Spring 1-1-2014

Investing in Safety Programs and Utility Analysis of Construction Safety Professionals

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INVESTING IN SAFETY PROGRAMS AND UTILITY ANALYSIS OF CONSTRUCTION SAFETY PROFESSIONALS

by

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University of Colorado – Boulder, 2014

A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado at Boulder in partial fulfillment

of the requirement for the degree of

Master of Science in Civil Engineering

Department of Civil, Environmental, and Architectural Engineering

2014

This thesis entitled:

Investing in Safety Programs and Utility Analysis of Construction Safety Professionals

written by Marcos Ricardo Duarte

has been approved by the Department of Civil, Environmental, and Architectural Engineering

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April 24, 2014

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

Abstract

Duarte, Marcos Ricardo (M.S. Civil Engineering)

Investing in Safety Programs and Utility Analysis of Construction Safety Professionals

Thesis directed by Professor Matthew R. Hallowell

This study focused on the investing practices and perceptions of safety professionals in the construction industry. The objectives of this study were carried out in two separate phases. First, interviews about current investing strategies were conducted on professionals in construction firms. A comparison of the strategies implemented by each of the interviewees showed specific distinctions in eight strategies and were identified as being a proactive, neutral, or reactive investment methods. The interviewees were categorized based on their investment methods and analyzed. A T-test was conducted and showed a difference between the lower Recordable Incident Rate from companies with a majority of proactive investment methods against those companies that didn't have a majority of their investment methods being proactive. In the second phase, a questionnaire with 25 independent scenarios was sent out to analyze how safety professionals responded to different investment scenarios. Each of the scenarios were constructed with three major variables. A safety intervention type (training/program, consultant, tools & equipment, and engineering system), injury severity level (first aid, medical case, lost work time, and fatality), and injury event (various incidents) were given as categories to analyze. Also, each scenario was given a reduction factor (percentage) and an initial cost or future savings expected from the intervention being implemented. The scenarios asked the respondent to choose whether he or she would invest in the scenario (yes or no) or asked the respondent to provide the cost he or she was willing to invest in the program. Utility values were calculated and analyzed based on the responses. An ANOVA analysis was used to determine the differences in the scenario variables. The results showed that each of the three variables had an effect on how much the respondents would give as an investment towards safety. The *intervention type* variable showed the greatest utility difference among the three variables. A Wilcoxon Rank-Sum test was performed on seven categories within the three variables and two categories from the reduction factor attribute. The results showed that the "Consultant" type, "All Incident" injury event, and reduction values of 100% had an effect on higher utility questionnaire responses.

Acknowledgements

First, I would like to express my appreciation to my grandparents, Alec & Minnie Duarte (deceased), for all of the support and values bestowed upon me. Their guidance has lead me to pursue these graduate studies and continue to challenge myself in new ways. They showed me the value of caring for individuals and how this action can have great rewards for them and myself. Researching and development my professional career in the workplace safety discipline can be attributed to their unlimited support.

Also, I would like to thank Professor Matthew R. Hallowell for academic and personal development he has given me over the past few years. He provided me with the necessary resources and abilities to continue with my life in this industry. As an advisor, who promoted this department to me for graduate research, he has evolved to one of the most influential people in my life. Thank you for everything, Matt!

Next, I would like to thank the entire Construction Engineering Management faculty for their understanding and the flexibility shown to me. I experienced several life obstacles during my graduate studies and always had the support of all the faculty members. They allowed me to make the appropriate decisions in my life, giving me their support, and allowing me to continue with my goals.

Last, I have to show my appreciation to all the current and past members of the Construction Safety Laboratory, especially, Alex Albert, Antoine Tixier, and Behzad Esmaeili. This group of individuals would go out of their way to assist each other in various research studies and projects. The level of interest each of them give to one another is truly a blessing to experience. It promoted a very positive environment which ultimately has led to my success.

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Introduction

The construction industry is very dynamic as well as complex in terms of the managerial obligations of each organization. While the priority levels of an organization's obligations vary considerably, several identifiable risks are notable. One important factor is the amount of money an organization determines to spend on the safety of its employee. The purpose of this study is to provide an overview of the relationship between construction safety interventions and investment behaviors and create a greater emphasis in this area of safety investment research for future developments.

In terms of the United States Gross Domestic Product, the construction industry contributed approximately 3.6% in 2012. While considering the relatively low percentage of GDP versus the approximately 20 major NAICS categories, construction makes a substantial impact on the economy (BEA, 2013). From a workforce point of view, the construction industry employs around 5.6 million workers per year or around 3.9% of the major sectors (Bureau of Labor Statistics, 2013a).

Unfortunately, the injuries and fatalities associated with the construction industry portray a risky and hazardous environment for these workers. In 2012, the construction and extraction industry ranked 3rd among major industries in terms of their fatal work injury rate including 19.11% of the fatal injuries. Statistics for non-fatal injuries reveal an even more hazardous working environment as construction is ranked 2nd in terms of incident rates, only behind the Transportation and Warehousing industry. Consequentially, the Bureau of Labor Statistics has developed a new analysis method concerning the effect of contractors on the different industries which ultimately employs them for services. In 2011, the BLS developed a new statistic section that showed the number of fatalities dropped in three major industries, including construction, when the fatalities from contractors were designated in the industry for which their hiring employer resides. The construction industry saw a 32% drop in the accountability of fatalities in the workplace (BLS, 2013b&c). These new statistics show the impact construction injuries and fatalities have with respect to other industries that employ contractors for their services.

In the recent past, numerous ideologies, methods, and strategies have been proposed to address the safety concerns of the construction industry; however, the effect of past research has not been seen to drastically impact the frequency and severity of injuries and fatalities. This study does not try to propose any new safety strategy, program, or awareness system. Rather, it focuses on the current methods used by safety officials in the industry. The study takes a unique approach by examining the professionals who make decisions regarding the appropriate amount of investments toward safety measures. It looks at the general strategies utilized to make decisions on safety programs and intervention types. Additionally, it attempts to quantify the amount safety professionals are willing to invest in safety interventions given the expected costs associated with different hazards and injuries.

Literature Review

Investment in Safety

The impacts of injuries and fatalities in the construction industry have produced new literature recognizing numerous attributes that involve risk, safety, and financial management. Hinze (2000) concluded that in terms of safety management in construction, determining cost-benefit analyses are unrealistic. The two reasons were found to be: 1) the difficulty in determining the cost savings to specific activities and, 2) the organization and complexity of construction activities prevents the production and synthesis of accurate data even from the most basic work activities. Hinze explored the dilemma of current safety efforts in the cost of injuries and the funding spent on safety when no injuries may occur. He stated this dilemma becomes “a game of probabilities”. Furthermore, Hinze believed that to develop the understanding in funding commitments toward “safety as investment rather than operational costs requires a cultural change”. His premise is clear. Injury costs will remain high as long as the level of emphasis on safety and prevention remains low. This study will further explore Hinze’s early work surrounding these compromises and efforts of safety management surrounding this safety intervention and investment topic.

Similarly, Dr. Paul Slovic (1987) stressed that those who professionally deal with “health and safety need to understand how people think about and respond to risk.” In much of his personal and fellowship research, Slovic aims at answering the fundamental question developed by the pioneering efforts of Star (1969) as to “How safe is safe enough?”

Additionally, Hallowell and Gambatese (2007) found many safety program elements are chosen in an “informal fashion” and they have “no unified method currently (to) implement” In their study, 59% of the small contractors surveyed revealed that their safety elements were chosen based on intuition and judgment. Furthermore, the results were nearly the same for the medium and large-sized contractor resulting in 63.6% and 59% respectfully.

Safety Programs and Elements

This study involves the selection of various safety program elements to reduce the cost incurred by construction accidents and injuries. The elements follow the research performed by Hallowell (2010), Hinze et al. (2001) and Liska et al (1993). A summary of three different research projects can be found in the Appendix outlining each author's contributing developments to the proactive implementation of safety methods. For the main focus of this study's objectives, Hallowell's 13 program elements are ideal as they have shown to be rated by their cost-effectiveness in later research (Hallowell, 2011). They also give a basis and validity concerning how the cost and reduction in severity results for the elements in each of the scenarios. From recommendation in the research performed by Hallowell and Gambatese (2009), two major elements or techniques from the body of knowledge were not considered as adequate elements for this study. Incentive programs and rewards/recognition programs are seen as elements that could hinder good safety performance and have led to underreporting from previous accounts. Also, these programs along with a few other elements from the above research were not seen as proactive methods to prevent injuries and accidents.

Cost of Safety Models

Many researchers have supported the claim by Behm et al. (2004), which stated the total cost of prevention and total cost of injuries should be minimized in a financial analysis (Hallowell, 2011). Behm et al. established the cost of safety (COS) model which illustrated the cost of failures along with the cost of prevention and detection. This method was modified from the cost of quality (COQ) model developed by Coble et al. (2000). The authors categorized four main cost groups: prevention, detection, internal failures and external failures. The proactive measures aiming to prevent failures, injuries, etc. are categorized in the prevention and detection groups. The failure groups are an assembly of items such as incident investigation, workers' compensations cases, regulatory fines, and other provisions associated with costs after an injury or failure occurs. Behm et al. (2004) performed a case study and analyzed the methods by implementing ergonomics cost in a controlled setting. While the case study may not seem applicable to all organizations the methods to analyze and compare benchmarks are not exclusive to any organization or industry. Collectively these authors believed that the optimum amount of safety investment funds should be the equilibrium point of the failures and prevention/detection functions. However, they noted that every organization has their own level of acceptable risk. Each organization can choose to spend more money on prevention and detection than their expected failure costs. This decision method is attributed to the unique risk perception of decision makers and behaviors in terms of the situations they face. This model produces limitations by not requiring a strong amount of data correlated to the cost of the safety programs. Likewise, the data shows no specific impact of the programs to reduce failures and defects over time. Also, the model is not based on any guidelines or strategies from proven risk-based or finanical principles (Hallowell, 2011). Figure 1 illustrates the theoretical Cost of Safety Model.

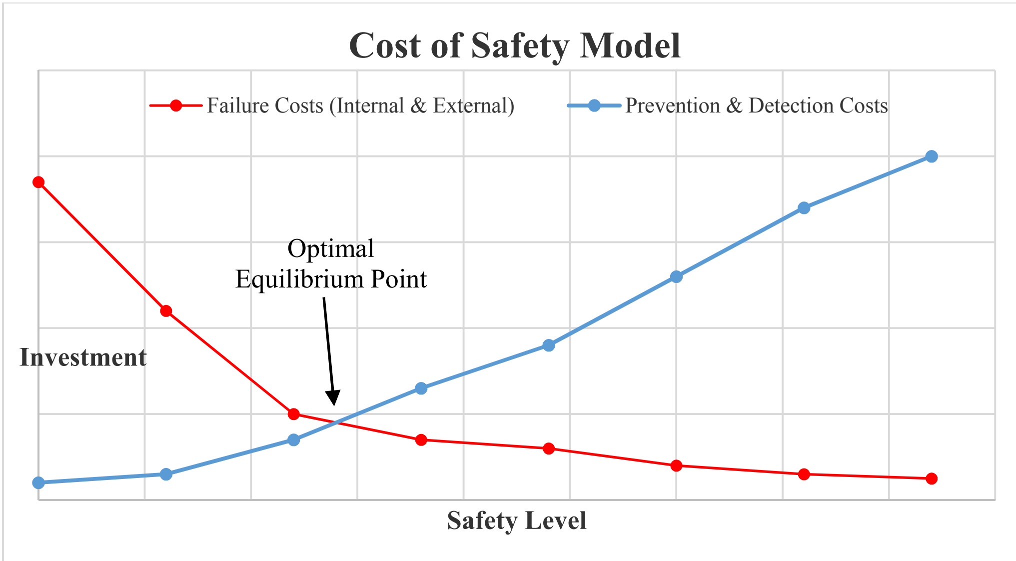


Figure 1 - Cost of Safety Model (Behm et al., 2004)

From Figure 1, the cost of safety (COS) model clearly illustrates that reaching the goal of zero-accident or defects becomes very costly to obtain. The authors revealed that this could essentially cause a financial strain on a business's operating strategy to achieve their ideal safety goal level. Conversely the determination of an investment is up to the organization and can be seen in their safety climate. As stated by Behm et al. (2004)'s recommendation, "if the prevention of an injury is deemed to be greater than the cost of the injury, it would not make financial sense to make the investment. However, such an investment may certainly make sense from a humane and business ethics standpoint." Furthermore, the model recognizes that some level of risk must be considered to keep an organization financially stable. Manuel and Main (2002) confirm this idea by summarizing that all activities have an inherent risk, and for the risk to be eliminated or nearly eliminated, very high costs are certain. Hallowell (2011) modified the cost model and constructed an investment profile based on the expected cost of injuries and reduction of the expected costs by imposed safety program elements. In this profile, the total cost of the expected injuries and total cost of the prevention elements are combined. The optimum point seen in this method is found when the Return on Investment reaches zero or at the minimum value of Tn from the profile in Figure 2.

