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Impact of LEED on Construction Worker Safety and Health

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IMPACT OF LEED ON CONSTRUCTION WORKER SAFETY AND HEALTH

by

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Find that both the content and the form meet acceptable presentation standards
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ABSTRACT

This thesis presents the first detailed exploration into the association between the Leadership in Energy and Environmental Design (LEED) green building certification system and the health and safety of construction workers. Significant improvements have recently been made in the field of construction safety; however, little is known about the effects green building designs and worker safety. The US Green Building Council (USGBC) sponsored LEED green building program represents the largest program in the United States for the measurement, verification, and certification of green buildings. A recent study found that LEED certified buildings have accounted for a higher injury rate than comparative traditional non-LEED buildings. This finding served as the impetus for this research, which examined why green buildings are more dangerous to build. To explore this topic, six detailed case studies were conducted following a strict protocol developed from guiding literature. The results indicate that the LEED requirements cause both positive and negative health and safety effects on the workers installing and constructing the design elements needed to meet the LEED specifications. The findings can be used to facilitate design for safety and advanced site safety management. It is expected that these results will have a positive impact on the safety and health of the construction workers because potential hazards associated with LEED building elements have been identified and described in detail.

DEDICATION

To my parents, you have shown unyielding support my entire life to all my endeavors, including constant willingness to listen to all problems that arose throughout the process of writing this thesis. Your love, guidance and eagerness to help me in any way possible over the last twenty-four years has been an irreplaceable ingredient in every success I have had throughout my life.

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CHAPTER ONE: INTRODUCTION

1.1 Research Importance

The rapid increase in adoption of sustainable designs and technologies and historically high injury and fatality rates of the construction warrant research into their relationship. In this study the researcher aims to develop a better understanding of the potential impacts that sustainable designs and technologies have on construction worker safety by answering the research question: "How do specific LEED credits influence construction worker safety and health?" While discussed in depth in Chapter 3, several propositions have been developed in order to guide the research:

1. The work associated with some LEED credits cause construction workers to face additional hazards and the work associated with other credits will cause a decrease in the hazards workers face.
2. The work associated with some LEED credits result in increases in exposures to known hazardous environments
3. The construction and installation of LEED design elements will cause workers to work in unfamiliar environments.

The goals and outcomes of this research are in line with the National Occupational Research Agenda (NORA) of the National Institute for Occupational Safety and Health (NIOSH). The research specifically addresses Strategic Goals 12 and 13 on the disparities in health and safety in construction and construction hazards prevention through design (CHPtD), respectively (NORA Construction Council Sector 2008). The need for this research is highlighted by the recent fatalities of three solar panel installers in California (CA/FACE 2008, CA/FACE 2009. CA/FACE 2010).

1.2 Safety in the Construction Industry

Construction is one of the largest industries in the United States, accounting for eight percent of the workforce, for a total of over seven million workers (U.S. Census Bureau 2006). However, since the end of World War II, only agriculture and mining have had injury and fatality rates that are comparable to those found in the construction industry (Hinze 1997). Given the number of workers employed in construction, the total number of injuries and fatalities has historically been the highest. The construction industry accounts for 21.7% of work-related fatalities in the United States, for a total of 1,178 fatal work injuries in 2007 alone (U.S. Census Bureau 2006, BLS 2008). The high injury and fatality rates are not only troublesome from a moral viewpoint but from a financial one as well, with direct and indirect costs of fatal and non-fatal construction injuries estimated to be $13 billion annually.

While construction has historically had a poor safety record, improvements have been made with the rate of serious non-fatal injuries dropping from 529.5 per 10,000 workers in 1992 to 239.5 in 2005 (CPWR 2007). This shows that through research, appropriate training, safety techniques, and hazard mitigation strategies the construction industry can become safer. It is the hope of the researcher that the findings of this thesis can help to continue the trend of decreasing injury and fatality rates in the construction industry, most specifically in the growing industry of green and sustainable construction.

1.3 Leadership in Energy and Environmental Design (LEED)

LEED is a green building rating system, measuring specific criteria related to the sustainability of the facility, which was developed by the United States Green Building Council (USGBC). The USGBC was founded in 1993 and released the first LEED rating system for new construction in 1998. Since then, the program has grown rapidly with refinements to the system made in 2003, 2005, 2007 and 2009. There are five categories that are considered in the 2007 versions of each of the LEED rating systems: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and Resources, Indoor Environmental Quality, Innovation in Design (USGBC 2010). The LEED program is the most popular green building accreditation program in the country, with an estimated value of $60 billion and ten percent of all construction starts in the United States in 2010 (Syal et al. 2007). There has been a rapid growth in the adoption of LEED since the first pilot project in 1998. The popularity of building green results from many perceived benefits that range from decreased impact on the environment to fiscal benefits, such as decreased utility costs and higher occupancy and rental rates (Eicholtz et al. 2008; Fuerst et al. 2008; Miller et al. 2008).

While the primary focus of LEED is on the design and the performance of the final facility, the LEED certification system has several impacts on the construction phase. A survey of twenty-two contractors who were involved with the construction of LEED certified buildings revealed that the LEED certification process involved more complex construction processes, greater risk without adequate compensation, and a significant amount of extra time for LEED documentation, recycling, salvaging, and transportation of materials (Schaufelberger et al. 2009). However, the study also found that LEED projects lend themselves to more integrated forms of project delivery such as design-build, which can be a benefit to the contractor as the project team is generally more coherent and the contractor is brought into the process earlier (Schaufelberger et al. 2007).

It is evident that sustainability and LEED certification will continue to increase in future years as energy, water, and material costs increase and the LEED certification process becomes more streamlined. Thus, it is imperative for owners, designers, and contractors to be aware of the implications of LEED designs on the safety and health of the construction workers. It has been shown through multiple studies that the introduction of new building technologies, geometries, project delivery strategies, and work environments leads to short-term increases in safety risk which last until appropriate safety interventions, training and orientation programs, and decision support tools have been developed.

1.4 Safety and LEED

While LEED projects have been shown to be more successful from an owner's perspective, these projects have also been shown to have some unfortunate safety-related consequences. Preliminary evidence indicates that LEED certified projects have higher injury rates than conventional construction projects (Rajendran et al. 2009). In a study of eighty-six projects it was found that green projects had a statistically significant higher mean and median recordable injury rate (RIR). This was shown to be especially true for projects that were privately funded (Rajendran et al. 2009).

The increased safety risk associated with LEED buildings is logically caused by new hazards that contractors must attempt to manage once the design is complete. For example, one of the most popular green building techniques is a green roof, which covers a building's roof with plant life and organic matter. Green roofs reduce storm water runoff, insulate the building, and decrease the heat island effect. Green roofs, however, must be installed by landscaping contractors, who are not familiar with work at height, generally do not have appropriate safety equipment, and are not provided with adequate tie-offs in the facility's design (Mulhern 2008).

Furthermore, new technologies, such as the use of photovoltaic (PV) panels and atriums create hazards for workers as they increase the duration of work at height (Gerhold 1999). PV panels also put workers at risk of electrical shock and can create electric arcs due to the DC circuit (Gerhold 1999). Increased risk is not limited to simply a few examples. In fact, Rajendran et al. (2009) found that some LEED design credits require an increase in the use of hazardous scenarios such as the need for increased use of skylights and openings, increased material handling, and more complex designs and Mulhern (2008) found that green design elements place workers in unfamiliar work environments which increase the frequency of human error. Unfortunately, the safety risks associated with specific LEED design elements have yet to be evaluated within the context of active projects on a detailed study.

1.5 Designing for Safety

The Design for Safety (DfS) strategy, also known as construction hazard prevention through design (CHPtD), Safety Constructibility, and Prevention through Design (PtD), is the explicit consideration of construction site safety in the design of the permanent facility (Behm 2005). Due to its strong observed benefits, DfS has received increased attention in the United States over the past two decades and has become a common part of the project delivery process in several European countries. DfS is considered in this research because it is the ultimate application of the research results. These results when partnered with the design for safety concept and construction site hazard mitigation strategies can help to create a safer environment for construction workers on projects pursuing LEED certification.

Research has shown that a significant percentage of construction injuries and fatalities are related to decisions made upstream of the construction process (Behm 2004, Gambatese et al. 2007). In 1991, the European Foundation for the Improvement of Living and Working Conditions (1991) found that 60% of all fatal accidents on construction sites were related to decisions made before the construction phase begins. While the benefits of DfS are well known and the technique has gained increasing attention, there are still many barriers to achieving its potential benefits such as safety knowledge of the designers, fear of liability, a lack of incentives for designers, and a lack of tools that facilitate designer consideration of construction safety. As a result, DfS continues to be slowly adopted in the US; however, several European countries and Australia have passed laws that require all designers to consider construction worker safety in design.

1.6 Research Objective

The primary objective of this research is to answer the following question:

"***Why** may projects that include green design elements be experiencing higher injury rates than non-green projects, specifically those project that have achieved or are attempting to achieve LEED Certification?*"

In order to answer this question, the following three research objectives were formed:

1. Identify commonly used strategies for the achievement of each LEED credit;
2. Identify the alternatives for these strategies when LEED certification is not being pursued; and

3. Identify the increases and decreases in hazards faced by the construction workers when the LEED strategy is chosen when compared to the traditional non-LEED strategy.

CHAPTER TWO: LITERATURE REVIEW

2.1 Profile of Construction Injuries

It was important for the researcher to understand the nature of construction injuries and the primary safety concerns within the industry before beginning the data collection process. In this literature review an examination of common injury types, their causes and their outcomes is examined. Knowledge of the causes of common injury types allowed the researcher to better identify environments and activities that affected the hazards that construction workers faced in each of the cases studied. Furthermore this knowledge base enabled the researcher to be more effective interviewing project participants with more thorough questions and a better understanding of the answers that were given.

2.1.1 Falls

According to the Center for Construction Research and Training (CPWR 2005), falls accounted for 32% of all fatalities and 23.1% of all non-fatal injuries on construction sites in 2005. This study also showed that falls are the leading cause of fatalities and second leading cause for non-fatal injuries. Over half of all fatal falls in construction have been classified as either falls from a roof or falls from scaffolding or staging. Falls from ladders and from structural steel also were common causes. Given this profile, it is not surprising that ironworkers and roofers were the most vulnerable and experience the highest frequency of fatal falls.

Falls that resulted in non-fatal injuries had different statistics and causes then those of fatal falls. Non-fatal fall injuries were most commonly classified as a fall on the same level or a fall from a ladder (CPWR 2007). Fall related injuries are composing an increasing percentage among OSHA investigated construction incidents, accounting for over 40% in 2001 (Huang et al. 2003).

A study in Korea found that a certain level of experience decreased the fall rate of workers to a certain point, beyond which it is believe that older workers are unable to react as quickly and fall incident frequencies begin to increase again (Chi et al. 2005). These findings also apply to construction workers in the United States (Huang et al. 2003). The most common cause of falls, however, was shown to be unguarded openings (Chi et al. 2005).

Fall incidents tend to be of a high severity, with two-thirds of all fall incidents resulting the worker's death. A significant amount of research has been conducted in the field of fall prevention and protection. A safety hierarchy was developed by Cameron et al. (2007) to create a best practices guideline for fall protection and prevention. The best practices indicate that prevention is better than protection and that passive protection (personnel protection that does not required action by the workers) was preferable to active protection, which requires individual action. These finding can be easily summarized in Table 2.1 seen below.

Table 2.1: Fall Protection selection ranking (Cameron et al. 2007)

	Prevention	Arrest
Passive	Guard Rails to prevent falls, including rails on purlin trolley systems	Fall arrest mats or safety nets
Active	Cable or track-based systems with attached lanyards too short to reach fall danger area	Cable or track-based systems with harness and lanyards

The Fall Protection Guidelines published by the Construction Safety Association of Manitoba (CSAM 2003) breaks fall protection and prevention into six main categories: (1) surface protection; (2) fixed barriers; (3) surface opening protection; (4) travel restraint systems;

(5) fall arrest systems; and (6) fall containment systems. These guidelines provide diagrams, definitions, and methods for preventing falls. Many of the suggestions in this manual are similar to the standards required by OSHA in the United States; however, these guidelines are concisely summarized in a seventeen-page document. The best use of this manual would be for determining the appropriate fall protection and prevention strategy for a given scenario (CSAM 2003).

2.1.2 Overexertion

An overexertion injury is when a worker suffers a musculoskeletal injury through either repetitive or acute exposure to a physical force. Overexertion injuries accounted for 18.2% of all nonfatal construction injuries in the United States in 2005, making it the third leading cause of non-fatal injuries. Many overexertion injuries are categorized as work related musculoskeletal disorders (WMSD), which construction workers have a higher rate of than the cumulative rate of the rest of the American workforce. Overexertion was the cause of over three quarters of the WMSDs that had missed workdays in construction (CPWR 2007). Overexertion injuries can be caused by single incidents; however, many times repetitive motions that occur over the course of days, months, or even years cause them. Because of the long-term nature of overexertion injuries, many times they are difficult to classify (Everett 1999). Back injuries are the most common form of an overexertion injury, and make up nearly 20% of all nonfatal injuries with days away from work. It was also found that lumbar spine injuries are the second most common injury type for injuries that do not result in missed work days (Hinze et al. 2006).

Back injury claims are the most frequently reported in the industry and, therefore, make up the largest proportion of claim costs in construction (CPWR 2007). Among construction worker injuries that do not result in missed work, lumbar spine injuries accounted for 20% of the total charges and had the second highest average cost per patient (Hinze et al. 2006).

While overexertion injuries are one of the more common injury types on a construction site, they are also one of the most preventable. In recent years, the materials and tools used in construction have gotten consistently heavier. Unfortunately, few lifting methods and related technologies have improved (Bernold et al. 1993). A study conducted by Everett (1999) aimed to find activities that were of high risk for overexertion injuries. This was done by closely examining the most common tasks performed and assigning a risk factor to for different causes of overexertion. It was found that posture stresses followed by static, forceful and repetitive exertions were the most significant risk factors for overexertion injuries (Everett 1999).

2.1.3 Caught-In or Between

Caught in or between incidents on construction sites can have a variety of causes, but two of the most prominent are trench cave-ins and incidents involving heavy machinery. While caught in or between accounted for only seven percent of construction fatalities from 1992 to 2002, they accounted for twelve percent of the fatalities involving machinery. Operating engineers and laborers were the most at risk for this type of incident with a failure to set vehicle brakes or lock out the vehicle or parts of the vehicle being the primary cause (McCann 2006). Trench work, however, is a notoriously dangerous activity on construction sites and cave-ins are a major cause of caught in or between injuries and fatalities (McManamy 2004).

After the revision of the OSHA excavation standards in 1989, the five-year fatality rate from trench collapses decreased by two-thirds from the five years before the revisions. While this is progress, there were still fifty-three recorded trenching deaths in 2003, 74% of which were due to trench cave-ins (McManamy 2004). Typically there are three methods of worker protection during trench work, which are sloping, shoring, and the use of trench boxes (Hinze 2005).

New technology is emerging that could eliminate much of the need for workers to venture into a trench. A teleoperated pipe manipulator prototype (TPMP) was developed which can be attached to the bucket of an excavator and used to place and connect piping in trenches. In a study on the TPMP revealed that beyond the safety benefits, there were economic benefits. The need for fewer workers caused the TPMP to be a cheaper alternative to the traditional labor-intensive method of laying pipe. Additionally increased savings were found as the depth of the trench increased (Lee et al. 1999).

Table 2.2: Trenching Cost Comparison of Traditional Method vs. TPMP for 100 feet (Lee et al. 1999).

	Excavation ($)		**Pipe Installation ($)**		**Backfill ($)**		**Savings ($)**
Depth (ft)	Traditional	Manipulator	Traditional	Manipulator	Traditional	Manipulator	Total
5	607	475	1146	697	281	220	642
12	4195	3051	1146	697	1291	939	1945
19	5329	3771	1146	697	3019	2136	2890

2.1.4 Struck-By

Struck-by incidents primarily involve events in which workers are struck-by equipment, vehicles, and falling or moving materials. Struck-by incidents on construction sites were the leading cause of nonfatal injuries that resulted in lost workdays and the fourth leading cause of fatal injuries from 1992 to 2005 (CPWR 2007). The two leading causes for struck-by incidents on a construction site are vehicles and falling materials. Wood framing or formwork and concrete blocks are the most common types of material for a worker to be struck and injured by.

Workers struck-by materials however, have lower fatality rates than workers who are struck-by vehicles (Hinze et al. 2005).

Highway and street workers are particularly vulnerable to struck-by incidents that involve vehicles. An analysis of New York State Department of Transportation (NYSDOT) construction worker incidents revealed that workers being struck-by or pinned by large equipment was the leading cause of fatal injuries and injury costs from 1990 to 2001. Incidents involving non-construction vehicles entering the work site were fatal over thirty-five percent of the time. Workers being struck-by construction equipment or construction vehicles were the most common source of all injuries both fatal and nonfatal during the study period (Mohan et al. 2005). A study of 253 deaths involving vehicles in excavation work found that workers on foot were involved in 34% of the fatalities. Of workers struck-by vehicles while on foot, 43% of these incidents were caused by a vehicle backing over the worker (McCann 2006).

Injuries involving workers being struck-by both construction and non-construction vehicles are readily preventable. Physical barriers, such as concrete median barriers and truck mounted attenuators, as well as clear signage can help to prevent non-construction vehicles entering the work site (McCann 2006). Equipment warning devices and ground spotters can reduce the number of injuries and fatalities associated with workers being struck-by vehicles within the work zone. For protecting workers from falling materials, worker safety training and proper load securing procedures can decrease the number of incidents (Hinze et al. 2005).

2.1.5 Exposure to Harmful Substances

2.1.5a Noise

Constructions sites routinely expose construction workers to sounds louder than 85 decibels, the NIOSH recommended exposure limit. A study by NIOSH from 1997 to 2007 of construction workers that were formerly employed by the DOE found that over 58% of the workers suffered from abnormal hearing loss. Ironworkers, carpenters and boilermakers were the trades that experienced the highest levels of abnormal hearing loss (CPWR 2007). In Germany, almost 5,000 construction industry workers, aged 40 to 64, were given a baseline medical examination over the course of two years and then given the same exam five years later. This study found that over 50% of the blue collar workers in the industry had suffered some sort of hearing loss over the five year period, compared to 33.9% among white collar workers (Arndt et al. 1996). These among other studies point to hearing loss being a significant issue in construction, which not only lowers the standard of living for workers but also can create hazardous situations on construction sites.

Given the incidence rates among construction workers, prevention of hearing loss is often not a priority. OSHA guidelines require action of a hearing conservation program (HCP) at 85 decibels for general industry but the same regulations do not exist for construction (Suter 2002). Hearing protection devices (HPDs) are the primary method for noise protection in the construction industry. It was found that workers only reduced their exposure to sounds greater than 85 decibels twenty percent of the time through the use of HPD's. Additionally, when using HPDs workers achieved on average only half of than the labeled attenuation for the device used. Therefore, a need exists for more training on the proper use of HPDs as well as better programs to promote their use (Neitzel et al. 2005).

2.1.5b Contact with electricity

Contact with overhead power lines, transformers, wiring, and electrical equipment are the most common sources of electrical injury in the construction industry. Injuries involving electricity on construction sites tend to have a high severity. While electrocutions accounted for nine percent of all construction fatalities from 2003 to 2005, less than one percent of all nonfatal injuries involved electricity (CPWR 2007). Contact with overhead power lines was the leading source of deaths involving electricity from 2003 to 2006 with 232 fatalities, composing over forty-seven percent of all incidents. The leading cause of electrical death for workers over the age of forty-four was contact with wiring or transformers (Janicak 2008).

While electrical incidents have a high fatality rate, studies show that both fatal and nonfatal injury rates involving electricity have been dropping from 1992 to 2002. While this is a positive trend, in 2002 there was still one nonfatal injury involving electricity per ten thousand workers in construction, which is still several times higher than the all industry rate (Cawley et al. 2008). The main prevention strategies for electrical injuries are better employee training; this includes safe working distances from overhead power lines, and proper lock out tag out procedures of electrical equipment and wiring. There are also engineering controls that can be put in place such as guarding and proper maintenance of electrically powered tools and equipment (Janicak 2008).

