.5
$20,001 - $30,000	8	6.6	71.1
$30,001 - $50,000	14	11.6	82.6
$50,001 - $100,000	8	6.6	89.3
>$100,000	13	10.7	100.0
Total	121	100.0	

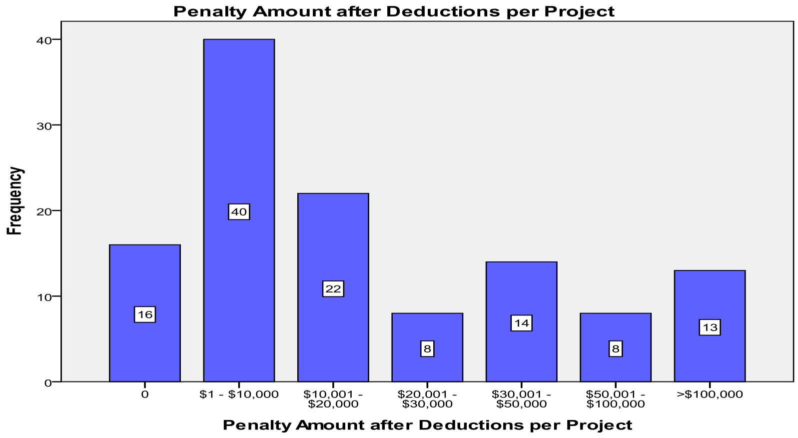


Figure 21: Frequency Distribution of Penalty Amounts after Reductions per Project

4.1.2.5 Project Duration (Days)

Frequency distribution of each project included in this study can be seen in Table 29 and Figure 22. As illustrated, project duration ranged from 12 days to 807 days with a mean of 158 days.

Table 29: Project Duration (Days)

	Frequency	Percent (%)	Cumulative Percent (%)
1-50	25	20.7	20.7
51-100	31	25.6	46.3
101-200	34	28.1	74.4
>200	31	25.6	100.0
Total	121	100.0	

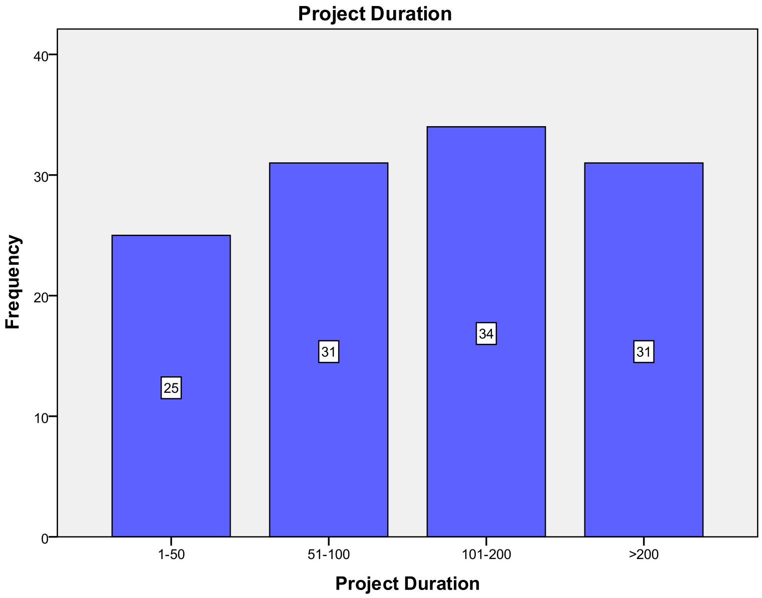


Figure 22: Frequency Distribution of Project Duration (Days)

4.1.2.6 Original Contract Amount

Contract Amounts were used to define the project size in this study and as seen in Table 30, 66.1% of the original contracts were less than $1,000,000. Original contracts between $1,000,000 and $5,000,000 comprised 18.2% of the 121 projects in this study and the majority of the projects ranged from $100,000 to $5,000,000.

Table 30: Original Contract Amount ($)

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
$1 - $100,000	18	14.9	14.9
$100,001 - $250,000	23	19.0	33.9
$250,001 - $500,000	15	12.4	46.3
$500,001 - $1,000,000	24	19.8	66.1
$1,000,001 - $5,000,000	22	18.2	84.3
>$5,000,000	19	15.7	100.0
Total	121	100.0	

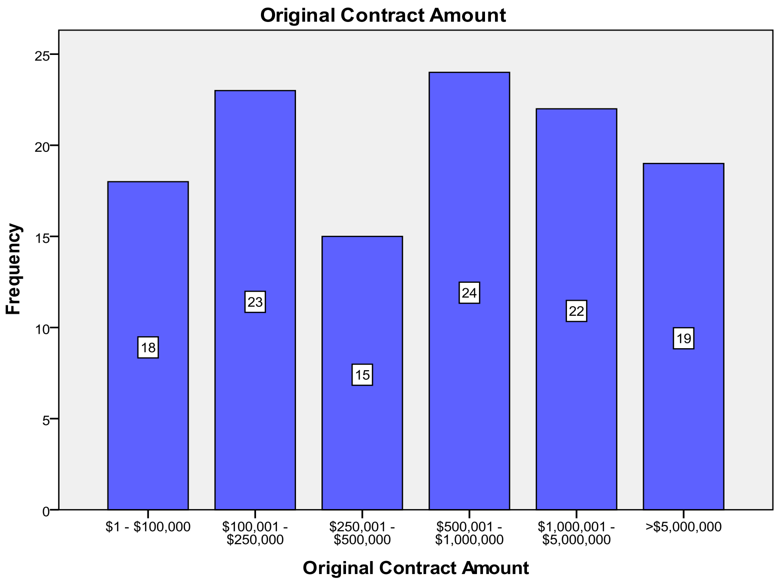


Figure 23: Frequency Distribution of Original Contract Amounts

4.1.2.7 Change Order Amount

There were 14 projects in the study, 11.6%, which there was either no change order or a deduct change order issued. As seen in Table 31 and Figure 24, 89.4% of the projects experienced some kind of a change which increased the overall cost. In addition, 66.1% of the projects experienced a cost change more than 5% and less than 40%. The majority of the changes, 74.4%, that were issued were less than $500,000. Table 31 demonstrates the fast nature of the capital improvement program.

Table 31: Change Order Amount

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
<=0	14	11.6	11.6
$1 - $10,000	11	9.1	20.7
$10,001 - $50,000	21	17.4	38.0
$50,001 - $100,000	12	9.9	47.9
$100,001 - $500,000	32	26.4	74.4
>$500,000	31	25.6	100.0
Total	121	100.0	

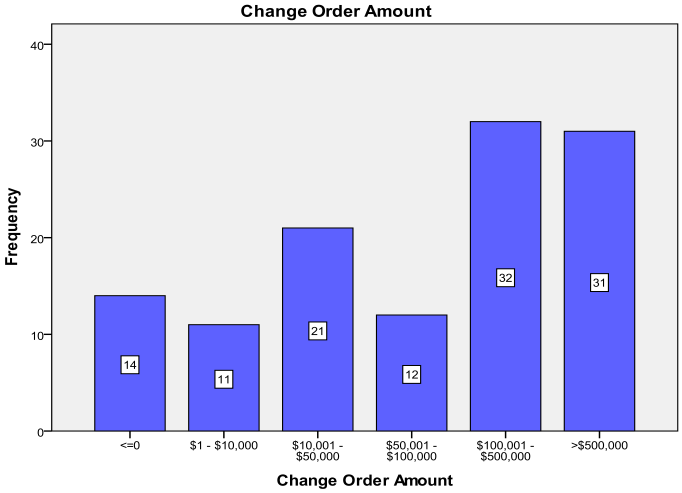


Figure 24: Frequency Distribution of Change Order Amounts

4.1.2.8 Final Contract Amount

Final Contact amount is the total of original contract amount and change order amount and in this study more than half of the projects had a final contract amount more than $500,000 as illustrated in Table 32 and Figure 25.

Table 32: Final Contract Amount

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
$1 - $100,000	13	10.7	10.7
$100,001 - $250,000	21	17.4	28.1
$250,001 - $500,000	17	14.0	42.1
$500,001 - $1,000,000	23	19.0	61.2
$1,000,001 - $5,000,000	26	21.5	82.6
>$5,000,000	21	17.4	100.0
Total	121	100.0	

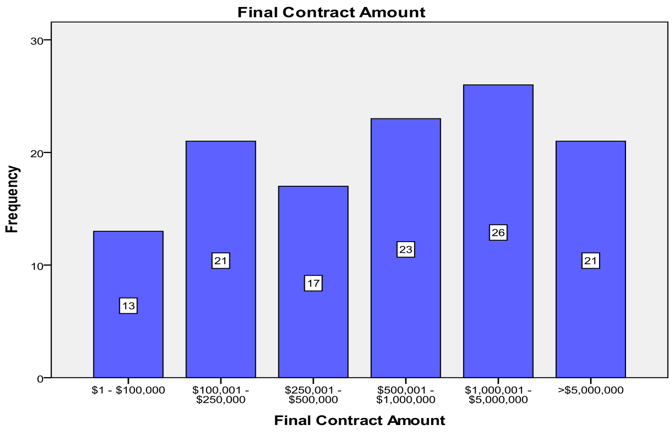


Figure 25: Frequency Distribution of Final Contract Amounts

4.1.2.9 Percent of Original Contract Amount Change (Change Factor)

Percent of original contract amount change provides with a different insight of a project. It enables one to see to what extent project is changing relative to the original contract amount. By reviewing Table 33 and Figure 26, it can be seen that 89.4% of the projects experienced some kind of a change that affected the overall cost. In addition, 66.1% of the projects experienced a change more than 5% and less than 40% (Figure 26). As mentioned earlier due to the schedule constraints, projects were overlapped and cost effects of this approach can be seen in Table 33.

Table 33: Percent of Original Contract Amount Change (Change Factor)

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
<=0	14	11.6	11.6
0.01% - 5%	13	10.7	22.3
5.01% - 10%	21	17.4	39.7
10.01% - 20%	24	19.8	59.5
20.01% - 30%	17	14.0	73.6
30.01% - 40%	18	14.9	88.4
>40%	14	11.6	100.0
Total	121	100.0	

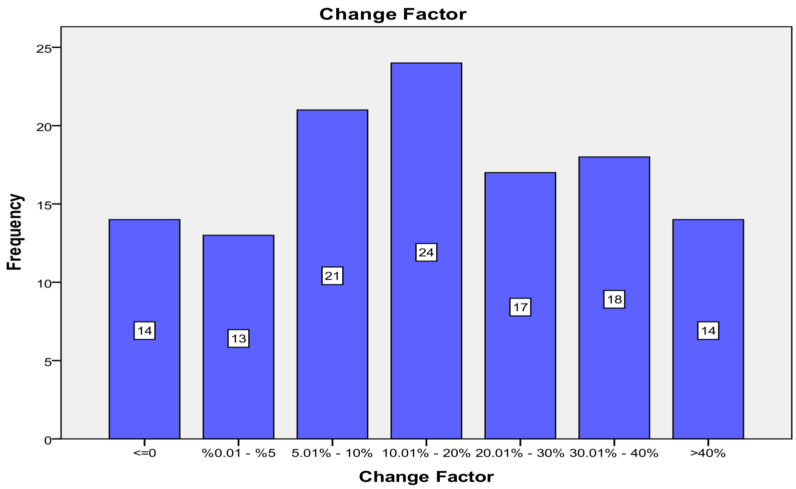


Figure 26: Frequency Distribution of Percent of Original Contract Amount Changes

4.1.3 Company Related Factors

The 121 projects visited by the safety and risk management department were managed by 56 companies. Thus, penalty amounts associated with each company needed to be reorganized to estimate the penalty amounts for each company. It must be noted that two of these fifty six companies were global companies which operated in many countries across the world. Experienced professionals suggest that when a large company operates in different territories, the individual offices start acting like as if they are a local firm because resource sharing becomes rather difficult and challenging and the offices get distanced from the core of the company. Therefore, in this study, the local offices of these two global firms were contacted to collect the data that would be applicable to the company's local and state operations, and this information was used in this study instead of the general company information.

Table 34: Descriptive Statistics for Company Related Factors

	Minimum	**Maximum**	**Mean**
Company Size	$500,000.00	$250,000,000	$ 2,945,666
Years of Experience	1	100	21.29
EMR	.56	1.31	.8648
Company Labor Workforce	5	325	63.73
Employee Hrs Worked Previous Year	7,800	540,179	112,907
Total Recordable Cases	0	40	4.25
Lost Workday Cases	0	13	1.48
Non-fatal Cases Without Lost Workdays	0	27	2.77
Total Recordable Incidence Rate	.00	93.90	7.74
Lost Time Incidence Rate	.00	12.50	2.95
Number of Site Visits per Company	1	68	10.55

TOTAL Number of Violations per Company	0	282	31.50
TOTAL Penalty Amounts per Company before Deductions	$.00	$ 1,105,000	$ 131,696
TOTAL Penalty Amounts per Company after Deductions	$.00	$913,365	$90,646

4.1.3.1 Number of Site Visits per Company

Some sites were visited more frequently than other sites. Therefore, number of site visits was used as a weight factor. As seen in Table 35 and Figure 27, some construction sites which were managed by the same company were visited more frequently than other companies.

Table 35: Number of Site Visits per Company

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
1	9	16.1	16.1
2-5	17	30.4	46.4
6-10	13	23.2	69.6
11-20	8	14.3	83.9
>20	9	16.1	100.0
Total	56	100.0	

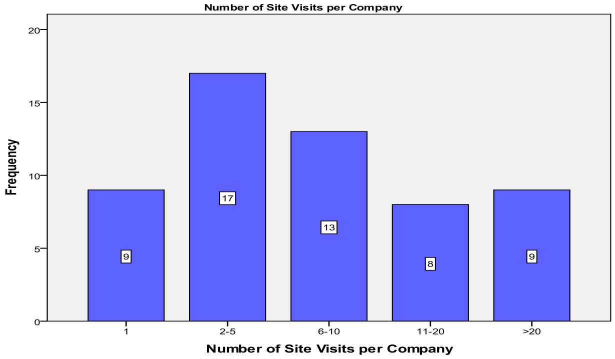


Figure 27: Frequency Distribution of Number of Site Visits per Company

4.1.3.2 Observed Violation Penalty Amounts before Reductions are applied per Company

Table 36 and Figure 28 represent the proposed penalty amounts before reductions per company. It can be seen that the construction sites that were managed by 4 companies did not have any observed violations. Yet, 44 out of 56 companies had proposed penalty amounts ranging from $1 to $250,000.

Table 36: Penalty Amount before Reductions per Company

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
0	4	7.1	7.1
$1 - $25,000	12	21.4	28.6
$25,001 - $50,000	9	16.1	44.6
$50,001 - $100,000	13	23.2	67.9
$100,001 - $250,000	10	17.9	85.7
>$250,000	8	14.3	100.0
Total	56	100.0	

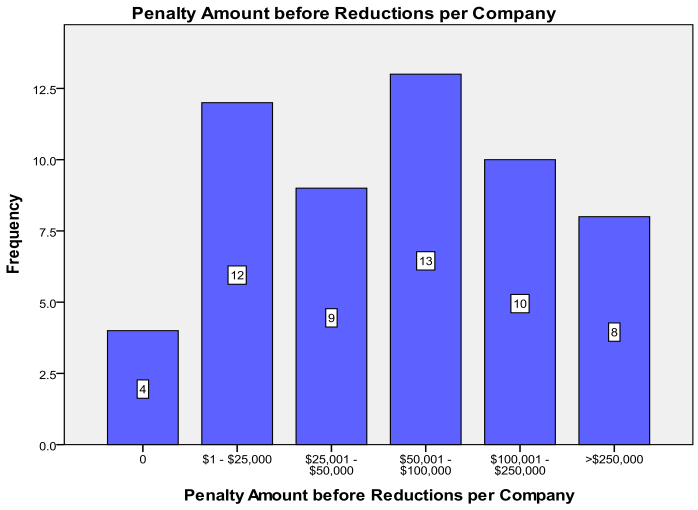


Figure 28: Frequency Distribution of Penalty Amounts before Reductions per Company

4.1.3.3 Observed Violation Penalty Amount after Reductions are applied per Company

As seen in Table 37 and Figure 29, proposed penalty amounts are relatively smaller after reduction factors are applied. More than 84% of the companies were proposed penalty amounts between $4,200 and $250,000.

Table 37: Penalty Amount after Reductions per Company

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
0	4	7.1	7.1
$1 - $25,000	17	30.4	37.5
$25,001 - $50,000	15	26.8	64.3
$50,001 - $100,000	8	14.3	78.6
$100,001 - $250,000	7	12.5	91.1
>$250,000	5	8.9	100.0
Total	56	100.0	

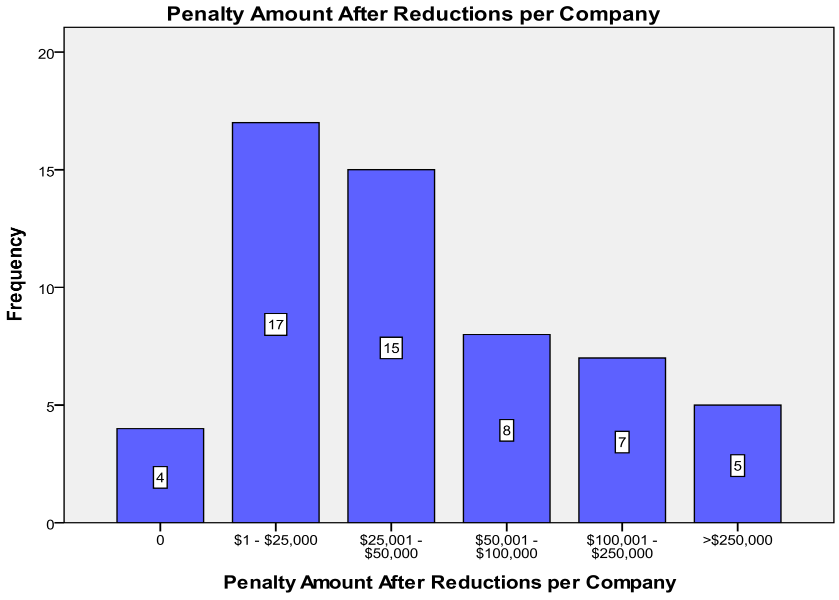


Figure 29: Frequency Distribution of Penalty Amounts after Reductions per Company

4.1.3.4 Company Size

Company size was defined as the annual revenue of a company and frequency distribution of company size are presented in Table 38 and Figure 30. As seen in the table and the figure, most of the companies are relatively large with annual revenue of more than $5,000,000 and less than $50,000,000 with over 5 years of experience (Table 38 and Table 39).