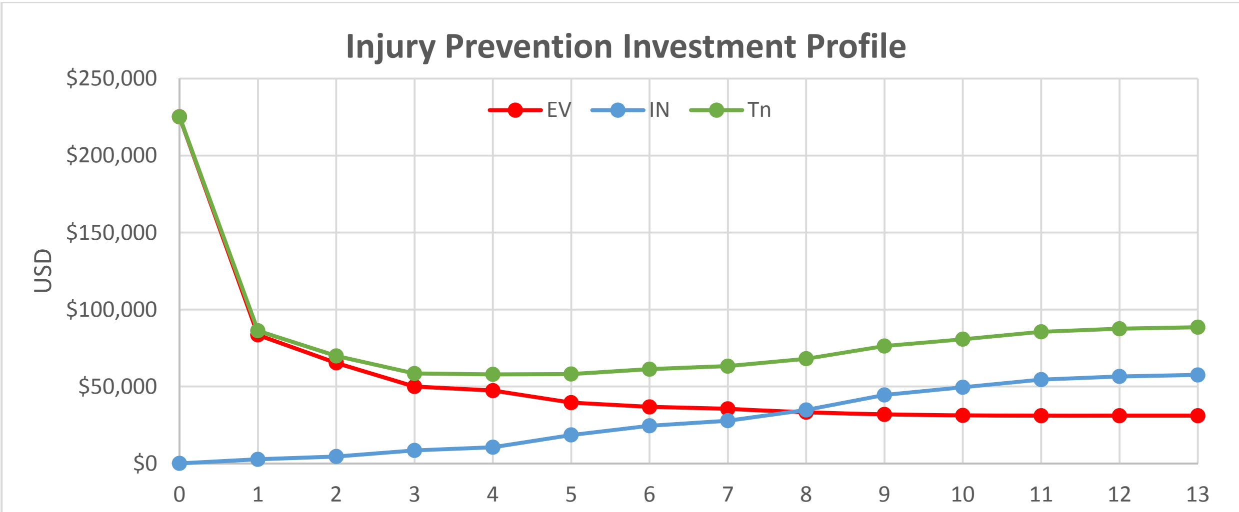


Figure 2 - Injury Prevention Investment Profile (Hallowell, 2011)

<u>Safety Climate and Culture</u>

The first research project regarding safety climate was performed by Zohar (1980). The basis of that research was to illustrate that climate can be reflected in employees' perception, specifically concerning conduct and behavior towards occupational safety. From this research, it was seen that perception had a specific psychological utility that aided as a framework for one's "appropriate and adaptive" behavior. Developing on this study, Guldenmund (2000) studied the safety climate of management and workers in relation to their risk perceptions and tolerances. This content refers to a "safety attitude measurement" which can be concluded as the risk attitudes from specific utility functions. Guldenmund found that comparing risk tolerances of employees and risk perceptions will result in a measurement of the company's safety climate. Also, he summarized that perceptions are more related to safety climate whereas attitudes are portions of the overall safety culture. Additionally, it was noted that the most important factors in studying an organization's safety climate were determined to be risk, safety systems, and its management approach.

Alternatively, Williamson et al. (1997) analyzed workers' behaviors as an indicator of the company's safety climate. Historically, many researchers have studied the behaviors and alternative models of the interaction between climates, cultures, and safety attitudes.

Subsequently, this study doesn't argue or confirm which previous research is more beneficial to the analysis. The description of climate and culture is given for the purpose of relating how the body of knowledge concerning this central topic has evolved over time. This current study follows more on Guldenmund's (2007) general view where safety climate research can be linked and related to theoretical attitude research. The purpose of this study is to determine the risk attitudes of the safety officials investing in proactive safety processes on a regular basis and not the specific culture or climate of various organizations.

Risk and Perception of Safety

The idea and definition of risk means numerous things to different individuals; however, psychometric developments have allowed current techniques to identify differences and similarities in regards to risk among various groups. Slovic (1987) proclaims that people who deal with health and safety must understand the perceptions of risk. Officials who promote and regulate policies associated with this field can make decisions with good intentions but could find these decisions to be ineffective without the understanding of how individuals respond and perceive the risks.

Utility and Risk

The first principle of the utility concept was conceived by Daniel Bernoulli in the 18th century and has since been developed by several others. Bernoulli revealed that people can make a decision from an intrinsic expectation other than a general numerical expectation, in which the expected monetary value does not equal a corresponding expected non-monetary value. The non-monetary value or utility value given to the situation is what people attempt to maximize. Friedman and Savage (1948) explored the function of utility based on the theory from von Neumann and Morgenstern (1944) involving rational choices and expected value calculations. This study attempts to follow the research methods of Friedman and Savage by illustrating utility as a function of a person's characteristics which influence the behavior in the decision making. Friedman and Savage examined the risk attitudes of individuals based on their personal income. This study will not consider the respondent's income but will examine other demographics of the respondent with regards to their occupations.

Also, von Winterfeldt & Edwards (1986) analyzed the behaviors of people and how money is viewed in different contexts from pocket cash to a company's investing capital. This study holds the position that the decision maker (respondent) is investing his or her company's capital. This position will hold consistent with their daily occupation to reduce the frequency of the injuries, which will provide a positive benefit to the management and workers combined, holding the consistency of the research work done by Hinze (2000), Ferry (1990), and Hallowell (2011).

Utility theory helps explain the human behavior phenomena in such relationships as spending and saving (e.g. insurance purchasing). Some of the axioms of utility theory are adequate and acceptable principles to determine behaviors involving uncertainty. However, it must be known that this theory only "provides a reasonable approximation to the behavior of individuals under conditions of uncertainty" (Tversky, 1975).

Expected Values

In risk perception research, analyses show/suggest that the impacts resulting from unfortunate events such as accidents can extend far beyond the direct costs or harm. These indirect costs can be significant both in monetary and nonmonetary terms that can dilute the initial direct costs (Slovic, 1987), while many risk safety decisions are difficult to analyze after the implementation. Thus determination of proper programs prior to implementation can aid in the effectiveness towards the overall safety program. Therefore expected values in terms of a program's benefits and cost are needed for accurate quantifiable decision making. Functions can be constructed with various mathematical techniques to model one's attitude with respect to risky situations. Here the functions provide a representation of a person or group of individuals' preference given a certain set of expected values (Clements, 2004).

Perception and Preference of Choice

Research on the topic of risk perception originated through a combination of various studies, such as decision-making processes, probability assessment, and utility assessment. Historical psychometric studies have found that risk perception can be predictable and quantifiable (Slovic, 1987). Within these psychometric studies, individuals who were found to have evaluations of identical risks were willing to accept to those risks, but in different cases. One psychometric finding determined that when a risk is voluntary, in one's control, and has a benefit to that individual, the individual is more accepting of the risk even if the risks and opportunities have equal magnitudes. This study will examine the benefits of implementing safety intervention to provide a financial benefit by reducing expected injury costs. Again, the study will hold consistent with this scientific finding by only questioning those individuals who control the decisions that can provide this financial and humane benefit.

From a lengthy history of research about utility decision making, the psychology field is by far the most examined. Psychology has found that many qualitative factors influence the perception of risk and decision making such as the unpredictability of outcomes, familiarity, the potential for catastrophic loss, and emotional reactions (Slovic, Fischhoff, and Lichtenstein, 1985). In regards to financial risks and the perception of loss, results of this relationship remain consistent with the recent body of knowledge. Here it is found that the perceived return/risk is highly connected to the likelihood of investing. Research shows that investing clients can perceive risk as a psychological burden attributed to the evaluation and monitoring of the investment's performance along with the general environmental and market risk factors (MacGregor et al., 1999).

Framing of Choices

From Tverksy and Kahnemann (1981), research has learned that the perception of decision analysis can yield predetermined shifts in the evaluations of one's preferences due to the different ways the problem is framed. The term "decision frame" references the "conception of the acts, outcomes, and contingencies" related with a specific choice or decision. The frame controls the decision-makers acts by exposing the "norms, habits, and personal characteristics" of him or her. In an experiment performed on students from the University of British Columbia and Stanford University, the effects of framing can be seen in results of this research by having the subjects select a program to save a different percentage of lives along with different probabilities. The results shifted due the framing of scenarios given by the phrasing of “lives saved” and “lives lost” [see appendix for full results of study].

> Imagine that the US is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimate of the consequences of the program are as follows:
>
> - If Program A is adopted, 200 people will be saved.
> - If Program B is adopted, there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved.
>
> Which of the two programs would you favor?
>
> Variation of problem.
>
> - If Program C is adopted, 400 people will die.
> - If Program D is adopted, there is 1/3 probability that nobody will die, and 2/3 probability that 600 will die.
>
> In the first series, 72 % picked Program A and in the second series, 78% picked Program D.

These frames have later been named the Survival and Mortality frames, respectively (Tverksy and Kahneman, 1986). From the respondents choices arose a commonly known pattern of psychological thought process that shows choices involving gains are seen to have a risk averse behavior. Subsequently, choices involving losses are often seen to have a risk taking behavior. While the psychological attitudes of risk averse and risk taking behaviors are crucial items involving utility and game theory, this study aims to dismiss the variations caused by framing of scenarios by consistently and thoroughly providing a solid framework of the same choices to the respondents of the study.

Additionally, Tversky et al. (1988) conducted a subsequent research project involving the weighting of these framing problems. In the problem below, the respondents are asked to choose between the programs. In the modification of this problem, respondents are asked if $55M was too high for the cost of Program X or to determine the appropriate amount Program X will cost. From these results, only 50% said Program X is too low at a cost of $55M but only 18% provided a cost value exceeding $55M. This shows the discrepancy between respondents' perception of the costs and their purported preference (higher than $55 million).

Traffic Accident Problem:

About 600 people are killed each year in Israel in traffic accidents. The ministry of transportation investigates various programs to reduce the number of casualties. Consider the following two programs, described in terms of yearly costs (in millions of dollars) and the number of casualties per year that is expected following the implementation of each program.

	Expected # of casualties	Cost	Response
Program X	500	$55M	68%
Program Y	570	$12M	32%

Which program do you favor?

Modification:

Determine the cost of Program X that would make it equivalent to Program Y.

Is this value higher or lower than $55M?

This study takes a further recommendation from Zohar (1980), Hallowell (2010) and Hinze (2000). First, this method is accomplished by phrasing all items in a positive manner to the respondents, which shall result in consistent but higher values in the results. Also, this method solicits in a standard style because risk perception is a subjective judgment and respondents will make a conclusion about specific risk in this study. Last, the term "cost of safety" implies a negative connotation, so this study takes the position to utilize the preferred phrase "investment in safety". The term, investment, has a connotation of a believed benefit or a greater return.

Also, the weighting of the questions is considered in this study, as the expected utility theory generalizes that people will weigh the outcome based on the probability. The developed scenarios do not provide probability, as the intention is to test the prospect theory instead. Here a decision weight is also given to an uncertain outcome and in the form of different variables not necessary in a probability context (Tverksy and Kahneman, 1981). To test the prospect theory, the variables are the reduction factor of the proposed safety intervention, and the severity of the injuries. Here this study will determine if any weighing effects are observed by the respondents.

This method follows previous research by McNeil et al. (1982) and Jones-Lee et al. (1985). McNeil et al. surveyed several patients, students, and physicians to determine the preferences of how medical treatments such a radiation therapy or surgery approaches are perceived through reliable statistical data. The survival and mortality frame was implemented interchangeably and the cumulative probability of different life expectancies was varied in the surveys. In the Jones et al. research, a questionnaire was given in an attempt to examine how people will actually choose between risk decisions. As the researchers determined that many people will "tailor" the questions to their perceptions based on the information he or she needs in the situation. Recently Slovic (1995) has outlined the objectives of these studies' scenarios by recommending equivalent stability across the descriptions and elicitation procedure in order to represent the maximization of one's utility preferences.

Slovic (1987) describes the study surrounding risk perception as "the judgments people make when they are asked to characterize and evaluate hazardous activities and technologies." This paper takes an unconventional approach in discovering the risk perceptions of professional safety officials who are faced with investment decisions surrounding safety and risk. Consequently, two elements are required in the assessment of risk perception. The first element is the expected value one perceives from the assessment. In this study, the expected value will be the risk calculation of an expected amount of cost saved from a safety intervention element. The second element is utility and has been the universal variable in the determination of risk perception and decision maker's attitude.

Risk and Safety Quantification

Tversky and Kahnemann (1981) propose that one restricts the handling of expected value theory to numerical probabilities and quantitative outcomes. This study will use the same concept and perform this study with the choices involving money saved from the reduction of injuries and fatalities. This method will be achieved by implementing quantitative research techniques in the safety engineering field.

Jannadi and Almishari (2003) developed an assessment equation from variables to quantify the expected cost of safety related risks. Their developments resulted in a Risk Assessment Model (RAM). This particular model explored the relationship between the three measurements: probability, severity and exposure. The model formed a product of the measurements to quantify the risk of certain activities in the construction industry. The product is then adjusted to form an Activity Risk Score by applying a justification factor and a degree of correction factor for cost. Additionally, Barandan and Usmen (2006) calculated the unit risk of construction tasks. The unit risk of any task was revealed to be the product of the task's severity and its frequency of occurrence. In this study, the authors focused on the severity component of the risk rather than the frequency or probability like other previous studies. It can be noted that the severity can be expressed in terms of lost days or, more importantly for this study, in terms of the cost associated with the projected lost days. However, the cost is not applicable for fatalities as quantification methods and standards associated with these situations extend much farther than the available data or reporting of events can offer. From these two equations, Hallowell (2011) calculated the excepted costs and severity of injury types. These injury types will be an adamant part of the scenario developed in the survey.

This study provides a glossary that quantifies various safety metrics associated with this research and the body of knowledge surrounding risk and safety management. In the glossary, proper association of the authors' developed equations are given and summarized. Numerous variables are identified and defined to maintain consistency throughout this study and future explorations.

Point of Departure

In this study, the author diverges from the previous body of knowledge surrounding the relationships between safety, financial assessment, and risk assessment. It looks at the risk perception and actions of management officials in regards to investing in activities to reduce the frequency and exposure of injuries and fatalities. Universal expected values on current injuries and fatality are calculated based on past research. The respondents' Recordable Injury Rate (RIR) will be analyzed to assess any variations between the utility and their RIR. Also, the current state of the decision maker's company budget along with other demographics are taken as attributes of the perception and availability of their investment choices. Initial data was collected and analyzed to provide the appropriate metrics and information in these scenarios. Additionally, previous measurements, criteria, and examples in the previous bodies of knowledge were utilized to aid in the framing the decision makers' scenarios for accurate calculations.

Research Methods

This study was performed in two phases to account for the lack of general knowledge surrounding the central topic of investing in safety. Each phase was constructed with separate objectives, yet were combined in the complete study. The separate phases aided in answering the questions on how companies make safety program decisions and what drives their investment decisions.

Phase 1

The main focus of this phase was to determine characteristics observed by construction companies regarding the specific strategies implemented in making financial decisions on safety programs. A series of case studies were conducted in order to obtain the characteristics of these particular strategies.

Interviews

The case studies explored a variety of individual companies with different demographics to compile an overview of investment strategies. Interviews with company officers were the main method of gaining the information for this phase. A predetermined set of questions developed to help gain the proper insight necessary for this case study [please see the appendix for the list of interview questions]. Upon completion of the individual interviews, the characteristics will be summarized and collected for analysis. If at any stage during the analysis, the content from the interviews do not possess the necessary information to continue in the analysis, the interview was disregarded in the final statistical analysis.