2.1.5c Silica

Silica can be found in most stone, sand, granite, and quartz, all of which are common materials of the construction industry. Inhalation of silica particles causes silicosis, a disease which causes scarring of the lungs, impairs breathing, leaves the sufferer more susceptible to tuberculosis, chronic bronchitis, emphysema and can even cause death. Many of these dangers of silica have been known since the 1970s, and it has been shown that the disease can progress even after individuals are no longer exposed to silica (Lahiri et al. 2005, NIOSH 2002). More recently, silica has been identified as a lung carcinogen by the International Agency for Research on Cancer (IARC, 1997). NIOSH has found that the construction industry had more deaths linked to silicosis than any other industry, with a proportionate mortality rate (PMR) for silicosis of 210, which is double that of men in all industries (Linch 2002).

The recommended exposure level (REL) of crystalline silica dust as given by NIOSH is 0.05 mg/m^3 as time weighted average over the course of a forty-hour workweek. However, studies have shown that construction workers are frequently exposed to levels far higher, with masonry and stone workers being exposed to levels up to ten times higher than the REL. Linch (2002) found that of fifty measurements taken thirty-five had respirable quartz levels greater than the REL. The measurements were taken of workers either abrasive blasting, drilling concrete pavement, or concrete grinding with no engineering controls in place.

While silicosis has no cure, the inhalation of silica dust by construction workers is preventable. The four main methods for the prevention of silica inhalation are substituting silica sand, the wet method, ventilation systems and worker training and use of personal protective equipment (Lahiri et al. 2005). Other than the complete removal of silica products, engineering controls such as the wet method and ventilation systems have been shown to be the most effective in preventing silicosis and have also been shown to be the most cost effective when measured in dollars per healthy year saved (Lahiri et al. 2005).

2.2.6 Aging Workforce

Similar to the overall United States labor force, the average age of construction workers has been increasing (CPWR 2007). Given the physical demands of the construction industry, the ability of the aging workforce to meets these demands comes into question. There is a great deal of research on the effects of aging on physical capacity. Studies have revealed that aerobic capacity as measured by VO2 max decreases 7-10% per decade after the peak at twenty-five for both men and women. Similarly steady declines in muscular capacity were found for both men and women after the age of thirty-five. This decrease in capacity exposes the aging work force to an increased number of sprains and strains, which account for a significant percentage of construction injuries and missed workdays. A study by Welch et al. (2008) study showed older workers were more likely to have medical conditions and or musculoskeletal conditions that could be associated with work limitations.

2.2 Leadership in Energy and Environmental Design (LEED)

2.2.1 Introduction

LEED is a green building rating system that was developed and is constantly reviewed and updated by the United States Green Building Council (USGBC). The USGBC was founded in 1993 and released the first LEED rating system for new construction in 1998. Since then the program has grown rapidly, with refinements to the system being made in 2003, 2005, 2007 and the newly released 2009 version (Schaufelberger 2009). Additionally the program has grown from just rating new construction and major renovation projects to nine separate rating systems (New Construction, Existing Building: Operations & Maintenance, Commercial Interiors, Core & Shell, Schools, Retail, Healthcare, Home and Neighborhood Development). There are up to nine categories that are considered in each of the 2009 LEED rating systems, which are Sustainable Sites, Water Efficiency, Energy & Atmosphere, Material & Resources, Indoor

Environmental Quality, Locations & Linkages, Awareness & Education, Innovation in Design and Regional Priority (USGBC 2010).

Buildings in the United States are the source of almost forty percent of CO_2 emissions and energy consumption in the United States as well as thirteen percent of water usage. The LEED system works as a third party certification system to achieve consensus on the decreased negative impacts a building has on the environment and the final occupants of the structure. Each rating system has a set of prerequisites that must be achieved and a set of one hundred other optional credits that can be achieved in order to achieve a rating ranging from LEED certified (40-49 credits) to LEED Platinum (80 credits or greater). The increase to one hundred available credits is change to the new 2009 version of LEED (USGBC 2009(a)). The majority of the projects examined in this research were using an older version, LEED New Construction and Major Renovations V2.2. This scoring system allows for a total of 69 points to be achieved with the first level of certification, certified, starting at the achievement of 26 credits. The scorecard for LEED New Construction and Major Renovations V2.2 is available in Appendix A.

The LEED program is the leading green building program in the United States. Since the inception of the LEED program in 1998, the market for green building construction has increased exponentially. The estimated value of green construction projects in 2000 was only $792 million, however this has grown to a projected value of $60 billion in 2010, comprising ten percent of all construction starts. Much of this growth has been through the LEED program, which has committed to certifying one million commercial buildings by the year 2020 (Syal et al. 2007).

The major drivers of this fast growth have been a threefold. First, there have been many government mandates and incentives for green construction. Many departments of the federal government, most state governments and scores of municipalities now have either requirements that their buildings be LEED certified to various levels or have created tax incentives for LEED certified buildings. Second, the demand in the private sector has rapidly increased from all sectors of the market, from homebuyers to large corporations, looking to receive the perceived benefits of a green building. Finally, the growth of this market has helped to perpetuate itself. As the demand from the first two drivers has increased, the availability of green building supplies and knowledge has become more available and less costly (USGBC 2009(b)).

2.2.2 Benefits of Green Construction

Green buildings have many perceived benefits; however, quantification of these benefits is still in the preliminary research stages and is largely unsubstantiated. The first benefit of green building is decreased impacts on the environment, ranging from thirty-three percent lower green house gas emissions to the elimination of heat islands, which is the increased temperature created in urban areas because of high building density. Green buildings also have fiscal benefits. Buildings with greater energy efficiency and better insulation decrease utility costs. Green buildings have also been shown to generate greater rents and have a three percent greater occupancy than their counterparts. Finally, the emphasis on indoor environmental quality leads to greater productivity in a workforce or in students in a school (USGBC 2009(b)).

Newsham et al. (2009) conducted a literature review of all the studies on comparing the energy consumptions of green buildings versus non-green buildings. They reviewed six previous studies all of which found that while green buildings overall performed better in energy usage, there was a large degree of variability in performance. Most of the studies found that green buildings did not usually meet their estimated energy use. Newsham et al. (2009) also conducted a study comparing energy consumption of green buildings versus non-green buildings. This study matched one hundred LEED certified buildings to a non-green buildings that had similar characteristics, including activity type, size and climate zone. Their findings were consistent with previous findings in that overall LEED buildings used twenty percent less power than their counterparts. However, over twenty-eight percent of the LEED buildings actually used more energy than the similar non-green building they were matched to (Newsham et al. 2009).

Similar research has been done on the fiscal benefits of green buildings. Three studies found that LEED or Energy Star rated buildings generally garner higher rents and have higher occupancy rates than conventional buildings (Miller et al. 2008, Fuerst et al. 2008, Eicholtz et al. 2008). LEED rated buildings showed higher rental rates per square foot for ten consecutive quarters compared to non-LEED buildings from 2004 to 2006. Also examined were the extra costs for a project to be green, which varied by region but on average were approximately five percent to achieve a silver rating, including all fees to the USGBC for the certification process. A survey of tenants found that although they were not willing to pay extra rent for a LEED certified space, they would want to pay less for a non-LEED certified space. The authors concluded that the higher rents and higher occupancy rates that green buildings achieve far outweigh the initial costs to build green (Miller et al. 2008).

A work place with higher indoor environmental quality can have various positive benefits for a company. Most of the benefits stem from increased employee productivity and decreased absenteeism, but in some cases also higher quality work. High performance ventilation systems in a building have shown to reduce respiratory illness by as much as twenty percent, and increase productivity by up to eleven percent. Another component of LEED is more individual thermal control, which has also shown to increase productivity and decrease instances of sick building syndrome (Loftness et al. 2007). Sick building syndrome according to the EPA (2010) is the "experience of acute health and comfort effects that appear to be linked to time spent in a building." The director of Patagonia's new distribution center in Reno, NV believes that the money spent upfront to achieve a LEED silver rating has paid itself back in improved productivity. For example, shipment error rates at the facility have dropped to a fraction of one percent since moving to the new facility (Greve 2006).

2.2.3 Impact of LEED on the Construction Phase

Because construction is such a vital component in the process to creating a LEED building, there are impacts on the contractors involved on these projects. The Cascadia Chapter of the USGBC identified seventeen credits of the 2007 version of the LEED new construction system as the responsibility of the contractor to implement and document (Schaufelberger et al. 2009). A survey of contractors involved in twenty-two LEED certified projects showed some of the effects on contractors working on a LEED certified project, such as the cost to track and prepare LEED documentation and need for LEED discussions at project coordination meetings. The LEED credits that were identified as the responsibility of the contractor were construction waste management, site development and material selection. In a survey of contractors, seventeen of the twenty-two contractors found the LEED certification process to be difficult and sixteen stated that a significant amount of extra time needed to be spent on the project for LEED documentation. Those surveyed also identified several methods to alleviate the extra work and costs of a LEED certified project such as: (1) inclusion of LEED requirements in the specifications; (2) starting LEED documentation early in the project and reviewing the status of the documentation with the owner's representative frequently and; (3) having a LEED accredited professional on the project team (Schaufelberger et al. 2009).

The early involvement of a contractor in the project process can have a great benefit. These potential benefits cause LEED projects to lend themselves to integrated project delivery forms such as design-build or construction manager at risk. The early inclusion of the contractor allows the project team to collectively create project goals. These project goals can include which LEED credits are to be achieved, allowing for a plan to be devised early in the process on how to achieve them (Schaufelberger et al. 2009).

2.3 Relationship between Safety and LEED

While not truly sustainable, the concept of green buildings places an emphasis on creating a more sustainable built environment. The vision of the USGBC even includes the idea stating "Buildings and communities will regenerate and sustain the health and vitality of all life within a generation" (USGBC 2010). A significant portion of the concept of sustainability is acting in a socially responsible manner, which should include the safety of the worker during the construction of green buildings (Gilding et al. 2002). In many ways the LEED system does help to minimize health impacts on workers. Erosion and sedimentation control help to decrease the amount of dust on a work site. The use of low emitting materials, while included to improve the health of the final occupants, can have benefits for construction workers as well (Silins 2009).

Presently, the LEED program has not explicitly considered worker safety as a requirement for certification. This became most apparent on the Las Vegas City Center project, which was attempting to achieve silver LEED status. The site was shut down at one point after a sixth worker fatality occurred in just six months. Proposals were put forth to incorporate the

OSHA construction industry standards as a prerequisite for LEED certification in the 2009 version; however, they ultimately were not included (Silins 2009). In order to achieve LEED certification a significant amount of consideration as to what credits will be pursued needs to take place in the design phase. This emphasis on the design phase had led experts to consider the concept of designing for safety and green construction as suitable partners because the best way to eliminate a construction site hazard is to design it out (Behm 2008, Silins 2009).

Preliminary evidence has shown that LEED certified projects have higher injury rates than conventional construction projects. In a study of eighty-six projects it was found that green projects had a statistically significant higher mean and median recordable injury rate (RIR), these results can be seen below in Table 2.3. This was shown to be especially true for projects that were privately funded where green projects had a RIR of 7.06 versus 4.96 for non-green projects. Several other factors were considered to evaluate the results, such as project size, project type LEED certification level. However, none of these were shown to have an effect on the RIR with respect to LEED versus non-LEED certified projects. Furthermore there was no significant difference found between lost time case rates (LTCR) between green and non-green projects (Rajendran et al. 2009).

Table 2.3: Green vs. Non-green project safety performance (Rajendran et al. 2009)

Safety Measure	Project Type	Number of Projects	Mean	Median	Standard Deviation	Mann-Whitney (2-tail p-value)
RIR	Green	38	6.12	6.86	5.36	0.186
	Non-green	48	5.63	4.63	7.65	
LTCR	Green	38	2.45	0.70	4.24	0.721
	Non-green	48	2.50	0.78	7.75	

LEED design elements also create new safety hazards for contractors to manage on the construction site. One of the most popular green building techniques is green roofs, which covers a building's roof with vegetation. Green roofs can help to reduce storm water runoff, better insulate a building and decrease the heat island effect of a building. The number of green roofs installed increased by twenty-five percent in 2006 for a total of over three million square feet installed (Mulhern 2008). Green roofs however, are installed by landscaping contractors, who are not familiar with the dangers of working on roofs. The use of fall protection and guardrails are new to many of the workers installing green roofs. Additional hazards of installing green roofs include the ability of the roof to structurally support the materials and transport of the materials to the roof. Since falls are the leading cause of death on construction sites these concerns need to be addressed (Mulhern 2008). New technologies, such as the use of photovoltaic (PV) panels create hazards for workers as well. PV panels put workers at risk of electrical shock and can create electric arcs due to the DC circuit (Gerhold 1999).

Rajendran et al. (2009) laid the groundwork for a system that rates a construction project's health and safety effort. The sustainable construction safety and health group system (SCHS) made available a scoring system similar to the LEED system in that it is broken into categories each with different elements. Each element has a credit value, and the entire system has a possible 100 credits for the project to achieve. Also in line with the LEED certification different levels of certification can be achieved: Certified 54-60 credits, Silver 61-75 credits, Gold 76-90 credits and Platinum 91-100 credits. An initial validation study was conducted on the program using twenty-five projects with a range of 9,500 worker-hours to over 30,000,000 worker-hours. A correlation was shown that for projects that had logged over 200,000 worker-hours a higher number of credits achieved resulted in lower total recordable injury rates, and this correlation was shown to be statistically significant (Rajendran et al. 2009).

2.4 Designing for Safety

An examination of the current literature on the topic of designing for safety is necessary as this concept represents the final applications of the results of this research. This research provides an examination of the effects of LEED design elements on the safety of the workers. Future research into the development of design alternatives to mitigate negative safety and health impacts of LEED design elements would provide designers with a set of design for safety techniques specific to the LEED green building system. Therefore, a thorough review of the designing for safety concept is provided in this research to facilitate future research that continues the development of these techniques and ultimately could provide a tool for designers and contractors. Further discussion of this concept for future research is discussed in Chapter 6 of this thesis.

2.4.1 Introduction

Designing for the safety of construction workers is a topic that is receiving increased attention in the construction and engineering community in the United States. Simply defined, design for safety is "the consideration of construction site safety in the design of a project" (Behm 2005 pp. 589). Traditionally, the safety of workers on a construction site has been the sole responsibility of the contractor. This has been due to the regulations set forth by OSHA stating that, "Each employer shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or likely to cause death or serious physical harm to his employees." (OSHA Act of 1970**).** However, recent research showed that designers and owners can have a substantial impact on the safety of workers during the construction phase of a project. This is significant because designers and owners are not the employers of the construction workers but they are affecting the safety of their work place. It is also believed that there is a limit to the amount of improvements that can be made in construction site safety by contractors acting alone and without help from the other parties involved (Szymberski 1997).

Hinze and Wiegand (1992) conducted one of the seminal design for safety studies. This study asked both designers and contractors about the current state of practice in terms of designing for safety. Eight of the twelve construction firms that responded to the survey felt that designers never or rarely considered worker safety. Five respondents mentioned that designers had implemented their safety suggestions on previous projects. A vast majority of the design firms stated that they conducted constructability reviews of their designs, three of which involved safety personnel in the reviews. Overall, however, 70% of the design firms did not consider the safety of construction workers at all (Hinze et al. 1992). This seminal paper gave the industry some of the first hard evidence that safety was not being considered in the design process and that the design for safety concept was worth further investigation.

2.4.2 Design's Effect on Worker Safety

In the past two decades there has been increasing evidence that many construction injuries can be directly related to the final design of the project. In 1991 the European Foundation for the Improvement of Living and Working Conditions (1991) found that 60% of all fatal accidents on construction sites were related to decisions made before the construction phase begins. One study on the matter looked at 224 fatal injury cases from the NIOSH Fatality Assessment Control and Evaluation (FACE) program (Behm 2004). The research evaluated whether a specific design feature caused each fatality and if one of the suggested design for safety concepts from

Gambetese et al. (1997) or the design or design process could have been altered to avoid the incident. The study concluded that 42% of the fatalities were linked to the design features and could have been prevented through known mitigation strategies (Behm 2004). This research was later validated when follow up research was conducted using ten of the NIOSH FACE cases (Gambatese et al. 2008).

In a validation effort, Gambatese et al. (2008) used the Delphi method in order to see if the expert opinions would converge on the same results from the previous study. The results from the Delphi method showed that over 70% of the time the panel agreed with the findings of the Behm (2004). Panel members who had a professional background in construction safety had the highest level of agreement with the findings from the previous study. These two studies along with others provide significant evidence that design plays a significant role in the safety of construction workers.

Research has shown that the implementation of the design for safety concept has been successful on a pilot project (Weinstein et al. 2005). On a project for the Intel Corporation several methods were used to identify how the project could be made safer for construction including focus group interviews, life cycle review, and technical review. The focus and review groups included representatives of all parties involved in the project including the designers, trade workers, and final users of the project. Many of the design suggestions made by the focus groups were implemented throughout the project. As trades completed their work, exit surveys were conducted and many of the design changes that were identified by the groups before hand were deemed successful based on worker appreciation of them. The main finding of this study was that the timing at which a design change suggestion is made is critical as to whether or not it is implemented (Weinstein et al. 2005). This shows that successful implementation of the design for safety concept requires early integration. These findings were consistent with previous studies (Szymberski 1997).

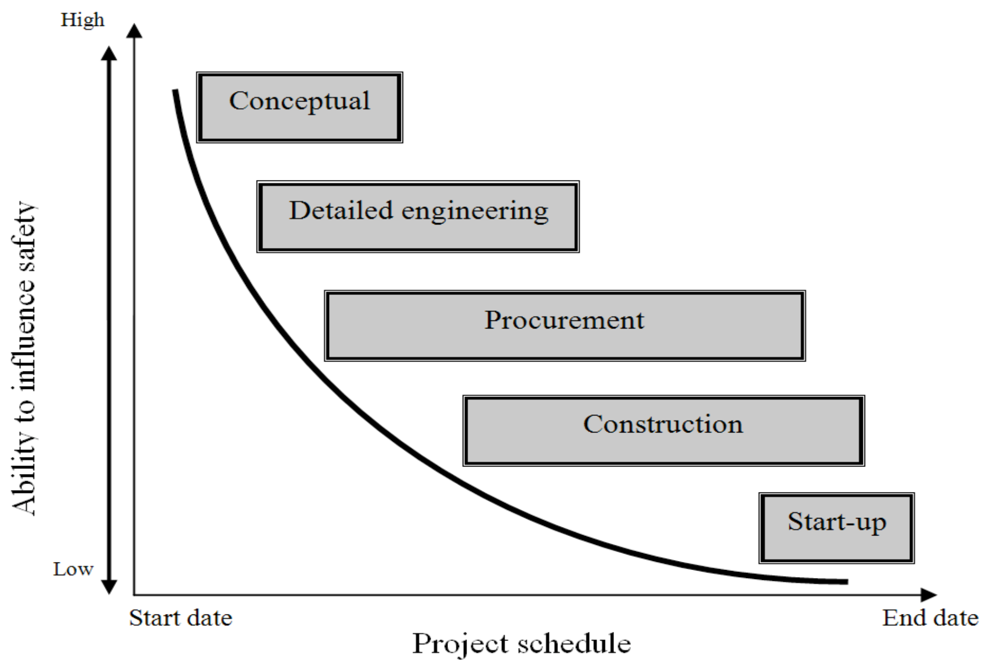

Figure 2.2: Time/safety influence curve (Szymberski 1997)

To aid in helping designers be more conscience of how their designs affect construction worker safety, Gambatese et al. (1997) developed a tool that identifies specific design for safety techniques. The research yielded over 400 design suggestions that were gathered from a combination of academics, design build firms, industry practitioners, safety design manuals, worker safety manuals, and suggestions from a Construction Industry Institute (CII) research team. These suggestions were compiled into a software program that is easily navigable. Designers can choose to search for suggestions by Project Components, Construction Site Hazards, and Project Systems. Additional suggestions can be input and saved as well, making the program a living document that can evolve with a company. The software is available through CII.

2.4.3 Implementation Abroad

2.4.3a Europe

In some areas of the world the design for safety concept has gained more acceptance and momentum than in the United States. The design for safety concept has been broadly implemented throughout Europe. In 1992, the Council of European Communities (CEC) passed Council Directive 92/57/EEC. This directive was created as guidelines for minimum improvements for the construction industry to be adopted in some from by all member countries. The Directive stated:

> "Whereas unsatisfactory architectural and/or organizational options or poor planning of the works at the project preparation stage have played a role in more than half of the occupational accidents occurring on construction sites in the Community" (CEC 1992, pp. 2).