Table 38: Company Size (Annual revenue $)

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
$0 - $5,000,000	17	30.4	30.4
$5,000,001 - $10,000,000	13	23.2	53.6
$10,000,001 - $50,000,000	19	33.9	87.5
>$50,000,000	7	12.5	100.0
Total	56	100.0	

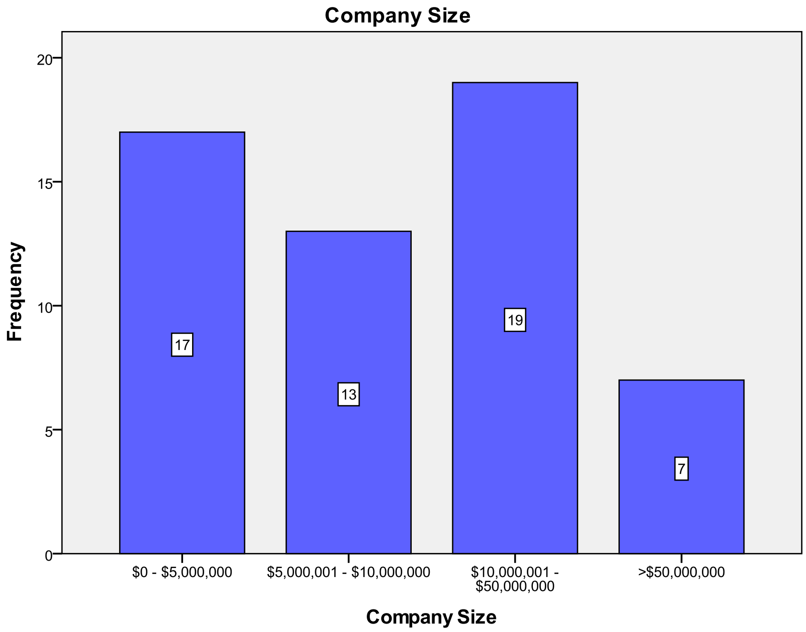


Figure 30: Frequency Distribution of Company Size

4.1.3.5 Years of Experience in Business

Over half of the companies included in this study had over 10 years of work experience as shown in Table 39 and Figure 31.

Table 39: Years of Experience

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
1-5	10	17.9	17.9
6-10	14	25.0	42.9
11-20	13	23.2	66.1
21-30	6	10.7	76.8
31-40	5	8.9	85.7
>40	8	14.3	100.0
Total	56	100.0	

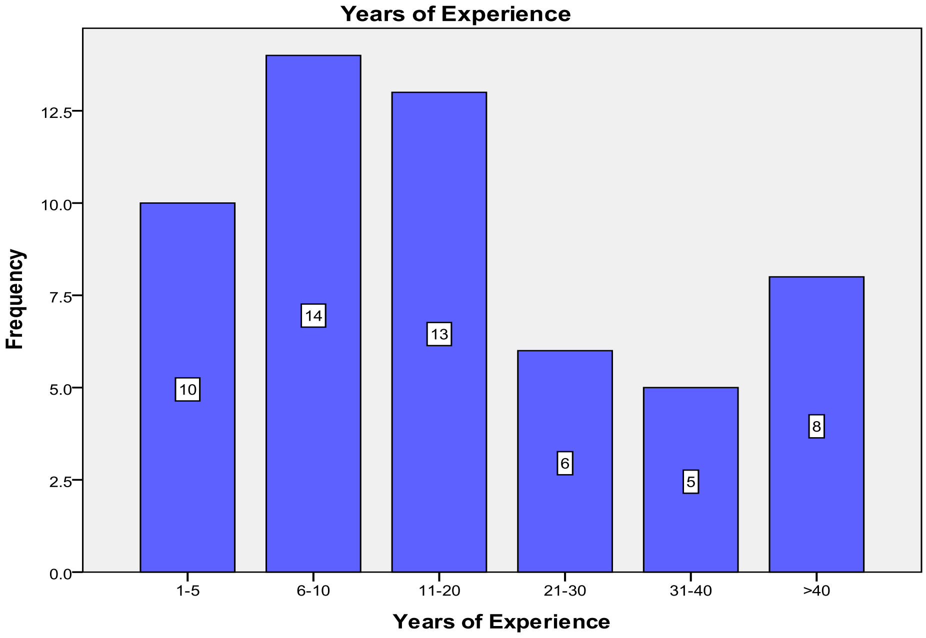


Figure 31: Frequency Distribution of Years of Experience

4.1.3.6 EMR

In the construction industry, EMR score 1.0 is considered as a neutral score since new companies are given this score when they are first established. Only 4 out of 56 companies in this study had an EMR value above 1.0 as seen in Table 40 and Figure 32.

Table 40: EMR Value Frequency Distribution

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
0.5 - 0.74	10	17.9	17.9
0.75 - 1	42	75.0	92.9
>1	4	7.1	100.0
Total	56	100.0	

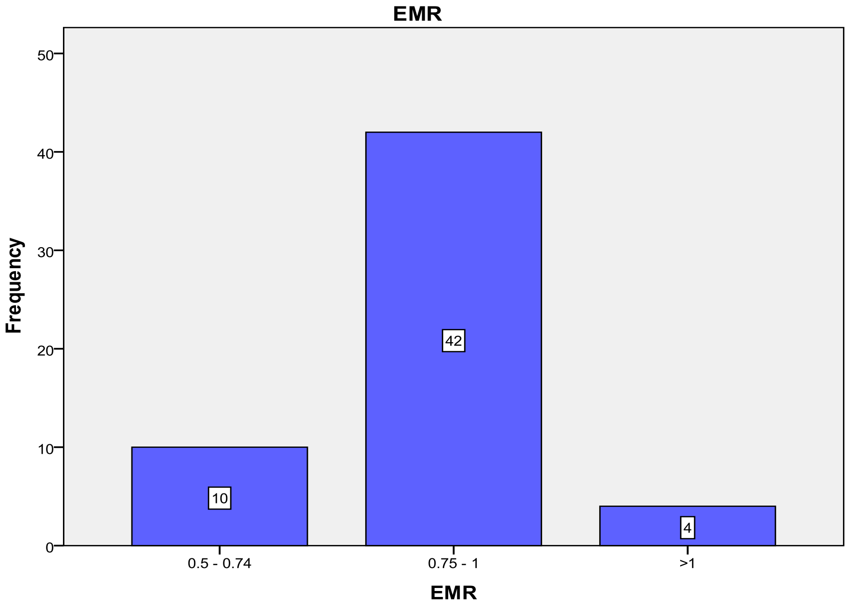


Figure 32: Frequency Distribution of EMR Values

4.1.3.7 Employee Hours Worked Previous Year

Employee hours worked previous year for each company are presented in Table 41. This value is used to calculate total recordable incidence rate.

Table 41: Employee Hours Worked Previous Year

	Frequency	Percent (%)	Cumulative Percent (%)
0 -25,000	12	21.4	21.4
25,001 - 50,000	13	23.2	44.6
50,001 - 100,000	12	21.4	66.1
100,001 - 200,000	9	16.1	82.1
>200,000	10	17.9	100.0
Total	56	100.0	

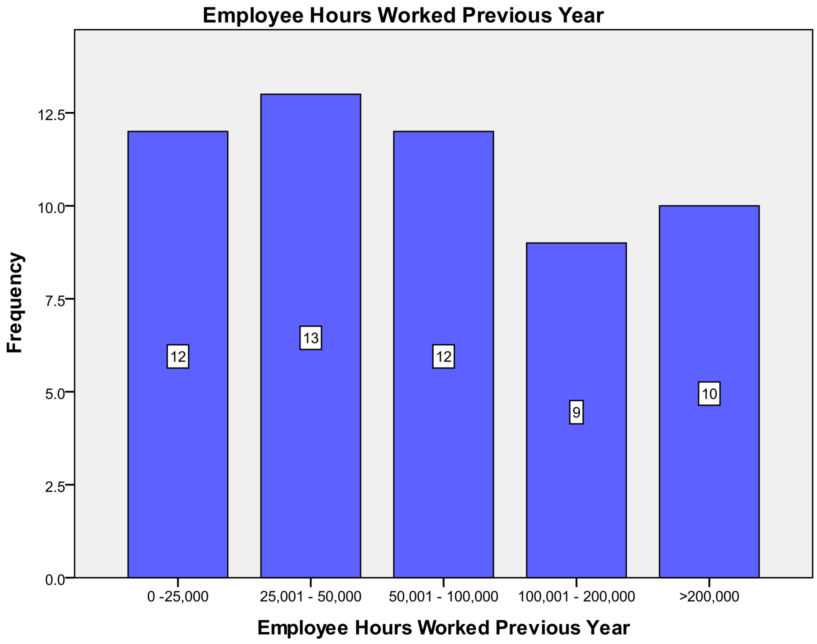


Figure 33: Frequency Distribution of Employee Hours Worked Previous Year

4.1.3.8 Total Recordable Cases

33.9% of the companies did not have any total recordable cases reported in the previous year as seen in Table 42.

Table 42: Total Recordable Cases

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
0	19	33.9	33.9
1	5	8.9	42.9
2	4	7.1	50.0
3	7	12.5	62.5
4	3	5.4	67.9
5	4	7.1	75.0
6	7	12.5	87.5
>6	7	12.5	100.0
Total	56	100.0	

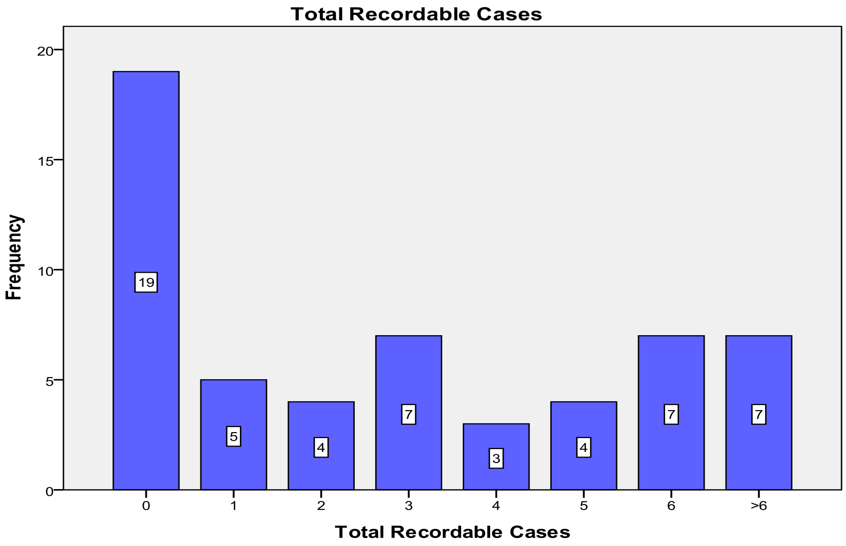


Figure 34: Frequency Distribution of Total Recordable Cases

4.1.3.9 Lost Workday Non-Fatal Cases

44.6% of the companies did not have any cases with lost workday injuries or illnesses reported in the previous year as seen in Table 43.

Table 43: Lost Workday Non-Fatal Cases

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
0	25	44.6	44.6
1	12	21.4	66.1
2	10	17.9	83.9
3	1	1.8	85.7
4	2	3.6	89.3
5	3	5.4	94.6
6	2	3.6	98.2
>6	1	1.8	100.0
Total	56	100.0	

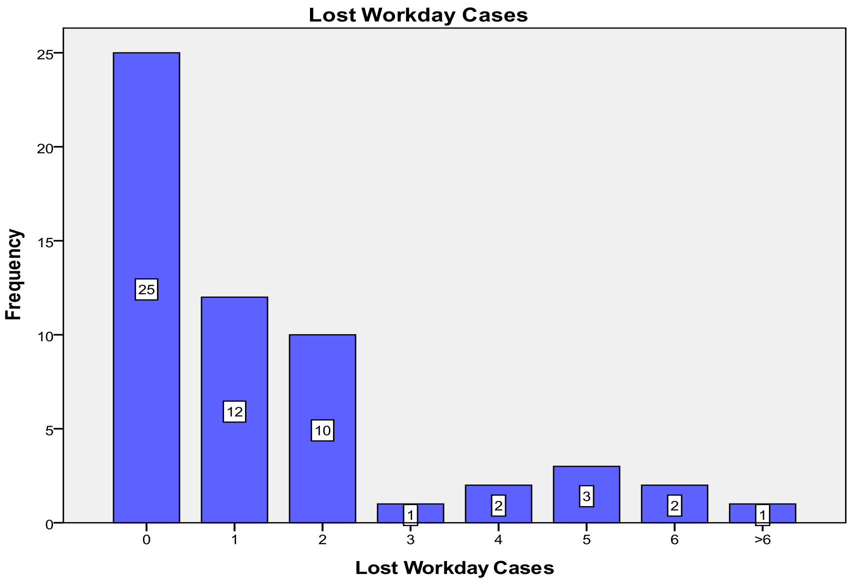


Figure 35: Frequency Distribution of Lost Workday Cases

4.1.3.10 Non-Fatal Cases without Lost Workday Cases

51.8% of the companies did not have any cases without lost workday injuries or illnesses reported in the previous year as seen in Table 44.

Table 44: Non-Fatal Without Lost Workday Cases

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
0	29	51.8	51.8
1	8	14.3	66.1
2	3	5.4	71.4
3	2	3.6	75.0
4	3	5.4	80.4
5	1	1.8	82.1
6	5	8.9	91.1
>6	5	8.9	100.0
Total	56	100.0	

Figure 36: Frequency Distribution of Non-Fatal Without Lost Workday Cases

4.1.3.11 Total Recordable Incidence Rate

2011 construction industry average incident rate was reported to be 3.9. Therefore, this rate was used as the limit in Table 45. Accordingly, 44.6% of the companies reported total recordable incidence rate below the industry average.

Table 45: Total Recordable Incidence Rate

	Frequency	**Percent (%)**	**Cumulative Percent (%)**
<=3.9	25	44.6	44.6
>3.9	31	55.4	100.0
Total	56	100.0	

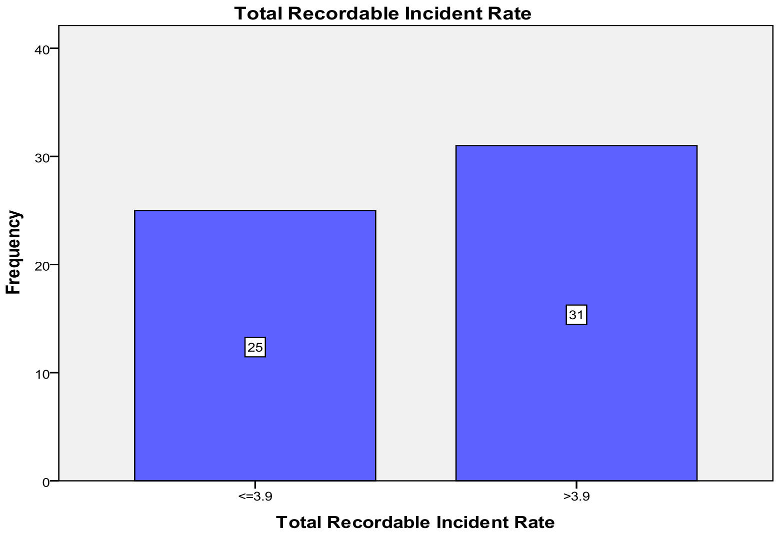


Figure 37: Frequency Distribution of Total Recordable Incidence Rate

4.1.3.12 Company Labor Workforce

As presented in Table 46 and Figure 38, the majority of the companies included in this research have labor workforce over 10 and less than 100 employees.

Table 46: Company Labor Workforce

	Frequency	Percent (%)	Cumulative Percent (%)
1-10	6	10.7	10.7
11-20	12	21.4	32.1
21-100	25	44.6	76.8
>100	13	23.2	100.0
Total	56	100.0	

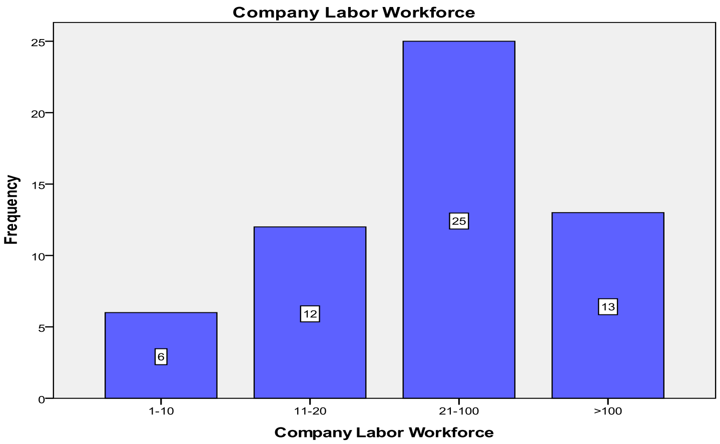


Figure 38: Frequency Distribution of Company Labor Workforce

4.2 Multiple Linear Regression Analysis Results

In this study, multiple linear regression analysis was used to investigate whether or not the proactive site safety performance can be predicted by the project and company related factors and how well. The basic equation of a multiple linear regression model is shown as follows:

$$Y_i = (b_o + b_1X_1 + b_2X_2 + b_3X_3 + \ldots\ldots\ldots + b_nX_n) + \varepsilon_i$$

In this model, Y is the predicted variable (dependent variable) and b_o is the constant in the model. X values are known as the predictors (independent variables) and b values are known as the coefficient values of the predictors. ε value is the difference between the predicted and observed value of Y.