Strategies

The analysis in Phase 1 was brief. The main focus of this phase was to first identify the strategies used in each of interviews by a content analysis. After the initial identification of pure strategies, the strategies was combined and consolidated to form a standard set of strategies shown to be utilized by companies for investing in safety programs. The third step involved categorizing this set of strategies into three distinct groups (i.e. proactive, neutral, and reactive) based on the methodology of investment strategies towards reducing safety issues [definitions of the strategies and methodologies can be found in this study's glossary]. Next, the companies were identified by their key demographics as well as the methodologies seen in the interviews [see appendix for a complete summary of the interviews]. Last, the only statistical analysis proposed was a comparison of the company's demographics and the general type of methodology each company possess regarding their investment methods concerning safety.

Phase 2

This phase focused on how high-level safety officials making the actual decisions regarding investments. A series of independent scenarios were the method utilized to determine the decision behaviors of these respondents. This phase had three objectives: (a) find how much respondents are willing to spend on a series of independent scenarios, (b) determine utility factors for each respondent, and (c) analyze the scenarios' results to discover any correlations between demographics, safety metrics, and utility factors.

Scenario Construction

The construction of each scenario brought about a number of concerns, especially from those identified from previous literature. A key item of focus was to develop realistic scenarios for the construction and validation of the scenarios to give to the respondents. Here, it was determined that each scenarios must possess a certain and consistent set of variables. By having realistic variables in each scenario, will allow the respondents to have a clearer and familiar sense of each scenario. Five variables are utilized in construction of the scenarios [see appendix for a list of each scenario along with a summary of variables corresponding to each scenario].

Scenario Variables

Each scenario had a hazard topic unique to the scenario. The scenarios possessed a severity level associated with the hazard along with an event or incident that is a result of the hazard. From these last two variables, appropriate cost values were given in the scenario that resembled realistic values and were supported by literature researched to each make the fourth variable. The fifth variable was the type of intervention proposed in the scenario. Here five intervention types are used stemming from research performed in the arena of effective safety programs. Another concern of the scenarios were to have a variety but equally distributed interaction among the variables. To achieve an equal distribution between the severity level, type of incident, and intervention type; performing many iterations were necessary to achieve a desirable level of interaction among the variables [see the appendix for the matrices and graphs representing the distribution of the variables].

Also, a concern for the length of the scenario in terms of word count is considered. An initial analysis examined the list of 25 scenarios was performed. One result of this analysis evaluated the distribution of each scenario's word counts. It is ideal that the word count must be held relatively consistent throughout the study. The goal was have the scenarios average approximately 60 words and not to exceed 75 words. Last, based on the literature surrounding the framing of questions in regards to life saving choices, all of the scenarios were constructed in a "positive" or "survival" frame. This ideology would have an impact on the evaluation of respondents as well as the mathematical analysis of the utility factors.

Utility Calculations

The utility value of safety investment was calculated in terms of Equation 1 seen below. Where $\boldsymbol{I_i}$ was the cost of the safety intervention, $\boldsymbol{EV_i}$ was the expected cost saving from the intervention, and $\boldsymbol{U_i}$ was the resulting utility value of the scenario. Here the expected cost savings of the safety intervention was given in each of the scenarios; however, the investment cost of the intervention was not given in all of the scenarios. The intervention which the respondent was asked to choose has a corresponding reduction factor, $\boldsymbol{R_i}$. This factor was said to reduce the cost of the original estimate cost of injuries, $\boldsymbol{EV_o}$. The expected cost saving could have been given in the scenario or calculated based on Equation 2.

Equation #1: $U_i = \dfrac{I_i}{EV_i}$

Equation #2: $EV_i = EV_o * R_i$

The scenarios were separated into two groups based on the utility values their scenarios produced. One group of scenarios held "fixed" utility values in which the respondents were asked to determine whether they would invest in the intervention scenario (yes) or decline the intervention (no). Here the amount (cost) of the intervention was given in the scenario enabling the utility value to be calculated based on the current scenario's information. This group incorporated 13 choosing scenarios that range in fixed utility values from 0.2 to 2.0 with incremental values of 0.2 and then proceeding to 8.0 in increments of 2.0. The second group of scenarios did not give the amount of the intervention in the scenario. The other scenarios asked the respondent to determine what he or she is willing to invest in the intervention. These scenarios held a "variable" utility value as the entry of the respondent will vary from response to response. There were 12 scenarios with this matching option [see the appendix for a breakdown of the calculation for each scenario].

Distribution of the utility and reduction values were examined to insure proper randomization and validity among the scenarios.

Survey

The scenarios were given to the respondents in an online survey form. The technology available through Qualtrics allowed the scenarios to be randomized in terms of order of scenarios as well as order of the choice options. Demographics similar to those asked in Phase 1 were also included in the survey [a full set of survey questions can be found in the appendix]. Statistical analysis was performed on the individual respondent's answer to determine an appropriate utility factor. Last, a series of correlation analyses from the various variables was examined.

Analysis

First, the scenarios' variable responses were examined for the range of outliers each of these 12 scenarios possessed. The Inner Quartile Range of each variable scenario was calculated based off the inner 50% of the data range. This calculation was achieved by subtracting the Upper Quartile (UQ_i) value minus the Lower Quartile (LQ_i) value as seen in Equation #3. Equation #4 determined the Outlier Factor (OF_{ia}) from each of respondent's answers (Q_{ia}). The Average Outlier Factors (AOFa) were populated from averaging the 12 outlier factors. It was discussed and determined that any respondent's AOF_a greater than 3.0 would result in that individual's response being removed from the data set prior to analysis. An outlier is defined as having a factor of 1.5 and an extreme outlier is one that holds a 3.0 factor (Peck et al., 2005). This extreme outlier value of 3.0 was the basis for determining the critical removal value from the AOF_a.

Equation #3: $IQR_i = UQ_i - LQ_i$

Equation #4: $OF_{ia} = Q_{ia} / IQR_i$

Equation #5: $$AOF_a = \Sigma\ OF_{ia} / 12$$

The next analysis performed on the newly edited data set was an ANOVA test of the three variables in each scenario. This analysis helped establish if there would be any statistical differences in the variance for each of the three variables. Based on the results of the ANOVA testing, Wilcoxon Rank-Sum Tests were implemented on the major categories found in the three variables as well as percentage categories within the Reduction Factors. The rank-sum testing was chosen based on the new data set still holding large outliers. This sequential testing procedure has permitted the case study to validate any hypotheses the descriptive data allowed us claim. Also, the rank sum testing has allowed the case study numerical evidence to show what categories in the scenario variables had the most significant effect on the utility values.

Data Results

Phase 1

This phase of the study consisted of 16 interviews from various construction companies. The goal was to determine what investment strategies these companies routinely use as part of their safety programs.

Initially, 20 different investment strategies were identified. After a content analyses was performed, the total number of investment strategies was narrowed down to eight. Then, these strategies were categorized as proactive, neutral or reactive methods [please see the Appendix for tables and Glossary of definitions for each strategy and method].

Seven companies were removed due to the variation of demographic values from the interviews. One company was removed based on being headquartered in France and another company was deemed a medium-sized contractor. Additionally, five other company interviews did not possess the necessary demographic statistics such as the Recordable Incident Rate. The removal of these interviews narrowed the sample population to only nine large U.S. companies.

<u>Phase 2</u>

The investment questionnaire was sent out electronically to approximately 70 individuals from various construction safety organizations and societies. There were 18 questionnaires started; however, only 12 were completed. Then the questionnaire's data were compiled to determine if a large number of the respondent's answers resulted in outliers in the data. The data in Table 1 depicts the initial statistics of the variable utility scenarios.

Table 1 - Summary of Outliers per Each Variable Utility Scenarios

Outlier Summary of Scenarios												
	Q1	Q3	Q5	Q8	Q10	Q13	Q16	Q19	Q22	Q23	Q24	Q25
Count	12	12	12	12	12	12	12	12	12	12	12	12
Median	150,000	110,000	62,500	55,000	50,000	10,000	22,500	27,500	250,000	12,000	425,000	7,750
Lower Quartile	130,575	63,750	6,000	25,000	25,000	4,875	10,000	20,000	98,125	10,000	87,500	5,000
Upper Quartile	237,500	287,500	137,500	87,500	87,750	47,500	50,000	93,750	486,000	21,000	500,000	68,750
IQR	**106,925**	**223,750**	**131,500**	**62,500**	**62,750**	**42,625**	**40,000**	**73,750**	**387,875**	**11,000**	**412,500**	**63,750**

Individual outlier factors were generated by the Inner Quartile Ranges in Table 1 for all questionnaire responses. Then the outlier factors were averaged for each of the questionnaire responses shown in Table 2. Response IX has an overwhelmingly high average outlier factor. The pre-determined boundary for the outlier factor was set at 3.0. Response IX had seven of the 12 outlier factors for each scenario greater than 3.0. No other response had more than two outlier factors greater than 3.0. As a result, Response IX was removed from the data set, leaving 11 respondents to analyze.

Table 2 - Average Outlier Factor for Questionnaire Responses

Questionnaire Response	Avg. Outlier Factor
I	1.61
II	0.62
III	1.06
I	0.21
V	0.76
VI	0.70
VII	1.12
VIII	0.75
IX	45.32
X	0.49
XI	0.71
XII	1.95

The average Recordable Incident Rate was 0.60 with a median value of 0.47. The highest RIR was a 1.80 while the lowest reported RIR was 0.0. The respondents had an average revenue of $29.3 billion with a median value of $800 million. The largest revenue reported was $135 billion and the lowest was $40 million. Additionally, the responses yielded an average number of 35,638 employees. The most significant statistics of the demographics was seen in the years of experience and years of employment at their current firms. The average amount of experience was 22.1 years of experience with an average duration of 14.2 years at their current firm. Also, seven of 11 (63.6%) respondents operated in international firms. Table 3 below is a summary of the demographic responses.

Table 3 - Data Summary of Respondents' Demographics

Data Summary	RIR	Revenue	Personal Experience	Employed Years	Number of Employees
Average	0.60	$29,348,181,818	22.09	14.18	35,638
Median	0.47	$800,000,000	25	8	15,000
Minimum	0.00	$40,000,000	8	1	520
Maximum	1.80	$142,000,000,000	36	33	130,000
Standard Deviation	0.49	$54,446,963,335	9.19	11.18	46,630

An overwhelming majority of the respondents answered "Yes" to accepting the fixed utility scenarios. Only two questionnaire scenarios, #18 and #15 returned far below average acceptance percentages. Hypothetically, one can conclude that a fixed utility of 8.0 was too high for the respondents to accept in scenario #15. As for scenario #18 with a fixed utility of 2.0, the scenario's variables will be examined to determine possible conclusions for the low acceptance percentage results. This scenario dealt with hiring a consultant to mitigate slip, trip, and fall events that resulted in medical case injuries.

Table 4 - Fixed Utility Scenario Summary

Fixed Utility Summary				
Scenario Layout		Respondents	Acceptance	
Fixed Ui	Question #		Yes	%
0.2	Q7	11	11	100.0%
0.4	Q20	11	10	90.9%
0.6	Q11	11	10	90.9%
0.8	Q4	11	11	100.0%
1.0	Q6	11	11	100.0%
1.2	Q12	11	9	81.8%
1.4	Q14	11	11	100.0%
1.6	Q2	11	9	81.8%
1.8	Q9	11	9	81.8%
2.0	Q18	11	5	45.5%
4.0	Q21	11	10	90.9%
6.0	Q17	11	11	100.0%
8.0	Q15	11	5	45.5%

Due to the low number of responses, the data is skewed significantly in the scenario results due to a few respondents' high scenario answers. The median values provide a glimpse of the general respondents' utility ranges. The average utility factor for all the variable scenarios was 6.51 with a median of 1.00. Scenarios #5 and #13 have significantly high average utility factors. Further examination was performed as these two scenarios share a similar intervention type attribute. Only 10.61% of the 132 variable questionnaire responses had utility factors greater than 8.0. Additionally, 84.85% of the variable responses were equal or less than a utility of 4.0. From the individual scatterplots, the high acceptance results are visible in the fixed utility graph. [Please Appendix for Individual Summary of Respondents' Utilities].

Table 5 - Variable Utility Scenario Summary

Variable Utility Summary						
Scenario Layout		Respondents	Statistic Summary			
Expected Value	Question #		Average	Avg. Ui	Median	Std. Dev.
$661,500	Q1	11	$248,891	0.38	0.23	0.55
$120,000	Q3	11	$151,364	1.26	0.83	0.96
$1,500	Q5	11	$86,409	57.61	33.33	62.90
$72,000	Q8	11	$51,091	0.71	0.69	0.43
$51,000	Q10	11	$66,000	1.29	0.98	1.60
$3,000	Q13	11	$18,864	6.29	3.33	6.21
$22,000	Q16	11	$29,036	1.32	0.91	1.29
$24,500	Q19	11	$42,591	1.74	1.02	1.39
$438,750	Q22	11	$297,409	0.68	0.57	0.65
$11,500	Q23	11	$14,818	1.29	1.04	1.11
$350,000	Q24	11	$402,273	1.15	1.00	0.99
$7,500	Q25	11	$32,705	4.36	1.00	6.51

Data Analysis

Phase 1

From the sample population of the Phase 1 case study, four companies were summarized as having proactive methods for investing in their safety program. Investing methods used by companies labeled as neutral were combined with reactive methods for this analysis. Alternatively, five companies were labeled as having reactive methods or not implementing proactive methods to their investment strategies [Please see Appendix for detailed summary of investment method for each company]. Illustrated in Figure 3 below is the average RIR for companies possessing either proactive or neutral and reactive methods.