These findings prompted clauses in Articles 3 and 4 of the CEC Directive to speak directly to new requirements on designers and architects to include and consider safety plans and prevention principles in the planning stages of a project (CEC 1992).

The adoption of this directive into law by the member countries however, has been slow and problematic due to lack of enforcement and measures for hazard management (Bluff 2003). The CEC directive is not specific in its requirements for the implementation of the design for safety concept and this has led to varied levels of requirements by the member states. The two consistent concepts in the laws of all the member states are improved planning of construction works and improved information transfer between parties involved in a project. These are most commonly addressed through requirements placed on the owners and designers/architects. The appointment of an Occupational Health and Safety (OHS) supervisor and creation of an OHS plan/file for information transfer are the most common requirements (Bluff 2003).

It is still unclear whether the adoption of the design for safety concept into law in many European countries has decreased the frequencies of injuries and incidents on construction sites. Unfortunately, just as the laws of the different countries are varied on this issue, so are the reported results. The Netherlands and Finland have claimed to have experienced a decrease in both injuries and lost work days since the implementation of such laws. However, such numbers cannot be definitively tied to the implementation of design for safety concepts. Other countries, such as the United Kingdom, saw initial drops in their incident rates only to see them increase again (Bluff 2003).

2.4.3b Australia

Adoption of design for safety laws has also begun in Australia. However, unlike in the UK, these laws have been enacted by local jurisdictions instead of being a national initiative. Such legislation has been passed in only three states of Australia (i.e., Queensland, South Australia, and Western Australia), but this legislation has increased the interest of other jurisdictions and the national government (Bluff 2003).

Court findings that designers and architects could be held liable for designs that were negligent and that put construction workers in harm's way led to the adoption of design for safety laws in these three jurisdictions. Negligence was derived from Australian law that requires designers to take the probability of harm into account during design and to determine reasonable precautions when completing their work. The tort of negligence was established through case precedent from cases with similar results to those that have taken place in the United States. The courts in Australia found that a designer or architect could be found negligent as long as the foreseeable risk was "not far-fetched or fanciful" (Bluff 2003 pp. 3).

In Western Australia, following these court rulings the Occupational Safety and Health Act 1984, (OSHA (WA): s23(3a)) states:

> "a person who designs or constructs any building or structure for use at a workplace shall, so far as is practicable, ensure that the design and construction of the building or structure is such that: (a) a persons who properly construct, maintain, repair or service the building structure; and (b) persons who properly use the building or structure, are not, in doing so, exposed to hazards" (Bluff 2003 pp. 5).

The design for safety laws of the other two jurisdictions in Australia are similar.

2.4.3c South Africa

Design for safety legislation has been established in South Africa as well. In 1993, South Africa passed the Occupational Health and Safety Act, which placed the responsibility of site safety on the employer, similar to the OSH Act of 1970 in the United States. This bill was then followed by the Construction Regulations of 2003, which outlined the safety-related requirements for owners, and designers of construction projects. These requirements include designing for safety. Specifically, these regulations state that designers must modify the design or change the materials when the design or materials present a hazard to the health and safety of the workers whenever reasonable (Smallwood 2004).

South Africa has had similar difficulties as other countries in keeping worker health and safety a primary objective of designers. A study found that of five parameters of project performance (i.e., Project Quality, Public Health and Safety, Schedule, Cost and Project Health and Safety), project health and safety ranked was last by a significant margin by designers. However, when the same designers were ranking the frequency at which situations that were dangerous to worker health and safety arise, two of the top three were aspects related strictly to the design. This study shows that, although many designers in South Africa understand the effect of the design on worker safety and health, they are still not making it a priority in the design process (Smallwood 2004).

2.4.5 Barriers to the Implementation of Design for Safety

2.4.5a Legal / Contractual

A study by Gambatese et al. (2005) that interviewed nineteen different designers found that sixteen, or 84%, thought that their liability would increase if they used designed for safety concepts in their work. Similarly, five of the nineteen stated that this increased liability was a significant barrier to the implementation of the design for safety concept. It has been shown, however, that this fear of increased liability by designers has no evidence to be rooted in and there actually exists evidence to the contrary. Much of this fear is based on advice from legal council that has been unchanged for decades.

A previous study showed that designer liability during the construction phase for negligence was only truly at risk in two conditions. The first was that the designer had knowledge of the unsafe design and knowledge of how to prevent it, even if it was outside of standard practice, yet failed to act. The second scenario is if the designer failed to follow standard practice in the implementation of safety knowledge into the design. It was also shown that whenever a designer acted in good faith and implemented all the safety knowledge they had that they were not found guilty of negligence, when an injury occurred (Gambatese 1998). Therefore, increased liability is a barrier that should be able to be overcome, once proper education on liability and the design for concept is received.

Table 2.4: Designer Liability for Worker Injuries or Fatalities (Gambatese 1998).

	Safety Knowledge Implemented	Safety Knowledge Not Implemented
Not Standard Practice	Not Liable	Liable
Standard Practice	Not Liable	Liable

Traditional construction contracts, while easily adjusted to include mandatory safety programs, do not contain wording that lends itself to the design for safety concept (Korman et al. 2001). This problem is especially apparent in the traditional low bid method of contractor selection (Gambetese et al. 2005). Most construction contracts place full responsibility for construction safety on the contractor by giving them sole discretion on means, methods and sequencing (Behm 2005).

2.4.5b Education

It has been found that many designers lack the educational background or construction experience that is needed to implement design for safety concepts. Gambatese et al. (2005) found that only seven of nineteen designers in a study had any construction experience, with the median being three years of experience. This shows that many designers may not be fully aware of the dangers that exist in the typical activities of a construction site. In the same study only four of the nineteen respondents were shown to be knowledgeable of the design for safety concept.

In addition to lack of construction experience or knowledge of the design for safety concept many designers are not receiving safety education during their formal education. A study was conducted in an effort to find out how much construction safety is included in civil engineering and construction programs at colleges and universities in the United States. In civil engineering programs, 64% had courses that had construction safety content, which among these programs made up 10% of that particular course. Presence of construction safety education was much higher in civil engineering departments that had construction programs. Construction programs had better results with 90% of programs offering a course completely devoted to construction safety, most of which were three credits (Gambetese 2003). However, many of these construction programs were not for students who wanted to be on track for licensing as a professional engineer, meaning they would not end up as designers implementing this construction safety education into the design phase of a project.

2.4.5c Designer Resistance

A survey was conducted by Gambatese et al. (2005) determine how designers felt about the design for safety concept. This study found that only seven of nineteen respondents replied yes when asked if they were interested in the designing for safety concept. Leaving 63% of the other designers surveyed either as not interested or neutral on the concept. Furthermore, 42% of the designers were not accepting of the concept. Some reasons stated for not being accepting of the concept included they were not responsible for the means and methods of the contractor and believed that the concept would lead to increased project costs, lower productivity and the limiting of their creativity in design. In fact when asked the importance of six priorities for their work, construction safety ranked the lowest behind quality, end user safety, cost, schedule, and aesthetics (Gambatese et al. 2005). A separate, aforementioned study by Smallwood (2004) in South Africa yielded similar results as to the priorities of designers there.

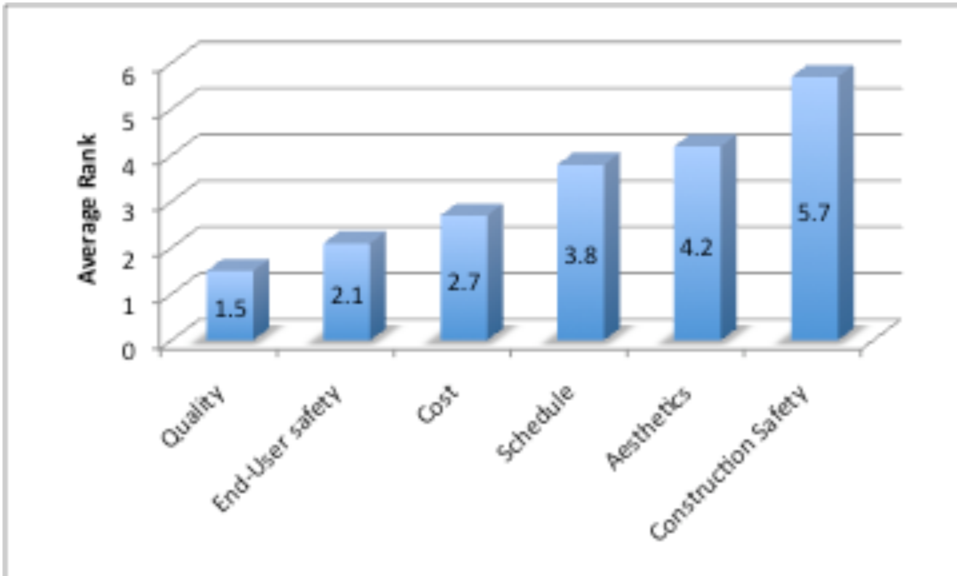

Figure 2.3: Rank of Priority given to project criteria (1=highest priority, 2=second highest priority, etc.; lower ranking indicates higher priority) (Gambatese et al. 2005)

This disinterest and insistence that legally designers are not responsible for construction worker safety led to the contesting of several OSHA citations in the 1990s. OSHA issued citations specifically to designers that spent time on the construction site. These contested cases have ended with mixed results. Some design companies have fought the citations to eventually have them dropped with the legal fees sometimes exceeding the cost of the citation. A handful of firms have taken the citations as reason to change their attitude toward construction safety, some to the point that they are now marketing their new safety expertise when pursuing projects (Korman 1999).

CHAPTER THREE: METHODOLOGY

3.1 Research Objective

The objective of this research was to identify the strategies commonly used to achieve LEED credits, the traditional design alternatives and the hazards created and mitigated by including LEED design elements. The impetus for this research stems from the recent study by Rajendran et al. (2009), who found that LEED certified buildings incurred higher injuries rates than traditional non-LEED buildings. The primary question examined in this research was:

(1) Why are projects that include green design elements experiencing higher injury rates than non-green projects, specifically those projects that have achieved or are attempting to achieve LEED certification?

3.2 Point of Departure

A review of the current literature revealed that there was limited information on the health and safety risks of green design elements on construction sites. The aforementioned research by Rajendran et al. (2009) represents the first findings that LEED certified buildings have higher injury rates than non-LEED buildings. Several proposals have been developed to incorporate OSHA construction industry standards as a prerequisites for LEED certification, however they were not included in the newest version of the LEED standards (Silins 2009).

The majority of the decisions about which LEED credits to pursue are made early in the design phase of a building's life cycle. Because designing out a hazard is the most effective way to protect the safety and health of construction workers, it seems as though the LEED process offers an excellent opportunity to further protect workers (Behm 2008, Silins 2009). The sustainable construction safety and health system, developed by Rajendran et al. (2009), was built in a similar fashion to the LEED system, and has shown a correlation between a higher achievement level and lower total recordable injuries. However, because of this limited literature that combines LEED, construction injuries and/or designing for safety, a majority of the literature review was conducted by looking at each of these topics separately to develop the point of departure as can be seen in Figure 3.1.

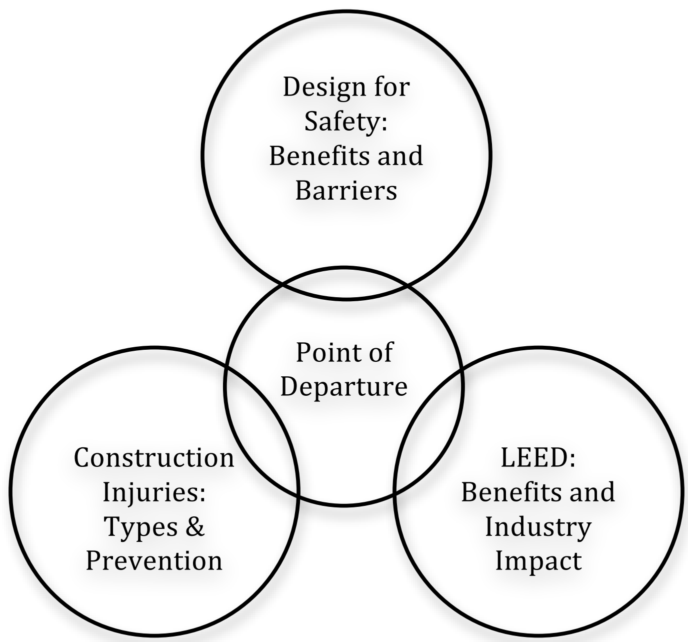

Figure 3.1: Development of the Point of Departure

3.3 Method Justification

The questions that were asked in this research lend themselves to being examined through multiple case studies. According to Yin (2003), cases studies are an appropriate strategy when the investigator is asking "how" or "why" questions about a contemporary event in which they have little or no control over the phenomenon. The objects and subjects that were studied in this research were best studied through in-depth investigations of active construction sites, on which the numerous variables are out of the control of the investigator. This made the boundaries between the activity studied and their context not easily defined or separable.

A case study allows for a researcher to cope with a technically distinctive situation. In this study, there were contextual variables that influenced the design and construction of the green design elements on building projects. In order to build theory from these cases the investigator had to examine multiple sources of evidence, including interviews, field observations, and project plans and specifications. This allowed for the triangulation of these multiple data sources in order to arrive at conclusions of the study (Eisenhardt 1989).

The final decision in the use of case studies for the research methodology was to use multiple case studies to examine the reasons for higher injuries on LEED projects versus traditional, non-LEED projects. Having data from multiple cases allowed the researcher to look for similarities between seemingly different cases and vice versa. This forced the investigator to look at each case and its results critically and further strengthened the results of the research (Eisenhardt 1989). By studying multiple cases, patterns and replication were found in the results between the different cases, which made the results more robust than if only an individual project was studied (Yin 2003). These factors led the investigator to pursue the research in the form of a cases study.

Several other research methods were examined when deciding how to pursue this research; however, most had critical limitations that did not make them ideal for this style of research. The lack of control of the environment made the creation of an experiment a nearly impossible task. Examining past cases and archival evidence alone would have lacked the ability to make observations, which was a useful method of data collection for this research. Surveying industry experts or professionals in the field would not have led to as diverse a data set and may not have provided enough information to reach conclusions (Yin 2003).

3.4 Research Plan

This research process was conducted over multiple distinct research phases. Each of these research phases, the specific research protocol, and the contribution made by each phase is discussed in detail below. The detailed framework for this study can be seen in Figure 3.2. This figure summarizes the research process and the general methods of data collection planned for each phase.

Table 3.1 can also be seen below, which lists the different methods of data collection for each phase of the research. While there are at least five potential sources of data listed for each of the research phases, it was not possible to obtain information from all the sources. This list simply served as a goal for the researcher.

Table 3.1: Data Collection Methods of each Research Phase

LEED Element Identification	Traditional Design Alternative	Hazards introduced or removed due to LEED Design Elements
LEED Scorecard	Interview with Designers	Interview with Project Manager
Specifications	Interview with Fac. Mgmt.	Interview with Superintendent
Interview with Designers	MasterSpecs	Interviews with Foreman
Interview with Owner	Sample Specifications	Interviews with Workers
Project Tour	Submittals	JHA's
Submittals		Accident Reports
Generic LEED Plans / Specs		Direct Observation

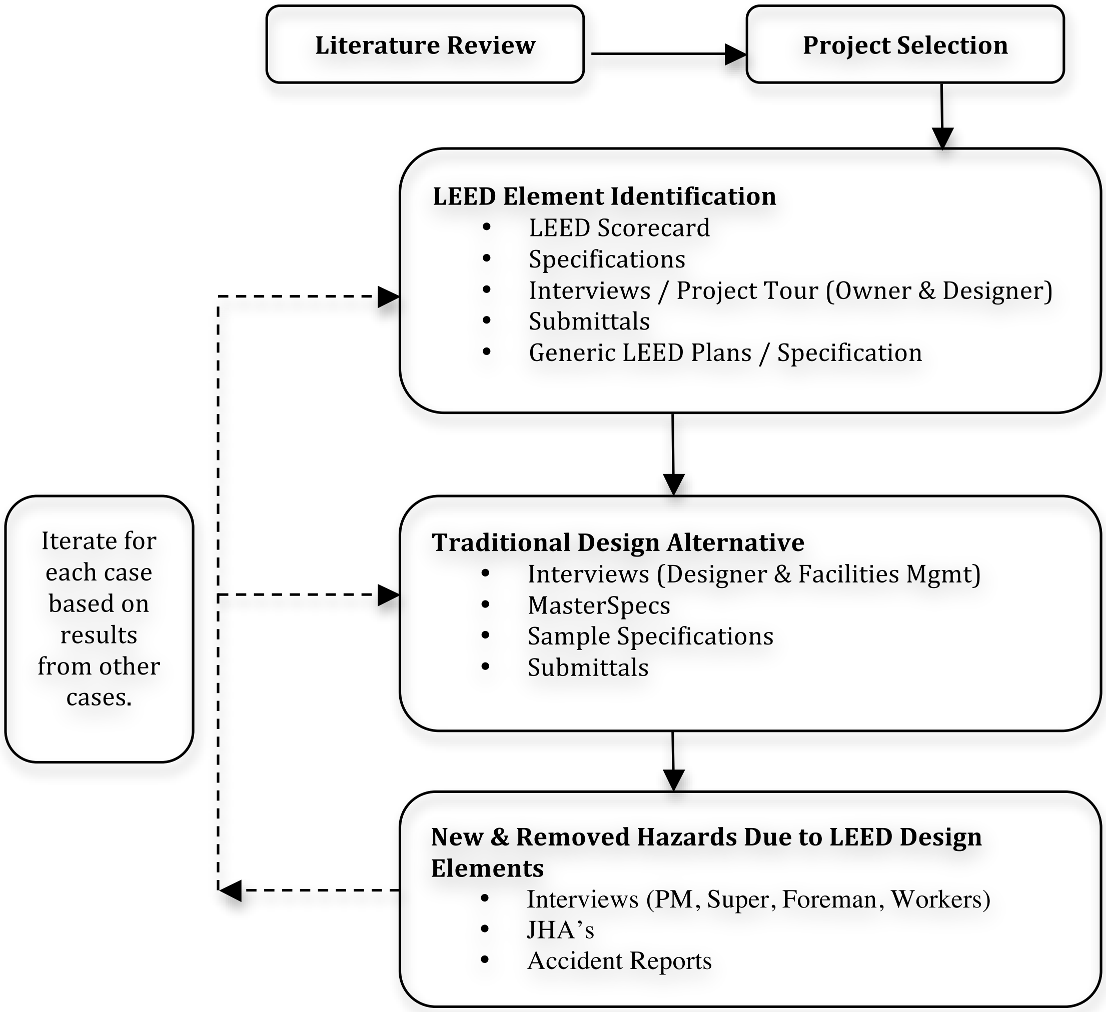

Figure 3.2: Research framework

3.4.1 Case Study Protocol

The following is a detailed description of the protocol implemented in the six case studies that were conducted in this research. As will be discussed later, following a well-defined case study protocol is essential for establishing internal, external, and construct validity and to enhance the confidence in and reliability of the resulting data. The case study protocol described here is based on guidance provided by Yin (2003), Taylor et al. (2009), and Eisenhardt (1998).

3.4.2 Number and location of case studies

Six case studies were conducted in Colorado on projects with a scope of $10M or greater. Projects over $10M were selected because they had a sufficient number of individuals involved in the project and complexity to gather a significant data set. Colorado was selected as the geographic focus for two reasons: (1) projects were within a reasonable travel distance of the researchers location thus minimizing travel costs and (2) there is reason to believe that research findings in Colorado can be extended to other geographic regions.

According to Taylor et al. (2009), construction research consisting of multiple cases strives to obtain both literal and analytic replication through the analysis of embedded subunits of analysis. When the researcher has achieved these measures then enough cases have been conducted in order to draw conclusions. After a total of six cases, comparison between the individual cases yielded sufficient replication between the individual LEED credits in order for the researcher to be confident that enough data had been collected. The researcher determined that sufficient replication had been reached when all the credits fell in either the increase, decrease, no change or not applicable categories as defined in Chapter 4.

The case studies included a combination of active projects that have progressed to late in the construction phase and case histories of recently completed, LEED certified projects. Studying projects in the late construction phases and recently completed projects allowed for all the possible data about the project to be collected as well as for all the information about the project to be fresh in the minds of the research participants that were interviewed. Commercial and institutional projects were considered for this research. Six in-depth case studies typically provide the researcher with sufficient replication in order to pattern match the data according to Yin (2003). Case studies were purposefully selected by choosing those projects that were attempting to achieve higher levels of LEED accreditation, so that each case study yielded as much data as possible.