Wright (1997) suggests using stepwise regression methods for exploratory model building and Field (2009) suggests using backward method over forward method in stepwise regression when there are numerous independent predictors to run a multiple regression model to observe which variables predict the dependent variable significantly and well. Therefore, in this study, the backward method was utilized because forward selection is more likely to exclude predictors that impact the outcome than backward elimination method. In other words, forward selection is more prone to missing a predictor that does in fact contribute to the prediction of the outcome.

This method starts with placing all independent variables (predictors) in the model and calculates the contribution of each predictor by examining the significance value through t-test (test the null hypotheses that the value is zero). If a predictor does not report any significance, meaning that it is not found to contribute (meaning not changing the outcome) how well the model predicts the outcome, it is removed from the model and model is re-run with the remaining independent variables and re-assessed. As stated earlier, there are key issues such as sample size in regression, multicollinearity and generalization that need to be addressed while running multiple regression analyses in order to obtain reliable estimates.

Green (1991) set two rules of thumb for minimum acceptable sample size. He stated that the sample size should be larger than 50+8k or 104+k, whichever is greater, where k is the number of predictors. This study included 591 site safety status reports which is an indicative of a sufficient sample size for a regression analysis.

When there are several predictors, multiple correlation coefficients need to be reviewed. Correlation matrix illustrates the Pearson correlation coefficients and significance in between each variable. The two tail test was used in this study because the nature of the relationship between the dependent and independent variables could not be foreseen. Two variables can either be positively related or negatively related if there is a correlation. When a variable is perfectly correlated with another variable, r value is 1 (r=1). Significance tells us whether or not this correlation occurrence is due to chance. For instance: if Pearson correlation coefficient value is 0.439 between two variables, ($r = .439$, $p < .01$), it means that the two variables are positively related and one can explain the other one 19.27% ($r^2 = 0.439^2$) and there is a less than 0.001 probability that a correlation coefficient would have occurred by chance in the sample. Correlation matrix is also valuable to identify possible multicollinearity issues between variables. Field (2009) suggests that if a correlation coefficient value is more than 0.9 ($r>0/9$), it may be an indication of multicollinearity and suggests dropping one of the variables from the analyses. In our multiple regression models, this rule was taken into account and independent variables suggesting high correlation value, $r>0.9$, were removed from the model due to multicollinearity concerns and model was rerun. The decision as to which variable is dropped is based on the contribution level of each variable in the model, and the one with less contribution is removed.

Once the regression model is re-run, it is essential to review analysis of variance (ANOVA) and the F-ratio derived from ANOVA table. F-ratio is used to assess how well a regression model can predict an outcome compared to the error within the model. Essentially, the significance of the model is tested by the F ratio. The model is considered good if F ratio is greater than 1. (Field, 2009) It can be read that whatever the significance value is for instance $p<0.001$, there is less than 0.1% chance that F ratio value arrived is by chance. (p values are used to show the level of significance in the model) In the model, this is represented as F(number of significant predictors, df) p< significance level, where degree of freedom (df) is calculated by the sample size minus the number of predictors minus one.

If the model yields significance, R square (R^2) and Adjusted R square (Adj R^2) values are reviewed. The minimum R^2 value can be zero, and the maximum value can be 1. When R^2 Value gets close to zero, it is an indication of a weaker model. For instance: an R^2 value of 0.564 means that the predictors (independent variables) can predict 56.4% of variation in the dependent variable.

R square (R^2) and Adjusted R square (Adj R^2) values are used to cross validate the model and Adjusted R square value explains how well the model can work with future samples. For generalization purposes shrinkage is used, which is the difference between R square value and Adj R square value. Lower proportional shrinkage values imply better generalization of the model. The amount of shrinkage is affected by the sample size and the number of predictor variables: The larger the sample size and the fewer predictors are, the lower the shrinkage gets. There are no guidelines in the literature as it relates to the tolerance of shrinkage. For instance: for a model with a R square value of 0.459 and an Adjusted R square value of 0.454, the shrinkage value would be 0.005, which is 0.5%. This means that if the model was derived from the population rather than our sample it would account for around 0.5% less variance in the outcome which also means the model can be generalized. Data splitting is also another method for large samples used to determine if the model can be generalized but was not utilized in this study due to the number of variables and sample size.

As it was mentioned earlier, after the model is run multicollinearity needs to be looked at and any variable that may suggest multicollinearity should be dropped from the model. This can be performed by reviewing the tolerance and variance of inflation (VIF) factors. In this study, all predictors were examined and when the tolerance was found less than .20 and VIF value was found above 4 (Menard, 1995, Myers, 1990), that particular variable was removed from the model and the model was re-run.

In regression analysis, standardized coefficients are used to show the importance of a predictor in the model and how they influence the dependent variable, positively or negatively. On the other hand, unstandardized coefficient values indicate the individual contribution of each predictor to the model and explain the relationships between the dependent and independent variables.

It must be noted that there were 591 site safety reports, 121 projects and 56 companies used in the regression models. Due to their relative importance within the model, project and company related factors where some companies and projects were visited more frequently were given more weight and multiplied by the number of site visits. This study contained seven regression models (Figure 5) and the dependent and independent variables included in the models will be explained in detail in each model. As previously mentioned, before the regression analyses were run, correlation analyses were performed and results were reviewed to address any multicollinearity issues. Table 47 presents the correlations between the variables entered in Model 1 thru Model 4.

Model 1

The variables included in Model 1 are as follows:

Dependent Variable (591 site safety reports): Penalty amounts based on OSHA's gravity based penalty system per Company

Independent Variables:

- Project Related Factors (121 projects): Duration, Total Number of Employees at Site, Original Contract Amount, Change Order Amount.
- Company Related Factors (56 companies): Company Size, Years of Experience, EMR, Employee Hours Worked, Total Recordable Cases, Lost Workday Cases, Non-Fatal Cases without Lost Workdays Cases, Company Labor Workforce, Gender Ratio

Table 47: Correlation Analysis for Model 1 thru Model 4

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Penalty Amount based on OSHA Penalty System	1	,873**	,451**	,410**	,552**	,272**	,515**	,017	-,260**	,439**
2. Numbers of Observed Violations		1	,295**	,297**	,318**	,145**	,294**	-,016	-,198**	,136**
3. Project Duration (Days)			1	,767**	,850**	,760**	,886**	-,009	-,466**	,470**
4. Number of Employees at Site per Company				1	,859**	,686**	,873**	-,048	-,386**	,465**
5. Original Contract Amount					1	,660**	,979**	-,044	-,347**	,708**
6. Change Order Amount						1	,800**	,031	-,338**	,269**
7. Final Contract Amount							1	-,027	-,369**	,639**
8. Percent of Original Contract Amount Change								1	-,032	-,051
9. Number of Projects per Company									1	-,182**
10. Company Size										1
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
11. Years of Experience	1	-,511**	,124**	,345**	,185**	,349**	,160**	,002	,108**	-,043
12. EMR		1	-,160**	-,117**	-,053	-,122**	,164**	,077	-,199**	,191**

13. Employee Hours Worked Previous Year			1	,523**	,370**	,489**	-,038	-,182**	,931**	-,410**
14. Total Recordable Cases				1	,678**	,949**	,599**	,239**	,528**	-,235**
15. Lost Workday Cases					1	,412**	,309**	,577**	,393**	-,209**
16. Non-Fatal Cases Without Lost Workdays						1	,610**	,049	,486**	-,202**
17. Total Recordable Incidence Rate							1	,456**	,023	-,051
18. Lost Time Incidence Rate								1	-,105*	-,008
19. Company Labor Workforce									1	-,494**
20. Gender Ratio (Female/Male)										1

*Correlation is significant at the .05 level (2 tailed), ** Correlation is significant at the .01 level (2 tailed)

Dependent variable was calculated by taking an average of all penalty amounts proposed for all sites visited for each company and weighted by total number of site visits per company. Independent variables were calculated in a similar method. An average of each project related factor was calculated based on the number of projects each company had and weighted by the total number of site visits per company. Moreover, company related factors were weighted by the total number of site visits per company.

In the backward run model, 13 variables were entered in the model and based on the correlation analyses shown in Table 47, variables suggesting high correlation were removed from the model, and the model was re-run. The analysis revealed that the model was significant, (F (6, 584) = 125,849, p < .01). Seven variables did not yield significant results and six variables were proved to be significant in determining site safety performance, verified by the two tail t-test with 0.01 level of significance. Company Size, Years of Experience, EMR, Lost Workday Cases, Non-Fatal Cases without Lost Workdays, Company Labor Workforce predicted the site safety performance based on OSHA's GBP system penalty significantly. The following table, Table 48, illustrates the unstandardized and standardized coefficients for this model.

Table 48: The Stepwise Regression Analysis Coefficients Results for the Site Safety Performance Measure and Project And Company Related Factors – Model 1

Variables	**Unstandardized**		**Standardized**	**Collinearity Statistics**	
	B	**Std. Error**	**β**	**Tolerance**	**VIF**
(Constant)	-7383.433**	1104.391	-	-	-
Company Size ($)	0.00001357**	.000	.277	.851	1.175
Years of Experience	56.485**	6.937	-.282	.622	1.606
EMR	13555.673**	1126.782	.408	.649	1.541
Lost Workday Cases	-760.284**	59.059	-.401	.771	1.297
Non-Fatal Cases Without Lost Workdays	181.806**	28.450	.224	.610	1.639
Company Labor Workforce	33.302**	2.461	.481	.592	1.690

Note. R = .751, R^2 = .564, Adjusted R^2 = .559, N = 591, Dash indicates no value

* $p < .05$, ** $p < .01$ (p represents a level of statistical significance level)

The regression equation of Model 1 that was developed is of the following form:

SSPV = -7,383.43 + 13.57 x Company Size (Million) – 56.49 x Years of Experience + 13.56 x EMR – 760.28 x Number of Lost Workday Cases + 181.81 x Number of Non-Fatal Cases Without Lost Workday + 33.3 x Company Labor Workforce + ε

The model accounted 56.4% of the total variance in the proposed penalty amounts. Company Labor Workforce had the highest and positive impact on the safety performance when standardized scores were compared. When it is increased by one point and all other variables are held constant, the penalty amount increases 33.302 dollars meaning decrease in safety performance. The second highest characteristic was EMR score. When EMR score of a company is increased by 0.1 and all other variables are held constant, the penalty amount increases 1,355.67 dollars. The third highest characteristic was the number of lost workday cases with -.401 standardized coefficient. It was negatively associated with the penalty amount meaning increased safety performance. This means that after an injury or illness occurs with lost time, the company takes extra measures to avoid a similar situation which leads to an increase in safety performance as a proactive measure. When a project experiences one lost day work incident and all other variables are held constant, the penalty amount decreases 760.28 dollars. The fourth highest characteristic was years of experience and was negatively associated. When experience of a company is increased by one year and all other variables are held constant, the penalty amount decreases 56.49 dollars meaning the safety performance increases. The fifth highest characteristic was company size and was positively associated. When company size is increased by one million dollars and all other variables are held constant, the penalty amount increases 13.57 dollars meaning the safety performance decreases. The least impactful was Non-Fatal Cases without Lost Workdays cases. When the Non-Fatal Cases without Lost Workdays is increased by one and all other variables are held constant, the penalty amount increases 181.81 dollars.

Model 2

The 2nd model is not much different than the first model. Incidence cases were replaced by the incidence rates and also Original Contract Amount and Change Order Amount were replaced by Final Contract Amount, Percent of Original Contract Amount Change. The purpose of this model was to utilize the widely used industry performance measure incidence rates and probe the effect over the site safety performance. The variables included in Model 2 are as follows:

Dependent Variable (591 site safety reports): Penalty amounts based on OSHA's gravity based penalty system per Company

Independent Variables:

- Project Related Factors (121 projects): Duration, Total Number of Employees on Site, Final Contract Amount, Percent of Original Contract Amount Change
- Company Related Factors (56 companies): Company Size, Years of Experience, EMR, Total Recordable Incidence Rate, Lost Time Incidence Rate, Number of Hours Worked Previous Year, Company Labor Workforce, Gender Ratio

Dependent variable was calculated by taking an average of all penalty amounts proposed for all sites visited for each company and weighted by total number of site visits per company. Independent variables were calculated in a similar method. An average of each project related factor was calculated based on the number of projects each company had and weighted by the total number of site visits per company. Moreover, company related factors were weighted by the total number of site visits per company.

In the backward run model, 12 variables were entered in the model and based on the correlation analyses shown in Table 47, variables suggesting high correlation were removed from the model and model was re-run. The analysis revealed that the model was significant, (F (7, 583) = 85.403, p < .01). Seven variables were proved to be significant in determining site safety performance, verified by the two tail t-test with 0.01 level of significance. Company Size, Years of Experience, EMR, Lost Time Incidence Rate, Total Recordable Incidence Rate, Company Labor Workforce and Percent of Original Contract Amount Change predicted the site safety performance based on OSHA's GBP system penalty significantly. Table 49 illustrates the unstandardized and standardized coefficients.

Table 49: The Stepwise Regression Analysis Coefficients Results for the Site Safety Performance Measure and Project And Company Related Factors – Model 2

Variables	**Unstandardized**		**Standardized**	**Collinearity Statistics**	
	B	**Std. Error**	**β**	**Tolerance**	**VIF**
(Constant)	-5339.721	1213.408	-	-	-
Percent of Original Contract Amount Change	172.983	50.522	.101	.972	1.029
Company Size	.00001**	.000	.283	.833	1.200
Years of Experience	45.347**	7.174	-.226	.660	1.515
EMR	11419.987**	1254.760	.344	.593	1.685
Total Recordable Incidence Rate	93.170**	12.935	.254	.682	1.466
Lost Time Incidence Rate	-291.256**	36.969	-.262	.765	1.307
Company Labor Workforce	27.297**	2.199	.394	.840	1.190

Note. R = .712, R2 = .506, Adjusted R2 = .500, N = 591, Dash indicates no value

* p < .05, ** p < .01 (p represents a level of statistical significance level)

The regression equation of Model 2 that was developed is of the following form:

SSPV = -5339.72+ 10 x Company Size (Million) – 45.35 x Years of Experience + 11.42 x EMR – 291.26 x Lost Time Incidence Rate + 93.17 x Total Recordable Incidence Rate + 27.3 x Company Labor Workforce + 172.98 x Percent of Original Contract Amount Change + ε

The model accounted 50.6% of the total variance in the proposed penalty amounts. Total Labor Workforce had the highest and positive impact on the safety performance when standardized scores were compared with .394 standardized coefficient. When labor workforce is increased by one employee and all other variables are held constant, the penalty amount increases 27.30 dollars. The second highest characteristic was EMR value with .344 standardized coefficient. When EMR of a company is increased by 0.1 and all other variables are held constant, the penalty amount increases 1142 dollars. The third highest characteristic was company size and was positively associated. When company size is increase by one million dollars and all other variables are held constant, the penalty amount increases by 13.84 dollars meaning safety performance decreases. The fourth highest characteristic was the lost time incidence rate. It was negatively associated with the penalty amount. When an incidence rate is increased by 0.1 and all other variables are held constant, the penalty amount decreases 2912.6 dollars meaning safety performance increases. The fifth highest characteristic was total recordable incidence rate and was positively associated. When the total recordable incidence rate is increased by 0.1 and all other variables are held constant, the penalty amount increases 931.7 dollars. The sixth highest characteristic was years of experience and was negatively associated. When years of experience of a company is increased by one year and all other variables are held constant, the penalty amount decreases 45.35 dollars meaning safety performance increases. The least impactful characteristic was percent of original contract change and was positively associated. When percent of original contract increase by 1% and all other variables are held constant, the penalty amount increases 192.98 dollars meaning safety performance decreases.

Model 3

The variables included in Model 3 are as follows:

Dependent Variable (591 site safety reports): Number of observed OSHA violations per company

Independent Variables:

- Project Related Factors (121 projects): Duration, Total Number of Employees at Site, Original Contract Amount, Change Order Amount.
- Company Related Factors (56 companies): Company Size, Years of Experience, EMR, Employee Hours Worked, Total Recordable Cases, Lost Workday Cases, Non-Fatal Cases without Lost Workdays Cases, Company Labor Workforce, Gender Ratio

Dependent variable was calculated by taking an average of observed violations noted for each company and weighted by total number of site visits per company. Independent variables were calculated in a similar method. An average of each project related factor was calculated based on the number of projects each company had and weighted by the total number of site visits per company. Moreover, company related factors were weighted by the total number of site visits per company.

In the backward run model, 13 variables were entered in the model and based on the correlation analyses shown in Table 47, variables suggesting high correlation were removed from the model and model was re-run. The analysis revealed that the model was significant, (F (5, 585) = 78.015, p < .01). Eight variables did not yield significant results and five variables were proved to be significant in determining site safety performance, verified by the two tail t-test with 0.01 level of significance. Years of Experience, EMR, Lost Workday Cases, Non-Fatal Cases without Lost Workdays, Company Labor Workforce predicted the number of observed violations significantly. Table 50 presents the unstandardized and standardized coefficients.