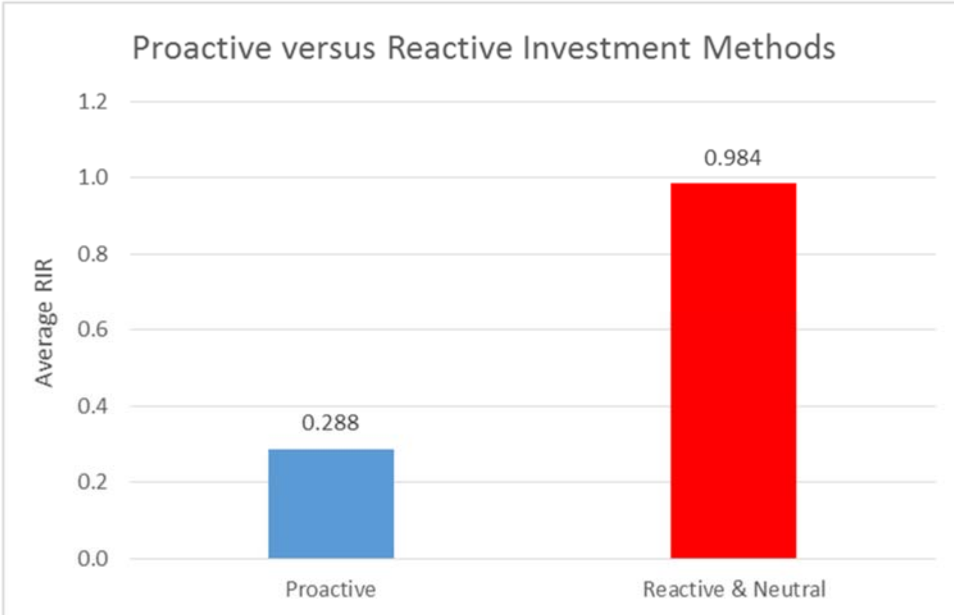


Figure 3 - RIR related to Proactive and Reactive Methods

A noticeable difference between the companies' RIR can be observed from Figure 3. An analytical comparison of the data set was performed in an attempt to validate the difference between the methods. The results of the completed T-Test can be seen in Table 6 below. An obvious difference of nearly 0.7 RIR and a T-test result of a 0.001 chance concluded that the case study data could be recreated randomly.

Table 6 - Comparison of Safety Strategies

Comparison of Safety Strategy		
Statistics	**Proactive**	**Reactive & Neutral**
Average RIR	0.288	0.984
Difference between AVG.	0.6965	
T-Test	0.001001996	

Phase 2

There was a noticeable difference in the utility values for the consultant and training/programs intervention types seen in Figure 4. The total average utility for the “Consultant” intervention type was 2.75 with a median of 1.0. The total average utility for the “Training/Program” was 21.74 with a median of 2.50. The other three intervention types each held average utilities between 0.99 and 1.26 with medians between 0.82 and 0.87 [Please see the Appendix for complete summary of utility statistics for the scenarios’ three attributes].

Scenario question #5 resulted in an average utility factor of 57.61. Analysis of this particular scenario found that eight of the eleven respondents gave answers that returned utility values between 10 and 166.7. Also, three of the same eight respondents gave the three highest utility values for scenario question #13. Two of the same eight respondents previously identified, gave similar high utility values for scenario question #25.

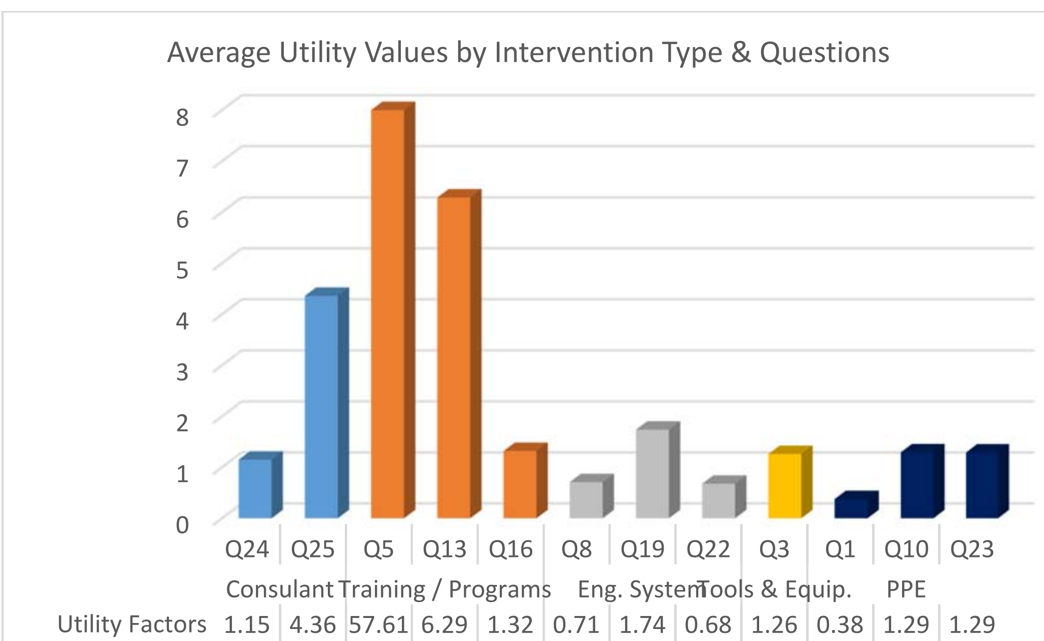


Figure 4 - Average Utility Values by Safety Intervention Types

In Figure 5, scenario questions #13, #25, and #5 dominate the graphical representation again. The "First Aid" and "Medical Case" levels have average utility factors of 0.99 and 1.4 respectfully, while the "Lost Work Time" and "Fatality" severity levels each have average utility factors of 3.79 and 19.71. However, the medians of these four severity levels have all near consistent values of 0.74, 1.01, 1.07, and 1.00 in respected order. In this analysis, scenario questions #13 and #25 now share a common attribute in the severity level of "Lost Work Time" in the attribute category.

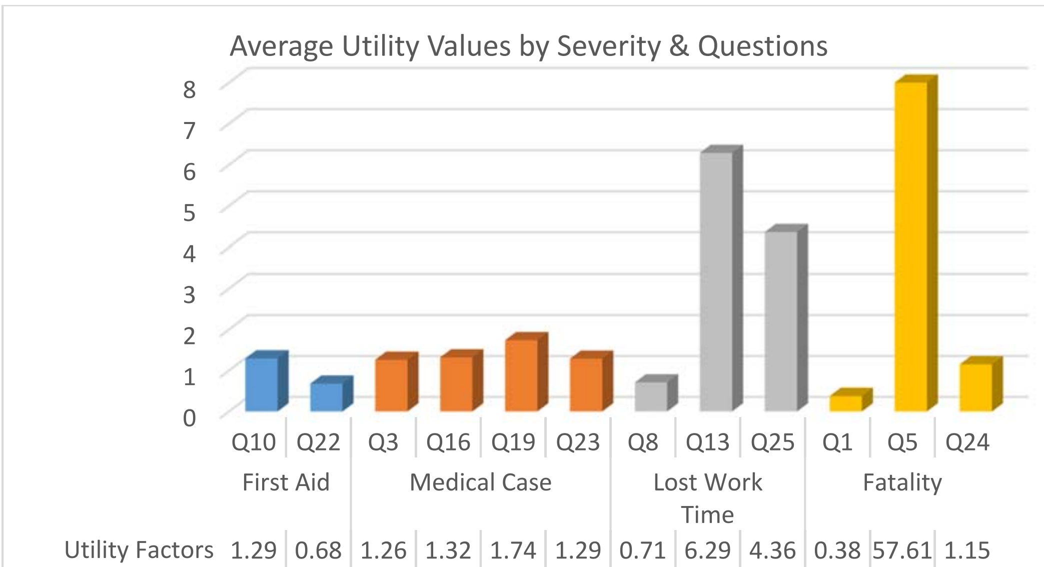


Figure 5 - Average Utility Values by Severity Levels

A clear observation can be drawn by the three dissident scenarios in this study from Figure 6. While there is no combinations of injury events except "fall to lower level" and "fire/explosion", a conclusion of the effects of these events is difficult to justify. There may be no effect given toward the utility the respondents placed on this attribute.

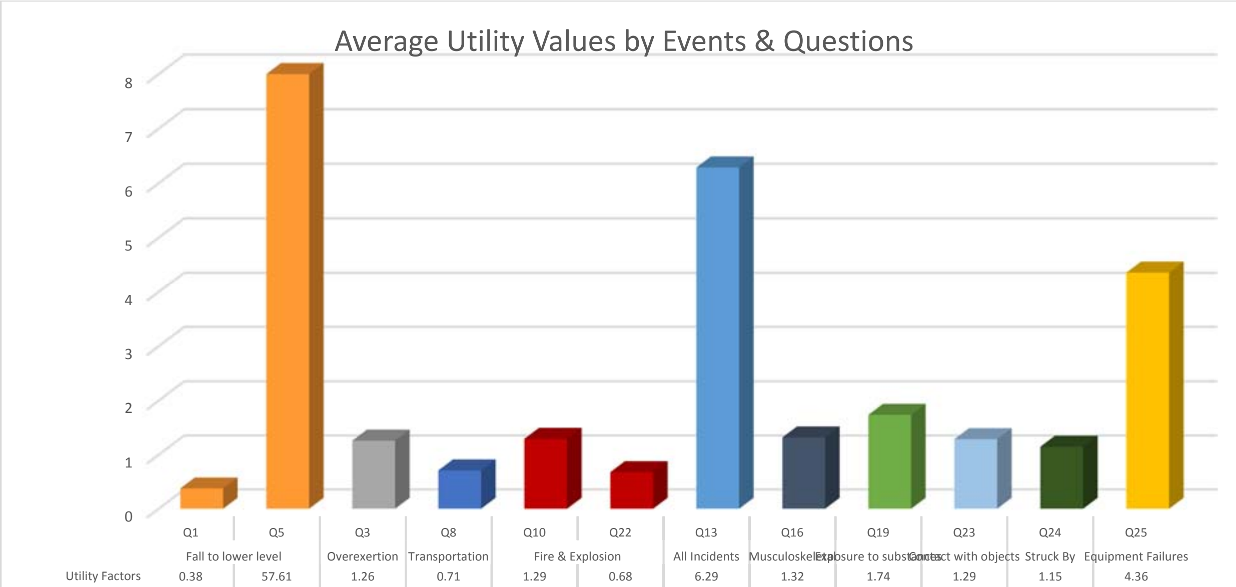


Figure 6 - Average Utility Values by Injury Events

An analysis of the individuals' various utility factors was compared to the current RIR of the respondents' firms. Table 7 shows the various factors of this case study by each respondent. Respondent #1 and #7 by far have the most significantly high utility average. The most notable values being that each of these respondents had a maximum utility of 166.7. These values can be found in the results from scenario question #5.

Table 7 - Summary of Individual Respondents

Summary of Individual Repsondents' Variable Utilities											
Respondents	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Max Fixed Utility	8	6	8	8	8	6	8	6	6	6	6
Average Variable Utility	16.9	6.3	2.5	0.6	3.9	4.2	15.2	7.7	1.0	9.8	3.5
Median	2.0	0.8	1.2	0.2	1.0	0.8	1.0	1.1	0.7	0.9	1.5
STD	47.4	19.0	3.6	0.9	9.3	7.3	47.7	19.1	0.9	28.5	4.1
Max	166.7	66.7	13.3	2.5	33.3	20.0	166.7	66.7	3.3	100.0	13.3
Range	166.7	66.4	13.0	2.5	33.1	19.9	166.3	66.4	3.3	99.9	12.6

The ANOVA testing concluded that there is a difference between the type of attributes and their respected categories. The summary of the ANVOA results in Table 8 establishes that all three attributes had effects on the respondents' answers. The intervention type attribute had the greatest difference between the F(value) and F(critical). It should be acknowledged the SSW values, while large in the table were divided by the denominator degree of freedom. This degree of freedom was calculated by the difference between the number of observations (132) and the number of categories (equal to and less than 10). This disproportionate range between the two factors led to a high F(calcuated) and low F(critical) value. Lastly, a P(value) or α of 0.05 was used to calculate the P(critical).

Table 8 - ANOVA Testing of Scenario Attributes

ANOVA Testing of Scenario Attributes for Average Utilities					
Attributes	**Number of Categories**	**SSB**	**SSW**	**F Value**	**F(critical) Value**
Intervention Type	5	10,259.1	61,903.4	**5.26**	**2.443**
Severity Level	4	7,814.6	64,347.9	**5.18**	**2.675**
Injury Events	10	13,677.4	58,485.1	**3.17**	**1.957**
Average Utility = 6.51; Total Reponses = 132; SST = 72,165.5					

Table 9 summarizes the Wilcoxon Rank-Sum analysis. These results show that there was a statistical difference in three of the categories and in three of the four attributes. Again an α of 0.05 was used in determining the upper right boundary of the data. The test alternative hypothesis testing of the right upper boundary called for a corresponding Z value greater than 1.645. The intervention type "Consultant" had the largest Z value among the nine categories with a 4.701. Also, "All Incidents" category results in a Z value of 4.191 just slightly higher than the "Reduction Factors = 100%" category with 4.137. Additionally, two other categories ("Lost Work Time" and "0%<R<50%") possess nearly high enough *Z* values that show a difference in the utility answers, but nothing statically valid..

Table 9 – Rank Sum Test of Scenario Attributes by Major Categories

Wilcoxon Rank Sum Testing of Scenario Attributes							
Testing Attribute	**Category**	**N1**	**T value**	**N2**	**Z value**	**Z(α=.05)**	**Test Type**
Intervention Type	Training / Programs	22	1443.5	110	-0.012	1.645	**Right**
	Consultant	33	3089.0	99	*4.701*	*1.645*	***Right***
Severity Level	Lost Work Time	33	2462.5	99	1.408	1.645	**Right**
	Fatality	33	2173.0	99	-0.113	1.645	**Right**
Injury Event	Fall to Lower Level	22	1501.5	110	0.235	1.645	**Right**
	All Incidents	11	1240.5	121	*4.191*	*1.645*	***Right***
	Equipment Failures	11	772.0	121	0.334	1.645	**Right**
Reduction Factor	0% < R < 50%	55	3957.0	77	1.382	1.645	**Right**
	R = 100%	11	1234.0	121	*4.137*	*1.645*	***Right***

Conclusion

From the Phase 1 case study, it was concluded that there was an effect on the current RIR of companies and the current investment methods were proactive, neutral, or reactive when the companies implemented various safety investment strategies. The T-test value of 0.001 showed a significant difference between the lower RIRs of companies who used proactive methods and the other companies who had higher RIRs and used non-proactive methods.