3.4.3 Unit of Analysis

The main unit of analysis for this research was individual construction projects. As the research progressed several possibilities existed for the development of embedded units of analysis. The most easily identifiable embedded unit of analysis of was the different LEED credits that were examined. One of the final products of this research is a spreadsheet containing the new and removed hazards that are created as a result of the LEED design elements. Each one of these LEED credits was found to have different risks between the LEED designs versus the traditional design has an in depth discussed in order to make identification of the risks trade offs easier. Another spreadsheet contains the LEED credits that have no change in their associated risks. As the results were gathered other subunits of analysis emerged, such as differences between the LEED categories.

3.4.4 Propositions

The development of propositions allowed the researcher to the keep data collection throughout this project focused on the initial research questions. The proposition of this research is that some *green design elements pose additional health and safety risks to the workers constructing and installing them and others lead to reduced hazards*. Limiting the scope to commercial and institutional projects made the proposition that these building types will experience increased worker risk when the studied green design elements are included in the structure. While this scope allowed the research to be manageable and maintain focus another proposition of this research is that the findings in these specific green design elements and in these building types will be able to be directly applied to different green design elements and building types.

To further concentrate the research there were propositions for the answers to the research questions based on previous research and literature. First, the achievement of some LEED design credits require an increase in the use of hazardous scenarios such as the need for increased use of skylights and openings as well as increased material handling (Rajendran et al. 2009). Next, new green design elements incorporate more complex designs and create new hazards for workers, such as the risk of electrical arc from photovoltaic panels converting electricity from DC to AC current (Rajendran et al. 2009; Gerhold 1999). Finally, green design elements place workers in unfamiliar situations and environments in which they may not be trained in all safety procedures and may be more likely to make an error (Mulhern 2008).

3.4.5 Case Study Process

The six steps for each case study are summarized and illustrated in Figure 3.3 below. The first step in all cases was to conduct an opening interview with the lead designer to orient the researcher to the project and to obtain plans, specifications, submittals, and other documentation related to LEED design elements. The second step was to review the documentation provided in order to identify the LEED components in the building's design. The third step involved the identification of the different hazards by conducting interviews with both design and construction personnel on the case study projects including the project manager, foremen, and workers. This step was critical as the goal of the interviews was to identify the specific hazards associated with the LEED design elements. Additionally, accident analyses, inspection reports, and JHA's were be obtained in this step.

The identified elements and changes were validated through interviews with the owner's representative and members of the design and construction teams in step four. These interviews were also used to identify the non-LEED design elements that would have been used if LEED certification were not sought. At the completion of the data collection phase for each of the seven cases a concise case study report was written, the case study reports are available in Appendix A. The volume and multiple types of data were collected pose a problem for all case studies. The case study reports served to organize all the data and information from a case immediately after all the data was collected. This ensured more accurate information during the cross case analysis toward the end of the research project. The final step in the case study process was to conduct follow-up interviews with the project managers of the case study projects in an effort to validate the patterns observed across cases.

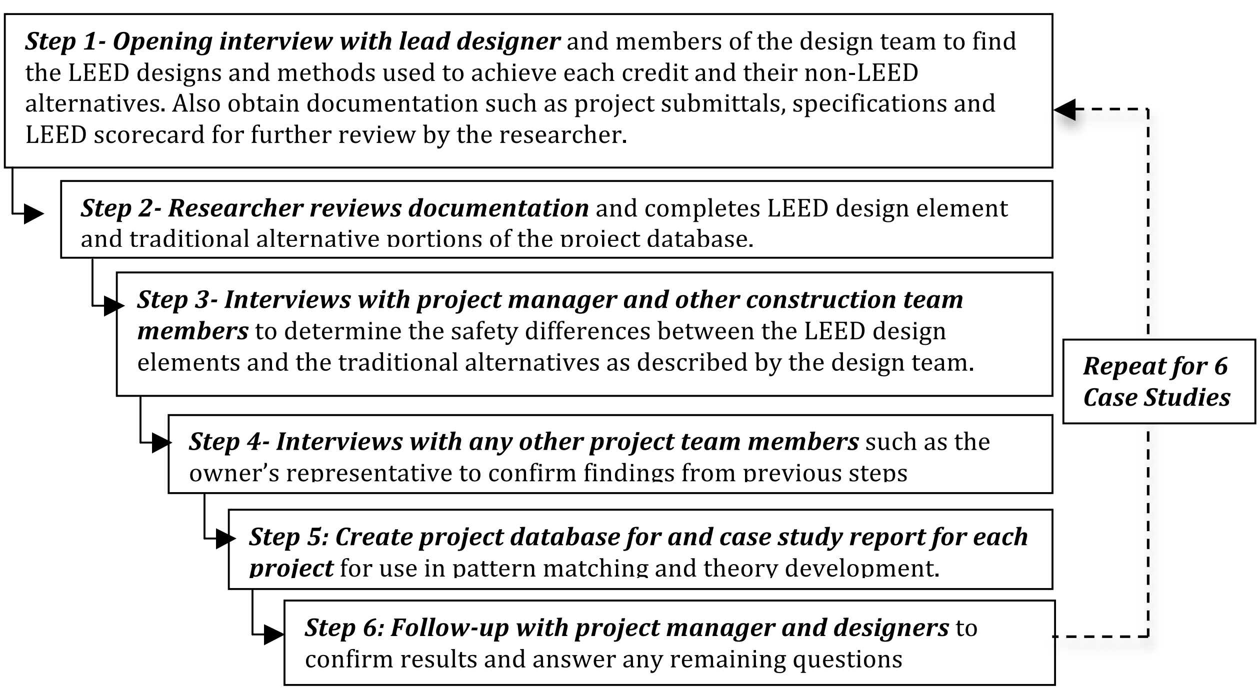

Figure 3.3: Case study protocol

3.5 Validity and Reliability

Any research study that incorporates case studies as a part of the data collection process must be carefully designed to ensure internal validity, external validity, construct validity and reliability to promote confidence in the results (Taylor et al. 2009). Since the purpose of this research was to develop a causal relationship between LEED design elements and construction hazards, the optimization of internal validity was critical. Internal validity was established and preserved in this research by pattern matching. Specifically, replication of the case study protocol and the demonstration that safety hazards are consistent for each green design element across all six case study projects established a pattern that supports the propositions. The protocol that will be followed for all the case studies was described in detail. In addition to promoting internal validity, the consistent application of the case study protocol helped to establish external validity as well. That is, following the protocol and replicating the results from case to case allowed for the results to be applied to the larger population of LEED buildings. Additionally, because the design elements will be applied similarly to different buildings not involved in the case studies the results can be applied to the greater population.

Construct validity was created in this research by collecting multiple sources of evidence such as interviews with different individuals, reviews of the plans and specifications and direct observation of the installation and construction of some of the design elements. Further, the review of the results and findings with the participants of the studies after data collection ensured that the researcher does not include their own bias in the results of the research.

Finally, the careful documentation of the procedures followed throughout the research ensured reliability in the study. The procedures documented included the field protocol and the questions asked during the interviews. All the results and data collected during the research were kept and organized in a case study database so it is easily accessible by the researcher and other interested parties. The creation of the case study reports immediately after the end of data collection for a case also served as important documents by making concise overviews available of all the data collected.

The final validation of this research lies in the return of the results to project managers and designers interviewed in the beginning of each case study. If the parties of each independent case consider the results of the research accurate then they were considered valid. To further validate the results the three primary phases, as seen in Table 3.2, of this research were repeated for each case after all the cases are completed. This will allow the parties to consider the results of the other cases and possibly confirm those results.

Table 3.2: Salient case study details

Case Study Characteristic	Design/Protocol	Justification
Number of cases	6	Six cases on large projects typically provides sufficient repetition and pattern matching (Yin 2003)
Project Locations	Colorado	Provides cost-effective project access, contacts held by researcher, high number of LEED projects.
Interviewees	Project manager, foreman, worker, designers, owner's representatives	Includes all individuals actively involved in the green design element selection, construction and implementation.
Other Sources of Data	Plan, Specification, JHA & Injury Report Reviews, Direct Specifications	Allows for triangulation of multiple data sources increases construct validity of results (Eisenhardt 1989).
Building Types	Commercial and Institutional	Well-established LEED criteria, similar green design elements used. Two types used in order to confirm results are due to green design elements and not building type and promote external validity.
Project Size	> $10 Million	Ensures projects have sufficient complexity, data, and parties involved for conclusions to be drawn.
Data Organization	Case Study Reports and Database	Allows for easy access to data by researcher and other parties. Will also ensure reliability of study results.
Research Validation	Pattern matching, replication, follow up survey	These three tactics will build internal & external validity as well as reliability for the results (Taylor et al. 2009, Eisenhardt 1989, Yin 2003)

3.6 Data Collection Process

In each case the initial contact and data collection was completed with the lead designer of the facility. The primary objectives of this initial meeting were to identify the LEED design elements used in the facility to achieve each credit and the identification of traditional design alternative had LEED certification not been pursued. The second portion of the data collection process involved interviews with the construction project manager and any other members of their team that were able to participate. During this phase the objective was to identify the hazard differences the workers faced by constructing or installed the LEED design element as opposed to the traditional design option indicated by the design team. By consistently applying this process to each of the six cases that were studied, internal and external validity were established.

It was essential that as many data sources as possible were collected in each case. Multiple sources of data allowed for the triangulation of data between the different sources and enhanced construct validity. For each cases that was examined separate in-person meeting took place with a member of the design team and a member of the construction. The meeting with the design team took place either at the design team's office or at the project site. All the meetings with the construction team took place at the project site.

By conducting the data collection with project team members in person the construction plans and specifications were available during all but one meeting throughout the entire process. By having the plans and specifications available the project team was able to illustrate and accurately describe the different elements of the project that were of interest. The one meeting in which the plans and specifications were not available to the research during the data collection was during a phone interview. The phone interview was not the primary data collection meeting for that case. This interview was done over the phone because several follow-up questions arose from the primary data collection and the design team member interviewed over the phone was unable to attend the initial meeting.

In addition to design team member interviews, construction team member interviews, project plans and specifications being examined for every case there were other sources of data for the research. For every case the researcher was able to obtain a copy of the LEED scorecard used to guide the project team. Other sources of data which were collected from some of the cases included: (1) interviews with additional design team members, (2) owner or owner's representative interviews, (3) project submittals, (4) generic LEED specification, (5) interviews with project superintendents, (6) interviews with project engineers, (7) direct observation of work, and (8) tours of the site. A complete listing of the project participants interviewed can be seen in Table 3.3. In addition, a complete listing of all data sources that were collected for each of the cases can be seen below in Table 3.4.

During the data collection process information was entered in to templates that were created to serve as a case study database for each project. After data collection was complete for each of the six cases a case study report was written within two days of when the final data was collected. Each one of these case study reports is available in Appendix B. Immediately entering data into the database as it was collected and creating a final case study report soon after data collection was complete ensured reliability in the data collected.

Table 3.3: Project Participants Interviewed

	Project A	Project B	Project C	Project D	Project E	Project F
Lead Designer	x	x	x	x	x	x
Additional Designer	x	x	x		x	
Owner's Representative	x					x
Project Manager	x	x	x	x	x	x
Superintendent			x	x		
Project Engineer	x		x		x	
LEED Representative					x	

Table 3.4 Project Data Collection Sources

		Project A	**Project B**	**Projet C**	**Project D**	**Project E**	**Project F**
	Delivery System	Design Build	Design Build	CM at Risk	CM & GC	Design Build	CM & GC
	Building Type	Office Building	Institutional	Institutional Research	Institutional Lab	University Housing	Institutional
	Cost		$70 Million	$50 Million	$65 Million	$ 35 Million	$45 Million
	Size	304,000 sq ft	318,000	165,000	200,000 sq ft.	131,000	92,000
	LEED Rating	Gold	Gold	Gold	Gold	Gold/Platinum	Gold
	Phase	Completed- Punch Out	Construction / Punch	Under Construction (85%)	Completed & Occupied	Under Construction (60%)	Complete / Occupied
	Payment Strategy	GMP	GMP	Cost Plus Fee	Cost Plus Fee	GMP	GMP
Research Phase	Data Type						
LEED Elements	LEED Scorecard	V 2.1 C&S	NC V 2.2	NC V2.2	NC V 2.2	NC V2.2	NC V2.2
	Project Specs	x	x	x	x	x	x
	Designer Interview #1	x	x	x	x	x	x
	Designer Interview #2	x	x	x		x	
	Owner Interview	x					x
	Project Submittals	x		x	x		
	Generic LEED Specs	x			x	x	
	Plans	x	x	x	x	x	x
Alternatives	Designer Interview #1	x	x	x	x	x	x
	Designer Interview #2	x	x	x		x	
	Fac. Mgmt. Interview						x
	Project Specs	x	x		x	x	x
	Project Submittals	x			x		

Hazard Differences	PM Interview	x	x	x	x	x	x
	Superintendent Interview			x	x		
	Proj. Eng. Interview	x		x		x	
	JHA's		x				
	Specs	x	x	x	x	x	x
	Direct Observation		x				

CHAPTER FOUR: DATA AND ANALYSIS

4.1 Introduction

This chapter provides the data gathered during the data collection process and an analysis of these data. Provided are the methods, definitions and thresholds used in the analysis of this data so this research can be repeated and analyzed by other researchers using the methods. Of specific importance are the definitions of the different data categories and the thresholds that need to be met for a credit to trend to a category.

4.2 Data Categories

In order to ensure reliability in the study, a set of rules were created in order to classify the data into four hazard categories: (1) increase, (2) decrease, (3) no change and (4) not applicable. The rules were as follows:

Increase**:** An increased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard.

Decrease**:** A decreased hazardous situation was defined as either an increase in frequency, severity, exposure time, or complete removal of a pre-existing hazard

No Change**:** A no change in hazard situation was one in which the work processes to install or construct the design element to achieve LEED neither created, removed or changed the frequency, severity or exposure time of pre-existing hazards.

Not Applicable**:** The achievement of a LEED credit was deemed as not applicable to the study when there was no construction process needed to achieve the credit.

Projects team members could identify the work associated with a credit as causing both an increase and a decrease in the hazards faced by the construction workers. This was due to the fact that most credits have multiple requirements or tasks that need to be completed in order to achieve them. Therefore, the work associated with a credit could result in an increase for one task required for the credit and a decrease for another task. This allows for the sum of projects in the different data categories to be greater than the total number of projects pursuing a credit in the tables found throughout this chapter of the thesis.

4.3 Combining of Credits

Within the LEED accreditation process there are several credits that allow for multiple points to be achieved through the same processes, which are listed later in this section. Different percentage levels achieved for these credits determine how many points are awarded to the project. The researcher determined that, in order to more accurately depict the total changes in hazards faced by the construction workers due to these LEED credits, they were best viewed as one credit. Credits were only combined when there was no difference in the work processes performed by the construction workers for the different levels of achievement for a credit. The following credits were viewed as one credit; however, several of the projects achieved more than one point toward their LEED accreditation for these credits.

Water Efficiency Credit 3: Water Use Reduction

Credit 3.1: Water Use Reduction, 20%

Credit 3.2: Water Use Reduction, 30%

Energy and Atmosphere Credit 1: Optimized Energy Performance

Credit 1.1: Optimized Energy Performance, 10.5%

Credit 1.2: Optimized Energy Performance, 14%

Credit 1.3: Optimized Energy Performance, 17.5%

Credit 1.4: Optimized Energy Performance, 21%

Credit 1.5: Optimized Energy Performance, 24.5%

Credit 1.6: Optimized Energy Performance, 28%

Credit 1.7: Optimized Energy Performance, 31.5%

Credit 1.8: Optimized Energy Performance, 35%

Credit 1.9: Optimized Energy Performance, 38.5%

Credit 1.10: Optimized Energy Performance, 42%

Materials and Resources Credit 2: Construction Waste Management

Credit 2.1: Construction Waste Management, Divert 50% from Disposal

Credit 2.2: Construction Waste Management, Divert 75% from Disposal

Materials and Resources Credit 3: Materials Reuse

Credit 3.1: Materials Reuse, 5%

Credit 3.2: Materials Reuse, 10%

Materials and Resources Credit 4: Recycled Content

Credit 4.1: Recycled Content, 10% (post consumer + ½ pre-consumer)

Credit 4.2: Recycled Content, 20% (post consumer + ½ pre-consumer)

Materials and Resources Credit 5: Regional Materials

Credit 5.1: Regional Materials, 10% Extracted, Processed and Manufactured Regionally

Credit 5.2: Regional Materials, 20% Extracted, Processed and Manufactured Regionally

4.4 No Change or Not Applicable Credits

Several themes were found as to why the work associated with a credit experienced no change in the hazards faced by construction workers or they were found to be not applicable to the research. Overall, there were a total of 10 primary reasons for the work associated with a credit to have no change or to be not applicable between the 6 cases that were examined. A complete listing of the credits that created no change in the safety and health of the workers on 50% or more of the projects pursuing that credit can be found in Table 4.1 at the end of this section.

4.4.1 The scope of the project ensured it would achieve the credit due to its location.

The site selection was the main reason for the achievement of several credits, and therefore required no additional work processes for the construction workers. Credits were considered not applicable when this was the primary reason the credit was achieved.

Example: All 6 of the cases that were examined were located near to pre-existing sources of public transportation and required no additional work to achieve Sustainable Sites Credit 4.1 because there was already sufficient access to public transportation from the facility to meet the requirements.

4.4.2 Smoking regulation in the state of Colorado require that new construction meet standards that also meet LEED standards.

The state laws and in addition the policies of many of the campuses met the requirements of Indoor Environmental Quality Prerequisite 2. This credit was considered as not applicable to this research.

4.4.3 The installation or construction process of an element was the same as on a non-LEED project.

On each project there were several items of work that were designed to a standard that met the LEED requirements and required installation or construction by a construction worker, however the worker faced no change from the hazards faced installing or constructing the traditional design element. The work associated with these credits fell into the no change category because a work process was still required whether the credit was targeted or not.

Example 1: The use of low flush water closets and urinals. On every project the construction team indicated that this work was the same as installing traditional water closets and urinals. Therefore, Water Efficiency Credit 3 could be achieved without changing the task for the workers.

Example 2: The selection of native and low use water plants in order to achieve Water Efficiency Credit 1.2. Construction teams indicated that the landscaping work required for the native and low water use plants was the same as traditional vegetation that may not have qualified for the LEED credit. A specific example of this was the use of bluegrass instead of fescue turf around the facility.

4.4.4 Achievement of the credit had no impact on the construction phase of the project.

Credits that were achieved with no impact on the construction phase of the project required additional administrative work in most cases and did not affect work done on the construction site. Therefore, they were considered as not applicable to this study.

Example: Five of the projects purchased green energy credits, which ensures that the energy for the facility comes from or pays for a renewable energy grid source. This requires no additional work processes, only a contract agreement by the facility owner to purchase green energy.

4.4.5 Designing to the LEED specifications has become a standard practice for the designer.

Some credits were achieved because designing to LEED specification has become standard for the designer. Credits falling under this reason for no change to the safety and health to the workers represent a significant finding in this research. As LEED becomes more of a standard for the industry design firms are making it a policy to design to the LEED requirements. These designs still require installation and construction of the systems and therefore were categorized as no change in the hazards faced by the construction workers.

Example: Indoor Environmental Quality Prerequisite 1 requires that the building ventilation system meet the minimum requirements set forth by ASHRAE. Some design firms are beginning to make designs of this level policy within their organization not only because of the LEED requirement but because many local building codes are adopting this standard as well.

4.4.6 The contractor has a standard policy of using work methods that meet LEED requirements.

The LEED requirements for several credits dictate that the means and methods used by the contractor meet a certain quality level. The growth of LEED has caused several construction firms to simply adopt policies for all projects that meet these requirement both because of LEED and because many of the methods are considered an industry best practice.
Example: In order to achieve Indoor Environmental Credit 3 contractors must create and follow an Indoor Air Quality (IAQ) management plan. During the construction phase the HVAC system must be protected from pollutants as well as several other control measures. By adopting methods for all projects that meet these requirements there is no change in the hazards faced by the workers of these firms from traditional non-LEED projects.