Table 50: The Stepwise Regression Analysis Coefficients Results for the Site Safety Performance Measure and Project And Company Related Factors – Model 3

Variables	**Unstandardized**		**Standardized**	**Collinearity Statistics**	
	B	**Std. Error**	**Tolerance**	**Tolerance**	**VIF**
Constant	-2.292**	.341	-	-	-
Years of Experience	.015**	.002	-.283	.627	1.596
EMR	5.208**	.344	.584	.691	1.448
Lost Workday Cases	-.172**	.019	-.337	.772	1.295
Non-Fatal Cases Without Lost Workdays	.061**	.009	.280	.622	1.607
Company Labor Workforce	.005**	.001	.281	.671	1.491

Note. R = .632, R^2 = .400, Adjusted R^2 = .395, N = 591, Dash indicates no value

* $p < .05$, ** $p < .01$ (p represents a level of statistical significance level)

The regression equation of Model 3 that was developed is of the following form:

SSPV = -2.29 – 0.015 x Years of Experience + 5.21 x EMR – 0.172 x Number of Lost Workday Cases + 0.061 x Number of Non-Fatal Cases Without Lost Workday + 0.005 x Company Labor Workforce + ε

The model accounted 40 % of the total variance in the number of observed OSHA violations. EMR was the highest predictor in the model with .584 standardized coefficient. While EMR score increases one point, the number of observed violations increases 5.208. The second highest predictor was the Lost Workday Cases with -.337 standardized coefficient. However, its impact was negative. When Lost Workday Cases is increased by one, the number of observed violations is decreased by .172. The third highest predictor was found to be years of experience with .283 standardized coefficient. When experience of a company is increased by one year, the number of observed violations decreases by 0.015. Other two variables had the similar amount of positive impact on the number of observed violations.

Model 4

The 4th model is not much different than the 3rd model. Incidence cases were replaced by the incidence rates and also Original Contract Amount and Change Order Amount were replaced by Final Contract Amount, Percent of Original Contract Amount Change. The variables included in Model 4 are as follows:

Dependent Variable (591 site safety reports): Number of observed OSHA violations per company

Independent Variables:

- Project Related Factors (121 projects): Duration, Total Number of Employees on Site, Final Contract Amount, Percent of Original Contract Amount Change
- Company Related Factors (56 companies): Company Size, Years of Experience, EMR, Total Recordable Incidence Rate, Lost Time Incidence Rate, Number of Hours Worked Previous Year, Company Labor Workforce, Gender Ratio

Dependent variable was calculated by taking an average of all observed violations noted for each company and weighted by total number of site visits per company. Independent variables were calculated in a similar method. An average of each project related factor was calculated based on the number of projects each company had and weighted by the total number of site visits per company. Moreover, company related factors were weighted by the total number of site visits per company.

In the backward run model, 12 variables were entered in the model and based on the correlation analyses shown in Table 47, variables suggesting high correlation were removed from the model and model was re-run. The analysis revealed that the model was significant, (F (6, 584) = 63.035, p < .01). Six variables were proved to be significant in determining site safety performance, verified by the two tail t-test with 0.01 level of significance. Final Contract Amount, Years of Experience, EMR, Lost Time Incidence Rate, Total Recordable Incidence Rate and Company Labor Workforce predicted the number of observed violations significantly. Table 51 illustrates the unstandardized and standardized coefficients.

Table 51: The Stepwise Regression Analysis Coefficients Results for the Site Safety Performance Measure and Project And Company Related Factors – Model 4

Variables	**Unstandardized**		**Standardized**	**Collinearity Statistics**	
	B	**Std. Error**	**β**	**Tolerance**	**VIF**
Constant	-1.358**	.346	-	-	-
Original Contract Amount per Company	.00000009**	.000	.156	.885	1.129
Years of Experience	.011**	.002	-.212	.671	1.491
EMR	4.033**	.358	.452	.629	1.589
Total Recordable Incidence Rate	.034**	.004	.349	.696	1.436
Lost Time Incidence Rate	-.067**	.011	-.223	.733	1.363
Company Labor Workforce	.004**	.001	.209	.910	1.099

Note. R = .639, R^2 = .408, Adjusted R^2 = .402, N = 591, Dash indicates no value

* $p < .05$, ** $p < .01$ (p represents a level of statistical significance level)

The regression equation of Model 4 that was developed is of the following form:

SSPV = -1.36 + 0.09 x Original Contract Amount per Company (Million) – 0.011 x Years of Experience + 4.03 x EMR – 0.067 x Lost Time Incidence Rate + 0.034 x Total Recordable Incidence Rate + 0.004 x Company Labor Workforce + ε

The model accounted 40.8 % of the total variance in the number of observed OSHA violations. EMR was the highest predictor in the model with .452 standardized coefficient. While EMR score increases one point, the number of observed violations increases 4.033. The second highest predictor was Total Recordable Incidence Rate with .349 standardized coefficient. When Total Recordable Incidence Rate increases one, the number of observed violations increases .034. Lost Time Incidence Rate had -.223 standardized predictor impact. When it increases one, the number of observed violations decreases .067. The fourth highest predictor was found to be years of experience with .212 standardized coefficient. When experience of a company is increased by one year, the number of observed violations decreases 0.011. Other two variables had the similar amount of positive impact on the number of observed violations.

Model 5

The variables included in Model 5 are as follows:

Dependent Variable (591 site safety reports): Penalty amounts based on OSHA's gravity based penalty system per project.

Independent Variables:

- Project Related Factors (121 projects):: Construction Type, Duration, Total Number of Employees on Site, Original Contract Amount, Change Order Amount

Dependent variable was calculated by taking an average of all penalty amounts proposed for all sites visited for each project and weighted by total number of site visits per project. Independent variables were calculated in a similar method and project related factors were weighted by the total number of site visits per project.

The project type was categorized based on its complexity and sorted from difficult to less difficult as new construction, addition, renovation and demolition respectively. The project complexity was defined based on the type of construction and sorted the complexity from difficult to less difficult as new construction, addition, renovation and demolition respectively. The less complex type of construction was given one point and the most complex was given four points in the analysis.

Table 52: Correlation Analysis for Model 5

	1	2	3	4	5	6
1. Penalty Amount based on OSHA Penalty System	1	,441**	,304**	,419**	,393**	-,486**
2. Original Contract Amount		1	,680**	,807**	,894**	-,673**
3. Change Order Amount			1	,793**	,627**	-,399**
4. Duration of the Project				1	,746**	-,546**
5. Number of Employees at Site per Project					1	-,811**
6. Construction Type						1

** Correlation is significant at the .01 level (2 tailed)

In the backward run model, five variables were entered in the model and correlation analyses results shown in Table 52 were reviewed. The analysis revealed that the model was significant, ($F(2, 588) = 51.616$, $p < .01$). Two variables were proved to be significant in determining site safety performance, verified by the two tail t-test with 0.01 level of significance. Construction type and original contract amount predicted the site safety performance based on OSHA's GBP system penalty significantly. Table 53 demonstrates the unstandardized and standardized coefficients.

Table 53: The Stepwise Regression Analysis Coefficients Results for the Site Safety Performance Measure and Project Related Factors – Model 5

Variables	**Unstandardized**		**Standardized**	**Collinearity Statistics**	
	B	**Std. Error**	**β**	**Tolerance**	**VIF**
(Constant)	15044.354**	813.064	-	-	-
Original contract amount	.00004**	.000	.155	.547	1.829
Construction type	1557.980**	302.561	.265	.547	1.829

Note. $R = .386$, $R^2 = .149$, Adjusted $R^2 = .146$, $N = 591$, Dash indicates no value

* $p < .05$, ** $p < .01$ (p represents a level of statistical significance level)

The regression equation of Model 5 that was developed is of the following form:

SSPV = 15044 + 40 x Original Contract Amount Size (Million) + 1557.98 x Type of Construction (1 to 4) + ε

The model accounted 14.9 % of the total variance in the proposed penalty amounts. Construction type was the most important predictor. When construction type gets more complex meaning for instance renovation to addition, the penalty amount as safety performance indicator increases 1557.99 dollars. The second predictor was Original contract amount. When it is increased by one million dollars, the penalty amount as safety performance indicator increases 40 dollars.

Model 6

The variables included in Model 6 are as follows:

Dependent Variable (591 site safety reports): Penalty amounts based on OSHA's gravity based penalty system per site

Independent Variables:

- Project Related Factors associated with a site (591 site safety reports): Number of Trades, Number of Employees at Site and SOC Building Trades (Brick, Block, Stone Masons, Concrete Finishers, Glaziers, Painters, Steel Workers, Drywall Installers, Floor Installers, Equipment Operators, Tile setters and marble setters, Insulation Workers, Sheet Metal Workers, Roofers, Plumbers, Construction Laborers (Bleacher, Fence, Survey Included), Carpenters, Electricians)

Field (2009) suggests that continuous variables and categorical variables can be run together when categories are coded as zero and one (dichotomous). In the backward run model, 2 continuous and 16 categorical variables were entered in the model and correlation analyses results shown in Table 54 were reviewed. SOC variables were coded as zero meaning that there was no employee from that specific trade and one meaning that there was/were employee(s) from that specific trade in presence.

Table 54: Correlation Analysis for Model 6 and 7

	1	2	3	4	5	6	7	8	9	10
1. Penalty Amount based on OSHA Penalty System	1	,912**	,267**	,228**	,197**	,162**	-,055	-,076	,230**	,036
2. Numbers of Observed Violations		1	,219**	,181**	,165**	,108**	-,029	-,075	,171**	,031

3. Number of Employees at Site			1	,747**	,423**	,397**	,285**	,145**	,238**	,326**
4. Number of Trades at Site				1	,500**	,477**	,340**	,268**	,374**	,447**
5. Brick masons, Block masons and Stonemasons					1	,216**	,083*	,009	,184**	,112**
6. Concrete Finishers						1	,008	-,114**	,504**	,003
7. Glaziers							1	,440**	-,114**	,261**
8. Painters								1	-,179**	,223**
9. Steel Workers (Ironworkers)									1	-,096*
10. Drywall Installers										1
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
11. Floor Installers	1	-,124**	-,043	,046	-,017	,014	,189**	-,099*	,246**	,206**
12. Equipment Operators		1	-,070	,081*	-,012	-,220**	,037	,262**	,051	-,027
13. Tile setters and marble setters			1	-,053	,009	-,016	,013	-,076	-,098*	,018
14. Insulation Workers				1	,342**	,344**	,156**	-,101*	,167**	,189**
15. Sheet Metal Workers					1	,526**	,308**	-,256**	,239**	,194**
16. Roofers						1	,091*	-,306**	,134**	,096*
17. Plumbers							1	-,195**	,338**	,427**
18. Construction Laborers								1	-,082*	-,137**
19. Carpenters									1	,243**
20. Electricians										1

*Correlation is significant at the .05 level (2 tailed), ** Correlation is significant at the .01 level (2 tailed)

The analysis revealed that the model was significant, (F (4, 586) = 17.707, p < .01). Fourteen variables did not yield significant results and four variables were proved to be significant in determining site safety performance, verified by the two tail t-test with 0.01 and 0.05 level of significance. brick, block, stone masons, steel workers, equipment operators and roofers predicted the site safety performance significantly. Table 55 reports the unstandardized and standardized coefficients.

Table 55: The Stepwise Regression Analysis Coefficients Results for the Site Safety Performance Measure and Project Related Factors – Model 6

Variables	**Unstandardized**		**Standardized**	**Collinearity Statistics**	
	B	**Std. Error**	**β**	**Tolerance**	**VIF**
(Constant)	5367.240**	514.867	-	-	-
Brick, Block, Stone Masons	2283.013**	651.786	.140	.949	1.053
Steel Workers (Ironworkers)	3012.746**	800.391	.165	.791	1.264
Equipment Operator	1642.049*	813.060	.089	.776	1.288
Roofers	3077.217**	709.230	.176	.924	1.082

Note. R = .328, R^2 = .108, Adjusted R^2 = .102, N = 591, Dash indicates no value

* $p < .05$, ** $p < .01$ (p represents a level of statistical significance level)

The regression equation of Model 6 that was developed is of the following form:

SSPV = 5367.24 + 2283.01 x Brick, Block, Stone Masons (0 or 1) + 3012.75 x Steel Workers (0 or 1) + 1642.05 x Equipment Operators (0 or 1) + 3077.22 x Roofers (0 or 1) + ε

The model accounted 10.8 % of the total variance in the proposed penalty amounts. The most important predictor was Roofers. When a roofer trade is involved in a project, the safety penalty amount increases 3077.22 dollars. Steel workers had the second highest predictor. When a steel trade is involved in a project, the safety penalty amount increases 3012.75 dollars. The third highest predictor was brick, block, stone masons; when this trade is engaged in a project, the safety penalty amount increases 2283.01 dollars. The final and the least impactful predictor was Equipment Operators. When equipment operators are present at a project, the safety penalty amount increases 1642.05 dollars.

Model 7

The variables included in Model 7 are as follows:

Dependent Variable (591 site safety reports): Number of observed OSHA violations per site.

Independent Variables:

- Project Related Factors associated with a site (591 site safety reports): Number of Trades, Number of Employees at Site and SOC Building Trades (Brick, Block, Stone Masons, Concrete Finishers, Glaziers, Painters, Steel Workers, Drywall Installers, Floor Installers, Equipment Operators, Tile setters and marble setters, Insulation Workers, Sheet Metal Workers, Roofers, Plumbers, Construction Laborers (Bleacher, Fence, Survey Included), Carpenters, Electricians)

In the backward run model, 2 continuous and 16 categorical variables were entered in the model and correlation analyses results shown in Table 54 were reviewed. SOC variables were coded as zero meaning that there was no employee from that specific trade and one meaning that there was/were employee(s) from that specific trade in presence.

The analysis revealed that the model was significant, ($F(3, 587) = 12.645$, $p < .01$). Fifteen variables did not yield significant results and three variables were proved to be significant in determining site safety performance, verified by the two tail t-test with 0.05 level of significance. Brick, block, stone masons, steel workers and roofers predicted the site safety performance significantly. Table 56 presents the unstandardized and standardized coefficients.

Table 56: The Stepwise Regression Analysis Coefficients Results for the Site Safety Performance Measure and Project Related Factors – Model 7

Variables	**Unstandardized**		**Standardized**	**Collinearity Statistics**	
	B	**Std. Error**	**β**	**Tolerance**	**VIF**
(Constant)	2.226**	.167	-	-	-
BBSMasons	.679**	.226	.123	.950	1.053
Steel	.904**	.251	.146	.966	1.035
Roofers	.681**	.239	.115	.983	1.018

Note. R = .246, R^2 = .061, Adjusted R^2 = .056, N = 591, Dash indicates no value

* $p < .05$, ** $p < .01$ (p represents a level of statistical significance level)

The regression equation of Model 7 that was developed is of the following form:

SSPV = 2.23 + 0.68 x Brick, Block, Stone Masons (0 or 1) + 0.90 x Steel Workers (0 or 1) + 0.681 x Equipment Operators (0 or 1) + ε

The model accounted 6.1 % of the total variance in the number of observed OSHA violations. The most important predictor was steel workers. When a steel trade is involved in a project, the number of observed violations increases .904. The second highest predictor was brick, block, stone masons; when this trade is engaged in a project, the number of observed violations increases .679. The third highest predictor was roofers; when a roofer is involved in a project, the number of observed violations increases .681.

CHAPTER 5 DISCUSSION of RESULTS

5.1 Discussion of Results

It is essential to understand how these results compare with previous studies and whether they are easy and practical to implement. The study found significance between project and company related factors and site safety performance values and whether they influenced the safety performance positively or negatively. The study relied on the OSHA based penalty amounts and number of observed violations as the safety performance values. As the proposed potential penalty amounts escalated, the safety performance value was considered to be declining. This can be clarified in a way that when a company incurs penalty fees, this is in result of non-compliance with the OSHA rules and regulations which signifies poor safety performance. The higher the penalty amount is, the poorer the safety performance gets. As observed, there is a negative correlation between safety performance and proposed penalty amounts (site safety performance value, SSPV). The same approach applies to the number of observed violations. The more violations observed on site translates into a poor safety performance for that specific site due to the lack of OSHA compliance. The following discussions were based on this approach and the interpretations reflected as such. Overall seven regression models were developed (Figure 5) based on using different project and company related factors.

Model 1 and Model 2

Model 1 and Model 2 employed proposed penalty amounts as the site safety performance value (dependent variable) based on OSHA GBP system. The only difference between these two models were the company and project related factors where one included recordable cases, lost time cases and the number of employees worked previous years while the other one included total recordable rates and lost time rates. The industry uses the incidence rates as a safety measure but it can be believed that the rates may not be well understood in the industry because they are calculated based on the number of hours worked by 100 full time employees. On the other hand, the cases are a demonstration of the occurring incidents. The study intended to explore whether using the number of cases will predict the proactive safety performance value better than the rates themselves because of their complexity.

Model 1 and 2 were run separately. They disclosed that when project and company related factors were entered into a model together they both revealed similar results with different predictability rates. As expected, Model 1, where the number of cases was used, developed a more mature model with a higher rate of predictability. Model 1 accounted for 56.4% of the total variance in the penalty amounts (Table 48) and Model 2 accounted for 50.6% (Table 49). Total labor workforce, EMR, company size, recordable incidence rates and cases, non-fatal Cases without lost workdays, lost workday cases and rates, years of experience, and lastly change factor, were found to be significant factors in improving site safety performance.

These findings suggest that in Model 1, more than 56% of variability in the proposed penalty amounts can be predicted by the significant related factors such as total labor workforce, EMR, company size, lost workday cases, non-fatal cases without work lost workday cases and years of experience of a company. Nonetheless, in Model 2, more than half of variability in proposed penalty amounts can be predicted by the significant related factors such as total labor workforce, EMR, company size, total recordable incidence rates, lost time incidence rate, years of experience and percent of original contract change which also can be considered as the change factor. Because these factors have positive and negative correlations with the site safety performance values, they need to be explained further.