In Phase 2, the questionnaire data resulted in five categories showing effects on the utility of scenarios given to the respondents. It should be noted that three of the categories were combined in one of the scenarios. Scenario #5 possessed the highest utility average of 57.61, which could be a combination of the effects seen from these three categories or from the overwhelming subjectivity of one of the categories, however with each of the categories having more than one scenario category, none were observed to show such a drastically high utility value. Another reasoning behind the high utility values seen in Scenario #5 and Scenario #13 was the respondents could have mis-calculated the expected saving of the scenario. In both of these scenarios, a probability was given. The respondents may not have applied the probability of the incidents occurring. They could have calculated the expected saving solely from the severity amounts. Here the severity amount should have been multiplied by the probability to give the expected savings (risk).

Also, looking back at the fixed utility results, the analysis revealed and confirmed many of the psychological research cited in this study. Typically, respondents have higher utilities when asked to choose alternatives than match numerical equivalents to their utilities. Revisiting scenario question #18, the variable utility did not offer any conclusions to why the acceptance rate was lower than the other fixed utility response around it. The ideal reasoning is reduction factor of 10% is too low for the acceptance of the respondents. As seen in the rank-sum test, when the reduction factor was 100% or would eliminate the event from occurring, the respondents gave higher utility values. The author hopes this study provides a framework to other researchers who wish to follow the utility concept in the safety investment realm.

Recommendations

Based on the results and conclusions drawn from Phase 1, the author suggests that more research and lengthy analysis be conducted to capture the effects of proactive and reactive methods on the fluctuations of the company's RIR. This future research could show if the RIR improves more in the following years with reactive investment methods than with only implementing proactive methods.

Also from Phase 1, a recommendation towards the ideal combination of methods should be pursued. An additional case study on construction companies and their investment in safety methods can add to the body of knowledge further. In this case study, the author would suggest attempting to determine at what increase or decrease in RIR the company would decide to change investment methods if at all.

Additionally, the author would like to suggest an analysis of the current professionals in the construction safety field. While this study looked at a very high level of professionals in this industry, other professionals who were contacted for questionnaire responses did not possess the adequate company information or investment knowledge to complete the questionnaire. The high level of knowledge among this sample population in Phase 2 gives a small perspective to the overall safety professionals in the construction industry. Along with construction safety field, the author recommends exploring the relationship between the workman's compensation field and the effects on a company's insurance premiums by implementing ideal safety intervention elements.
In terms of developments from this case study, the author suggests future researchers to construct an alignment study based on the scenario categories seen in Phase 2. From this research, one can hope to conclude the variability of different perspectives at different managerial levels and possible contractor sizes. This study could aid the in evaluation of the discrepancy between the knowledge of safety investments and ideal implementations around the construction industry.

Glossary of Key Terms

Bureau of Labor Statistics: Government agency devoted to the collections of labor statistics consisting of economic, social, and occupational health databases.

Contractor Sizes: Categories describing three main levels of contractors based on the number of company employees or revenue generated by the company.
Please see Appendix for table of parameters

Cost-Benefit Analyses: Technique utilized in determining benefits of decisions from investments or projects based on the cost of decisions. Technique can result in ratio of cost incurred over benefits from the decision cost.

Cost of Safety (COS) Model: Model established to illustrate the theoretical cost of prevention and detection methods versus cost of failures from internal and external sources.

Decision Frame: Framework for communicating social perspectives influencing an individual's perception by providing information in positive or negative contents.

Direct Costs: Cost solely recognized as being produced or traced to a specific product or event.

Elicitation Procedure: Technique used for the collection of scientific data from the analysis of human beings.

Event (Incident): Description of injury or fatality event based on the Occupational Injury and Illness Classification System (OIICS). Also utilized by the Bureau of Labor Statistics in databases.

Expected Injury Costs: Calculated cost of specific injuries from nationally recognized historical data and scientific literature.

Expected Value: Value of an item a person deems optimal based on historical data, probability, or personal utility.

Exposure: In terms of unit risk, amount of time a person is vulnerable to a hazardous activity in units of time such as hours, days, years, or type of unit degree.
Please see Risk Assessor Model (RAM)

Frequency: Statistic based on number of occurrences likely to happen, such as injuries or fatalities in a unit of time or other activity.

Hazard Topic: Activity subject that has shown to be associated with hazardous situations and/or other potential negative outcomes.

Indirect Costs: Cost that cannot be determined by a specific product or event but are attributed towards the items based on accounting methods.

Investment (Capital): Company funding designated to achieve a business objective or working company strategy for adding value and improvement.

NAICS Categories: North American Industry Classification System assigns classification to businesses based on standards from the goods and services the company produces.

Neutral Safety Method: Method that does not change based on the increase or decrease in the number of safety issues.

Occupational Safety: Area of protecting and serving the welfare of working individuals in various occupations and industries.

Operational Costs: Costs associated with business expenses by performing daily operations to keep business in regular production.

Proactive Safety Method: Method that is developed and implemented before safety issues are seen or considerably increase.

Probability: Likeliness or level of confidence measurement as a percentage or ratio that a particular event or action will occur.

Psychological Utility: Level of satisfaction or preference gained by merely the act of making choices or gambling and not achieving the expected utility value of the situation.

Reactive Safety Method: Method that reacts to an increase or decrease in the amount of safety issues.

Recordable Injury Rate (RIR): Measurement of the amount of injuries per 200,000 work hours. Rate is based on 100 individuals working 40 hours a week and 50 weeks per year.

Return on Investment (ROI): Ratio for evaluating the effectiveness of an investment similar to a cost-benefit analysis, but the benefit or gains from the investment is subtracted from the cost of the investment, which is then divided by the cost of the investment.

Risk Assessor Model (RAM): Model established to determine and assess risks of construction activities. Activity Risk Score is the product of severity, exposure, and probability.

Risk Perception: An individual's judgment or belief about the uncertainty and severity of a risk.

Risk Tolerance: An individual's variability in terms of willingness to invest in an economic situation based on risk parameters and current status when making the decision.

Safety Climate: Organizational description concerning the personal safety attitudes, knowledge, and motivation seen of its employees.

Safety Culture: Managerial description regarding the management practices, level of importance, behavior of the company in terms of safety as a whole.

Safety Intervention Types: Programs, elements, or a combination of other techniques implemented to reduce or proactively mitigate a hazard.

Safety Management: An organization's techniques devoted to handling the occupational safety and health of the public and its employees.

Safety Program: An entire organization's collection of safety elements, techniques, and consulting towards improving safety.

Safety Program Elements: Specific strategies deem to improve hazard topics and safety performance. Elements can be combined in specific safety programs for effectiveness.

Severity: Measurement of the type injury or fatality either in terms of days lost from work, risk scores, or amount of money (direct and indirect costs) attributed to the injury or fatality.

Severity Level: Levels categorizing by the severity of type injury based on the unit of severity utilized.

Please See Appendix for injury table.

Unit Risk of Task: Measurement of risk associated with various construction activities or tasks. Unit Risk is the product of frequency and severity.

Utility Concept: Psychological behavior observed by individual's unique preference towards an item of choice.

References

Baradan, S., Usmen, M. (2006). "Comparative injury and fatality risk analysis of building trades." *Journal of Construction. Engineering Management*, 132(5), 533-539.

Behm, M., Veltri, A., and Kleinorge, I. K. (2004). "The cost of safety." *Professional Safety*, 49(4), 22-29.

Bureau of Economic Accounts (2013). Gross Domestic Product by Industry Data (Value Added). <http://www.bea.gov/industry/gdpbyind_data.htm>. XLSX file. Last accessed: February 1, 2014.

Bureau of Labor Statistics (2013a). Employment by Major Industry Sector. <www.bls.gov/emp/ep_table_201.htm>.Last accessed: February 3, 2014.

Bureau of Labor Statistics (2013b). Fatal Occupational Injuries by Industry and Event or Exposure. < http://www.bls.gov/iif/oshwc/cfoi/cftb0268.pdf>. Last accessed: February 1, 2014.

Bureau of Labor Statistics (2013c). Fatal Occupational Injuries in 2012 – Chart package. <www.bls.gov/iif/oshwc/cfoi/cfch0011.pdf >. Last accessed: February 1, 2014.

Clements, R., and Reilly, T. (2004). *Making hard decisions with decision tools suite update edition.* Pacific Grove, CA: Duxbury.

Coble, R.J., Hinze, J., and Haupt, T.C. (2000). *Construction Safety and Health Management*. Upper Saddle River, NJ: Prentice Hall Inc.

Ferry, T. (1990). *Safety and Health Management Planning*. New York, NY: Van Nostrand Reinhold.

Friedman, M. and Savage, L.J. (1948). "The utility analysis of choices involving risk." *Journal of Political Economy*, 56(4), 279-304.

Guldenmund, F. (2000). "The nature of safety culture: a review of theory and practice." *Safety Science*, 34, 215-257.

Guldenmund, F. (2007). "The use of questionnaire in safety culture research – an evaluation." *Safety Science*, 45(6), 723-743.

Hallowell, M.R. (2010). "Cost-effectiveness of construction safety programme elements." *Construction. Management. Economics*, 28(1), 25-34.

Hallowell, M.R. (2010). "Safety risk perception in construction companies in the Pacific Northwest of the USA." *Construction. Management Economics*, 28(1), 403-413.

Hallowell, M.R. (2011). "Risk-based framework for safety investment in construction organizations." *Journal of Construction Engineering Management*, 137(8), 592-599.

Hallowell, M.R., and Gambatese, J.A. (2007). "A formal model of construction safety risk management." *2007 Construction and Building Research Conference (COBRA)*, sponsored by the Royal Institution of Chartered Surveyors and Georgia Tech, Atlanta, GA, September 6-7, 2007.

Hallowell, M.R., and Gambatese, J.A. (2009). "Activity-based safety and health risk quantification for formwork construction." *Journal of Construction Engineering Management*, 135 (10), 990-998.

Hinze, J.W. (1997). *Construction Safety*. Columbus,OH: Prentice Hall.

Hinze, J. (2000). "Incurring the costs of injuries versus investing in safety." *Construction safety and health management*, in R. Coble, J. Hinze, and T. Haupt, eds. Columbus, OH: Prentice Hall, 23-41.

Hinze, J., Mathis, J., Frey, P.D., Willson, G., DeForge, P., Cobb, M. and Marconnet, G. (2001). "Making zero accidents a reality, " *Proceedings, Annual Conference of the Construction Industry Institute.* San Francisco, CA: Construction Industry Institute.

Jannadi, O., Almishari, S. (2003). "Risk assessment in construction." *Journal of Construction Engineering Management*, 129(5), 492-500.

Jones-Lee, M.W., Hammerton, M., and Philips, P.R. (1985). "The value of safety: results of a national sample survey." *The Economic Journal*, 49-72.

Liska, R.W., Goodle, D., and Sen, R. (1993). *Zero accident techniques: a report to the construction industry institute*. Austin, TX: Construction Industry Institute.

MacGregor,D., Slovic, P., Berry, M., Evensky, H. (1999). "Perception of financial risk: a survey study of advisor and planners." *Journal of Financial Planning*, 68-86.

Manuele, F.A. and Main, B.W. (2002). "On acceptable risk." *Occupational Hazards*, 64(1) 57-60.

McNeil, B.J., Pauker, S.G., Sox Jr., H>C>, and Tverksy, A. (1982). "On the elicitation of preferences for alternative therapies." *The New England Journal of Medicine*, 306 (21), 1259-1262.

Peck, R., Olsen, C., and Devore, J. (2005). *Introduction to Statistics and Data Analysis*.Belmont, CA: Brooks/Cole – Thomson, 173-174.

Slovic, P. (1987). "Perception of risk." *Science*, 23(4799), 280-285.

Slovic, P. (1995). “The construction of preference.” *American Psychologist*, 50 (5), 364-371.

Slovic, P., Fischhoff, B., and Lichtenstein, S. (1985). “Characterizing perceived risk. *Perilous progress: managing the hazards of technology*, 91-125.

Starr, C. (1969). “Social benefits versus technological risks.” *Science*, 165 (3899), 1232-1238.

Tversky, A. (1975). “A critique of expected utility theory: descriptive and normative considerations.” *Erkenninis*, 9, 163-173.

Tverksy, A., and Kahnemann, D. (1981). “The framing of decisions and the psychology of choice.” *Science*, 211, 453-458.

Tverksy A., and Kahneman, D. (1986). “Rational choice and the framing of decisions.” *Journal of Business*, 59 (4), 251-278.

Tversky, A., Sattath, S., and Slovic, P. (1988). “Contingent weighting in judgment and choice.” *Psychological Review*, 95, 371-384.

von Neumann, J., and Morgenstern, O. (1944). *Theory of games and economic behavior*, *3rd ed.* Princeton, NJ: Princeton University Press.

von Winterfeldt, D., and Edwards, W. (1986). *Decision analysis and behavioral research*. New York: Cambirdge.

Williamson, A.M., Feyer, A.M., Cairns, D., & Biancoti, D. (1997). “The development of safety climate: the role of safety perceptions and attitudes.” *Safety Science*, 25, 15-27

Zohar, D. (1980). “Safety climate in industrial organizations: theoretical and applied implications.” *Journal of Applied Psychology*, 65(1), 96-102.