4.4.7 The owner has policies that meet the requirements of LEED.

In this case the owner has adopted policies on all their new facilities that meet the LEED requirements and therefore the project achieved the credit. The owner requirements still required construction work to achieve the credit and therefore credits having this primary reason were listed as no change.
Example: Two of the projects took place on the same university campus, which has building commissioning requirements that meet the LEED requirements for Energy and Atmosphere Prerequisite 1: Fundamental Commissioning. This still required the commissioning agent to enter the construction site and therefore be exposed to the hazards of the site. However, this process would have taken place on these projects whether or not they were attempting to achieve LEED certification.

4.4.8 Manufacturer installation requirements meet LEED requirements.

An Innovation in Design credit can be achieved by through additional testing and commissioning of certain laboratory equipment. Some manufacturers already require this level of commissioning in order for their warranty to be valid, therefore this level of testing must be completed resulting in no change in the hazards faced by the construction workers.

Example: One of the institutional laboratory facilities had fume hoods that in order to meet the requirements of the fume hood manufacturers warranty, needed extensive testing and commissioning. This additional testing earned the project an innovation and design credit.

4.4.9 Credits were achieved by meeting the requirements of a laboratory facility.

Laboratory facilities have special requirements in order to ensure the safety and health of the final occupants. Appropriate sizing of the equipment, ventilation of the laboratory spaces and procedures and methods for handling hazardous waste are just a few of the additional considerations needed when designing a laboratory facility. Some of these additional considerations call for designs that in addition to meeting the needs of the laboratory spaces meet LEED requirements.

Example: The laboratory needed to have a larger ventilation system then would normally be used in a comparably sized space. This larger ventilation system qualified the facility for Indoor Environmental Quality Credit 2: Increased Ventilation.

4.4.10 Credits were achieved by meeting the requirement of a Class A office building.

One of the projects studied in this research was a Class A office building that as indicated by the designers and construction team would qualify for LEED credits because of some requirements to reach Class A status. Because of the Class A status several systems and measures were included during the design and construction of the facility that met LEED requirements.

Example: According to the designer and construction team a Class A office facility needs to include climate controlled parking for the tenants. In this case the climate controlled parking was provided by the inclusion of an underground parking structure. By including the underground parking structure there was additional open space, qualifying the project for Sustainable Sites Credit 5.2: Maximize Open Space.

Table 4.1: Credits with no change to site safety

Credit	Projects Attempting Credit	Increase	No Change	Decrease	N/A
Sustainable Sites					
Prereq 1: Construction Activity Pollution Prevention	6	0	6	0	0
Credit 4.2: Bicycle Storage and Changing Rooms	6	1	5	0	0
Credit 4.3: Low Emitting and Fuel Efficient Vehicles	6	2	4	0	0
Credit 5.2: Maximize Open Space	6	0	3	0	3
Credit 7.1: Heat Island Effect- Non-roof	5	1	4	0	0
Water Efficiency					
Credit 1.1: Water Efficient Landscaping: Reduce by 50%	5	0	5	0	0
Credit 3: Water Use Reduction	6	0	6	0	0
Energy and Atmosphere					
Prerequisite 1: Fundamental Commissioning of Building Energy Systems	6	1	5	0	0

Prerequisite 2: Minimum Energy Performance	6	1	5	0	0
Prerequisite 3: Fundamental Refrigerant Management	6	0	5	0	1
Materials and Resources					
Prerequisite 1: Storage & Collection of Recyclables	6	1	5	0	0
Credit 4: Recycled Content	6	2	4	0	0
Credit 5: Regional Materials	6	0	6	0	0
Credit 6: Rapidly Renewable Materials	2	0	2	0	0
Credit 7: Certified Wood	5	0	5	0	0
Indoor Environmental Quality					
Prerequisite 1: Minimum IAQ Performance	6	0	6	0	0
Credit 2: Increased Ventilation	4	1	3	0	0
Credit 3.2: Construction IAQ Management Plan- Before Occupancy	5	0	5	0	0
Credit 5: Indoor Chemical and Pollutant Source Control	4	2	2	0	0
Credit 6.2: Controllability of Systems- Thermal Comfort	4	1	2	1	0
Credit 7.1: Thermal Comfort- Design	6	0	5	1	0
Credit 8.2: Views for 90% of Spaces	4	1	3	0	0

4.5 Innovation in Design Credits

The Innovation in Design portion of the LEED scoring system is designed to encourage designers to include unique and cutting-edge designs into their facilities. Up to four credits can be awarded for Innovation in Design Credit 1, each credit for a different system or process in the design of the facility or used during the construction phase. These four credits are awarded in no particular order and this makes it impossible to compare each of the four credits between each project. An additional complicating factor is that these credits are to be unique to the project.

These two factors led the researcher to decide that these credits could not be included or considered in the main data set of each project and those patterns or trends about their effect on worker safety could not validly be determined. Data was collected for each of the projects on these four credits however, and can be viewed in the Project Databases included in Appendix C.

Of the six projects studied, all six were attempting to achieve all four credits associated with Innovation in Design Credit 1. This created twenty-four data points to examine. Six (25%) of the twenty-four credits earned in this section increased the hazards faced by the construction workers. Zero of the twenty-four credits decreased the hazards faced by the construction workers. The final eighteen credits were found to either have no effect on the safety of the workers or to be not applicable to this study.

Many of the credits earned for Innovation in Design were for exemplary work for one of the credits in one of the other portions of the scoring system. For example, some projects earned an Innovation in Design credit for exemplary purchase of Green Energy Credits or use of Certified Wood. In these cases the work associated with the Innovation in Design credits had the same hazard effects on the workers as were found for the other credit and this would prove repetitive. This was another reason that the Innovation in Design Credits were not included in the main data sets.

4.6 Credits with an Increased Hazard

The work associated with twelve credits was found to increase the hazards that were faced by the construction workers during the installation or construction of the green design elements included in the facility solely to meet the LEED credit requirements. These credits were cited by the contractor as increasing the hazard faced by the workers as compared to the traditional design alternative. An increased hazardous situation was defined as either an increase in frequency or severity of injuries or the exposure time to a pre-existing hazard or the creation of a new hazard. The work associated with entire credits was deemed to have an increase in hazard for the workers, if an increase was found on at least 50% of the projects attempting to achieve the credit. Table 4.2 shows a complete listing of all the credits that showed that the associated work had an increase in the hazards for the construction workers. Further description of each individual credit can be found below Table 4.2.

Table 4.2: Credits Experiencing an Increase

Credit	Projects Attempting Credit	Increase	No Change	Decrease	N/A
Sustainable Sites					
Credit 6.2: Stormwater Quality Control	4	3	1	0	0
Credit 7.2: Heat Island Effect- Roof	5	3	2	0	0
Water Efficiency					
Credit 2: Innovate Wastewater Technologies	1	1	0	0	0
Energy & Atmosphere					
Credit 1: Optimize Energy Performance	6	4	2	0	0
Credit 2: On-Site Renewable Energy	2	2	0	0	0
Credit 3: Enhanced Commissioning	5	3	2	0	0
Materials and Resources					
Credit 2: Construction Waste Management	6	5	0	1	0
Indoor Environmental Quality					
Credit 1: Outdoor Air Delivery Monitoring	5	3	2	0	0
Credit 3.1: Construction IAQ Management Plan- During Construction	6	3	2	3	0
Credit 4.1: Low-Emitting Materials- Adhesives and Sealants	6	3	1	4	0
Credit 5: Indoor Chemical and Pollutant Source Control	4	2	2	0	0
Credit 6.1: Controllability of Systems- Lighting	5	5	0	0	0

4.6.1 Sustainable Sites Credit 6.2: Stormwater Quality Control:

Three of the 4 projects that were attempting to achieve Sustainable Sites Credit 6.2 indicated that the work associated with this credit increased the hazards faced by the construction workers. This credit is reached by increasing the capacity of the detention system and ensuring that run off from the facility is handled in an environmentally friendly manner. These three projects completed this requirement through the use of an underground detention system with increased capacity, a series of detention ponds, and a bioswale, respectively. These three methods all shared similar hazard increases for the workers.

All of these systems required excavation, which exposed workers to heavy machinery and in particular struck-by and struck-against incidents and increased the exposure time to such incidents. In the case of the underground detention system, the project manager cited that the constant protection of the holes was required to prevent falls by workers and machinery. The creation of the detention ponds required trench work for the workers, exposing them to cave-in hazards as well. Finally, once completed, the detention ponds created a standing water hazard to the workers near to the site.

4.6.2 Sustainable Sites Credit 7.2: Heat Island Effect Roof:

Three of the 5 projects that were attempting to achieve Sustainable Sites Credit 7.2 indicated that the associated work increased the hazards faced by the construction workers. This credit is achieved by having a roofing system that has a Solar Reflectivity Index (SRI) meeting the LEED specifications for that roof type (sloped or flat). Two of the projects that indicated an increase in hazard for this credit used a white themoplastic polyolefin (TPO) roofing system, which had a traditional alternative of an Ethylene Propylene Diene Monomer

(EPDM) roofing system. The third project used clay tiles, which the designer cited asphalt tile as the traditional alternative that was listed in the original contract proposal.

Contractors stated that the TPO roofing material was heavier than EPDM materials, making the installation process more labor intensive for the roofers, increasing the severity for an overexposure injury. As compared to a black EPDM roof, the white TPO material is “blindingly” bright and a more slippery surface. In addition, the white surface does not melt roof snow as well and makes the roof even more slippery. The surface impairing the vision of workers and being more slippery increases the severity of the hazards faced while completing roof work. The most notable hazard for such work is falling from heights, which can often lead to severe injury (CPWR 2005). A slippery material can increase the number of falls to the same level as well, which is a leading cause of musculoskeletal injuries suffered by construction workers.

The clay tiles used on the third project are heavier than more traditional asphalt tiles that were the alternative for the project. Similar to the TPO material versus the EPDM material, his increased the severity of overexertion injuries for the roofers. This hazard was of particular concern to the project manager of this project because the roof of the facility had a steep slope.

4.6.3 Water Efficiency Credit 2: Innovative Wastewater Technologies:

Only one of the projects studied attempted to meet the requirements of the innovative wastewater technologies credit. The design of the waste water system on this project utilized a dual waste water system. This dual waste water system uses water from sinks and showers and then dyes and reuses it as water for the water closets and urinals. This dual wastewater system requires significantly more piping throughout the entire facility, resulting in increased man-hours and exposure time to construction site hazards. Before the water is sent to the toilets from the showers and the sinks it undergoes a filtration and chlorination process. The installation of this system exposes the workers to the chlorine, which is hazardous at high exposure levels. This represents a new hazard for the plumbers on this project.

4.6.4 Energy and Atmosphere Credit 1: Optimize Energy Performance:

Four of the six projects that achieved Energy and Atmosphere Credit 1 found that the achievement of this credit required the construction workers to face increased hazards. Multiple points are available for the achievement of this credit through the LEED scoring system. More points are awarded as the facility's energy usage design becomes increasingly lower than ASHRAE/IESNA Standard 90.1-2004. In general, the four projects agreed that this credit causes the facility to have more wiring and controls, which increases the exposure time to electricity for the construction workers.

There were two designs that were shared by two projects that the contractors stated increased the hazards workers faced. The first was the utilization of a heavy continuous insulation system around the shell of the facilities. The heavier insulation on the shell of the building increases the severity of potential overexertion injury as well as increasing the severity of a fall incident because these materials must be handled at height with exposed edges. The second design shared by two projects was the use of an evaporative cooling chiller. This system has more controls that require wiring than traditional systems and, therefore, workers have a longer exposure time during installation. The evaporative cooling chiller, according to the contractor, is heavy and requires additional piping. The additional piping increases the exposure time for workers and the heavy equipment increases the severity of an overexertion hazard.

One design used to achieve points under this credit, which was specific to a single project was the inclusion of what is known as an enthalpy wheel. The enthalpy wheel causes the Energy and Heat Recovery Ventilators (ERV) to be heavier, which must be considered during crane picks of these units. For workers directing these units into place the severity of the pre-existing struck-by hazard is increased.

4.6.5 Energy and Atmosphere Credit 2: On-Site Renewable Energy:

Two projects were attempting to achieve Energy and Atmosphere Credit 2; one through the full installation of photovoltaic (PV) panels on the roof and the second by roughing in for the installation of PV panels. Installation of the PV panels requires that they be lifted onto the roof by the crane on the site. These additional picks increase the frequency which workers are exposed to hazards associated with working around cranes, such as materials falling on them. In addition, the PV panels need to be installed by electricians that do not commonly work on roofs. This creates a fall hazard for the electricians that they were not normally encounter. The rough in for the PV panels still creates the fall hazard for the electricians, as this requires them to work on the roof.

4.6.6 Energy and Atmosphere Credit 3: Enhanced Commissioning:

Five of the six projects that were studied attempted to achieve Energy and Atmosphere Credit 3, and three of these projects found that the associated work increased hazards faced on the construction site such as noise and falls through openings, whose hazards have been discussed in detail in Chapter 2. The commissioning process brings additional personal on to the site, exposing them to the hazards of a construction work site. The commissioning process requires the commissioning agent to spend a significant amount of time climbing up ladders and inspecting work done above the ceiling. This exposes them to more falls as compared to the standard building commissioning process.

4.6.7 Materials and Resources Credit 2: Construction Waste Management:

All six of the projects were attempting to achieve this Materials and Resources Credit 2. Five of the projects studied claimed that the work associated with this credit increased the hazards that workers were exposed to on the construction site. This credit is achieved by having construction site waste diverted from landfills by sorting the different waste materials (e.g. concrete, wood, drywall) in separate dumpsters, which are then taken to recycling facilities. In order to make sure materials were properly sorted workers are occasionally required to "dumpster dive" to sort materials that were not disposed of properly. This activity exposes the workers to scrapes, abrasions, and lacerations. Working on the uneven surfaces experienced in dumpsters can also cause ankle sprains. This dumpster diving process increased the number of laborers needed on the site, increasing man-hours and in turn exposure time on the project.

Using separate dumpsters to sort the materials also increases the frequency with which dumpsters are picked up and dropped off at the site. The hazards associated with the pick-up and drop-of off the dumpsters are workers being struck-by or struck-against the truck involved in this process. On one project the site tower crane moved the waste and recycling dumpsters, to keep them in convenient locations. Having extra dumpsters on this project increased the frequency of crane picks on the site and the hazards associated with this activity.

One of the main materials recycled on construction sites is excess drywall. Time spent in a dumpster with a significant amount of drywall will expose the workers to airborne gypsum particulates. This could have a long-term negative health impact on the workers respiratory system, such as silicosis, which has well documented effects (Lahiri et al. 2005, NIOSH 2002).

4.6.8 Indoor Environmental Quality Credit 1: Outdoor Air Delivery Monitoring:

Five of the 6 projects examined attempted to achieve Indoor Environmental Quality Credit 1 by including devices in the facility, which would set off an alarm if air quality levels fell outside a preset range. Three of the 5 projects stated that installation of this system increased the hazards workers faced; because the traditional design option was to not include this air quality monitoring system, the man-hours of the project are increased to include this design. Therefore, worker exposure time is increased as a result of having to mount and wire the devices and the frequency of times spent up on a ladder increases as well.

4.6.9 Indoor Environmental Quality Credit 3.1: Construction Indoor Air Quality (IAQ) Management Plan-During Construction:

All 6 of the projects examined worked to achieve Indoor Environmental Quality Credit 3.1 and three of the projects found that the work associated with this credit increased the hazards faced by workers. The main activities need to achieve this credit are covering of the end of ducts, keeping absorptive materials away from moisture and not running generators or other exhaust producing equipment inside. The covering of the ducts increases the time spent by workers installing the HVAC system and causes them to use ladders more frequently. Therefore, their total exposure time on the site is increases as well the frequency they are exposed to fall hazards.

4.6.10 Indoor Environmental Quality Credit 4.1: Low-emitting Materials- Adhesives and Sealants:

All 6 of the projects examined worked to achieve Indoor Environmental Quality Credit 4.1 and three of the projects found that the work associated with this credit increased the hazards faced by workers. The credit is achieved by the selection and use of adhesives and sealants that emit low levels of Volatile Organic Compounds (VOCs). The problem with these materials is that they have a lower quality than traditional adhesives. This causes workers to spend more time both preparing surfaces and on rework. When the low emitting adhesives are used on floors the preparation work includes the grinding and smoothing of the concrete surface. The grinding process creates a silica dust hazard for the workers, which is known health hazard (Lahiri et al. 22005, NIOSH 2002).

It was repeatedly stated on multiple projects that the low emitting adhesives used on roofs were of particularly low quality, increasing the frequency that rework was required. This increases the exposure time that roofers are exposed to fall hazards. Overall, the low-emitting adhesives increase worker exposure time throughout the project and create a new hazard of the silica dust exposure, which can eventually lead to diseases such as silicosis (Linch 2002).

4.6.11 Indoor Environmental Quality Credit 5: Indoor Chemical and Pollutant Source Control:

Four of the projects studied attempted to achieve Indoor Environmental Quality Credit 5 and of these four, on two of these projects, project team members stated that the achievement of this credit increased the hazards faced by the workers. The primary method for achieving this credit is ensuring that copy rooms and custodial closets have separate ventilation from the rest of the facility. Construction of extra ductwork and installation of an extra fan is needed for each space that requires separate ventilation. This adds extra work to the project that would not occur if the project was not attempting to obtain LEED certification, therefore worker exposure time is increased.

4.6.12 Indoor Environmental Quality Credit 6.1: Controllability of Systems-Lighting:

Five of the 6 projects attempted to achieve Indoor Environmental Quality Credit 6.1 by including occupancy sensors in the facility, which helps ensure that lights are not on in unoccupied spaces. All five of the projects stated that installation of this system increased the hazards workers faced because the traditional design option was to not include the occupancy sensors throughout the facility, the man-hours of the project are increased to include this design. Therefore, worker exposure time is increased as a result of having to mount and wire the devices and the frequency of times spent up on a ladder increases as well.

4.7 Credits with a Decreased Hazard

The work associated with five credits was found to decrease the hazards that were faced by the construction workers during the installation or construction of the green design elements included in the facility solely to meet the LEED credit requirements. The work associated with these credits was cited by the contractor as decreasing the hazard faced by the workers as compared to the traditional design alternative. A decreased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard. The work associated with entire credits was deemed to have a decrease in hazard for the workers, if a decrease was found on at least 50% of the projects attempting to achieve the credit. Table 4.3 shows a complete listing of all the credits that the associated work showed a decrease in hazard for the construction workers. Further description of each individual credit can be found below Table 4.3.

Table 4.3: Credits Experiencing a Decrease

Credit	Projects Attempting Credit	Increase	No Change	Decrease	N/A
Indoor Environmental Quality					
Credit 3.1: Construction IAQ Management Plan- During Construction	6	3	2	3	0
Credit 4.1: Low-Emitting Materials- Adhesives and Sealants	6	3	1	4	0
Credit 4.2: Low-Emitting Materials- Paints and Coatings	6	0	2	4	0
Credit 4.3: Low-Emitting Materials- Carpets	5	0	1	4	0
Credit 4.4: Low-Emitting Materials- Composite Wood and Agrifiber Products	5	0	1	4	0

4.7.1 Indoor Environmental Quality Credit 3.1: Construction Indoor Air Quality (IAQ) Management Plan- During Construction:

All six of the projects studied attempted to achieve Indoor Environmental Quality Credit 3.1, and three of those six indicated that the work associated with this credit decreased hazards faced by the construction workers. The main activities needed to achieve this credit are covering of the end of ducts, keeping absorptive materials away from moisture and not running generators or other exhaust producing equipment inside. In some cases workers are also required to use different chemicals during specific processes than are traditionally used. Specifically mentioned by project participants were acetones during cleaning and cutting fiberboard that does not contain urea formaldehyde. Both of these chemicals can be harmful to the health of the workers and these hazards are eliminated through the processes used to achieve these credits.

Another reason that contractors sited for this credit as decreasing the hazards faced by the workers was that this credit promoted better housekeeping of the site, meaning that the site was kept cleaner from debris. The cleaner site decreases the hazards faced by workers in two ways. First, having a clean site means that the workers are exposed to less trip and fall hazards than on traditional sites. Second, the clean site meant that workers could be more productive because they would be less likely to lose track of items needed to complete their work and would spend less time avoiding construction debris. This increased productivity should theoretically decrease the number of hours the workers are exposed to construction site hazards.

The final reason that was found for decreasing the hazards that workers were exposed to was that generators were not run inside the facility. By not running generators inside the workers are exposed less directly to the exhaust from the generators. Less exposure to the exhaust decreases the severity of the potential health hazards created by running the generators inside.