Total Labor Workforce: It was found that this factor is positively associated with the site safety performance value when standardized scores were compared in both Model 1 and Model 2. It means that when number of employees increase, the safety performance decreases. Company Labor Workforce was defined by the total number of labor workforce employed by the company. A similar concern with the company size increase arises with increasing the number of labor workforce of a company which may cause lack of proper training or not using the right resources. Hinze (1997) suggested that new hires are more prone to being injured. Also, Hinze and Gambatese (2003) discovered that using the same group of employees increases safety performance by reducing the worker turnover. It was found that higher the turnover, higher the number of new hires which results in higher injury rates.

Another factor that can adversely impact the site safety performance is resource allocation. Findley, et al. (2004) emphasized the importance of hiring a full time safety manager and providing him/her with continuous education, and indicated that this practice increases the safety performance at the company level. However, based on the discussions with the safety professionals as well as construction executives from the construction industry who are involved in decision making process on submitting a bid or in providing a go, no-go analysis, it can be said that some companies do not necessarily take their safety personnel’s workload into account and analyze their ability during the bidding process. The work overload can overwhelm the safety person and can cause him/her not to perform his/her tasks to the fullest. Safety professionals acknowledged that until a project is awarded bidding for a job, meaning preparing the bid documents, making financial arrangements and assembling the subcontractors, usually take precedence and safety personnel resource allocation is not fully considered. When the project is awarded, the assumption is sometimes made in a way that safety personnel already employed by the company are adequate and proportional safety commitment is not necessary due to budget constraints.

Vague language in construction contracts as it relates to the requirement of safety personnel can be another obstacle in providing a job site with the right amount of safety personnel. Some contracts require one full time safety person where companies can get away with only having one safety person for the entire company whereas some contracts require one full time safety person at the job site at all times. These produce challenges for safety personnel as well as employees and result in reduction in relative site safety performance because essentially resource allocation proportion is not adequate. This is consistent with Huang and Hinze's (1996) findings in their study, Owner's Role in Construction Safety. They found that requiring at least one full-time safety person for a project and including a requirement of submitting their resumes for the owner's approval in a contract are significantly related to project safety performance. This presents an opportunity where safety can be improved by establishing a safety person and the number of labor workforce proportion rate which can be integrated into the bidding documents as a mandatory requirement to prequalify.

EMR: The study uncovered that the EMR value was negatively correlated with the safety performance value as a proactive measure, and the second highest predictor of site safety performance. It is known that EMR is a value used to calculate insurance premiums, and as the EMR values go higher, the safety performance decreases which is consistent with Jaselski, Anderson, Russell (1996) study. However, in this study different from the preceding studies, EMR value was explored from another perspective to find out if it has an impact on a site safety performance as opposed to having an influence of company performance. In other words, it was essential to understand if a company learns from its mistakes and improve its safety in their future construction sites based on its EMR value. Even though, the study found that EMR is a significant factor in calculating site safety performance, it is negatively correlated with site safety performance meaning companies' high EMR values do not help them improve their site safety performance. It can be assumed that EMR is just seen as a rating in the industry and cannot be used to identify any hazards or areas of concern, so the necessary precautions can be taken to eliminate or mitigate them. The companies with higher EMR values, nevertheless, still have a tendency to have poor safety performance at a site specific level. This again can be explained by the shortcomings of EMR value. One of the main shortcomings of EMR was that it is based on the first three years of the last four years of company's number of injuries and illnesses and loss claims. Hence, company's last year in terms of safety performance is not taken into account. If there has been improvements made on how it operates in terms of safety or safety performance has been deteriorated, there is a high chance that these transformations will not be recognized instantly. Because of the structure of how an EMR value is calculated, it takes a period of time to change the movement of an EMR value. Levitt and Samelson (1993) discussed that EMR’s main purpose of motivating employers is no longer effective, and Hoonakker et al. (2004) stated that EMR does not present the current safety performance. These findings support the results of this study.

Company Size: Company size was defined as the company’s previous year’s revenue which was the value of all contracts the company was awarded within the specified time period. As seen from the analysis, it is positively correlated with the safety performance value calculated based on the proposed penalty amounts which indicate that as the company assumes more work and increases its labor workforce, the safety performance is adversely affected. The findings are in line with Hinze and Gambatese’s (2003) study as they realized that for smaller companies, there is a tendency to have higher incidence rates as the company size increases. This can be explained by analyzing the company’s financial capacity in conjunction with the value of contracted work. It is apparent that the company has to grow its’ resources as it gets larger up to a certain extent to deliver the projects to the owner’s satisfaction in both public and private sectors. However, this presents some challenges as even companies that are well qualified and safe react differently as it relates to safety performance under different workloads. A company which bids and undertakes more contracts than it is capable of handling gets more exposed to risk and liability, and might compromise on safety performance in order to get the job done. Despite the precautions that may be taken, putting pressure on employees and demand more than what they are capable of can cause poor safety performance. Sawacha, Naoum and Fong (1999) examined the impacts of the psychological and organizational issues on safety performance and found that providing a stress-free environment by the management improves construction safety.

Also, Leung, Chan, and Yu (2012) studied how personal stress and organization stressors shape safety performance through managing them to prevent the incidents. The results revealed that there is a direct relationship among these factors. Five organizational stressors, two types of personal stress and safety behaviors were identified impacting worker injury incidents. Out of these factors, construction worker injury incidents were confirmed to be substantially affected by the organization factors and their safety behaviors. Based on the findings of this study, worker stress caused by the organizational stressors can be the reason of company size and its' effects on poor site safety performance. This can be investigated further in future studies. In another study performed by Chan (2011), three types of stress, work, emotional, and physical stress, were identified that influence injury incidence rates. It was discovered that in order to reduce the number of injury incidents among construction workers, management needs to maintain the work stress of the workers at moderate level by adjusting their workload.

Because of this concern, many federal states in the United States have developed and started to integrate a workload and capacity rating evaluation system in their contractor solicitation procedures as a result of benchmarking, which means comparing and learning from Best Practices, in the construction industry (Palaneeswaran and Kumaraswamy, 2000). For instance, Washington State Department of Transportation utilizes ratings such as a maximum capacity rating which is the value of maximum incomplete contracted work a company can assume and a work class rating which is the value of maximum specific type of work such as demolition, transportation, renovation and so forth a company can undertake to establish rules if a company is eligible to participate in bidding (Palaneeswaran and Kumaraswamy, 2000). This approach can both protect the owner and the contractor from unwanted situations before it is too late. Without knowing, during the procurement phase, what the company's capacity is in terms of its ability to manage multiple projects concurrently can lead to reduction in construction safety performance. In other words, increasing the company size without knowing its resources can adversely impact safety performance. Companies can take this as an opportunity to reassess their finances and resources prior to submitting a new bid, and to organize their workforce accordingly without compromising safety and efficiency and to avoid overloading its employees.

Lost Workday Cases or Lost Work Time Incidence Rate: It was negatively associated with site safety performance value. It may seem counterintuitive but when it is thought thoroughly, it can benefit the site safety performance significantly. This means that after an injury or illness occurs with lost time, companies have a tendency to take extra measures to avoid a similar situation. This leads to an increase in safety performance as a proactive measure. If an injury and illness results in a lost work day, it represents severity and can be considered significant. It can get management involved and start an accident investigation which requires further examination of the situation. This also was evidenced by the Jaselski and Suazo's (1994) study conducted to explore the importance of safety in construction industry. The study found that the management is notified of the lost time incident cases upon occurrence which lead them to take the necessary measures to mitigate and eliminate future incidences and an important factor in improving safety performance.

The construction industry still remains the most dangerous amongst all industries based on the number of lost work day cases. Therefore, this rate sometimes is used to measure the safety performance of a company. This figure presents with an opportunity for the construction industry to transform this weakness into strength by learning from the mistakes and use this element in a proactive safety performance measurement approach. A reduction in the number of lost workday cases directly results in an increased safety performance due to better flow in production or output on the job.

Non-fatal Cases without Lost Workdays Cases: It was positively associated with the site safety performance value which leads the researcher to believe that if the injury/illness does not prevent the employee return to Work, the companies may not recognize the potential hazards and take measures to prevent them to reoccur which reduces the safety performance. This can identify an area that may have been overlooked by the professionals for decades. Hinze and Godfrey (2003) touched on this concern in their study that many companies promote their safety success based upon having no lost workday injury or illness cases. When companies depend on this criterion in terms of safety performance, there is a possibility they become hesitant to report the seriousness of such injury or illness and may seek methods not to report lost workdays. They may keep the employee on the payroll even if the employee is not working or in some cases re-assign the employee to perform office tasks such as copying or data entry or to less difficult tasks which do not require physical fitness (also known as cases with job transfer or restriction) even if it not recommended by the doctor. These types of behaviors can cause serious injuries to be reported as non-serious injuries which can result in focusing on the outcome than the root causes of an injury or illness. This can be misleading and indicate no major changes in safety performance. The literature suggests that in some instances management is not notified of the severity of these injuries and illness. Jaselskis and Suazo’s (1994) survey based study found that the top management is not completely informed of the lost time incident cases. On the other hand, as mentioned earlier, the same study showed that the management is notified of the lost time incident cases. Without knowing how severe these cases are, it is rather challenging to recognize the hazards causing them and take the necessary precautions to mitigate or eliminate them. This explains why cases without lost workday have a negative association with the proactive site safety performance. It certainly is essential to understand the severity of these cases and analyze cases which employee returns to work to perform his/her routine task and cases which employee transfers to another job or have restrictions individually. Studying these factors separately might present different findings. Hinze, Devenport and Giang (2006) also investigated the types of minor injuries that do not result in work lost days and found that causes of minor injuries are different than causes of major injuries and are associated with other factors such as lacerations, eye injuries or back problems. They recommended these factors be considered while establishing safety programs as they are not given the attention they need. Regardless of the extent of an injury or illness, whether it is major or minor, it needs to be taken seriously as it causes human suffering and costs money. As reported, this factor can easily become a positive proactive measure by keeping the management informed of these incidents, and by better recordkeeping.

Total Recordable Incidence Rate: It was found that total recordable incidence rate, which is calculated by the number of all injuries and illness including the injuries and illness without lost workday cases, was positively associated with site safety performance value meaning decreases the proactive site safety performance when the rate is increased. As previously noted, non-fatal cases without lost workdays do not provide improvement on site safety performance as the hazards may not be recognized. It is still a significant predictor, yet a good total recordable incidence rate does not necessarily indicate that the company will operate in a safe manner in future projects. It is observed that safety enhancements made as a result of the cases that cause lost workdays are offset by the lack of attention given to the cases that do not cause lost workdays.

Hinze and Gambatese (2003) probed into factors that influence safety performance of specialty contractors, mechanical and roofing contractor, and discovered that as the company size increases in terms of the annual revenue or projects completed per year or number of employees, it can lead to higher OSHA recordable injury incidence rate for firms with revenues less than fifty million dollars per year, which comprises the majority (88%) of the companies included in this study. The same study revealed that for companies ranging from fifty million dollars to six hundred million dollars per year, which were considered to be large enough to require an advanced safety program, may have lower incidence rates. In other words, company growth can adversely affect the safety performance by increasing the incidence rates unless it is supported with a well developed safety program.

In addition, another study that was conducted by Garza, Hancher and Decker's (1998) found that recordable incidence rate is affected by the company size which also is negatively associated with site safety performance. Similar to this study, company size was defined by the dollar amounts of new contracts received in a specific year in their study and supports the findings of this study regarding the adverse effects of company size and total recordable incidence rates on site safety performance. It was discussed by Garza, Hancher and Decker (1998) that large contractors, defined as companies with revenues over one hundred million dollars per year, are able to afford having on site first-aid personnel or first aid treatment facilities to examine the injuries prior to redirect them to health clinics or hospitals. Incidents that do not require medical treatment are not recorded which can influence the recordable rate of the company in a positive manner even though the safety of employees may be questionable. Hinze and Godfrey (2003) also indicated that having an on-site medical staff compromises the integrity of recordable incidence rate system. They stated that two projects, one with on-site nurses or emergency medical technicians, and the other with no on-site medical staff, cannot be compared equally because some injuries treated by the on-site medical staff would have been an OSHA recordable incident if it was not for the on-site treatment. It must be noted that large projects included in this study had on-site safety personnel. These factors can be considered as the main reasons of why total recordable injury can be low but it may not affect the future site safety performance in a constructive manner. Hinze and Godfrey (2003) also expressed a concern about the bonus system and incentive programs and their effects on site safety performance by not reporting the incidents.

Years of Experience: It was negatively associated with the site safety performance value which was an indication of an increased safety performance. The findings revealed that as a company gains more experience, they understand the value of safety better and learn to educate their employees which result in improved safety performance. Jaselski, Anderson, Russell (1996) analyzed in their study the effects of years of company experience on company safety performance and found that there is a negative relationship between company's EMR value and the years of experience which is in accordance with this study. They stated that the more experience a company gains in construction business, the less its EMR value gets. The findings are also corresponding to Lingard and Rowlinson (1994) study which pointed out that firms with more resources and experience have a better handle on health and safety issues. These findings are not unexpected given the realization of importance of construction safety over the years. In order to survive in a competitive environment such as the construction industry, it has become clear that it is more effective and efficient to invest in safety to save money. This can force companies to comply with the safety rules and regulations, and teach them that the projects that are driven by safety are less likely to suffer from budget and schedule setbacks (Cooper, 2001), which lead to improvement in safety performance.

Change Factor: It was positively associated with the site safety performance value, meaning safety performance decreases as the change order amount increases. This means that the scope changes or any unforeseen conditions in a project may create adaptation problems which may be caused by loss of motivation and discouragement which may decrease productivity along with the safety performance. Productivity is one of the fundamental elements of a construction project, and high productivity enables the work to continue as planned without interruptions and be completed in a timely manner or even ahead of schedule. When a change occurs that breaks this uniformity, it causes inefficiencies with continuing work and/or loss of production due to re-work which changes workers and management’s perception. The worker’s priorities may change as a result of a change in management’s expectancy from the worker which shifts worker’s focus to on-time completion than performing tasks in a safe manner, which may lead to reduction in safety performance. As noted earlier, there was no fatality in this program. It can be said that, considering the amount of changes experienced in this program, conducting random inspections at intervals can go a long way in improving site safety performance.

Model 3 and Model 4

OSHA’s penalty system works in a way that because of grouping and combining violations and reduction factors based on company’s size, history and good faith, proposed penalty amount for one violation may very well be more than total proposed penalty amount for multiple violations together. Therefore, Model 3 and Model 4 employed the number of observed violations as the site safety performance value (dependent variable) to examine if they would provide with better results than the OSHA’s GBP system. The difference between Model 3 and 4 were the company and project related factors where one included recordable cases, lost time cases and the number of employees worked previous years, and the other one included total recordable rates and lost time rates. As explained earlier, this comparison intended to explore whether using the number of cases predict the proactive safety performance value better than the incidence rates.

Models 3 and 4 were run separately and they revealed that when project and company related factors were entered into a model together they both revealed similar results with quite close predictability rates. Model 3 accounted for 40.0% of the total variance in number of observed violations and Model 4 accounted for 40.8%.

The findings suggest that in Model 3, 40% of variability in number of observed violations can be predicted by the five significant related factors; years of experience, EMR, lost workday cases, non-fatal cases without lost workdays, company labor workforce (Table 50). Nonetheless, in Model 4, 40.8% variability in number of proposed violations can be predicted by the six significant related factors; years of experience, EMR, lost workday cases, non-fatal cases without lost workdays, company labor workforce and final contract amount (Table 51). These factors both have positive and negative correlations with the safety performance values and were found significant in improving site safety performance. They were explained further except for the final contract amount which can also be named as the project size.

Project Size: It was found that total project size is positively associated with site safety performance value, meaning decreases the site safety performance when the project size is increased. Aksorn and Hadikusumo (2008) also found that project size affects the safety performance, however, in a negatively correlated manner which indicates that as the project size gets larger, the safety performance increases. Aksorn's study described the project size based on the project cost and number of employees. In contrast, in this study project size was based only on the project cost and the total number of employees on site was entered as a separate variable which did not yield significance in improving construction safety in this study. Hinze and Gambatese (2003) also conducted a study analyzing safety performance of specialty contractors and found that project size affects the safety performance of a special contractor through involvement of general contractors and construction managers. This suggests that site safety performance depends on the emphasis placed by the general contractors on safety. Larger projects are associated with larger scope of work which requires more manpower. More manpower requires more coordination and planning which can cause clashes between different trades and reduce the site safety performance. The hierarchy needs to be well established prior to starting a project in order to eliminate these obstacles and improve safety performance.

As seen from Model 1 and Model 3 results, as well the results from Model 2 and Model 4 analysis, it was found that OSHA Gravity Based Penalty System is a more sophisticated safety performance system than the number of observed violations as expected. In view of this, it can be stated that it is a well established system which performs risk assessment for an observed violation by taking severity and probability into account, and this produces a more mature model.

Model 5

After entering project and company related factors combined into the regression analysis, it left open the question as to whether or not they can provide significant results if they were to run separately. As a result, company related factors were entered into a model individually with proposed penalty amounts as the site safety performance value (dependent variable) and did not yield significance. Subsequently, project related factors were entered into a model individually and two factors, project complexity and original contract amount, predicted proposed penalty amounts significantly. The project complexity was defined based on the type of construction and sorted the complexity from difficult to less difficult as new construction, addition, renovation and demolition, respectively. The less complex type of construction was given 1 points and the most complex was given 4 points in the analysis. Model 5 accounted for 14.9% of the total variance in proposed penalty amounts (Table 53).

The results revealed that complexity in construction projects presents higher challenges in site safety performance as new construction and projects involving addition are more complicated and present different challenges. They require working in an environment where many contractors work together with at times without a clear definition of roles and responsibilities. Moreover, they require extensive coordination amongst the contractors which can lead to problems if not performed properly. Huang and Hinze (2003) indicated that falls most frequently occur in new construction, renovation, maintenance and demolition, highlighting the challenges encountered with more complex projects.