Appendix Table of Contents:

Appendix A. Safety Programs & Elements

Table of safety program research by title, reference, and program elements

8 Techniques – Zero Injury Techniques		
	Liska et al., 1993, Zero accident techniques	
	1	Pre-project /Pre-task planning
	2	Safety training/orientation
	3	Safety incentives
	4	Alcohol and substance abuse program
	5	Accident and near miss investigation
	6	Recordkeeping and follow-up
	7	Safety meeting
	8	Personal protective equipment
9 Elements – Best Practices		
	Hinze et al., 2001, Making zero accidents a reality	
	1	Demonstrated management commitment
	2	Staffing for safety
	3	Safety planning/training/education
	4	Worker participation and involvement
	5	Recognition and rewards
	6	Subcontractor management
	7	Accident/Incident reporting
	8	Investigation
	9	Pre-project and pre-task planning
13 Elements – High Effective Safety Programme Elements		
	Hallowell, 2010, Cost-effectiveness of construction safety programme elements	
	1	Upper management support
	2	Subcontractor selection and management
	3	Employee involvement and evaluation
	4	Job hazard analyses (JHA)
	5	Project-specific training/meetings
	6	Frequent worksite inspections
	7	Safety manager on site
	8	Substance abuse programmes
	9	Safety and health committees
	10	Safety & Health committees
	11	Written safety and health plan
	12	Record keeping/analyses
	13	Emergency response planning

Appendix B. Contractor Designations and Classifications

Contractor Classifications	Contractor Annual Revenue ($US)		
	Low Range		High Range
Small	$ --	≤	$ 10 million
Medium	$ 10 million	≤	$ 100 million
Large	$100 million	<	$ ---

Table - Hallowell, 2010, Cost-effectiveness of construction programme elements

Appendix C. Psychology Utility Literature Reviews

Tverksy and Kahneman, 1981, The framing of decisions and the psychology of choice.
Problem 1: [N = 152]
Scenario: Imagine that the US is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimate of the consequences of the program are as follows:

- If Program A is adopted, 200 people will be saved.
- If Program B is adopted, there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved.

Question: Which of the two programs would you favor?
Results:
Adopted Program A [72 percent] and Program B [28 percent]

Variation of Problem 1: [N=155] (same base scenario and question)

- If Program C is adopted, 400 people will die.
- If Program D is adopted, there is 1/3 probability that nobody will die, and 2/3 probability that 600 will die.

Results:
Adopted Program C [22 percent] and Program B [78 percent]

Tverksy et al., 1988, Contingent weighting in judgment and choice
Problem 3: Traffic Accident Problem
Scenario: About 600 people are killed each year in Israel in traffic accidents. The ministry of transportation investigates various programs to reduce the number of casualties. Consider the following two programs, described in terms of yearly costs (in millions of dollars) and the number of casualties per year that is expected following the implementation of each program.

	Expected number of causalities	**Cost**
Program X	500	$55M
Program Y	570	$12M

Question: Which programs do you favor?
Results:
Adopted Program X [68 percent] and Program Y [32percent]

Modification of Problem 3: [N=105]
Question: Determine the cost of Program X that would make it equivalent to Program Y.
Is this value of $55M too high or too low?
What is the value you consider appropriate?
Results:
50% said Program X is too low and 18% provided cost exceeding $55M

Appendix C. Psychology Utility Literature Reviews (continued)

McNeil et al., 1982, On the elicitation of preferences for alternative therapies
<u>Problem</u>
Scenario 1: (Cumulative probability data) Of 100 people having surgery, 10 will die during treatment, 32 will have died by one year, and 66 will have died by five years. Of 100 people having radiation therapy, none will die during treatment, 23 will die by one year, and 78 will die by five years.
Scenario 2: (Life expectancy data) At this single hospital, 10 percent of the patients who have surgery die during the perioperative period. The patients who survive treatment have a life expectancy (e.g. average number of remaining years) of 6.8 years. The life expectancy of all patients who undergo surgery (including those who die in the postoperative period) is 6.1 years. Within radiation therapy, nobody dies during treatment, and the life expectancy of the patients who undergo radiation therapy is 4.7 years.
Question: Which treatment would you prefer?
Results:

Overall Percentages of Subjects Choosing Radiation Therapy over Surgery					
	Outcome and Treatment Variables				*Total*
Type of Data	*Dying Frame*		*Living Frame*		
	Identified	*Unidentified*	*Identified*	*Unidentified*	
N =	*336*	*259*	*247*	*311*	*1153*
Cumulative probability[*]	*44%*	*61%*	*18%*	*37%*	*40%*
Life expectancy[+]	*25%*	*42%*	*11%*	*31%*	*27%*
* Immediately after treatment and at one and five years thereafter.					
+ Probability of surviving or dying from immediate treatment ply life expectancy thereafter. The dichotomy between probability of dying and probability of living in this group applies only to the data concerning the immediate treatment period					

Jones-Lee et al., 1985, The value of safety: results of a national sample survey
<u>Problem 14(a):</u> Cause of death to be reduced
Scenario: Each year in England and Wales, motor accidents, heart disease and cancer cause roughly these number of death among people under the age of 55:

Motor accidents cause 4,000 deaths, Heart disease, 11,000 deaths, and cancer 16,000 deaths.

Question: Suppose that, for a given amount of money it were possible to reduce the number of deaths from just one of these causes by 100 next year. Which one cause would you choose to have reduced?
Results: Motor accidents 11% (±3), heart disease 13% (±3), cancer 76% (±4),

Appendix D. Expected Cost per Injury Types

Safety Data from Case Contractor				
Injury type	**Cost ($)**	**Frequency of injury (w-h / injury)**	**Probability (%)**	**Expected cost ($)**
Minor first aid	$214	720	6944%	$14,861
Major first aid	$623	1,260	3968%	$24,722
Medical case	$68,417	51,450	97%	$66,489
Lost work time	$101,480	86,400	58%	$58,727
Disablement	$268,467	262,800	19%	$51,078
Fatality	$1,600,000	8,640,000	1%	$9,259

Table - Hallowell, 2011, Risk-based framework for safety investment in construction organizations

Appendix E. Description and Cost-effectiveness of Programme Elements

Safety programme element descriptions	
Safety programme element	**Description**
Upper management support	Explicit acknowledgement from upper management that worker safety and health is a primary goal for the firm demonstrated by participation in regular safety meetings and committees, and sufficient funding
Subcontractor selection and management	Consideration of safety and health performance during the selection and management of subcontractors (e.g. pre-qualification and required compliance).
Employee involvement and evaluation	Including all employees in the formulation and execution of other safety elements and including participation and safe worker behavior in evaluations.
Job hazard analyses	Review and recording activities associated with a construction process, highlighting potential hazardous exposures, and documenting safe work practices that prevent injury.
Project-specific training/meetings	Establishing and communicating project-specific safety goals, plans and policies before the construction phase of the project.
Frequent worksite inspections	Inspections performed internally by a contractor's safety manager, safety committee, representative of the contractor's insurance provider or by an OSHA consultant to identify uncontrolled hazardous exposures.
Safety manager on site	Employment of a safety and health professional (i.e. an individual with formal construction safety and health experience and/or education) whose primary responsibility is to perform and direct the implementation of safety and health programme elements and serve as a resource for employees.
Substance abuse programmes	Identification and prevention of substance abuse of the workforce (includes random testing and testing after an injury).
Safety and health committees	Committee with the power to effect change and set policies, consisting of a diverse group including supervisors, labourers, representatives of key subcontractors, owner representatives, OSHA consultants may be formed with the sole purpose of addressing safety and health on the worksite.
Safety & Health orientation/training	Participation of all new hires or transfers in orientation and training sessions that have a specific focus on safe work practices and company safety policies.
Written safety and health plan	Development of a documented plan that identifies project-specific safety objectives, unique hazards and methods for achieving success.
Record keeping/analyses	Regular reporting of the specifics of all accidents including information such as time, location, work-site conditions and cause.
Emergency response planning	Creation of a plan that documents the company's policies and procedures in the case of a serious incident or catastrophe such as fatality or an incident involving multiple serious injuries.

Table - Hallowell, 2010, Cost-effectiveness of construction programme elements

Injury Prevention Cost and Risk Mitigation Data			
Safety Program element	**Average increase in w-h per incident (Hallowell and Gambatese, 2009)**	**Average cost per $10 million scope (Hallowell, 2010)**	**Cost / effectiveness ($ / w-h)**
Upper management support	138,165	$2,690	0.02
Subcontractor selection and management	87,176	$1,810	0.02
Employee involvement and evaluation	138,165	$4,000	0.03
Job hazard analyses	34,705	$2,000	0.06
Project-specific training/meetings	138,165	$8,000	0.06
Frequent worksite inspections	69,246	$6,000	0.09
Safety manager on site	34,705	$3,250	0.09
Substance abuse programmes	69,246	$7,000	0.10
Safety and health committees	55,004	$9,750	0.18
Safety & Health orientation/training	21,897	$5,000	0.23
Written safety and health plan	8,717	$5,000	0.57
Record keeping/analyses	347	$2,000	5.76
Emergency response planning	69	$1,000	14.49

Table - Hallowell, 2011, Risk-based framework for safety investment in construction organizations

Appendix F. Phase I – Questions

Main Question:

- How do decision makers choose how much money to invest in safety / injury prevention?

Demographic Questions:

- Geographic location (headquarters location)
- Size of the organization (annual revenue and number of employees)
- Size of the organization unit from which safety budgets are dictated
- Company recordable injury rate per 200,000 worker-hours (approximations are ok if data are sensitive)
- Type of work performed
- Years of personal experience in the industry
- Years of safety investment / decision making experience

Investment Questions

- How do you decide how much money will be allocated to safety-related efforts?
- What are some examples of recent safety investment decisions that you have made?
- What information did you rely up on when making those decisions?
- How did you use this information?
- What factors determine how much you invest? What factors would lead you to invest more money in safety? What factors would lead you to invest less money in safety?
- What is an example of one of the best safety investments that you have made? What made it great?
- What was one of the worst safety investments that you have made or seen made? What made it poor?
- How often do you revisit your safety budgeting?
- How do you evaluate whether or not your investment are actually improving safety?
- When do you know that you have invested too much or too little in safety?
- Do you fund safety activities on a project or corporate budget? Why?
- What recommendations would you give to me (the student) if I were in a position to determine safety budget in the future?

Appendix G. Phase I – Methodologies

Proactive Safety Strategy:

High Risk: Companies invest a large amount of resources in high risk activities. The focus of this strategy is to decrease the number of safety hazards and the amount of risk on a job site.

Safety Analysis: Companies perform a proactive safety analysis before a project begins by using historical data and direct interviews with safety professionals. The companies also integrate concepts to improve safety and hazard recognition while analyzing the value added to the company versus the risk reduced to decide what safety programs are funded.

Neutral Safety Strategy:

Standard: Companies require a standard number of safety technicians proportionate to the number of people forking for a contractor.

Percentage: Companies that allocate a percent of the income form the company / project toward safety.

Set Budget: Companies that have a set budget for safety investment that is based on what they spent the previous year / project.

Tailored Budget: Companies that create a safety budget based on the type of project, operational hazards, and specialty needs.

Reactive Safety Strategy:

Clean up: Companies invest a large amount of resources once every few years to try and clear up major safety issues.

Number of incidents: Companies invest in safety based on the number of safety incidents and an increase in safety issues would results in an increase in safety investment, increase in safety regulations, and an assessment of the current program would be conducted.

Appendix H. Phase I – Table of Companies' Responses

Company Designation	Number of Employees	Revenue	Safety Investment Strategy			RIR
			Proactive	Neutral	Reactive	
1	250	240 Million		F, C	H	1.3
2	2,000	4 Billion		F	H	1.03
3	369	75 Million		D	H	1.0
4	55	8.2 Million		E		0.94
5	175,000	50 Billion		D	G, H	0.65
6	60,000	11 Billion	B	F	H	0.33
7	80,000	3 Billion	A		H	0.3
8	16,000	6.7 Billion	B	F	H	0.25
9	1,400	Unknown	B	D, F		0.24

Appendix I. Identification of Safety Investment Strategies

ID for Strategy	Safety Investment Strategy
A	Large investment in High risk activities and a safety focus on decreasing safety hazards and risk
B	Proactive safety analysis done before a project using historical data and direct interviews and integrating concepts to improve safety and hazard recognition while analyzing the value added to company versus risk reduced to decide what safety programs are funded.
C	Company standard of a required number of safety techniques proportionate to the number of people working for a contractor.
D	Percent of income form the facility / project is invested in safety.
E	Set budget for safety investment based on what was spent the previous year / project.
F	Safety budget determined by the type of project / operation hazards / specialty needs.
G	Relatively large investment once every few years to try and clear up major safety issues.
H	Safety investment driven by number of incidents (high number then investment high, if low number then decrease investment.) Increase in accidents would drive increase in safety regulations and money spent and an assessment of the current program conducted.
	Proactive, a method that is developed before safety is an issue.
	Neutral, a method that does not change based on the increase or decrease of number of safety issues.
	Reactive, a method that reacts to an increase in safety issues.

Appendix J. Phase II – Questionnaire

Greetings,

The purpose of this questionnaire is to assess the non-monetary value (utility) that safety investment decision makers have for worker safety with respect to their investments in programs, equipment, PPE, consultants, etc.. We are interested in the values and the stability among industry representatives. There is no correct/incorrect answer to any of the questions posed. Your name and organization will not be recorded and the responses are completely confidential in this assessment.

****

You will be presented with 25 safety investment scenarios that will take approximately 15-20 minutes to complete. Although each scenario would not apply directly to your firm, we ask you to think about the hypothetical case and give us your professional opinion for that particular case if you were faced with the decision. Please assume that all estimates of costs and reductions in probability are completely reliable. Please do not answer a particular question if you have a bias (past experience with a particular strategy that would cause you to reject a particular investment on principle). Fill free to use a calculator to aid in your responses. Please enter "N/A" if you cannot answer any of the scenarios.

****

Below you will observe a summary of the scenario structure you will be asked in this questionnaire:

Initially you will be asked several questions regarding you and your company's information such as your RIR and annual revenue amounts. You will be given a series of investment scenarios. Each scenario includes a probability of injury and a cost of injuries if they are realized. Additionally, you will be provided with a potential safety intervention that reduces the probability of injury at a specific cost. We will be asking you to either decide if you would invest in a safety strategy given its cost (yes/ or no) or to indicate the maximum amount of funds you would invest in the scenario (variable).

First, we are going to inquire about some of your experience.