4.7.2 Indoor Environmental Quality Credit 4.1: Low-Emitting Materials- Adhesives and Sealants:

All six of the projects studied employed the use low-emitting adhesives and sealants in the facility in order to meet the requirements of this credit. Findings on four of the six projects concluded that this credit decreased the hazards associated with the work for the construction workers. By using low VOC materials workers are exposed to lower VOC levels during the installation and construction of these products. Because the workers are exposed to lower levels of VOCs they should have a less detrimental health impact than the traditional alternative of using materials that contain and emit higher levels of VOCs (Silins 2009).

4.7.3 Indoor Environmental Quality Credit 4.2: Low-Emitting Materials- Paints and Coatings

All six of the projects studied employed the use low-emitting paints and coatings in the facility in order to meet the requirements of this credit. Findings on four of the six projects concluded that this credit decreased the hazards associated with the work for the construction workers. By using low VOC materials workers are exposed to lower VOC levels during the installation and construction of these products. Because the workers are exposed to lower levels of VOCs they should have a less detrimental health impact than the traditional alternative of using materials that contain and emit higher levels of VOCs (Silins 2009).

4.7.4 Indoor Environmental Quality Credit 4.3: Low-Emitting Materials- Carpets

Five of the six projects studied employed the use low-emitting carpets in the facility in order to meet the requirements of this credit. On four of the six projects this credit decreased the hazards associated with the work for the construction workers. By using low VOC materials workers are exposed to lower VOC levels during the installation and construction of these products. Because the workers are exposed to lower levels of VOCs they should have a less detrimental health impact than the traditional alternative of using materials that contain and emit higher levels of VOCs (Silins 2009).

4.7.5 Indoor Environmental Quality Credit 4.4: Low-Emitting Materials- Composite Wood and Agrifiber Products

Five of the six projects studied employed the use low-emitting composite wood and agrifiber products in the facility in order to meet the requirements of this credit. Findings on four of the six projects concluded that this credit decreased the hazards associated with the work for the construction workers. By using low VOC materials workers are exposed to lower VOC levels during the installation and construction of these products. Because the workers are exposed to lower levels of VOCs they should have a less detrimental health impact than the traditional alternative of using materials that contain and emit higher levels of VOCs (Silins 2009).

4.9 Variability Index

In order to determine the credits for which the associated work had the greatest overall impact on the safety and health of the construction workers, a variability index was developed. The variability of a credit represents the likelihood that a credit's associated work will have an effect on the construction worker's safety and health. The variability index is calculated by the sum of the number of projects that found either a decrease or an increase in the hazards faced by the construction workers divided by the total number of projects attempting the credit. Table 4.5 lists the ten credits with the highest variability index, which is multiplied by ten for ease of reading and comparison.

Table 4.5: Credits with the Highest Variability Index

Credit	Projects Attempting Credit	Increase	No Change	Decrease	N/A	Variability Index
Sustainable Sites						
Credit 6.2: Stormwater Quality Control	4	3	1	0	0	7.5
Water Efficiency						
Credit 2: Innovate Wastewater Technologies	1	1	0	0	0	10.0
Energy & Atmosphere						
Credit 2: On-Site Renewable Energy	2	2	0	0	0	10.0
Credit 5.2: Measurement and Verification- Tenant Submetering (C & S)	1	1	0	0	0	10.0
Materials and Resources						
Credit 2: Construction Waste Management	6	5	0	1	0	10.0
Indoor Environmental Quality						
Credit 4.1: Low-Emitting Materials- Adhesives and Sealants	6	3	1	4	0	11.7
Credit 3.1: Construction IAQ Management Plan- During Construction	6	3	2	3	0	10.0
Credit 6.1: Controllability of Systems- Lighting	5	5	0	0	0	10.0
Credit 4.3: Low-Emitting Materials- Carpets	5	0	1	4	0	8.0
Credit 4.4: Low-Emitting Materials- Composite Wood and Agrifiber Products	5	0	1	4	0	8.0

The credits in this table are important to consider because the work associated with them is the most likely to have an impact on the safety of the construction workers. These credits are likely to have many considerations when evaluating different designs and construction means and methods. For example Indoor Environmental Quality Credit 4.1 has the highest variability score of 11.7 due to the fact that many projects found either or both an increase and a decrease in the hazards workers faced when pursuing this credit as compared to a more traditional design alternative. Therefore, it is essential that the project team consider methods and designs that will emphasize the positive impacts this credit can have on worker safety and health, while simultaneously avoiding the negative impacts.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Increase in Exposure Time

The most consistent and repeated finding of this research effort was that projects that are pursuing LEED certification might increase the total exposure time to known, high-risk hazards of the construction workers as compared to traditional non-LEED facilities. Increased exposure time were instances that added a continuous period of time to the work required to construct the facility. Of the twelve credits that the associated work was found to cause an increase in the hazards faced by the construction workers, ten (83%) had an increase in exposure time as one of the reasons for this change. An increase in exposure time due to the achievement of a LEED credit was found to occur in three ways: (A) an increased amount of time is spent installing or constructing a design element that would be included in a non-LEED facility; (B) additional personnel are required on the site in to complete the task increasing the total exposure time for the project or; (C) an additional design element is required to achieve the LEED credit but the tasks to install or construct the element are the same as other non-LEED elements.

Of the ten credits that the associated work may have caused an increase in exposure time, three fell under case A. An example of this case is Indoor Environmental Quality Credit 4.1: Low-emitting materials- Adhesives and Sealants. No additional design element was included in the project to achieve this credit, the only difference between LEED and a non-LEED project was the material used. The lower quality of the adhesives however, caused workers to spend more time prepping for their application and in some cases required rework.

Therefore, the change in exposure time is solely due to an increased amount of time installing a design element that would be the same in a traditional non-LEED facility.

Case B accounted for two of the ten credits that the associated work may have increased exposure time for the workers. These two credits were Energy and Atmosphere Credit 3: Enhanced Commissioning and Materials and Resources Credit 2: Construction Waste Management. Both cases required additional personnel on the site in order to achieve the credit. The enhanced commissioning process requires that a commissioning agent enter the construction site, exposing them to any of the hazards on the site as well as those that are specific to completing their task. In the case of construction waste management, contractors from different projects repeated stated that additional laborers were required on the project in order to ensure that the necessary processes were followed to achieve this credit.

The final case accounted for half of the possible increases in exposure time for construction workers found in this study. The achievement of all of these credits required the installation or construction of an additional design element that according to the designers would not have been included if the facility was not attempting to achieve LEED certification. The amount of time needed to install these additional elements varied. An example of a short increase in exposure time is Indoor Environmental Quality Credit 5: Indoor Chemical and Pollutant Control. This credit required that rooms that created indoor pollutants, such as copy rooms and custodial closets, have separate ventilation from the rest of the facility. This required workers to add an extra fan and duct to the ventilation system for each of these rooms. Sustainable Sites Credit 6.2 is an example of a larger increase in exposure time due to an additional design element. The inclusion of design elements like bioswales and detention ponds greatly increases the time that workers are exposed to hazards such as being struck-by heavy equipment or falling in the holes created from the excavation.

5.2 Increased Frequency of Hazard Exposure

An increase in the frequency to a hazardous exposure is an increase in the number of discrete events that a worker is exposed to a hazard in order to construct the facility. Five (42%) of the twelve credits for which the associated work may increase the hazards a construction worker faced included an increase in the frequency for which they were exposed to a specific hazard. The frequency of exposure to three different hazards was found among the twelve credits. These three hazards were: (1) crane picks; (2) struck-by or struck-against and; (3) times going up and down a ladder.

Two credits had more frequent crane picks due to the achievement of LEED certification, these were Energy and Atmosphere Credit 2: On-site Renewable Energy and Materials and Resources Credit 2: Construction Waste Management. The lifting of PV panels onto the roof of one facility increased the number cranes picks on that site. At another project because dumpsters were lifted into convenient places throughout the site and more dumpsters were needed to achieve Materials and Resources Credit 2, there were more crane picks than would have been experienced on a non-LEED project.

Materials and Resources Credit 2 was also responsible for the increase in the frequency that workers were exposed to struck-by or struck-against injuries. More dumpsters on the site meant that there were more frequent dumpster deliveries and pick-ups. This exposes workers to being struck-by the large truck needed to deliver and pick-up the dumpsters.

Finally, an increased frequency of a worker moving up and down a ladder was found to occur on three of the twelve credits. The achievement of Indoor Environmental Quality Credit 1: Outdoor Delivery Monitoring, Credit 3.1: Construction IAQ Management and Credit 6.1: Controllability of Systems-Lighting all were found increase the number of times workers went up and down a ladder. The best example of which is Credit 6.1, which added occupancy sensors to high occupancy rooms in each facility and was found on all five projects attempting to achieve it to increase the hazards workers faced. Many types of occupancy sensors are placed in the corner of a room at the ceiling in order to give them the best view of the entire space. Installation of these units therefore requires workers to climb up and down a ladder in each room when they would not have to on many non-LEED projects.

5.3 Placement of Workers in Unfamiliar and Dangerous Environments

A trend found throughout the research is that the achievement of LEED certification may place workers in unfamiliar work environments and also increases worker exposure to inherently dangerous work environments. This finding confirms two of the original propositions of the research. The use of atriums in two of the projects gave workers unfamiliar work environments as compared to more traditional facilities. Additional trench work, an inherently dangerous environment, was required on two projects in order to achieve LEED certification. Finally, the need to for additional work on the roof placed workers in both an unfamiliar work place in some cases as well as increasing their exposure to an inherently dangerous work environment.

5.3.1 Atriums

Two projects had large atriums located in the center of the building and one of the projects had two identical atriums. All three atriums on the two projects were at least four stories tall and allowed for sunlight to enter the middle of the facility through windows around the top. While both of these projects ultimately did not meet the day lighting requirements in order to achieve LEED points, both designers stated that the inclusion of the atriums was in the spirit of LEED and green design. In further discussion with the contractors from both projects and an owner's representative from one of the projects the increased dangers of having an open atrium in the middle of a building were discussed. Both projects stated that it created an increased fall hazard and that additional time needed to be spent by carpenters to ensure fall protection was in place. One project also found that finishes, such as paint, in the atriums were more difficult and hazardous than compared to a facility without an atrium.

5.3.2 Trenches

Trenches, as discussed in the literature review, are one of the most dangerous work environments on a construction site (McManamy 2004). Two of the projects examined, in an effort to achieve LEED certification, required that workers spend additional time in trenches than if the project were not pursuing LEED requirements. The design elements that caused the additional trench work were storm water detention and management systems as well as an underground parking facility. In one case that was examined it was made clear by the designer that the design of a series of detention ponds was included solely to achieve Sustainable Sites Credit 6.1: Storm water Quantity Control and Credit 6.2: Storm water Quality Control. These detention ponds caused additional trench work on the site according to the contractor.

5.3.3 The Roof

Additional roof work was required on five of the six projects examined in this research due to the pursuit of LEED certification. The amount and type of additional roof work necessary varied from project to project, nevertheless working on a roof is one of the most dangerous activities on a construction site (Huang et al. 2003, CPWR 2005). Some of the additional roof activities placed workers in unfamiliar environments. The danger lies in the fact that these workers may are likely not as familiar with fall protection procedures as workers who frequently work on the roof. For example in order install PV panels electricians are required to work for a significant period of time on the roof. Other LEED motivated activities that required roof work increased the exposure time of workers already exposed to the hazards of this work. For example, the lower quality of some low-emitting adhesives required rework to be completed on the roof of one of the case studies.

5.4 Increased Overexertion Hazards

Two (17%) of the twelve credits found that there may be an increase in the severity of the overexertion hazard while completing the work associated with achieving that credit. Sustainable Sites Credit 7.2: Heat Island Effect- Roof, Energy and Atmosphere Credit 1: Optimize Energy Performance and Indoor Environmental Quality Credit 8.1: Daylight 75% of Spaces all had cases in which there was increase in the severity of an overexertion hazard. This finding is significant because overexertion injuries compose a significant percentage of lost timework injuries as well as accounting for the largest percentage of claim costs in the construction injuries (CPWR 2007, Hinze et al. 2006). For the three credits listed at least one member of the construction team stated that the materials that were used because of the pursuit of LEED were heavier than those that would be used on traditional non-LEED projects. The materials of discussion were heavier insulation, larger windows, an evaporative cooling chiller and TPO roofing membranes. This finding is of particular concern because of the aging of the construction industry workforce and their increased vulnerability to overexertion hazards (CPWR 2007, Welch et al. 2008).

5.5 Physical versus Health Hazard Changes

Examination of the credits that had an affect on worker safety and health revealed that credits with associated work that may increase the hazards were in almost every case related to a physical hazard. While credits with associated work that may decrease the hazards were health related hazards. According to these findings, LEED projects are increasing the frequency and number of physical hazards that the workers are facing but are having a potentially positive impact on the long-term health of the workers.

As already discussed in the conclusions it is clear that projects pursuing LEED certification are increasing the hazards that workers are facing. Greater exposure times, frequencies and severities when multiplied against steady injury rates will undoubtedly result in a greater number of injuries based on single incidents. Because such incidents are easier to track, they show up readily in statistics. However, of greater importance may be the positive long-term health impacts of LEED on all construction workers. Contractors consistently stated that the use of low-emitting materials as having a positive health impact on the construction workers, especially those who install them. This is a logical conclusion given that these materials are designed to create healthier spaces for the final occupants of a facility (Silins 2009).

There are several additional ways in which LEED may be having a positive impact on the health of construction workers. Three contractors felt that the requirements of Indoor Environmental Quality Credit 3.1: Construction IAQ Management had a positive impact on the health of the workers because generators, which create exhausts, were no longer being run inside the facility or without proper ventilation and because the use of certain chemicals, most notably cleaning with acetones, was no longer allowed. The requirements of this credit, in combination with the requirements of many of the facility owners did not allow smoking on or near to the facility. One contracting team stated that this had caused a significant decrease in the smoking done by the workers because walking several hundred feet to smoke proved to be a strong dissuasion against smoking. They stated that several workers even used this as an impetus to quit smoking altogether, which would have proven positive health benefits for these workers.

5.6 Standardization of LEED Requirements

One of the most important findings to come from this research is that while the LEED system is constantly being updated, designers, contractors, manufacturers, owners and public regulations are even more quickly standardizing LEED requirements. Design firms and contractors and are quickly adopting LEED designs and processes as company policies in order to stay in line with industry best practices. Concurrently owners and government agencies are adopting policies and putting in place regulations that meet the LEED requirements. Additionally manufacturers are creating materials that meet LEED specifications and in some cases themselves specifying installation methods that meet or exceed LEED requirements. This evolution becomes apparent when reviewing the reasons that the work associated with credits either resulted in “No Change” or “Not Applicable,” because five of those ten reasons are related to this finding.

During interviews many contractors stated that LEED requirements are becoming “industry best practices” and, therefore, their company had decided to adopt means and methods that meet LEED requirements for all projects they work on, regardless of whether or not the project is pursuing LEED certification. A prime example of this is that Sustainable Site Prerequisite 1: Construction Activity Pollution Prevention was achieved with no change to the hazards faced by construction workers on all six projects because all six contractors stated that processes such as the use of silt fences and protecting storm water drains from sediment had become standard practice for their company.

On the design side, design firms have adopted many of the Indoor Environmental Quality credits as standard practice. Many designers stated the adoption of these standards was because of a professional belief in creating a facility for that is healthy and pleasant for the final occupants. Designers also stated that creating a facility with these standards makes good business sense, because a facility is enjoyed by its occupants and owners, can help to earn repeat business.

Many of those interviewed, including owners representatives, contractors and designers agreed that the LEED certification process has become more common due to the availability of materials that met LEED specifications. Multiple designers, on different projects, said that in the last five to ten years the availability of materials, such as low-emitting carpets and certified wood, has increased dramatically. This has both driven down the cost of these materials and given designers more choices, which combined has had the effect of making materials that meet LEED more common.

The final reason for more projects achieving LEED certification has been the a combination of the desire of owners to have projects LEED certified as well as government regulations forcing projects to meet specifications that also meet LEED requirements. The smoking regulations of the state of Colorado alone force all new buildings to meet the requirements of Indoor Environmental Quality Prerequisite 2. Additionally, many municipalities are adopting ASHRAE recommendations as building code requirements; therefore the requirements of several credits are met by following building codes. Finally, large owners such as universities are adopting policies such as the use of low flow water closets and urinals and use of LED lights in external fixtures, which meet LEED requirements for if nothing else, fiscal reasons.

The standardization of the LEED process resulted in several interesting conversations with both designers and contractors. Opinions on the future of green buildings varied from LEED needing to push the envelope further to LEED eventually disappearing. Two design teams felt strongly that the LEED scoring system no longer had requirements that were difficult enough. They promoted the idea that LEED should move from the promotion of green building techniques toward sustainable building techniques. One owner's representative, who was also a licensed Architect, felt that LEED requirements were "simply good practice" and should not be perceived as extraordinary. He went on to say that LEED had served an important role in bringing what he described as good practice to the forefront of conversation. On the other end of the spectrum there were many who felt that as LEED requirements were adopted as building codes the program will have served its purpose and could be eliminated.

5.7 Effects on Facility Maintenance

While not the primary focus of the study, there were several discussions with research participants on some of the effects on the maintenance of the facility as it concerned LEED design elements. The primary example found on two of the six cases was the use of permanent exterior windows making the cleaning of the windows more difficult and possibly increasing the exposure time of the worker at height. There were examples, however, of LEED designs possibly decreasing the hazards for workers maintaining the facility. Two of the projects received Innovation in Design Credits for adopting green cleaning and pesticide free landscaping maintenance policies. One project owner pointed out on a tour of the facility that continuing the exterior stone finish on some of the interior walls eliminated the need to maintain those walls. The same facility also chose a finished polished concrete floor because it would be easy to clean and maintain compared to other options such as tile systems.

5.8 Disconnect between Designers and Contractors

One consistent finding on all six projects was that designers had little knowledge on the means and methods that were required to achieve the LEED credits that were the primary responsibility of the construction team. Three credits were of specific interest in this area: Sustainable Sites Prerequisite 1: Construction Activity Pollution Control, Materials and Resources Credit 2: Construction Waste Management and Indoor Environmental Quality 3.1: Construction IAQ Management Plan. Most designers when asked what the LEED design element or process was to achieve this credit either gave vague answers or stated something similar to the policy found in the LEED handbook. When asked for the design or process alternative had LEED not been pursued on the project many of the designers simply referred the researcher to the contractor for this information.

Interestingly, two of these credits proved to have a significant impact on the safety of the construction workers. Construction waste management on LEED projects proved to be one of the most hazardous activities associated purely with the pursuit of LEED certification. This process introduced additional hazards and increased the total exposure time of five of the six cases that were studied. Construction IAQ management, had one of the greatest total impacts on worker safety and health of all the credits. This credit increased the hazards of the workers by increasing exposure time and frequency of ladder use while simultaneously having a positive impact on worker health by not allowing the use of acetones for cleaning or the running of equipment that emitting exhaust inside the facility unless properly ventilated to the outside.

5.9 Research Limitations

As with any research there are limitations to the results. The primary limitation of this research is that a majority of the data were received anecdotally through interviews with project participants. The findings were not supported through the inclusion of a significant amount of additional data such as accident reports or organizational job hazard analyses. Such information would strengthen the evidence of the causal relationships that make of the conclusions of this research. The limitations of this anecdotal evidence also extend to the lack of quantitative metrics in the analysis. The change in the severity, frequency and exposure of the risks encountered could not be quantified in this research. This limitation should be considered an opportunity for future research, which could serve as additional validation of the results.

A final limitation of this research was that there were no interviews conducted with the workers that were physically constructing and installing the LEED design elements. Ultimately, the individual at the workface are likely to have the most intimate knowledge of the hazards that they face. In some cases, collection of this data was not possible as the projects were complete and workers had moved on to other sites. Future research into the relationship of LEED and construction worker safety and health should consider examining this relationship from the perspective of the workers in order to gain to a more complete understanding.