Model 6 and 7

Model 6 and 7 investigated the construction trades to find out which ones carry the highest risk in terms of site safety, and identify those affect the safety performance the most. Model 6 employed proposed penalty amounts based on OSHA GBP system as the site safety performance value (dependent variable), and Model 7 utilized the number of observed OSHA violations as the site safety performance value (dependent variable). 2 continuous and 16 categorical variables, SOC construction trades, were entered into Model 6 and 7. Similar to company and project related factors' regression analysis, both models revealed similar results with different predictability rates. As expected, Model 6 developed a more mature model with a higher rate of predictability. Model 6 and Model 7 accounted for 10.8% and 6.1% of the total variance in the safety performance value, respectively. The findings suggest that in Model 6, 10.8% of variability in the proposed penalty amounts can be predicted by the four significant factors; brick, block, stone masons, steel workers (ironworkers), equipment operators and roofers (Table 55). Nonetheless, in Model 7 (Table 56), 6.1% variability in the number of observed OSHA violations can be predicted by the three significant factors; brick, block, stone masons and steel workers (ironworkers). These findings are in agreement with the findings of Baradan and Usmen's (2006) study in improving site safety performance. Baradan and Usmen (2006) pointed out that roofers and ironworkers are the two most dangerous building trades and ranked the top two in risk scores as it relates to fatality data, injury data and both fatality and injury data analysis. This study also presented that the roofers and steelworkers (ironworkers) have the biggest impact on site safety performance.

When hazards associated with these trades are analyzed, they appear to be in line with the leading causes of death in construction sites per OSHA. Falls are the leading cause of construction fatalities per OSHA and roofers and steel workers (ironworkers) are exposed to falls more than other trades which make them more susceptible to injuries and place them in a high risk category. Hinze and Russell (1995) conducted a research and analyzed fatalities recorded by OSHA. They proved that special fall protection systems should be put into practice in order to improve the safety performance. Huang and Hinze (2003) also investigated fall accidents and discovered that main causes of accidents are human errors and inadequate and inappropriate use of fall protection system. Fredericks et al (2005) presented in their study that roofing industry is the most challenging industry based on the number of injuries/illness and indicated that majority of them are caused by the falls and overexertion. It was also suggested by Irizarry and Abraham (2006) that ironworkers have one of the most dangerous occupations in the United States and injuries and illnesses and suggested that steel erection industry should be given special attention for safety.

Moreover, equipment operators were found to be affecting site safety performance. Struck by a vehicle is the number two leading cause of death per OSHA, and equipment operators are involved in 75% of these accidents (Baker et al. 1994). Also, caught in between is one of the main causes of fatalities and mainly associated with workers being caught under overturned equipment or in moving equipment parts (Hinze et. all 2005). Construction industry is unique in a sense that construction equipment operates close to workers in a dangerous work environment, which increases the risk of getting involved in an equipment related incident.

Based on previous research as described above, construction trades of ironworkers and roofers exhibit higher risks in terms of working conditions and hazards. The results of this model can identify the areas that may need improvement from the construction trade stand point and can be utilized for a better understanding of the main sources of injuries, recognizing the relevant hazards, and establishing preventive measures for construction trades.

CHAPTER 6 CONCLUSIONS AND FURTHER RESEARCH

6.1 Conclusions

This study recognized an area in construction safety performance metrics that requires improvement and aimed to address this concern by introducing a new proactive safety performance measurement system through observed violations of OSHA standards. The new metric, site safety performance value (SSPV) was based on OSHA's Gravity Based Penalty system and quantified general contractors' site safety and measured their ability to comply with OSHA safety rules and regulations. It is a leading indicator based on pre-accident driven data. Thus, it was used to develop a new predictive model to estimate and evaluate general contractors' safety performance which can improve safety based on site specific knowledge. The statistical model constructed predicts future contractor safety performance, and it may contribute to the contractor selection process.

Laitinen (1999) suggested that utilizing a methodical observation approach can open up new doors concerning safety in the construction industry which also was one of the underlying factors of this study. He believed that controlling the work environment and understanding the work habits can help identify a trend between accident rates and site observations. This study followed a similar approach and identified the demographics of company and project related factors that may have an impact on site safety performance value. The results revealed the importance of safety inspections and their roles in improving construction site safety performance. It was discovered through citation rates that in an inspected environment where the safety audits are conducted at intervals and when a company management is made aware of its site will be inspected any time during construction, the safety performance increases. This is consistent with Aksorn’s (2008) findings concerning the importance of safety inspections.

In an evaluation of the average number of observed safety violations and the average proposed penalty amounts and comparing them with OSHA’s statistics, it was proved that safety professionals interpreted the OSHA standards in a similar fashion, and they share the same perspectives on safety rules and regulations while citing violations. OSHA’s strong presence and successful history as well as success in implementing safety rules and regulations brought uniformity to the safety rules and regulations and streamlined the process in terms of the procedures followed during the inspections.

The findings of this study can be used by numerous groups including the general contractors, owners, safety professionals and researchers.

General Contractors and Safety Professionals

It was revealed that the top 25 safety violations comprise of 70% of all proposed violations, and correspond with the four leading causes of death per OSHA in construction sites. This signifies that violations are a good indication of potential accidents. Yet, they have traditionally not been given sufficient consideration to be utilized as an effective accident prevention tool to address these concerns. Therefore, in order to transform the violations to an efficient tool, the subparts that were outlined in top 25 violations should be given additional attention by the contractors and can help establish special safety training programs with these violations being focal points. In other words, re-emphasizing the proper use of personal protective equipment, stressing the importance of fall protection and housekeeping, explaining the hazards associated with the use of scaffolding and ladders, making clear the value of signs, signals and barricades, and clarifying essential elements of electrical hazards in a job site can eliminate large percentage of accidents.

The study investigated the relationship amongst the project and safety related concerns and site safety performance by developing predictive models, and discovered that they were significant. Different predictive models depicted different company and project related factors influencing site safety performance. Total labor workforce, EMR, experience of company, company size, recordable rates, and number of recordable cases were the common factors influenced proactive site safety performance. An important conclusion that could be drawn from this study was that consideration of the number of recordable injury and illness cases supersedes the total recordable injury and illness rates when it comes to improving safety performance at project sites. The model developed using the injury and illness cases explained a higher level of variance for site safety performance derived from OSHA GBP system. This suggests that the importance of incidence rates as a safety metric should be called to the attention of management.

In addition, this study presented an opportunity to see how much injury and illness cases that do cause lost work day and cases that do not cause lost work day influence site safety performance. It is apparent that injury or illness cases that cause lost work days direct companies to focus on the potential hazards and to find ways to mitigate and eliminate them and improve site safety performance. On the other hand, injuries or illnesses that do not cause lost work days, in fact, decrease the site safety performance. This is most likely due to them not being considered worthwhile to be examined in depth to identify the underlying factors that lead to incidents, which can end up causing even larger issues in the long run from a safety stand point.

Owners and General Contractors

The current study also investigated the impacts of the construction trades on the overall construction site safety performance and found that when the roofers, steel workers, brick, block, stone masons and equipment operators are present at a construction site, they can influence the site safety performance significantly. By implementing special training program for these trades and identifying the risk exposures associated with their scope of work as it relates to safety, proactive site safety performance can be improved.

Owners and Safety Professionals

It was found that total labor workforce employed by the company, EMR value, total recordable incidence rate, company size and percent change of original contract amount impacted the proactive site safety performance value adversely. In other words, as these variables' values increased, the site safety performance value is decreased. On the other hand, company's experience in business had a positive impact on the proactive safety measurement system. It can be argued that these values can make a good representation of a company's future safety performance at a site specific level, and might be employed as an efficient tool in the bidding process. They also can make recommendations to improve the bid solicitation system in place. Several studies (Hatush and Skitmore, 1997; Fong and Choi, 2000; Wong, Holt and Cooper, 2000) showed that owners have started changing their perception of a successful bidder and introduced new criteria affecting decision making during prequalification and contractor selection process. Owners and safety professionals are becoming more involved in this process, and besides, financial health, technical ability and managerial capability, safety and health performance of a company have come to the forefront. Consistent with the findings of this study, some improvements can potentially be made to the current bidding system. For instance, introducing a safety personnel allocation rate based on the number of labor workforce employed by a company and the number of safety persons employed by a company can be taken into consideration. This would be expected to positively impact safety performance. This rate can be examined in future studies, and upon establishing an industry proportion rate it can be integrated into the process as a mandatory requirement to prequalify and establish resource allocation. Another enhancement that can be made on the existing procurement system is that incorporating a mandatory maximum capacity rating system that signifies the financial capacity of a company in terms of its ability to manage multiple projects concurrently. It can be calculated based on companies' incomplete contracted work, its' bonding capacity and financial strength. This might enable companies to reassess their finances and resources prior to submitting a new bid and organize their workforce accordingly without compromising safety and efficiency.

It was found that complexity in construction projects presents higher challenges in site safety performance as they require more coordination and planning. This study also revealed that EMR and incidence rates can also be used in the process of identifying proactive safety performance value when they are used together. This can prove that they are in fact useful safety measures and good indices of safety performance of a company, but not in their current state.

Researchers

It was found that proactive safety measurement system can be an effective tool in improving safety performance but can be developed further. Based on the models developed using multiple linear regression analysis, OSHA's gravity based penalty system was found to be a better proactive safety performance metric than the number of violations observed during inspections as the OSHA's penalty system is more sophisticated and inclusive of factors contributing to safety. It was determined that the safety performance values which were quantified based on the OSHA Gravity Based Penalty System predicted the performance values better than the number of observed violations.

Finally, it is in the nature of the construction industry that it is prone to more injuries and illness than other industries as it is labor intensive. Previous knowledge of a general contractor can go a long way and can provide assistance in areas that may need improvement. This study showed that relying solely on a contractor's incidence rates is in reality not a good illustration of company's current safety status as the statistics are an average of the overall contractor performance. Safety performance is driven by the contractors and their workers, especially safety personnel's perception of a safe project.

6.2 Limitations of the Study

- The data was not collected through a methodical approach.
- Results are applicable only to General Contractors in Public Sector.
- Data was acquired from a Capital Improvement Program and contains only construction building projects completed between 2002 and 2007. It is not

applicable to residential, industrial, highway, and heavy construction (dams, water sewer, etc.) projects.

- Data collected from an environment where safety was monitored closely by safety professionals, and a risk management department contracted by an insurance company to avoid future potential safety claims.
- All general contractors that participated in the capital improvement program were mandated to have a written safety program that was approved by the safety and risk management department. Thus, results are products of an improved safety culture.
- There are limitations as to the determination of penalty amounts given the fact that some penalties can be only proposed by the OSHA Area Director's discretion. For instance, even though the maximum other than serious penalty amount is $1,000, The Area Director can increase this amount up to $7,000 to provide a deterrent effect.
- There are limitations as to the determination of the types of violations. Repeat violations and failure to abate violations are applicable to only violations that were previously cited by OSHA, therefore disregarded in this study.

6.3 Further Research and Recommendations

It is recommended that a Return of Investment (ROI) study be performed in which the safety inspection and other safety improvement costs are compared with penalties, to analyze whether or not they are good investments from the performance point of view. OSHA Gravity Based Penalty system, with the help of proposed penalty amounts, can help the company realize that the money spent on safety is a good investment.

As noted earlier, BLS releases workplace injury and illness statistics every year and the 2010 Occupational Injuries and Illnesses numbers showed that there is a drop in private industry non-fatal incidents whereas public sector continues to be higher. It is clear that there is a different perception of construction safety between public and private sectors. Given that the focal point of this study was public sector, future research has the potential to replicate the current study for private sector projects to examine the generalizability of the findings repotted in this study.

In addition, this study was completed through observed violations of only one capital improvement program consisting of over 100 projects. The study can be expanded to other capital improvement programs which may require identification of other safety related factors influencing safety performance. With all the data collected from many other programs, program safety performance also can be studied and safety performance of programs can be examined.

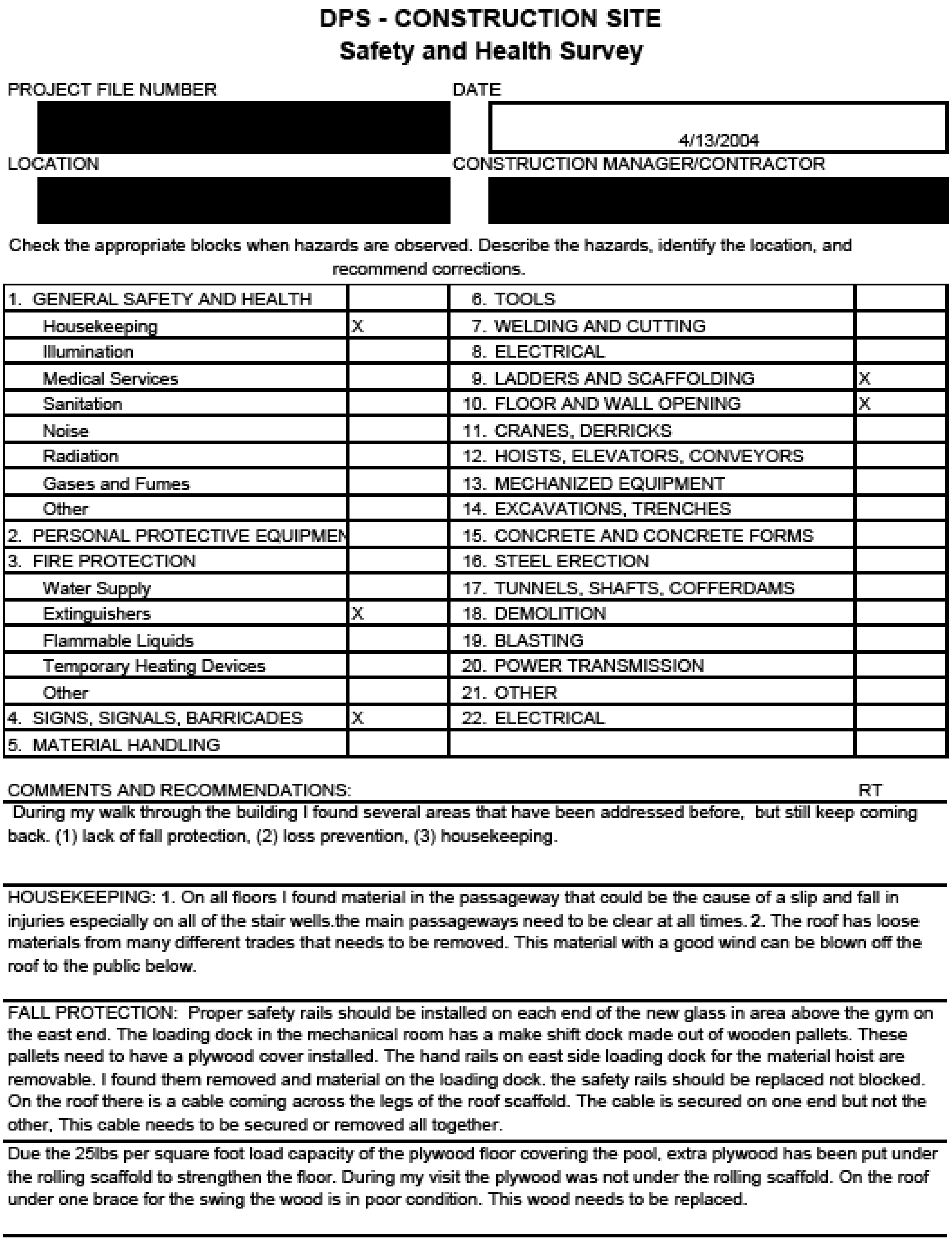
This study was performed by using data collected from a capital improvement program with the purpose of improving the condition of existing schools. Therefore, it may be applicable to commercial/institutional building construction projects. Similar studies can be extended to research residential projects or different types of construction projects such as highway, industrial, heavy construction projects.

The information of post project safety performance such as any incidents that may have transpired during construction was not available in this study. It is recommended that if a similar study is performed, pre-accident and post-accident information can both be obtained for assessment purposes to investigate whether or not the proactive safety measure established in this study is an effective tool that can be used to improve safety performance.

Previous studies suggest that subcontractors or specialty trades have an effect on construction safety and can adversely impact the performance when not managed properly, including when general contractor’s safety standards are not enforced. In the construction industry, there is a hierarchy in between the trades and the general contractors and the general contractor can be held liable for the safety of its subcontractors and sets the tone as far as safety is concerned. Therefore, a similar study can performed including the subcontractors or specialty trades and measure the safety performance of each, and investigate whether or not findings correspond with the findings of this study.

For data collecting purposes, when a similar study is to be performed, it is recommended that the safety inspections are completed through a checklist in a mobile device such as a tablet, cell phone, or PDA where information is more easy to access and documented in an electronic environment where the information can be sorted and organized the way the analyst desires. The data entry of this study was lengthy and could have been completed earlier if it the inspections were documented electronically and maintained in a database.

APPENDIX - A SITE SAFETY STATUS REPORT SAMPLE



DPS - CONSTRUCTION SITE
Safety and Health Survey

PROJECT FILE NUMBER: [redacted]

DATE: 4/13/2004

LOCATION: [redacted]

CONSTRUCTION MANAGER/CONTRACTOR: [redacted]

Check the appropriate blocks when hazards are observed. Describe the hazards, identify the location, and recommend corrections.

1. GENERAL SAFETY AND HEALTH		6. TOOLS	
Housekeeping	X	7. WELDING AND CUTTING	
Illumination		8. ELECTRICAL	
Medical Services		9. LADDERS AND SCAFFOLDING	X
Sanitation		10. FLOOR AND WALL OPENING	X
Noise		11. CRANES, DERRICKS	
Radiation		12. HOISTS, ELEVATORS, CONVEYORS	
Gases and Fumes		13. MECHANIZED EQUIPMENT	
Other		14. EXCAVATIONS, TRENCHES	
2. PERSONAL PROTECTIVE EQUIPMEN		15. CONCRETE AND CONCRETE FORMS	
3. FIRE PROTECTION		16. STEEL ERECTION	
Water Supply		17. TUNNELS, SHAFTS, COFFERDAMS	
Extinguishers	X	18. DEMOLITION	
Flammable Liquids		19. BLASTING	
Temporary Heating Devices		20. POWER TRANSMISSION	
Other		21. OTHER	
4. SIGNS, SIGNALS, BARRICADES	X	22. ELECTRICAL	
5. MATERIAL HANDLING			

COMMENTS AND RECOMMENDATIONS: RT

During my walk through the building I found several areas that have been addressed before, but still keep coming back. (1) lack of fall protection, (2) loss prevention, (3) housekeeping.