Demographics:

A. What is your company's current RIR (Recordable Incident Rate)?
B. Approximately, what is your company's annual revenue?
C. How many years of experience do you have in the EH&S (Environmental, Health, & Safety) field?
D. How long (in years) have you been with your current employer?
E. Does your company regularly operate internationally?
F. On an average, how many employees does your company employ annually?
G. **Do you have the authority to invest company resources in safety?**

Appendix J. Phase II – Questionnaire (continued)

Questionnaire:

1. Based on your project history, you know that a large carpentry crew has a .10% chance of a fall occurring that results in a fatal injury on your upcoming project. The estimated indirect and direct cost associated with such injuries is $1,323,000. How much would you be willing to spend on additional fall arrest PPE that would reduce the severity and costs of a fall by 50%?
   a. Variable
2. First aid injuries cost your firm $120,000 per year. Implementing a new foreman safety and leadership training program will cost your company $19,200. The consultant providing the training has reliable data that shows the training will reduce first aid injury costs by 10%. Would you make the investment?
   a. Y/N
3. Assume your company has a total of 15 medical case injuries per year resulting from overexertion incidents that cost $600,000 total. How much would you be willing to spend on new less physical-exertion tools designed to help with this incident type by reducing the number of these injuries by 20%?
   a. Variable
4. Your company spends $600,000 annually on first aid injuries resulting from hand tools. Purchasing new, higher quality hand tools will cost $24,000 per year. This new equipment will not affect productivity but will reduce this injury rate by 5% (saving roughly $30,000 in injury expenses per year). Would you purchase this new equipment?
   a. Y/N
5. Based on the history of large urban projects in your region, fatalities related to falls from scaffolding cost an average of $1,500,000 in both direct and indirect costs. The chance of such an injury on your upcoming project is 0.1% (a tenth of a percent). How much would you be willing to spend on a scaffolding audit and quality program that you are confident eliminates the potential for a fatality?
   a. Variable
6. A newly developed automated soil compactor will cost your company $60,000. These new compactors have been shown to reduce lost work-time injury rates by almost 40%, because of the reduction in repetitive motion trauma from past compactors. This reduction in these injuries would equate to a $60,000 savings in both indirect and direct injury costs. Would you make the investment?
   a. Y/N

Appendix J. Phase II – Questionnaire (continued)

7. A combined leadership safety training program would cost approximately $15,000 for an upcoming project. Your company has calculated that it will spend around $750,000 in direct and indirect costs for all medical case injuries. The program's history has shown to decrease the rate of medical case injuries by 10%. Would you make this investment?
   a. Y/N
8. Your risk management group projected that the cost of lost work time transportation-related injuries would average $90,000. A safety committee proposed a new work-zone protection system that will limit worker exposure to heavy equipment and other vehicles thereby reducing the probability of transportation these injuries by 80%. What is the maximum amount that you would be willing to invest in this system for the project?
   a. Variable
9. Your firm normally spends $80,000 per year on first aid injuries. Several of your colleagues have implemented near miss safety programs that decrease the instances of first aid injuries of 5%. If the estimated annual cost of implementing the program will be $7,200, would you make the investment?
   a. Y/N
10. A safety consultant has proposed that they supply your workers with new welding and fire resistant personal protective equipment (PPE). Fires and arc flash events have resulted in first-aid injuries that cost your firm a total of $85,000 per year. 60% of these injuries could have been prevented if this new PPE were provided. What is the maximum amount that you would be willing to spend on such a service?
    a. Variable
11. Investing in a special new power tool and hand tool training program consisting of hands-on classes for workers would cost $480 per worker. This consultant's program will not increase workers' productivity but will decrease musculoskeletal medical case injuries rates by 15%, saving roughly $800 per worker. Would you implement this new program?
    a. Y/N
12. Your firm spends $150,000 on direct and indirect costs of first aid injuries per year. Your safety managers are requesting an increase of the overall safety prevention budget of $10,000 for new slip, trip and fall consultant training. You suspect that the new investment can decrease injury rates by 5.6% based on their reliable estimates. Would you approve this budget increase?
    a. Y/N

Appendix J. Phase II – Questionnaire (continued)

13. You estimate that your company will incur $40,000 of direct and indirect costs of injuries in a large upcoming project. Because of the nature of the upcoming project you believe that half (50%) of the injuries would be lost work-time injuries related to marine safety issues. How much would you be willing to spend on marine and waterborne safety training that would reduce these injuries by 15%?
    a. Variable
14. Leasing a new crane for a large upcoming project will cost $105,000. This new equipment will not increase productivity but has a greater operator visibility. It has been shown to decrease associated struck-by events by 20%, lowering fatal injuries costs to $75,000 over the life of the equipment. Would you make this investment?
    a. Y/N
15. You have averaged $250,000 in lost work time injuries each year related to the existing fall protection system on a bridge. A new, certified safety protection equipment has shown to reduce those injuries by 50% each year. This equipment will cost your company $1,000,000 annually. Would you make the investment?
    a. Y/N
16. You are considering a health and ergonomic program for your masonry employees. The program will teach better ergonomics and stretching methods that will reduce musculoskeletal medical case injuries by 50%. These employee injuries have cost $44,000 each year. How much would you be willing to invest in this program?
    a. Variable
17. There are large concerns surrounding adequate ventilation of toxins and carcinogens on a new tunneling project. Projections show that future fatal injuries associated this concern cost your company $60,000. An innovative system would reduce nearly 100% all the pollutants to far below Permissible Exposure Levels and would cost $360,000 for this project. Would you make this investment?
    a. Y/N
18. Historically your company has estimated that walkway and housekeeping exposures have led to slip, trip, and fall incidents costing your company on an average project $45,000. A small safety company states that they will reduce all of your previous medical case incidents in this category by 10%. They will cost $9,000 for this project. Will you make the investment?
    a. Y/N

Appendix J. Phase II – Questionnaire (continued)

19. A new high quality hazardous materials engineering system is under consideration. Your research shows that exposure to hazardous materials costs approximately $98,000 per year in medical case injuries. You estimate that 25% of future incidents would be prevented if you implemented a new hazardous materials control program. What is the maximum annual amount that you would be willing to spend on such an intervention?
    a. Variable
20. A safety supplier has new lanyards and gloves that they believe will reduce hand injuries by 30%. This equipment would cost your firm $12,000 annually. Your research has shown that severe (lost work time) hand injuries cost your firm $100,000 per year. Would you make this investment?
    a. Y/N
21. A new state-of-the-art trench box that can be used in hazardous areas and cave-in events would cost $1,000,000. Implementing the trench box will keep production on the project the same, but will eliminate the probability of fatal injuries, saving your company an average of $250,000 in injury costs per year. Would you make this investment?
    a. Y/N
22. A new welding system boasts the reduction of arc flashes incidents. You have an estimated 30 welding-related incidents per year and typically result in first aid injuries, which cost an estimated $975,000 in direct and indirect costs. Your research shows that the system would reduce related injuries by 45%. How much would you be willing to invest in this system?
    a. Variable
23. A new eye protection supplier has developed more comfortable safety glasses. In your records, eye-related medical-case injuries that result from workers not wearing their eye protection cost your company $23,000 per year. You expect that half (50%) of eye injuries would be prevented because the comfortable eye glasses will be more consistently used. What is the maximum total amount that you would be willing to spend on these new safety glasses for your team?
    a. Variable
24. Incidents involving equipment striking workers on the ground typically result in fatal injuries that cost a total of $500,000 per year. A consultant has developed a field validated detection system that alerts workers and equipment operators of their proximity to one another. The consultant’s system would reduce the frequency of fatal collisions by 70%. What are you willing to spend to implement this system from the consultant across your projects?
    a. Variable

Appendix J. Phase II – Questionnaire (continued)

25. Your company has experienced improper crane rigging incidents that have resulted in lost work time injuries costing the company $75,000 total per year. From observing a crane rigging specialist's resume, you think this specialist will cut the frequency of these incidents by 10%. How much are you willing to pay this specialist than your current crane rigging engineer?

    a. Variable

Appendix K. Phase II – Calculations of Expected Savings and Utilities

1. EV_o = $323,000 R_i = 50% P_r = 0.1% /crew*incident
EV_i = EV_o = EV_o* R_i = ($1,323,000)*(0.5) **= $661,500**

2. I_i = $19,200 EV_o = $120,000 R_i = 10%
EV_i = EV_o* R_i = ($120,000)*(.1) = $12,000

$$U_i = \frac{I_i}{EV_i} = \frac{(\$19{,}200)}{(\$12{,}000)} = 1.6$$

3. EV_o = $600,000 R_i = 20%
EV_i = EV_o * R_i = ($600,000)*(0.20) **= $120,000**

4. I_i = $24,000 EV_i = $30,000 R_i = 5%

$$U_i = \frac{I_i}{EV_i} = \frac{(\$24{,}000)}{(\$30{,}000)} = 0.8$$

5. S_r = $1,500,000/incident R_i = 100% P_r = 0.1% per incident
EV_o = P_r* S_r = (0.001)($500,000) = $1,500
EV_i = EV_o * R_i = ($1,500)*(1.00) **= $1,500**

6. I_i = $60,000 EV_i = $60,000 R_i = 40%

$$U_i = \frac{I_i}{EV_i} = \frac{(\$60{,}000)}{(\$60{,}000)} = 1.0$$

7. I_i = $15,000 EV_o = $750,000 R_i = 10%
EV_i = EV_o * R_i = ($750,000)*(0.10) = $75,000

$$U_i = \frac{I_i}{EV_i} = \frac{(\$15{,}000)}{(\$75{,}000)} = 0.2$$

8. EV_o = $90,000 R_i = 80%
EV_i = EV_o * R_i = ($90,000)*(0.80) **= $72,000**

Appendix K. Phase II – Calculations of Expected Savings and Utilities (continued)

9. I_i = \$7,200 EV_o = \$80,000 R_i = 5%
$EV_i = EV_o * R_i$ = (\$80,000)*(0.05) = \$4,000

$$U_i = \frac{I_i}{EV_i} = \frac{(\$7{,}200)}{(\$4{,}000)} = \mathbf{1.8}$$

10. EV_o = \$85,000 R_i = 60%
$EV_i = EV_o * R_i$ = (\$85,000)*(0.60) **= \$51,000**

11. I_i = \$480/worker EV_i = \$800/worker R_i = 15%

$$U_i = \frac{I_i}{EV_i} = \frac{(\$480)}{(\$800)} = \mathbf{0.6}$$

12. I_i = \$10,000 EV_o = \$150,000 R_i = 5.6%
$EV_i = EV_o * R_i$ = (\$150,000)*(0.056) = \$8,400

$$U_i = \frac{I_i}{EV_i} = \frac{(\$10{,}000)}{(\$8{,}400)} = \mathbf{1.2}$$

13. S_r = \$40,000/project P_r = 50% per project R_i = 15%
$EV_o = P_r * S_r$ = (0.5)(\$40,000) = \$20,000
$EV_i = EV_o * R_i$ = (\$20,000)*(1.00) **= \$3,000**

14. I_i = \$105,000 EV_i = \$75,000 R_i = 20%

$$U_i = \frac{I_i}{EV_i} = \frac{(\$105{,}000)}{(\$75{,}000)} = \mathbf{1.4}$$

15. I_i = \$1,000,000 EV_o = \$250,000 R_i = 50%
$EV_i = EV_o * R_i$ = (\$250,000)*(0.5) = \$125,000

$$U_i = \frac{I_i}{EV_i} = \frac{(\$1{,}000{,}000)}{(\$125{,}000)} = \mathbf{8.0}$$

16. EV_o = \$44,000 R_i = 50%
$EV_i = EV_o * R_i$ = (\$44,000)*(0.5) **= \$22,000**

Appendix K. Phase II – Calculations of Expected Savings and Utilities (continued)

17. I_i = $360,000 EV_o = $60,000 R_i = 100%
$EV_i = EV_o * R_i$ = ($60,000)*(1.0) = $60,000

$$U_i = \frac{I_i}{EV_i} = \frac{(\$360,000)}{(\$60,000)} = 6.0$$

18. I_i = $9,000 EV_o = $45,000 R_i = 10%
$EV_i = EV_o * R_i$ = ($45,000)*(.10) = $4,500

$$U_i = \frac{I_i}{EV_i} = \frac{(\$9,000)}{(\$4,500)} = 2.0$$

19. EV_o = 98,000 R_i = 25%
$EV_i = EV_o * R_i$ = ($98,000)*(0.25) **= $24,500**

20. I_i = $12,000 EV_o = $100,000 R_i = 30%
$EV_i = EV_o * R_i$ = ($100,000)*(.30) = $30,000

$$U_i = \frac{I_i}{EV_i} = \frac{(\$12,000)}{(\$30,000)} = 0.4$$

21. I_i = $1,000,000 EV_i = $250,000 R_i = 100%

$$U_i = \frac{I_i}{EV_i} = \frac{(\$1,000,000)}{(\$250,000)} = 4.0$$

22. F_r = 30 incidents EV_o = $975,000 R_i = 45%
$EV_i = EV_o * R_i$ = ($975,000)*(0.45) **= $438,750**

23. EV_o = $23,000 total R_i = 50%
$EV_i = EV_o * R_i$ = ($23,000)*(0.5) **= $11,500**

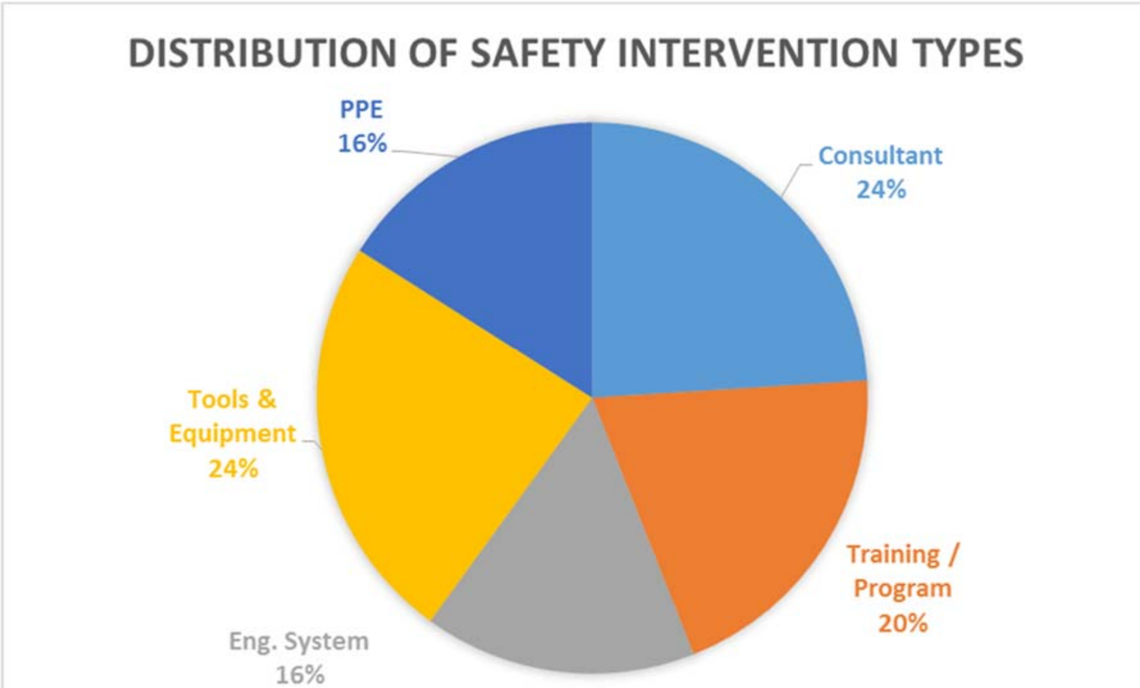
24. EV_o = $500,000 R_i = 70%
$EV_i = EV_o * R_i$ = ($500,000)*(0.70) **= $350,000**