CHAPTER SIX: FUTURE RESEARCH & APPLICATIONS

6.1 Development of Mitigation Strategies

This research served as the exploratory research into this topic and aimed to provide a strong foundation for future research to build upon. Answering following research question would be the next important step in this area of study: *How can the risks to construction worker safety and health presented by green design elements be alleviated or mitigated in the design or construction phase?* This question could be answered through a series of interviews with designers experienced with both LEED and non-LEED design elements. After being presented with the summary of LEED elements, the alternative non-LEED elements that would have been used had LEED certification was not sought, and the safety and health hazards posed by each LEED element the researcher and interviewees would brainstorm possible DfS techniques that may be incorporated into standard designs without compromising the ability of the project to be LEED certified. Examples of interventions may include grounding of electrical systems, appropriate clearances, tie-off locations for work at height, increased height of parapet walls, and others. Once interviews with designers are complete, the interventions could be presented to at least ten construction project managers to: (1) determine their feasibility, (2) determine their ability to prevent injuries and illnesses, and (3) to estimate their relative costs.

6.1.1 Tool Development

Once the mitigation strategies were identified the data could be packaged into a user-friendly MS Excel-based tool. This tool would function much in the same manner as the

Design for Safety Toolbox developed by Gambatese et al. (1997) and could possibly be merged with it to compile all the data in one place. It is expected that both designers and contractors could use the tool.

6.1.2 Designer Module

When provided with selected energy-efficient LEED design elements, the tool would provide the designer with safety and health hazard information, potential DfS interventions, and approximate costs associated with each intervention. It should be noted that this module would access data collected in every phase of the research.

6.1.3 Contractor Module

When provided with specific LEED design features the tool could access the data collected in the first phase of the research to produce a safety risk summary for each element along with best practices for safety management. The tool would access the safety risk information gathered through interviews with project managers, foremen, and workers and will be packaged in such a way that it can be easily integrated with safety orientation and training materials, inspections, job hazard analyses, and toolbox talks. It is expected that this tool can be used to significantly improve safety management on LEED projects.

6.2 Exposure Time Quantification

Another future study to build off of this would be the quantification of the additional exposure time created by a project pursuing LEED certification. Because an increased total exposure time for the workers was one of the major findings of this study it is important to be able to quantify these findings for several reasons. First, if on any project the injury rates were to remain steady but the overall exposure time were increased then in turn the total number of injuries on the project would increase. As past research as shown, increase in the number of injuries suffered on a project has an impact on many of the other project performance measures, such as cost, and schedule.

In order to conduct such a study, the number of projects reviewed would have be to greater than in this report, however the depth and quantity of data extracted from each project could be smaller. Data collection would need to center around those at the workface of a project, such as the subcontractors, foreman and the workers, as these individuals would likely be able to give the most accurate estimates for the increase in exposure time due to the credits that were found to increase exposure time in this research. Also of interest would be comparisons of total certified time sheets from LEED projects and comparable non-LEED project.

Due to the fact that research on the quantification of the increase of total exposure time would require more a broader sample of data but require less depth, a survey could likely be administered. The results of the research from this initial study could aid in the creation of specific questions, which also lends itself to a survey.

6.3 Administrative Costs of LEED

A final future study for this research would be to quantify the administrative costs of LEED. Many of the research participants in this study were eager to discuss the costs of LEED. While not the focus of this research, the researcher was able to gather interesting insight into some of what the research participants referred to as “the hidden costs” of LEED certification. The design and construction teams on Project E of this research both spoke at length about some of the hidden costs because they were fresh in their mind. The team had just finished a meeting to review comments on their LEED verification process recently received from the USGBC. One of the designers stated that the meeting "consisted of a dozen professionals, discussing LEED for approximately two hours. At $100 per hour per person it quickly becomes expensive." In this designer's estimate the project owner would ultimately pay $75,000 to $100,000 in extra administrative costs and time than if the project were not pursuing LEED certification.

A study to more accurately quantify the "hidden costs" of LEED could be informative in answering the question *"How much more does it cost to create a LEED certified building?"* Currently estimates exist, however many of these rely on increased material and labor prices. The quantification of the administrative costs could serve to give owners a better understanding of what their money goes toward when they choose to pursue LEED certification for their facility. This study could likely be examined as a series of case studies that could ultimately determine a percentage range of the additional costs that are incurred due to administrative LEED requirements.

6.4 Evaluation of LEED Scoring System by Section

When considering potential applications of the result of this research, the impact on future versions of the LEED scoring system was considered. The researcher found that the inclusion of credits for the project's safety record was not the only method that worker safety could be emphasized in the program. A positive affect on worker safety could also be made by systematically including in the specifications of individual credits safer designs and construction methods as recommendations or requirements. The sum of the variability index of the credits in each section of the LEED scoring system were evaluated in order to see where the largest impact could be made by implementing the findings of this study. These results are shown in Table 6.1.

Table 6.1: Summary of each LEED Scoring Section

Credit	Projects Attempting Credit	Increase	No Change	Decrease	N/A	Variability Index
Sustainable Sites	73	12	30	1	30	1.8
Water Efficiency	13	1	11	0	1	0.8
Energy & Atmosphere	46	14	21	1	10	3.3
Materials and Resources	31	8	22	1	0	2.9
Indoor Environmental Quality	84	20	37	20	11	4.8

Based on Table 6.1, construction worker safety adjustments to the Indoor Environmental Quality section of LEED would have the largest impact. This portion of the LEED scoring system had both the highest variability index and the greatest number of credits attempted by the projects that were studied in this research. There were a total of 20 increases and 20 decreases among the six projects in this section alone, which was composed of seventeen credits. Therefore, it would be the recommendation of this researcher if LEED were to pilot test such as program the most effective section to test would be the Indoor Environmental Quality section.

6.5 Recommended Applications of Research Findings

The final outcome of this research is to enable designers, contractors and owners to choose LEED design elements that the associated work has positive impacts on workers and avoid those that have a negative impact on workers. The researcher has identified five primary methods for designers and contractors to take advantage of the findings in this research: (1)

removal of the waste diversion processes from the site; (2) design of an under-floor HVAC system; (3) prefabrication or preparation of materials when possible; (4) pursuing credits that have no change on worker safety and health; (5) pursuing credits that were not applicable to this study.

6.5.1 Removal of Waste Diversion Process

On five of the six projects examined the research found that the achievement of Materials and Resources Credit 2: Construction Waste Management was one of the credits that the associated work had the greatest increase on the hazards faced by the construction workers. One of the projects, however, found a method to remove the hazards created from this work off the construction site and into a more controlled environment. Project C contracted with the dumpster removal and waste management company to send all the material from the site comingled to their locations. The waste management company would then sort and handle the materials in the appropriate manner and provide documentation of this process to the contractor. This documentation met the LEED requirements and the safety of the workers was not compromised. To build upon this, three representatives of the contracting team who were located on the site all found that by pursuing the credit in this manner the site actually became safer for the workers because there was added emphasis on keeping the site clean. Both the contractor and the designer, in separate interviews, agreed that having a cleaner site decreased the hazards faced by workers.

6.5.2 Under-floor HVAC System

Many of the project designers stated that LEED specifications require the project to have larger, more complex ventilation systems and HVAC systems with more controls. The contractors of these projects agreed with this and in turn stated that these HVAC systems caused workers to have an increased exposure time throughout the project. Project F, however, challenged this by designing their HVAC and ventilation systems to run under the floors. Having the HVAC system run under the floors made the installation process easier for the mechanical contractor. It eliminated the need for the workers to climb up ladders and install the ductwork in the ceilings. This easier installation made the process faster and decreased the exposure time of the workers. Additionally the occupants manually control many of the vents for the system and fewer thermostats were installed. The owner of the project went on to state that this under floor system was more efficient because it utilized the concept of heat rising and allowed occupants to have better control over their environments.

6.5.3 Prefabrication

This method for taking advantage of the findings of this research found focus on Indoor Environmental Quality Credit 3.1: Construction IAQ Management but certainly could have possible impacts on work associated with other credits. Three of the projects approaching this credit found that the need to cover open duct ends created extra work for the mechanical contractors, increasing exposure and frequency of ladder use. On Project C it was found that this credit had no change on worker safety and health because of the process used by the mechanical contractor to ensure that the extra work was not necessary. The general contractors stated that the mechanical contractor was making sure duct ends were covered previous to being delivered to the site. Because the plastic covering was already in place the worker on the site did not need to spend additional time on ladders ensuring that exposed duct ends were covered. This process could easily be duplicated on any LEED project with appropriate planning and lead times to create a safer process for the construction workers.

6.5.4 Pursuing No Change Credits

The most obvious solution to avoiding the additional hazards created by some credits and taking advantage of the findings in this research is to pursue the credits that the associated work was found to have no change in the safety and health hazards faced by the workers. Of the fifty-six credits that were evaluated after the grouping of credits that required the same processes and elimination of the Innovation in Design credits it was found that twenty-two (39%) credits had a no change impact on the workers. This leaves a project just four credits shy of achieving LEED certification, the lowest level of certification. Credits that fell in the "No Change" category were those that on at least 50% of the projects pursuing the credit found no change. Nine (41%) of these twenty-two credits were found to have no change on the workers on every project that pursued that credit. Therefore, the designs and construction means and methods to achieve these credits are readily available to designers and contractors.

6.5.5 Pursing 'Not-Applicable' Credits

In addition to pursuing credits that the associated work has no change on the health and safety of the construction workers there were thirteen credits (23%), which were found to be not applicable to the research over 50% percent of the time. Many of these credits are achieved because either the scope of the project ensured the project would achieve the credit due to its location or administrative work could be completed to meet the LEED specifications. These credits can be achieved through careful site selection and attention to detail in completing administrative paperwork that meets the LEED requirements, which has no impact on the safety and health of the construction workers. One additional credit not in the research data set, Innovation in Design Credit 2: LEED AP also falls in this category. This credit requires that certified LEED Accredited Professionals work on the project team. This brings the number of credits to fourteen that can be achieved and are "Not Applicable."

When combined with the credits that fell in the "No change" category a project can achieve thirty-six credits (64%) of the LEED credits in the data set of this research without having any impact on the safety and health of the workers. These thirty-six credits bring a project to LEED Silver. A project could then pursue the three credits that were found to cause only a decrease in the hazards faced by the workers to bring the total credits achieved to thirty-nine, qualifying the project as LEED Gold, the same level achieved on all six of the projects examined in this research. Therefore, it is possible for a project to choose only credits that either have no impact or a positive impact on worker safety and health and to still achieve LEED Gold certification.

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APPENDIX A: LEED SCORECARD

LEED-NC Version 2.2 Registered Project Checklist

<< enter project name >>

<< enter city, state, other details >>

Yes	?	No			
0	0	0		**Sustainable Sites**	14 Points
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
			Credit 1	**Site Selection**	1
			Credit 2	**Development Density & Community Connectivity**	1
			Credit 3	**Brownfield Redevelopment**	1
			Credit 4.1	**Alternative Transportation, Public Transportation Access**	1
			Credit 4.2	**Alternative Transportation, Bicycle Storage & Changing Rooms**	1
			Credit 4.3	**Alternative Transportation, Low-Emitting and Fuel-Efficient Vehicles**	1
			Credit 4.4	**Alternative Transportation, Parking Capacity**	1
			Credit 5.1	**Site Development, Protect of Restore Habitat**	1
			Credit 5.2	**Site Development, Maximize Open Space**	1
			Credit 6.1	**Stormwater Design, Quantity Control**	1
			Credit 6.2	**Stormwater Design, Quality Control**	1
			Credit 7.1	**Heat Island Effect, Non-Roof**	1
			Credit 7.2	**Heat Island Effect, Roof**	1
			Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
0	0	0		**Water Efficiency**	5 Points
			Credit 1.1	**Water Efficient Landscaping, Reduce by 50%**	1
			Credit 1.2	**Water Efficient Landscaping, No Potable Use or No Irrigation**	1
			Credit 2	**Innovative Wastewater Technologies**	1
			Credit 3.1	**Water Use Reduction, 20% Reduction**	1
			Credit 3.2	**Water Use Reduction, 30% Reduction**	1

Yes	?	No			
0	0	0		**Energy & Atmosphere**	17 Points
Y			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**Fundamental Refrigerant Management**	Required

Yes	?	No	Credit	Title	Points
			Credit 1	**Optimize Energy Performance**	1 to 10
			Credit 2.1	**On-Site Renewable Energy**	1 to 3
			Credit 3	**Enhanced Commissioning**	1
			Credit 4	**Enhanced Refrigerant Management**	1
			Credit 5	**Measurement & Verification**	1
			Credit 6	**Green Power**	1

Yes	?	No			
0	0	0		**Materials & Resources**	13 Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
			Credit 1.1	**Building Reuse, Maintain 75% of Existing Walls, Floors & Roof**	1
			Credit 1.2	**Building Reuse, Maintain 100% of Existing Walls, Floors & Roof**	1
			Credit 1.3	**Building Reuse, Maintain 50% of Interior Non-Structural Elements**	1
			Credit 2.1	**Construction Waste Management, Divert 50% from Disposal**	1
			Credit 2.2	**Construction Waste Management, Divert 75% from Disposal**	1
			Credit 3.1	**Materials Reuse, 5%**	1
			Credit 3.2	**Materials Reuse,10%**	1
			Credit 4.1	**Recycled Content, 10% (post-consumer + ½ pre-consumer)**	1
			Credit 4.2	**Recycled Content, 20% (post-consumer + ½ pre-consumer)**	1
			Credit 5.1	**Regional Materials, 10% Extracted, Processed & Manufactured Regionally**	1
			Credit 5.2	**Regional Materials, 20% Extracted, Processed & Manufactured Regionally**	1
			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1

Yes	?	No			
0	0	0		**Indoor Environmental Quality**	15 Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke Control**	Required
			Credit 1	**Outdoor Air Delivery Monitoring**	1
			Credit 2	**Increased Ventilation**	1
			Credit 3.1	**Construction IAQ Management Plan, During Construction**	1
			Credit 3.2	**Construction IAQ Management Plan, Before Occupancy**	1
			Credit 4.1	**Low-Emitting Materials, Adhesives & Sealants**	1
			Credit 4.2	**Low-Emitting Materials, Paints & Coatings**	1
			Credit 4.3	**Low-Emitting Materials, Carpet Systems**	1

Yes	?	No	Credit	Title	Points
			Credit 4.4	**Low-Emitting Materials, Composite Wood & Agrifiber Products**	1
			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
			Credit 6.1	**Controllability of Systems, Lighting**	1
			Credit 6.2	**Controllability of Systems, Thermal Comfort**	1
			Credit 7.1	**Thermal Comfort, Design**	1
			Credit 7.2	**Thermal Comfort, Verification**	1
			Credit 8.1	**Daylight & Views, Daylight 75% of Spaces**	1
			Credit 8.2	**Daylight & Views, Views for 90% of Spaces**	1

Yes	?	No		
0	0	0	Innovation & Design Process	5 Points

Yes	?	No	Credit	Title	Points
			Credit 1.1	**Innovation in Design: Provide Specific Title**	1
			Credit 1.2	**Innovation in Design: Provide Specific Title**	1
			Credit 1.3	**Innovation in Design: Provide Specific Title**	1
			Credit 1.4	**Innovation in Design: Provide Specific Title**	1
			Credit 2	**LEED® Accredited Professional**	1

Yes	?	No		
0	0	0	Project Totals (pre-certification estimates)	69 Points

Certified 26-32 points Silver 33-38 points Gold 39-51 points Platinum 52-69 points

APPENDIX B: CASE STUDY REPORTS

Project A

Project Introduction

Project A is a 304,000 square foot Class A office building located in Broomfield, CO. The design-build project was delivered by a joint venture between a large design firm and a medium-sized general contractor. The contract was a negotiated as a guaranteed maximum price with an incentive clause. The initial developer of the project quickly found a buyer and then acted as the owner's representative for the remainder of the project. The developer initially planned to achieve silver LEED certification; however, as the design progressed, the new Owner pushed for LEED Gold status. The expected final LEED certification level is Gold, with the building achieving 38 of the 61 available credits using the LEED Core & Shell V2.1 scoring system. During the time of the case study (August 2010), the project was substantially complete and the project was being closed-out. At this time tenants had begun to move into some of the spaces.

Case Findings

Ultimately, the project aimed to achieve a total of 38 credits, while meeting the additional 7 pre-requisites for LEED certification. After examination of the credits that were achieved the researcher determined that after combining similar credits there were 32 credits to examine for this case. The additional 7 pre-requisites to created a data set of 39 credits for this study. These 39 credits served as the data set for this study. Thirty-two of the 39 credits (82%) were found to have no impact on the hazards the construction workers faced while installing or constructing the facility. Those interviewed stated that there were 7 primary reasons for no change in the worker's safety between the LEED and traditional non-LEED design elements:

1. The scope of the project ensured the project would achieve the credit due to its location.
    a. Project was located near existing public transportation options.
    b. Office complex has a chiller building already meeting requirements.
    c. Office complex already uses a non-potable water system for landscaping maintenance.
2. Smoking regulations in the state of Colorado require that new construction meet standards that also meet LEED standards.
3. Credits were achieved by meeting the requirements of a Class A office building.
    a. A Class A offices require climate controlled parking that was met by the underground parking structure.
    b. Baseline level commissioning is standard for a Class A facility.
4. The installation or construction process of an element was the same
    a. Exterior light fixtures.
    b. The landscaping of the site, specifically the grass.
    c. Low flush water closets and urinals.
    d. Mechanical equipment throughout the building.
    e. All recycled, regional and certified materials.
    f. 90% of occupied spaces have views
5. Achievement of the credit had no impact on the construction phase of the project.
    a. The tenant manual describing LEED building elements created by the designer.
    b. The purchase of green energy credits.
    c. LEED AP certified team members.
6. Designing to the LEED specifications have become a standard practice for the designer.

    a. Designer complies with ASHRAE standards on all construction projects.
    b. Indoor air quality monitoring system
    c. Building ventilation system
    d. Low emitting materials such as carpets, paints and sealants.
    e. Building temperature and humidity controls
7. The contractor has a policy of using work methods that meet the LEED requirements.
    a. Indoor construction air quality management program.
    b. Contractor complies with ASHRAE standards on all construction projects.

The final seven credits (18%) that were achieved did have an impact on the safety and hazards encountered by the workers. According to the contractor, of these seven credits, six exposed the workers to additional hazards on the job site and one decreased the hazards that the workers faced. The designer cited two additional credits that had a hazard increase for the workers; however, the contractor did not confirm this finding.

Increase in Hazards

These credits were cited by the contractor as increasing the hazard faced by the workers as compared to the traditional design alternative. An increased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard.

1. *Sustainable Sites Credit 4.3: Installation of signage to indicate parking spaces that are dedicated for fuel efficient vehicles*– the concrete footing that the metal signage fits in exposes the workers to hitting underground utilities and, therefore, increased exposure to electrocution risks according to the Project Manager.

2. *Sustainable Sites Credit 7.2: Use of white Thermoplastic Olefin (TPO) roof vs. standard black ethylene propylene diene monomer (EPDM roof)*– the material used for the TPO roof is heavier and the installation process is more labor intensive. This exposes workers to overexertion injuries.
3. *Energy and Atmosphere Credit 5.2: Utility metering for each tenant space*– this requires the installation of more electrical wires, piping, and rough-ins throughout the facility, increasing exposure to electrical hazards.
4. *Materials and Resources Pre-requisite 1, Credit 2, and Innovation in Design Credit 1.2- All of these credits were achieved by the recycling program and the diversion of 95% of the construction waste throughout the project.* To achieve this credit additional laborers are needed to sort and direct the sorting of recyclables and waste. One primary material that was sorted was drywall and the gypsum, which posed an inhalation hazard for workers. A new hazard created by this activity was that workers occasionally entered the dumpsters to obtain recyclable materials, exposing them to potential cuts and punctures. Finally, because the materials were sorted into separate dumpsters there was an increase in the number of times the dumpsters were transported to and from the site. This exposes workers to struck-by and struck-against hazards from the large trucks.

Decrease in Hazards

These credits were cited by the contractor as decreasing the hazard faced by the workers as compared to the traditional design alternative. A decreased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard.

1. *Sustainable Sites Credit 4.4: Less parking spaces were designed for the building than would normally be required for this level of occupancy*- There was a decreased amount of time that workers were exposed to injuries from heavy machinery, most notably struck-by and struck-against incidents. This is because normally the facility would need an additional 14 parking spaces, which would require additional man-hours and therefore increased exposure time.

Miscellaneous Findings

There were two credits that the designer believed had an effect on the safety of the construction worker due to LEED. The contractor in later interviews did not echo these sentiments. The first credit was Water Efficiency Credits 3: The use of low flush urinals and low flush water closets with dual flush valves- The designer believed that the dual flush valve had a longer installation time than standard valves, therefore increasing exposure time. When asked, the contractor felt that the installation time was similar and that this posed no additional hazard, especially because these units were becoming standard in new office buildings.