HOUSEKEEPING: 1. On all floors I found material in the passageway that could be the cause of a slip and fall in injuries especially on all of the stair wells.the main passageways need to be clear at all times. 2. The roof has loose materials from many different trades that needs to be removed. This material with a good wind can be blown off the roof to the public below.

FALL PROTECTION: Proper safety rails should be installed on each end of the new glass in area above the gym on the east end. The loading dock in the mechanical room has a make shift dock made out of wooden pallets. These pallets need to have a plywood cover installed. The hand rails on east side loading dock for the material hoist are removable. I found them removed and material on the loading dock. the safety rails should be replaced not blocked. On the roof there is a cable coming across the legs of the roof scaffold. The cable is secured on one end but not the other, This cable needs to be secured or removed all together.

Due the 25lbs per square foot load capacity of the plywood floor covering the pool, extra plywood has been put under the rolling scaffold to strengthen the floor. During my visit the plywood was not under the rolling scaffold. On the roof under one brace for the swing the wood is in poor condition. This wood needs to be replaced.

DPS - CONSTRUCTION SITE
Safety and Health Survey

I found in several areas the fire extinguishers were missing. The missing fire ext, should be replace as soon as possible. A daily check needs to be made to confirm condition of each fire extinguisher station.

Baker (Perry) rolling scaffolds are very light and very narrow. The platform is design to move up and down to adjust the height for the task. The worker should not allowed to climb up the end of the scaffold and sit on the top to work. This extra weight on one end cans surly cause the whole unit to turn over. I found a worker doing just that standing on the end frame under to gain another foot in height to work.

PM

ORIG: CM / GC PM: ______________________________
CC: FILE
CC: SAFETY FILE

APPENDIX - B SOC CODES

Standard Occupational Classification System (Soc Codes)

47-2000 Construction Trades Workers

MASONRY and PLASTERER

Brickmasons and Blockmasons

Lay and bind building materials, such as brick, structural tile, concrete block, cinder block, glass block, and terra-cotta block, with mortar and other substances to construct or repair walls, partitions, arches, sewers, and other structures. Excludes "Stonemasons" (47-2022). Installers of mortarless segmental concrete masonry wall units are classified in "Landscaping and Groundskeeping Workers" (37-3011).

Stonemasons

Build stone structures, such as piers, walls, and abutments. Lay walks, curbstones, or special types of masonry for vats, tanks, and floors.

Plasterers and Stucco Masons

Apply interior or exterior plaster, cement, stucco, or similar materials. May also set ornamental plaster.

CARPENTER

Carpenters

Construct, erect, install, or repair structures and fixtures made of wood, such as concrete forms; building frameworks, including partitions, joists, studding, and rafters; and wood stairways, window and door frames, and hardwood floors. May also install cabinets, siding, drywall and batt or roll insulation. Includes brattice builders who build doors or brattices (ventilation walls or partitions) in underground passageways

FLOORING

Carpet Installers

Lay and install carpet from rolls or blocks on floors. Install padding and trim flooring materials. Excludes "Floor Layers, Except Carpet, Wood, and Hard Tiles" (47-2042).

Floor Layers, Except Carpet, Wood, and Hard Tiles

Apply blocks, strips, or sheets of shock-absorbing, sound-deadening, or decorative coverings to floors.

Floor Sanders and Finishers

Scrape and sand wooden floors to smooth surfaces using floor scraper and floor sanding machine, and apply coats of finish.

Tile and Marble Setters

Apply hard tile, marble, and wood tile to walls, floors, ceilings, and roof decks.

CEMENT MASONS, CONCRETE FINISHERS, AND TERRAZZO WORKERS

Cement Masons and Concrete Finishers

Smooth and finish surfaces of poured concrete, such as floors, walks, sidewalks, roads, or curbs using a variety of hand and power tools. Align forms for sidewalks, curbs, or gutters; patch voids; and use saws to cut expansion joints. Installers of mortarless segmental concrete masonry wall units are classified in "Landscaping and Groundskeeping Workers" (37- 3011).

Terrazzo Workers and Finishers

Apply a mixture of cement, sand, pigment, or marble chips to floors, stairways, and cabinet fixtures to fashion durable and decorative surfaces.

LABOR

Construction Laborers

Perform tasks involving physical labor at construction sites. May operate hand and power tools of all types: air hammers, earth tampers, cement mixers, small mechanical hoists, surveying and measuring equipment, and a variety of other equipment and instruments. May clean and prepare sites, dig trenches, set braces to support the sides of excavations, erect scaffolding, and clean up rubble, debris and other waste materials. May assist other craft workers. Construction laborers who primarily assist a particular craft worker are classified under "Helpers, Construction Trades" (47-3010). Excludes "Hazardous Materials Removal Workers" (47-4041).

EQUIPMENT OPERATORS

Construction Equipment Operators

Paving, Surfacing, and Tamping Equipment Operators

Operate equipment used for applying concrete, asphalt, or other materials to road beds, parking lots, or airport runways and taxiways, or equipment used for tamping gravel, dirt, or other materials. Includes concrete and asphalt paving machine operators, form tampers, tamping machine operators, and stone spreader operators.

Pile-Driver Operators

Operate pile drivers mounted on skids, barges, crawler treads, or locomotive cranes to drive pilings for retaining walls, bulkheads, and foundations of structures, such as buildings, bridges, and piers.

Operating Engineers and Other Construction Equipment Operators

Operate one or several types of power construction equipment, such as motor graders, bulldozers, scrapers, compressors, pumps, derricks, shovels, tractors, or front-end loaders to excavate, move, and grade earth, erect structures, or pour concrete or other hard surface pavement. May repair and maintain equipment in addition to other duties. Excludes "Crane and Tower Operators" (53-7021) and "Extraction Workers" (47-5000).

DRYWALL

Drywall Installers, Ceiling Tile Installers, and Tapers

Drywall and Ceiling Tile Installers

Apply plasterboard or other wallboard to ceilings or interior walls of buildings. Apply or mount acoustical tiles or blocks, strips, or sheets of shock-absorbing materials to ceilings and walls of buildings to reduce or reflect sound. Materials may be of decorative quality. Includes lathers who fasten wooden, metal, or rockboard lath to walls, ceilings or partitions of buildings to provide support base for plaster, fire-proofing, or acoustical material. Excludes "Carpet Installers" (47-2041), "Carpenters" (47-2031), and "Tile and Marble Setters" (47-2044).

Tapers

Seal joints between plasterboard or other wallboard to prepare wall surface for painting or papering.

ELECTRICAL

Electricians

Install, maintain, and repair electrical wiring, equipment, and fixtures. Ensure that work is in accordance with relevant codes. May install or service street lights, intercom systems, or electrical control systems. Excludes "Security and Fire Alarm Systems Installers" (49-2098).

Security and Fire Alarm Systems Installers (49-0000 Installation, Maintenance, and Repair Occupations)

Install, program, maintain, and repair security and fire alarm wiring and equipment. Ensure that work is in accordance with relevant codes. Excludes "Electricians" (47-2111) who do a broad range of electrical wiring.

GLAZIER

Glaziers

Install glass in windows, skylights, store fronts, and display cases, or on surfaces, such as building fronts, interior walls, ceilings, and tabletops.

INSULATION WORKERS

Insulation Workers, Floor, Ceiling, and Wall

Line and cover structures with insulating materials. May work with batt, roll, or blown insulation materials.

Insulation Workers, Mechanical

Apply insulating materials to pipes or ductwork, or other mechanical systems in order to help control and maintain temperature.

BOILERMAKERS

Construct, assemble, maintain, and repair stationary steam boilers and boiler house auxiliaries. Align structures or plate sections to assemble boiler frame tanks or vats, following blueprints. Work involves use of hand and power tools, plumb bobs, levels, wedges, dogs, or turnbuckles. Assist in testing assembled vessels. Direct cleaning of boilers and boiler furnaces. Inspect and repair boiler fittings, such as safety valves, regulators, automatic-control mechanisms, water columns, and auxiliary machines.

SHEET METAL WORKERS

Fabricate, assemble, install, and repair sheet metal products and equipment, such as ducts, control boxes, drainpipes, and furnace casings. Work may involve any of the following: setting up and operating fabricating machines to cut, bend, and straighten sheet metal; shaping metal over anvils, blocks, or forms using hammer; operating soldering and welding equipment to join sheet metal parts; or inspecting, assembling, and smoothing seams and joints of burred surfaces. Includes sheet metal duct installers who install prefabricated sheet metal ducts used for heating, air conditioning, or other purposes.

PAINTER and PAPERHANGERS

Painters, Construction and Maintenance

Paint walls, equipment, buildings, bridges, and other structural surfaces, using brushes, rollers, and spray guns. May remove old paint to prepare surface prior to painting. May mix colors or oils to obtain desired color or consistency. Excludes "Paperhangers" (47-2142).

Paperhangers

Cover interior walls or ceilings of rooms with decorative wallpaper or fabric, or attach advertising posters on surfaces such as walls and billboards. May remove old materials or prepare surfaces to be papered.

PLUMBING

Pipelayers, Plumbers, Pipefitters, and Steamfitters

Pipelayers

Lay pipe for storm or sanitation sewers, drains, and water mains. Perform any combination of the following tasks: grade trenches or culverts, position pipe, or seal joints. Excludes "Welders, Cutters, Solderers, and Brazers" (51-4121).

Plumbers, Pipefitters, and Steamfitters

Assemble, install, alter, and repair pipelines or pipe systems that carry water, steam, air, or other liquids or gases. May install heating and cooling equipment and mechanical control systems. Includes sprinklerfitters.

STEEL / IRONWORKER

Reinforcing Iron and Rebar Workers

Position and secure steel bars or mesh in concrete forms in order to reinforce concrete. Use a variety of fasteners, rod-bending machines, blowtorches, and hand tools. Includes rod busters.

Structural Iron and Steel Workers

Raise, place, and unite iron or steel girders, columns, and other structural members to form completed structures or structural frameworks. May erect metal storage tanks and assemble prefabricated metal buildings. Excludes "Reinforcing Iron and Rebar Workers" (47-2171).

ROOFER

Roofers

Cover roofs of structures with shingles, slate, asphalt, aluminum, wood, or related materials. May spray roofs, sidings, and walls with material to bind, seal, insulate, or soundproof sections of structures.

Solar Photovoltaic Installers

Assemble, install, or maintain solar photovoltaic (PV) systems on roofs or other structures in compliance with site assessment and schematics. May include measuring, cutting, assembling, and bolting structural framing and solar modules. May perform minor electrical work such as current checks. Excludes solar thermal installers who are included in "Plumbers, Pipefitters, and Steamfitters" (47-2152). Excludes solar PV electricians who are included in "Electricians" (47-2111).

47-4000 Other Construction and Related Workers

ELEVATOR INSTALLERS AND REPAIRERS

Assemble, install, repair, or maintain electric or hydraulic freight or passenger elevators, escalators, or dumbwaiters.

HEATING, AIR CONDITIONING, AND REFRIGERATION MECHANICS AND INSTALLERS

Install or repair heating, central air conditioning, or refrigeration systems, including oil burners, hot-air furnaces, and heating stoves.

CONTROL AND VALVE INSTALLERS AND REPAIRERS

Install, repair, and maintain mechanical regulating and controlling devices, such as electric meters, gas regulators, thermostats, safety and flow valves, and other mechanical governors.

FENCE ERECTORS

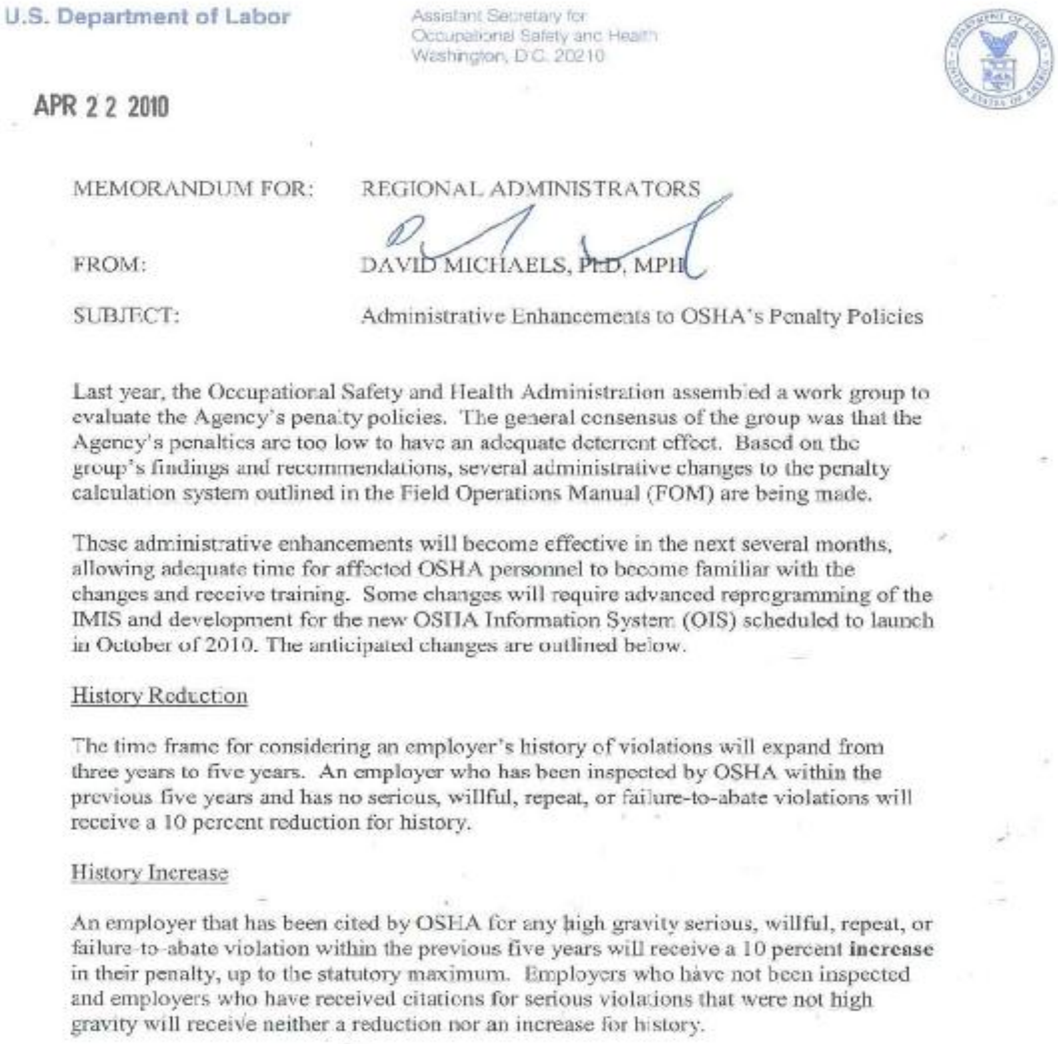
Erect and repair fences and fence gates, using hand and power tools.

HAZARDOUS MATERIAL

Hazardous Materials Removal Workers

Identify, remove, pack, transport, or dispose of hazardous materials, including asbestos, lead-based paint, waste oil, fuel, transmission fluid, radioactive materials, or contaminated soil. Specialized training and certification in hazardous materials handling or a confined entry permit are generally required. May operate earth-moving equipment or trucks.

APPENDIX - C MEMO FROM US DEPARTMENT OF LABOR ABOUT ADMINISTRATIVE ENHANCEMENTS TO OSHA'S PENALTY POLICIES



U.S. Department of Labor

Assistant Secretary for
Occupational Safety and Health
Washington, D.C. 20210

APR 2 2 2010

MEMORANDUM FOR: REGIONAL ADMINISTRATORS

FROM: DAVID MICHAELS, PhD, MPH

SUBJECT: Administrative Enhancements to OSHA's Penalty Policies

Last year, the Occupational Safety and Health Administration assembled a work group to evaluate the Agency's penalty policies. The general consensus of the group was that the Agency's penalties are too low to have an adequate deterrent effect. Based on the group's findings and recommendations, several administrative changes to the penalty calculation system outlined in the Field Operations Manual (FOM) are being made.

These administrative enhancements will become effective in the next several months, allowing adequate time for affected OSHA personnel to become familiar with the changes and receive training. Some changes will require advanced reprogramming of the IMIS and development for the new OSHA Information System (OIS) scheduled to launch in October of 2010. The anticipated changes are outlined below.

History Reduction

The time frame for considering an employer's history of violations will expand from three years to five years. An employer who has been inspected by OSHA within the previous five years and has no serious, willful, repeat, or failure-to-abate violations will receive a 10 percent reduction for history.

History Increase

An employer that has been cited by OSHA for any high gravity serious, willful, repeat, or failure-to-abate violation within the previous five years will receive a 10 percent **increase** in their penalty, up to the statutory maximum. Employers who have not been inspected and employers who have received citations for serious violations that were not high gravity will receive neither a reduction nor an increase for history.

Repeat Violations

The time period for repeated violations will also be increased from three to five years. Area Directors may continue to apply a size reduction to the penalty, as appropriate, after considering the need for a deterrent effect.

Area Director and Informal Conference Considerations

When circumstances warrant, Area Directors will retain the authority to determine if a size or history reduction should be granted. If an Area Director believes that imposing the full gravity-based penalty is necessary to achieve the appropriate deterrent effect, he or she may do so after fully documenting the rationale in the case file.