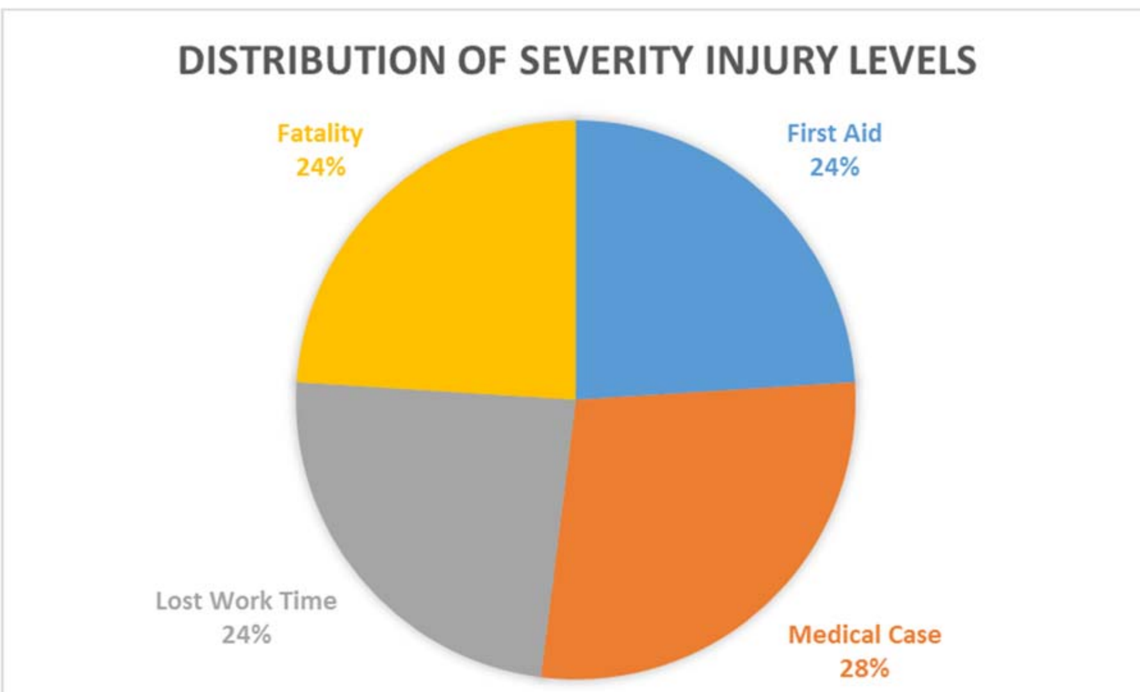
25. EV_o = $75,000 *$R_i$ = 10%*
$EV_i = EV_o * R_i$ = ($75,000)(0.10)* ***= $7,500***

Appendix L. Phase II – Summary Questionnaire's Attributes and Variables

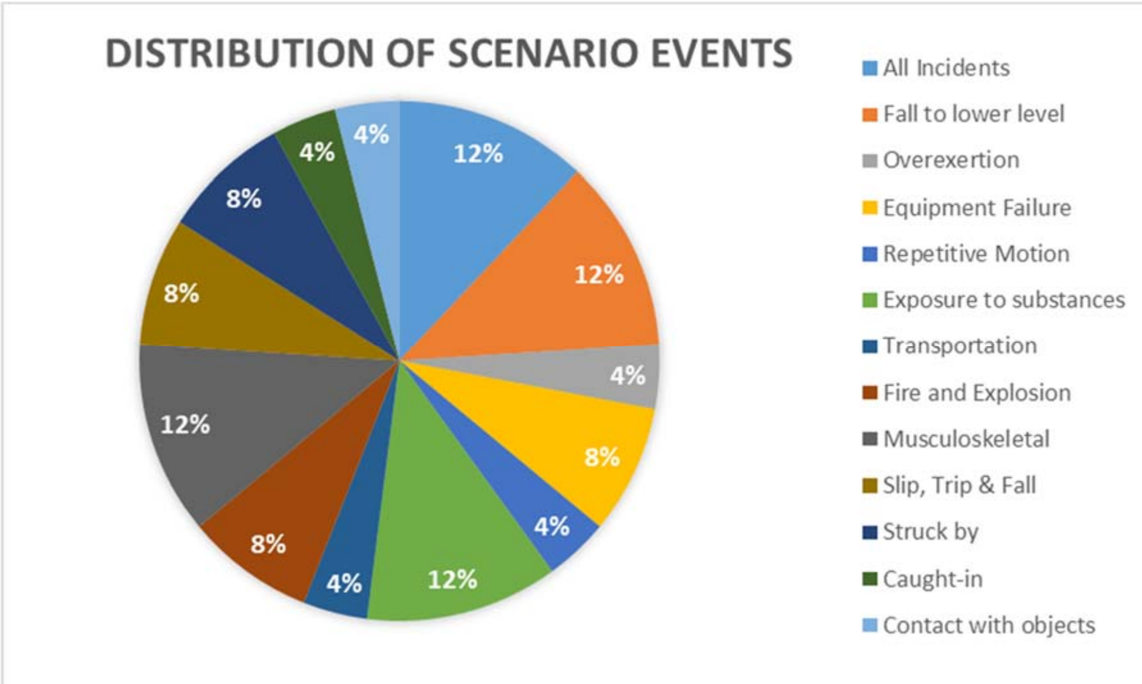
Scenario #	Hazard Topic	Injury Severity Level	Event or Incident	Type of Intervention	EV_i $	U_i $	R_i
1	New fall arrest PPE	Fatality	Fall to lower level	PPE	$661,500	Variable	50%
2	Foreman Safety Leadership Training	First Aid	All Incidents	Consultant	$12,000	1.6	10%
3	Physical Exertion Tools	Medical Case	Overexertion	Tools & Equipment	$120,000	Variable	20%
4	Tool Failures and Hazards	First Aid	Equipment Failure	Tools & Equipment	$30,000	0.8	5%
5	Falls from scaffolding	Fatality	Fall to lower level	Training / Program	$1,500	Variable	100%
6	New soil compactor	Lost Work Time	Repetitive Motion	Tools & Equipment	$60,000	1	40%
7	Leadership safety program	Medical Case	Exposure to substances	Training / Program	$75,000	0.2	10%
8	Transportation injuries	Lost Work Time	Transportation	Eng. System	$72,000	Variable	80%
9	First aid & near miss safety program	First Aid	All Incidents	Training / Program	$4,000	1.8	5%
10	Welding and fire retardant clothing	First Aid	Fire and Explosion	PPE	$51,000	Variable	60%
11	Power and hand tool training/program	Medical Case	Musculoskeletal	Consultant	$800	0.6	15%
12	Preventive budget increase	First Aid	Slip, Trip & Fall	Consultant	$8,400	1.2	5.6%
13	Marine and waterbourne training	Lost Work Time	All Incidents	Training / Program	$3,000	Variable	15%
14	New crane with increase visibility	Fatality	Struck by	Tools & Equipment	$75,000	1.4	20%
15	Fall protection system on bridge	Lost Work Time	Fall to lower level	Tools & Equipment	$125,000	8	50%
16	Health and ergoniomic program	Medical Case	Musculoskeletal	Training / Program	$22,000	Variable	50%
17	Ventilation system in tunneling	Fatality	Exposure to substances	Eng. System	$60,000	6	100%
18	Walkway and housekeeping	Medical Case	Slip, Trip & Fall	Consultant	$4,500	2	10%
19	High hazardous material	Medical Case	Exposure to substances	Eng. System	$24,500	Variable	25%
20	Hand tool and PPE audit program	Lost Work Time	Musculoskeletal	PPE	$30,000	0.4	30%
21	Trenching wall & cave-ins	Fatality	Caught-in	Tools & Equipment	$250,000	4	100%
22	Arc flash injuries	First Aid	Fire and Explosion	Eng. System	$438,750	Variable	45%
23	Comfortable eye protection	Medical Case	Contact with objects	PPE	$11,500	Variable	50%
24	Equipment and work collisions	Fatality	Struck by	Consultant	$350,000	Variable	70%
25	Improper crane rigging	Lost Work Time	Equipment Failure	Consultant	$7,500	Variable	10%

Appendix M. Phase II – Distributions of Variables





Appendix M. Phase II – Distributions of Variables (continued)



Appendix N. Distribution and Integration of Severity Types

Safety Intervention Types	Severity Injury Levels				Total
	First Aid	Medical Case	Lost Work Time	Fatality	
Consultant	2	2	1	1	6
Training / Program	1	2	1	1	5
Eng. System	1	1	1	1	4
Tools & Equipment	1	1	2	2	6
PPE	1	1	1	1	4
Total	6	7	6	6	25

Distribution of Severity Levels and Utility Questions				
Question	First Aid	Medical Case	LWT	Fatality
1				Variable
2	1.6			
3		Variable		
4	0.8			
5				Variable
6			1	
7		0.2		
8			Variable	
9	1.8			
10	Variable			
11		0.6		
12	1.2			
13			Variable	
14				1.4
15			8	
16		Variable		
17				6
18		2		
19		Variable		
20			0.4	
21				4
22	Variable			
23		Variable		
24				Variable
25			Variable	
Ui (avg)	1.3	0.9	3.1	3.8

Appendix N. Distribution and Integration of Severity Types (continued)

Distribution of Severity Levels & Reduction Factors				
Question	**First Aid**	**Medical Case**	**LWT**	**Fatality**
1				50.00%
2	10.00%			
3		20.00%		
4	5.00%			
5				100.00%
6			40.00%	
7		10.00%		
8			80.00%	
9	5.00%			
10	60.00%			
11		15.00%		
12	5.60%			
13			15.00%	
14				20.00%
15			50.00%	
16		50.00%		
17				100.00%
18		10.00%		
19		25.00%		
20			30.00%	
21				100.00%
22	45.00%			
23		50.00%		
24				70.00%
25			10.00%	
Ri (avg)	**21.77%**	**25.71%**	**37.50%**	**73.33%**
Count	**6**	**7**	**6**	**6**

Appendix O. Outlier Analysis of Phase II Questionnaire

Outlier Summary of Scenarios

	Q1	Q3	Q5	Q8	Q10	Q13	Q16	Q19	Q22	Q23	Q24	Q25
Count	12	12	12	12	12	12	12	12	12	12	12	12
Median	$150,000	$110,000	$62,500	$55,000	$50,000	$10,000	$22,500	$27,500	$250,000	$12,000	$425,000	$7,750
Lower Quartile	$130,575	$63,750	$6,000	$25,000	$25,000	$4,875	$10,000	$20,000	$98,125	$10,000	$87,500	$5,000
Upper Quartile	$237,500	$287,500	$137,500	$87,500	$87,750	$47,500	$50,000	$93,750	$486,000	$21,000	$500,000	$68,750
IQR	**$106,925**	**$223,750**	**$131,500**	**$62,500**	**$62,750**	**$42,625**	**$40,000**	**$73,750**	**$387,875**	**$11,000**	**$412,500**	**$63,750**

Questionnaire Response	Avg. Outlier Factor
I	**1.61**
II	**0.62**
III	**1.06**
I	**0.21**
V	**0.76**
VI	**0.70**
VII	**1.12**
VIII	**0.75**
IX	**45.32**
X	**0.49**
XI	**0.71**
XII	**1.95**

Appendix P. Summary of Scenario Variables

Summary of Safety Intervention Types					
Utility Statistics	Consulant	Training / Programs	Eng. System	Tools & Equip.	PPE
Average	2.75	21.74	1.04	1.26	0.99
Median	1.00	2.50	0.82	0.83	0.87
Std. Deviation	4.83	43.78	1.02	0.96	1.21

Summary of Severity Levels				
Utility Statistics	First Aid	Medical Case	Lost Work Time	Fatality
Average	0.99	1.40	3.79	19.71
Median	0.74	1.01	1.07	1.00
Std. Deviation	1.23	1.17	5.56	44.47

Appendix P. Summary of Scenario Variables (continued)

Summary of Injury Events										
Utility Statistics	Fall to lower level	Overexertion	Transportation	Fire & Explosion	All Incidents	Musculo-skeletal	Exposure to substances	Contact with objects	Struck By	Equipment Failures
Average	28.99	1.26	0.71	0.99	6.29	1.32	1.74	1.29	1.15	4.36
Median	0.83	0.83	0.69	0.74	3.33	0.91	1.02	1.04	1.00	1.00
Std. Deviation	52.36	0.96	0.43	1.23	6.21	1.29	1.39	1.11	0.99	6.51

Appendix Q. Summary of Individual Respondents

Summary of Individual Repsondents' Variable Utilities											
Respondents	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Max Fixed Utility	8	6	8	8	8	6	8	6	6	6	6
Average Variable Utility	16.9	6.3	2.5	0.6	3.9	4.2	15.2	7.7	1.0	9.8	3.5
Median	2.0	0.8	1.2	0.2	1.0	0.8	1.0	1.1	0.7	0.9	1.5
STD	47.4	19.0	3.6	0.9	9.3	7.3	47.7	19.1	0.9	28.5	4.1
Max	166.7	66.7	13.3	2.5	33.3	20.0	166.7	66.7	3.3	100.0	13.3
Range	166.7	66.4	13.0	2.5	33.1	19.9	166.3	66.4	3.3	99.9	12.6