Area Directors will be authorized to offer up to a 30 percent penalty reduction to employers at an informal conference; any reduction over 30 percent will have to be approved by the Regional Administrator. Area Directors will also be authorized to offer an employer with 250 or fewer employees an additional 20 percent reduction if that employer agrees to retain an outside safety and health consultant.

Furthermore, the Agency will no longer allow penalty adjustments to an employer at an informal conference where the employer has an outstanding penalty balance owed to OSHA for the establishment in question or any other location. However, if the employer is on a penalty payment plan and is making timely payments, this provision would not apply.

Expedited Informal Settlement Agreements

Area Offices utilizing expedited settlement agreements will generally be limited to offering a 30 percent reduction. If the employer commits to hiring an outside consultant, the Area Director may grant an additional 20% reduction.

Severe Violator Enforcement Program (SVEP) Violations

Where circumstances warrant, at the discretion of the Area Director, high gravity serious violations related to standards identified in the SVEP will no longer need to be grouped or combined, but can be cited as separate violations, each with its own proposed penalty. Furthermore, for individual violations for hazards identified in the SVEP, Area Directors must consider the adequacy of the proposed penalty and may, as appropriate, limit adjustment for good faith, history, or size when necessary to achieve the appropriate deterrent effect. The rationale for limited adjustments must be fully documented in the case file.

Gravity-Based Penalty (GBP)

OSHA will be adopting a gravity-based penalty determination that provides for a gravity-based penalty between $3,000 and $7,000, as described below.

Severity	Probability	GBP	Gravity
High	Greater	$7,000	High
Medium	Greater	$6,000	Moderate
Low	Greater	$5,000	Moderate
High	Lesser	$5,000	Moderate
Medium	Lesser	$4,000	Moderate
Low	Lesser	$3,000	Low

Size Reduction

The Agency will be adopting the new penalty reduction structure for size illustrated below, allowing for penalty reduction between 10 and 40 percent for employers with less than 250 employees. No size reduction will be applied for employers with 251 or more employees.

Employees	Percent Reduction
1-25	40
26-100	30
101-250	10
251 or more	None

Good Faith

The current good faith procedures in the FOM will be retained. A penalty reduction is permitted in recognition of an employer's effort to implement an effective workplace safety and health management system. Employers must have a safety and health program in place to get any good faith reduction; furthermore, good faith reductions are not allowed in the cases of high gravity serious, willful, repeat, or failure-to-abate violations.

The 15% Quick-Fix reduction, which is currently allowed as an abatement incentive program meant to encourage employers to immediately abate hazards found during an inspection, will also be retained. However, the 10% reduction for employers with a strategic partnership agreement will be eliminated.

Increase Proposed Minimum Penalties

The minimum proposed penalty for a serious violation will be increased to $500. When the proposed penalty for a serious violation would amount to less than $500, a $500 penalty will be proposed for that violation. The proposed minimum penalty for a posting violation will increase to $250 if the company was previously provided a poster by OSHA.

Additional Administrative Modifications to the Penalty Calculation Policy

Final penalties will be calculated serially, unlike the present practice in which all of the penalty reductions are added and then the total percentage is multiplied by the gravity-based penalty (GBP) to arrive at the proposed penalty. The penalty adjustment factors will be applied serially as follows: History, Good Faith, Quick-Fix and Size.

Sample Moderate Gravity Penalty Comparison: Summed versus Serially Calculation

Sample Data	**Summed**	**Serially***
High/Lesser	$5,000	$5,000
History (10%)		$4,500 -10%
Good Faith (15%)		$3,825 – 15%
Quick Fix (15%)		$3,251 – 15%
Size (30%)	10% + 15% + 15% + 30% = 70%	$2,275 - 30%
Result	$1,500	$2,275†

† - Results in an increase of approximately 50%

* - No proposed penalty shall exceed the statutory limit for a serious violation or $7,000.

Conclusion

These changes will serve to generally increase the overall dollar amount of all penalties. Furthermore, the average penalty for a serious violation will increase from approximately $1,000 to an average of $3,000 to $4,000. The Agency hopes that higher penalty amounts will provide a greater deterrent and further encourage employers to furnish safe and health workplaces for their employees. In the immediate future, OSHA will focus on outreach in preparation of implementing this new penalty policy. The enhancements outlined above will become effective over the next several months, and the FOM will be revised to reflect the new policy.

These changes will establish general agency policy and will not preclude the agency from assessing a different penalty where appropriate under The Act in light of all the circumstances, in a particular case.

REFERENCES

1. Stevens, J. P. “Applied Multivariate Statistics for the Social Sciences, 4th Ed.”, Lawrence Erlbaum Associates, Mahwah, New Jersey., 2001
2. Aksorn T; Hadikusumo B.H.W, “Measuring Effectiveness of Safety Programmes in the Thai Construction Industry”, Construction Management and Economic, 2008.
3. The Construction Chart Book, Fourth Edition, The Center for Construction Research and Training, 2007.
4. Cooper, D., “Improving Safety Culture, A Practical Guide”, 2001
5. Hale, A.R. and Glendon, A.I., “Individual Behaviour in the Control of Danger”, Industrial Safety Series, 1987.
6. Janicak, C., “Safety Metrics: Tools and Techniques for Measuring Safety”, 2010.
7. Alper, S.J., Karsh B., “A systematic Review of Safety Violations in Industry”, Accident Analysis and Prevention 41, 2009.
8. Maccollum D. V., “Construction Safety: Engineering and Management Principles, Designing and Managing Safer Job Sites”, 2006.
9. Top 25 MIOSHA Safety Violations, Fiscal Year 2009 – 2010 Prepared By Consultation Education & Training (CET) Division, Michigan Occupational Safety & Health Administration (MIOSHA), Michigan Department of Licensing and Regulatory Affairs (LARA).
10. Michaud, P. A., “Accident Prevention and OSHA Compliance”, 1995.
11. Preziosi, D., "Setting Sights on Safety". Civil engineering (New York, N.Y. 1983)(0885-7024), 59(1), p.44., 1989.

12. Heinrich, H. W., “Industrial Accident prevention: A scientific approach”, New York: McGraw Hill, 1959.
13. Laitinen, H., “The validity of the TR safety observation method on building construction", Accident analysis and prevention, 1999.
14. Weber, R.P., “Basic Content Analysis (Quantitative Applications in the Social Sciences)”, 1990.
15. Leung, Chan, Yu, “Preventing construction worker injury incidents through the management of personal stress and organizational stressors”, 2012.
16. Chan and Leung, “Impact of Stress on Injury Incidents Among Construction workers”, 2011.
17. Palaneeswaran E. and Kumaraswamy M.M, “Benchmarking contractor selection practices in public-sector construction—a proposed model”, 2000.
18. Noura A, Hadipriono H.C., “Construction Safety Performance in the United Arab Emirates” , 2002.
19. Molenaar K.R., Park J., Washington S., “Framework for Measuring Corporate Safety Culture and Its Impact on Construction Safety Performance” , 2009.
20. Aksorn T., Hadikusumo B.H.W, “Measuring effectiveness of safety programmes in the Thai construction Industry”, 2008.
21. Garza, J.M, Hancher D.E., Decker L., “Analysis of Safety Indicators in Construction”, 1998.
22. Kartam, N.A., “Integrating Safety and Health Performance into Construction CPM”, 1997.
23. OSHA Field Operations Manual, 2009

24. Petersen, D., “Analyzing Safety System Effectiveness”, Third Edition, 1996

25. Heinrich, H.W., “Industrial Accident Prevention”, McGraw Hill, New York, NY, 1931

26. Usmen, M. A., “Construction Safety and Health for Civil Engineers”, 1994

27. Spellman, F.R., “Safety Engineering, Principles and Practices”, 1999

28. Hoonakker, P., Loushine, T., Carayon, P., Kallman, J., Kapp, A., Smith, M. J., “The effect of safety initiatives on safety performance: A longitudinal study” Applied Ergonomics, 36, 461-469, 2005.

29. Hinze, J., Bren, D.C., Piepho N., “Experience Modification Rating as Measure of Safety Performance”, Journal of Construction Engineering and Management, 1995.

30. Everett, J.G., Thompson, W.S., “Experience Modification Rating for Workers’ Compensation Insurance”, Journal of Construction Engineering and Management, 1995.

31. Jaselskis, E.J., Anderson, S.D., Russell, J.S., “Strategies for Achieving Excellence in Construction Safety Performance”, Journal of Construction Engineering and Management, Vol.122, No.1, pp.61-70, ASCE, New York, NY, USA, 1996.

32. Sawacha, E., Naoum, S., Fong, D., “Factors affecting safety performance on construction sites”, International Journal of Project Management, v 17, n 5, Oct, 1999, p 309-315.

33. Abudayyeh, O., Fredericks, T.K., Butt, S.E., Shaar A., ”An investigation of management’s commitment to construction safety”, International Journal of Project Management 24, 167-174, 2006.
34. Huang, X., Hinze J., “Owner’s Role in Construction Safety: Guidance Model”, Journal of Construction Engineering and Management, 2006.p 174-181.
35. Hinze, J. and Gambatese, J., “Factors That influence Safety Performance of Specialty Contractors”, Journal of Construction Engineering and Management, 2003.
36. Mohan, S.B., Niles, B.D., “Effectiveness of the Occupational Safety and Health Administration Citations”, Practice Periodical on Structural Design and Construction, 2002.
37. Levitt R.E., Samelson N.M., “Construction Safety Management“, Second Edition, Chapter 1, 1993
38. Thomas, S.N., Cheng K.P., Skitmore, R.M., “A Framework for Evaluating the Safety Performance of Construction Contractors”, Building and Environment 40, 1347-1355, 2005.
39. Gleason, M.G., Barnum, D.T., “Effectiveness of OSHA Sanctions in Influencing Employer Behavior: Single and Multi-Period Decision Models”, 1978
40. Huang X., Hinze J., “Analysis of Construction Worker Fall Accidents”, Journal of Construction Engineering and Management, 262-271, May/June 2003
41. Hinze J., Devenport J.N., Giang G., “Analysis of Construction Worker Injuries That Do Not Result in Lost Time”, Journal of Construction Engineering and Management, 321-326, March 2006

42. Hinze J., Russell D.B., “Analysis of Fatalities Recorded by OSHA”, Journal of Construction Engineering and Management, 209-214, June 1995
43. OSHA Website (www.osha.gov)
44. The Occupational Safety and Health Review Commission Website (http://www.oshrc.gov)
45. The National Institute for Occupational Safety and Health Website (http://www.cdc.gov/niosh/homepage.html)
46. MIOSHA Webite (http://www.michigan.gov/cis/0,1607,7-154-11407---,00.html)
47. Bureau of Labor Statistics Website (www.bls.gov)
48. Menard, S., “Applied Logistic Regression Analysis”. Sage university paper series on quantitative applications in the social sciences, 07-106, Thousand Oaks, CA: Sage, 1995
49. Tabachnik, B.G., Fidell, L.S. “Using Multivariate Statistics”. New York, NY, College Publishers, 2007
50. Pedhazur, E., “Multiple regression in behavior research (3rd ed.). “ Harcourt-Brace: Fort Worth, TX, 1997.
51. Ho R., “Handbook of Univariate and Multivariate Data Analysis and Interpretation with SPSS”, 2006.
52. Fielding J. and Gilbert N., “Understanding Social Statistics”, 2001.
53. Myers, R., “Classical and Modern Regression with Applications”, 2nd edition, 2000.
54. Hinze J., Godfrey R., “An Evaluation of Safety Performance Measures for Construction Projects”, Journal of Construction Research, Vol. 4, No 1, 2003.

55. Hinze, J., “Construction Safety, Prentice-Hall” , 1997.

56. Mohamed, S., “Scorecard Approach to Benchmarking Organizational Safety Culture in Construction”, Journal Of Construction Engineering And Management, 2003.

57. Mohamed, S., “Empirical Investigation of Construction Safety Management Activities and Performance in Australia”, Safety Science 33, 1999.

58. Jaselskis, E. J., Suazo G.A.R, "A survey of construction site safety in Honduras", Construction Management and Economics, 1994.

59. Bergh, V.D., “Leading and trailing indicators: occupational safety”. Paper presented at the ISSA/Chamber of Mines Conference 2003—Mines and Quarries Prevention of Occupational Injury and Disease, Sandton Convention Center, Sandton, South Africa, 2003.

60. Grabowski, M., "Leading indicators of safety in virtual organizations". Safety Science, 2007.

61. Lingard, H., Rowlinson S., "Construction site safety in Hong Kong". Construction Management and Economics, 1994.

62. Fredericks, T.K., “Occupational Injuries and Fatalities in the Roofing Contracting Industry”, Journal Of Construction Engineering And Management, 2005.

63. Irizarry J., Abraham D.M., “Assessment Of Risk Perception Of Ironworkers”, Journal of Construction Research, 2006.

64. Green, S.B., “How Many Subjects Does It Take To Do A Regression Analysis?”, Multivariate Behavioral Research, 26 (3), 499-510, 1991.

65. Field, A., “Discovering Statistics Using SPSS”, Sage Publications, 2009.

66. Wright D. B., “Understanding Statistics: An Introduction for the Social Sciences”, 1997.
67. Sharot, T., “Weighting survey results”, Journal of the Market Research Society, 1986.
68. Tam, C. M., "Effectiveness of safety management strategies on safety performance in Hong Kong", Construction Management and Economics, 1998.
69. Poon, W. F., Ma, C. H., Ho, K. L., “Statistical analysis on factors in reducing construction site accident frequency rate in Hong Kong”, In: Proceedings of the 6th Annual Conference of the Australian and New Zealand Association of Occupational Health and Safety Educators, Hong Kong, 2000.
70. Laitinen, H., "The validity of the TR safety observation method on building construction", Accident Analysis and Prevention, 1999.
71. Findley et al, “Safety Program Elements in Construction”, Professional Safety, February 2004.
72. Wong, C. H., Holt, G. D. and Cooper, P. A., "Lowest price or value? Investigation of UK construction clients' tender selection process", Construction management and economics, 2000.
73. Fong, P.S., Choi, S.K., “Final contractor selection using the analytical hierarchy process”, Construction Management Economics, 2000.
74. Hatush, Z, Skitmore, M., "Criteria for contractor selection". Construction Management and Economics, 1997.
75. Hinze, J., Huang, X., Terry, L., "The Nature of Struck-by Accidents". Journal of Construction Engineering and Management, 2005.

76. Hill, D.C., “”Construction Safety Management and Engineering”, American Society of Safety Engineers, 2003.

ABSTRACT

DEVELOPMENT AND IMPLEMENTATION OF A PROACTIVE SAFETY PERFORMANCE EVALUATION SYSTEM FOR GENERAL CONTRACTORS

by

SELİM A ALPMEN

May 2013

Advisor: Dr. Mumtaz Usmen

Major: Civil Engineering

Degree: Doctor of Philosophy

Construction safety is an essential aspect of the construction industry and measuring safety performance has been of continuing concern. Most of the preceding studies concentrated on two widely used metrics in industry to evaluate and improve safety performance, EMR and incidence rates. However, it is recognized that these metrics have shortcomings, such as being reactive and not proactive, or representing a macroscopic approach and not microscopic approach, or disregarding the events that lead to accidents and only being result-oriented. Improving safety is one aspect of a research but using an appropriate safety measure is as important. Using these parameters comes with their limitations, and they need to be well understood while drawing conclusions so as not to mislead an owner while comparing companies' safety performance or making a decision to select a safe contractor, the same holds true for the contractor's own management while self-assessing its safety performance and deficiencies.

This study focused on a new safety performance metric by introducing a proactive safety performance measurement system through observed safety violations of OSHA standards. The new metric, site safety performance value (SSPV) was based on OSHA's Gravity Based Penalty (GBP) system and quantified general contractors' site safety performance to measure their ability to comply with OSHA safety rules and regulations. This metric is a leading indicator based on pre-accident driven data. It was also used to develop a new predictive model to evaluate general contractors' safety performance and examine the relationships between the project and company demographics and the proactive safety measure, SSPV, for advancement of construction safety performance. The statistical model constructed can predict future contractor safety performance, and it may contribute to the contractor selection process. The methodology additionally included an investigation of specific construction trades to find out which trades carry the highest risk in terms of safety and impact construction safety performance the most.

The findings of this study can be used by numerous groups including the general contractors, owners, safety professionals and researchers to identify where safety performance can be improved, and determine the significant parameters that could help identify the areas of concern by utilizing a new proactive safety performance evaluation system.

AUTOBIOGRAPHICAL STATEMENT

Ahmet Selim Alpmen was born in 1978 in Istanbul, Turkey. He attended Yildiz Technical University in Istanbul, graduating in 1999 with a B.S. degree in civil engineering. He later attended Istanbul Technical University in Istanbul and earned a certificate in Engineering Management for Construction program and came to USA in 2000. Upon arriving the USA, he attended Wayne State University, graduating with a M.S degree in civil engineering. He then pursued his studies in construction management PhD degree program at Wayne State University.

Ahmet Selim Alpmen is currently working as a Project Manager for the New Wayne County Consolidated Jail Facility project. He is involved in all aspects of the program and project management activities from construction through closeout phases containing providing procurement and construction oversight, administering budget, schedule, and cost issues and change order process. He ensures the compliance of the quality control provisions of the contract. He is also working as the project scheduler for Chicago Dirksen Courthouse and Maryland Montgomery County Judicial Center Annex projects with construction costs over $100M each.

Previously, he served as the Project Controls Manager for the rehabilitation and reconstruction of runways, taxiways and aprons on behalf of the Metropolitan Wayne County Airport as well as for the Detroit Public Schools Program Manager Team $1.5 Billion Capital Improvement Program (CIP). His position included overall management of project financial cost controls, quality, change, budget, schedule and claims, the development, assessment and analysis of the project and program schedules.