The second credit that the designer felt had an impact on worker safety was Energy and Atmosphere Pre-requisite 1: The building was commissioned in order to ensure that the HVAC and electrical systems were operating at optimum design levels. The designer felt that this increased worker exposure time by going through with this process because it would not normally be done. The contractor however stated that for a Class A office building of this cost and size the owner almost always wants commissioning done, whether the project is trying to achieve LEED certification or not. Therefore, this process has become a standard practice for the contractor on all projects of this type.

When asked whether any of these hazards were considered during job hazards analyses, the contractor replied that dumpsters were a constant point of conversation at safety discussions both in the office and on site. While the contractor had not yet developed a separate program to manage dumpster safety, they consider such a program to be a high priority.

During discussion of LEED in general the contractor felt that "a majority of the requirements for LEED credits are just becoming part of the industry's best practices." Therefore, any company that strives to keep up with the best practices could achieve LEED certification on virtually any building and he felt that this was a sign of "the LEED program doing its job." Because of these facts the contractor plans to construct every building in the spirit of LEED and sustainability. However, they will not necessarily pursue certification for the plaque because of the high cost charged by USGBC.

Project B

Project Introduction

Project B is a 318,000 square foot institutional facility composed of an underground parking structure, an industrial kitchen on the bottom floor, dining facilities on the main floor and several floors of offices above. The project is located within a large university in the city Boulder, CO. The design build project was delivered by a joint venture between a medium-sized design firm and a large contractor. An additional large design firm consulted on the project in order to keep the project cohesive with the overall aesthetics of the campus. The project had a guaranteed maximum price of approximately $70 million.

The project is expected to achieve LEED Gold certification when completed, with the building achieving 46 of 69 possible credits using the LEED New Construction and Major Renovations scoring system. During the time of the case study (August/September 2010), the project was substantially complete and the project was being closed out. At this time the industrial kitchen was working and dining area was open to students and the public. Occupants had also begun moving into some of the office spaces on the upper floors.

Case Findings

The project aimed to achieve a total of 46 credits, while meeting the additional 7 pre-requisites required for LEED certification. After examination of the credits that were achieved the researcher determined that after combining similar credits there were 40 credits to examine for this case. The additional 7 pre-requisites to created a data set of 47 credits for this study. These 47 credits served as the data set for this case study. Thirty of the 47 credits (64%) were found to have no impact on the hazards the construction workers faced while installing or constructing the facility. Those interviewed stated that there were 7 primary reasons for no change in the worker's safety between the LEED and tradition non-LEED design elements:

1. Smoking regulations in the state of Colorado and the University require that new construction meet standards that also meet LEED standards.
2. The contractor has a policy of using work methods that meet the LEED requirements.
    a. The contractor uses a storm water and site management plan that meets LEED requirements on all projects.
    b. Standard construction indoor air quality program of the contractor meets LEED requirements.
3. The scope of the project ensured the project would achieve the credit due to its location.
    a. The project is within the university property and therefore on developed land.
    b. Because the project is located centrally within the campus the building does not create any additional light pollution.
    c. The project is located near to public transportation.
4. The installation or construction process of an element was the same
    a. Changing rooms and bike racks
    b. Installation of signage in parking structure
    c. The selection of native and low water use plants.
    d. Low flush water closets and urinals
5. Achievement of the credit had no impact on the construction phase of the project.
    a. University manages the purchase of green space collectively and not from project to project.
    b. The use of light colored concrete has the same installation methods.

c. Monitoring of building energy output after completion.
d. Purchasing of green energy credits
e. All recycled, regional and certified materials
f. Submittals proving VOC's are not entering facility during construction
g. Thermal comfort survey of final occupants
h. LEED AP certified team members

6. The project owner has policies that meet the requirements of LEED.
   a. The use of LED exterior lights is a campus standard.
   b. Baseline level building commissioning is completed on all campus facilities.
   c. No CFC refrigerants used on the project.
   d. University recycling program meets requirements
7. Designing to the LEED specifications have become a standard practice for the designer.
   a. Building ventilation system.
   b. Building temperature and humidity controls

The final seventeen credits (36%) that were achieved did have an impact on the safety and hazards encountered by the workers. According to the contractor, of these seventeen credits, twelve exposed the workers to additional hazards on the job site and five decreased the hazards that the workers faced.

Increase in Hazards

These credits were cited by the contractor as increasing the hazard faced by the workers as compared to the traditional design alternative. An increased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard.

1. *Sustainable Sites Credit 4.4: Use of a multi level underground parking structure to minimize the area used for parking*- The large parking structure for the facility greatly increased the number of hazards and exposure time for workers involved in the creation of the foundations. This process caused workers to be exposed to trench work to install shoring and to remove the wood after the shoring was no longer needed. The removal of the shoring wood was tied specifically to LEED in order make sure that material did not count toward material used for construction, which would have jeopardized the project receiving credit for using a specified percentage of certified wood. Trench work is one of the most dangerous construction activities, this exposed workers to cave-in incidents. Additionally during the excavation process there were over 400 trucks entering and leaving site each day. This heavy truck traffic required workers control the traffic at the construction entrance to the site. Working near to controlled traffic is statistically one of the most deadly activities in the construction industry. Workers risk being struck-by both construction and non-construction vehicles. The final additional hazard created by including the parking structure was the fall hazard created by the large excavation. In order to prevent fall injuries the contractor needed a full time carpenter to ensure that all the fall protection for the excavation site was in place and safe.
2. *Sustainable Sites Credit 6.2: Increased size of the water detention system*- The additional work first creates additional exposure time. Specifically, the detention system was located in an area that trucks, other machinery and, workers could have fallen into the holes. Constant protection and awareness reminders of the detention system excavations were needed.

3. *Energy and Atmosphere Pre-requisite 2: Use of economizers in the mechanical system-* The economizers that were used require additional piping for hot water heating, which increases worker exposure time. The hoods in the kitchen, instead of exhausting all the air have another piece designed to remove grease and allow the air to be reused in the facility. The installation of this additional mechanism also increases worker exposure time.
4. *Energy and Atmosphere Credits 1, and 4: Use of evaporative chillers to increase the efficiency of the building systems-* This system has more controls that require wiring than traditional systems and therefore workers have a longer exposure time during installation.
5. *Energy and Atmosphere Credit 3: Enhanced commissioning process-* This process creates additional exposure time on the site for both the contracting and exposes the commissioning agents to the hazards of the construction site.
6. *Materials and Resources Credits 2: The recycling and diversion of construction waste throughout the project achieved these credits* - This occasionally required workers to "dumpster dive" in order to sort materials that were not disposed of properly. This activity exposes the workers to scrapes, abrasions and puncture injuries. Working on the uneven surfaces can also cause ankle sprains.
7. *Indoor Environmental Quality Credit 1: Installation of alarm system that monitors air quality in the facility-* This created extra exposure time as workers had to mount and wire the devices.

8. *Indoor Environmental Quality Credit 6.1: Installation of occupancy sensors in all offices, hallways and the parking structure-* This created extra exposure time as workers had to mount and wire the device.
9. *Innovation in Design Credits 1.2, 1.3 and, 1.4: Organic food and food waste composting program-* This program requires in the installation of a centrifuge mechanism which sends food waste to farms for composting and sends water to be used for non-potable uses. The installation of this system required more piping, increasing worker exposure time.

Decrease in Hazards

These credits were cited by the contractor as decreasing the hazard faced by the workers as compared to the traditional design alternative. A decreased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard.

1. *Indoor Environmental Quality Credit 3.1: Minimum IEQ performance for final occupants and during construction-* This requires that workers use different chemicals during specific processes than are traditionally used. This includes acetones during cleaning cutting fiberboard that does not contain urea formaldehyde. Both of these chemicals can be harmful to the health of the workers and this hazard is eliminated through the processes used to achieve these credits.
2. *Indoor Environmental Quality Credits 4.1, 4.2, 4.3 and, 4.4: Use of low VOC adhesives, sealants, paints, carpets, composite wood and agrifiber products-* Workers are exposed to lower VOC levels during the installation and construction of these products, therefore decreasing the severity of this hazard.

Miscellaneous Findings

When asked whether any of these hazards were considered during the job hazard analyses, the contractor replied that dumpsters were discussed and considered. The contractor stated that the company had a safety plan to mitigate the hazards created by dumpsters and the diversion of waste, but was unable to locate it. For this particular project a significant amount of time was spent discussing the shoring during the excavation for this project. While the discussion was not specifically focused around the shoring and its relationship to LEED, the contractor mentioned that a significant amount of time was spent ensuring the shoring work would proceed safely.

During a discussion of LEED and its impact within the industry the contract felt that a lot of the LEED products and procedures were becoming standard practice in the industry. The contractor felt that the impact from LEED was felt more during the design phase of a project. The main differences created by LEED for the contractors were additional paperwork, more careful buy-out procedures and occasionally additional staffing for the documentation. Another point noted by the contractor was the impact of LEED in the manufacture of materials for projects. They sited the example of the "cradle to cradle" carpet and glass that was used on the project. These materials are specifically designed and manufactured to be completely recycled. While the contractor did not know specifically they hypothesized that this could create significant changes in the manufacturing process, which may affect the safety of those workers.

Project C

Project Introduction

Project C is a 165,000 square foot institutional laboratory facility located on a medical campus in Aurora, CO. The building contains numerous teaching and research laboratories. The project was designed by a large design firm and delivered through a construction manager at risk delivery method. A large construction firm served as the construction manager with a cost plus fee contract with the owner worth approximately $50 million. At the time the case study was completed (September 2010) the project was approximately 85% complete. The project's expected LEED certification level is Gold, with the building achieving 44 of 69 available credits using the LEED New Construction and Major Renovations V2.2 scoring system.

Case Findings

Ultimately, the project aimed to achieve a total of 44 credits, while meeting the additional 7 pre-requisites for LEED certification. After examination of the credits that were achieved the researcher determined that after combining similar credits there were 37 credits to examine for this case. The additional 7 pre-requisites to created a data set of 44 credits for this study. Thirty-three of the 44 credits (75%) were found to have no impact on the hazards the construction workers faced while installing or constructing the facility. Those interviewed stated that there were 8 primary reasons for no change in the workers safety between the LEED and traditional non-LEED design elements:

1. The contractor has a policy of using work methods that meet the LEED requirements.
    a. The contractor uses a storm water and site management plan that meets LEED requirements on all projects.

2. The scope of the project ensured the project would achieve the credit due to its location.
    a. The project is within the university property and therefore on developed land.
    b. The project is located near to public transportation.
    c. No additional parking was needed for the facility
3. The installation or construction process of an element was the same
    a. Remediation of underground piping and asbestos.
    b. Changing rooms and bike racks
    c. Installation of signage in parking structure for low emitting vehicles
    d. Vegetation area around the building is equal to the building footprint
    e. Selection of native and low water use plants
    f. Low flush water closets and urinals
    g. Efficient mechanical and electric systems throughout the building
    h. No CFC refrigerants used on the project
    i. Enhanced commissioning process
    j. Installation of windows to provide views
    k. 90% of occupied spaces have views
4. The project owner has policies that meet the requirements of LEED
    a. Baseline level building commissioning is completed on all campus facilities.
    b. Recycling program of the campus meets requirements
    c. Campus
5. Achievement of the credit had no impact on the construction phase of the project
    a. All recycled, regional and certified materials
    b. Building flush out previous to occupancy

c. Thermal comfort survey of final occupants

d. A case study of the building and tours will be conducted.

e. The facility will maintain green cleaning policies.

f. Use of the Labs 21 program for laboratory equipment sizing and selection

g. LEED AP certified team members

6. Credits were achieved by meeting the requirements of the laboratory facilities

    a. Building ventilation system

7. Smoking regulations in the state of Colorado and the University require that new construction meet standards that also meet LEED standards.

8. Designing to the LEED specifications have become a standard practice for the designer.

    a. Building temperature and humidity controls

The final eleven credits (25%) that were achieved did have an impact on the safety and hazards encountered by the workers. According to the contractor, of these twelve credits, five exposed the workers to additional hazards on the job site, five decreased the hazards, and one both increased and decreased the hazards that the workers faced.

Increase in Hazards

1. *Sustainable Sites Credit 7.1: Use of exterior window shades to decrease the building's non-roof heat island effect*- The contractor stated that this design created a hazard for construction or later maintenance workers attempting to clean the windows. The permanent shades make it difficult to move from window to window and exposes the workers to fall injuries by extending the time they spend in a scissor lift to clean the windows.

2. *Sustainable Sites Credit 7.2: The use of a white TPO roof to reduce the building's roof heat island effect*- As compared to an black EPDM roof the white TPO material is "blindingly" bright and a more slippery surface. In addition, the white surface does not melt roof snow as well and makes the roof even more slippery. The surface impairing the vision of workers and being more slippery increases the severity of the hazards faced while completing roof work. The most notable hazard for such work is falling from heights, which can often lead to severe injury.
3. *Indoor Environmental Quality Credit 1: Inclusion of CO2 monitoring system throughout the building*- Worker exposure time is increased as a result of having to mount and wire the devices.
4. *Indoor Environmental Quality Credit 5: Inclosing of janitorial and copy room spaces to control pollutants*- To achieve this credit workers need provide a small amount of extra duct work with a fan. This task increases their exposure time to construction site hazards.
5. *Indoor Environmental Quality Credit 6.1: Installation of occupancy sensors in all offices and hallways*- This created extra exposure time as workers had to mount and wire the device.

Decrease in Hazards

These credits were cited by the contractor as decreasing the hazard faced by the workers as compared to the traditional design alternative. A decreased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard.

1. *Energy and Atmosphere Credit 4: Use of a refrigerant that has less impact on the ozone*- The contractor believe that because this refrigerant released less compounds into the environment it was healthy for the workers during and after installation.
2. *Materials and Resources Credits 2: Diversion of construction waste from disposal*- This credit puts an emphasis on the contractors keeping a site clean. Both the contractor and the designer, in separate interviews, agreed that having a cleaner site decreased the hazards faced by workers in two ways. First, having a clean site means that the workers are exposed to less trip and fall hazards then they traditionally would. Second, the clean site meant that workers could be more productive because they would be less likely to lose track of items needed to complete their work and would spend less time avoiding construction debris. This increased productivity should theoretically decrease the number of hours the workers are exposed to construction site hazards.
3. *Indoor Environmental Quality Credits 4.2, 4.3 and, 4.4: Use of low VOC paints, carpets, wood and agrifiber products*- Workers are exposed to lower VOC levels during the installation and construction of these products, therefore decreasing the severity of this hazard. The designers also felt that the low VOC products were safer for the workers.

Both an Increase and Decrease in Hazards

1. *Indoor Environment Quality Credit 4.1: Use of low VOC adhesive products*- Workers are exposed to a lower VOC level while installing these products therefore decreasing the severity of this hazard. However, the project superintendent stated that because the adhesives are not as effective as the non-LEED materials more time is spent preparing for their application. The longer prep time alone increases worker exposure time. The

preparation process often includes grinding and smoothing the concrete surface. The grinding of concrete creates a silica dust hazard for the workers.

Miscellaneous Findings

The construction team felt that a LEED certified building added “no huge inherent risk” to worker safety. Things such as recycling and sorting waste quickly become standard practice for the workers. This was of particular note because this project was achieving the waste diversion credits through a third party. The waste and dumpster company, for a fee, also sorted the waste for the contractor and provided documentation that the construction debris was diverted from landfills. While this may increase the severity or exposure time of the workers at the waste management facility this removed the “dumpster problem” from LEED construction sites.

Another point that was made by the construction team was the emphasis on the indoor air quality and the smoking regulations during the construction phase. The combination of not being able to smoke on the site or on the campus surrounding the site, forced workers to walk further then they were used to in order to smoke. According to the construction team this was causing workers to actually smoke less and in a few cases served as an impetus for workers to actually quit smoking all together. The positive health impacts for the workers who quit smoking are well documented. In addition, this removes other non-smoking workers from second hand smoke, which research has also shown to have negative health impacts.

Project D

Project Introduction

Project D is a 200,000 square foot institutional laboratory located on university campus shared by several institutions in Denver, CO. The building contains numerous research and teaching laboratories. The project was designed by a medium-sized design firm and delivered by a large construction company as the construction manager. The cost plus fee contract between the contractor and the owner was worth approximately $65 million. At the time the case study was completed (August-September 2010) the project was complete and occupied. The project's expected LEED certification level is Gold, with the building achieving 51 of 69 available credits using the LEED New Construction and Major Renovations V2.2 scoring system.

Case Findings

Ultimately, the project aimed to achieve a total of 51 credits, while meeting the additional 7 pre-requisites for LEED certification. After examination of the credits that were achieved the researcher determined that after combining similar credits there were 42 credits to examine for this case. The additional 7 pre-requisites to created a data set of 49 credits for this study. Thirty-seven of the 49 credits (76%) were found to have no impact on the hazards the construction workers faced while installing or constructing the facility. Those interviewed stated that there were 7 primary reasons for no change in the workers safety between the LEED and traditional non-LEED design elements:

1. The contractor has a policy of using work methods that meet the LEED requirements.
    a. The contractor uses a storm water and site management plan that meets LEED requirements on all projects.

2. The scope of the project ensured the project would achieve the credit due to its location.
    a. The project is within the university property and therefore on developed land.
    b. The project is located near to public transportation.
    c. Old foundations were found and were removed from the site.
3. The installation or construction process of an element was the same
    a. Changing rooms and bike racks
    b. Installation of signage for low emitting vehicles
    c. Use of light colored concrete.
    d. Exterior light fixtures
    e. Low flush water closets and urinals
    f. No CFC refrigerant system
    g. Regional and certified materials
    h. Low emitting paints, carpets and composite wood materials
    i. Location of laboratories ensured sufficient light and views
4. Achievement of the credit had no impact on the construction phase of the project.
    a. No additional parking was added
    b. Vegetation area around the building is equal to the building footprint
    c. Measurement and verification of the energy output of building after completion
    d. Building flush out process of mechanical systems
    e. Thermal comfort survey of occupants after completion
    f. LEED AP on the project team
    g. Signage installed by facilities management after completion
    h. Campus purchase of green power

5. Designing to the LEED specifications have become a standard practice for the designer.
    a. Indoor air quality meets ASHRAE standards
    b. Building temperature and humidity controls
6. Credits were achieved by meeting the requirements of the laboratory facilities
    a. Use of CO2 monitors in laboratory spaces
    b. Ventilation system
7. Manufacturer requirements meet LEED requirements
    a. Testing of the fume hoods used in the laboratories

The final thirteen credits (24%) that were achieved did have an impact on the safety and hazards encountered by the workers. According to the contractor, of these thirteen credits, twelve exposed the workers to additional hazards on the job site, none of the credits decreased the hazards and one credit both decreased and increased the hazards that the workers faced.

Increase in Hazards

These credits were cited by the contractor as increasing the hazards faced by the workers as compared to the traditional design alternative. An increased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard.

1. *Sustainable Sites Credits 6.1 and 6.2: Use of detention ponds to limit erosion in storm water stream channels*- Overall the storm water management of the site needed to be larger and this required the use of detention ponds. The construction of the detention ponds increased worker exposure time to heavy machinery and therefore struck-by or struck-against incidents. This work also required trench work, creating an exposure to

cave-ins. Finally once completed the detention ponds created a standing water hazards to the workers near to the site.

2. *Energy and Atmosphere Pre-requisite 1 and Credit 3: Building commissioning and enhanced commissioning*- The commissioning process brings additional personal on to the site, exposing them to the hazards of a construction work site. The commissioning process requires the commissioning agent to spend a significant amount of time climbing up ladders and inspecting work done above the ceiling. This exposes them to falls.
3. *Energy and Atmosphere Credits 1 and 4: Use of evaporative cooling chiller in the building*- The evaporative cooling chiller, according to the contractor, is heavy and requires additional piping. This increases the exposure time for workers and the heavy equipment increases the severity of an overexertion hazard.
4. *Materials and Resources Credit 2: Diversion of construction waste from landfills*- This credit increases the number of laborers needed on the job and therefore the number of exposure hours. Additionally, workers sometimes need to enter the dumpsters to sort waste that was improperly disposed of. This exposes them to punctures and abrasion injuries.
5. *Materials and Resources Credits 4: Use of fly ash in concrete as a recycled material*- The fly ash concrete is more difficult to finish than typical concrete and takes more man-hours, increasing exposure time. While it did not occur on this project, the contractor stated that they had heard of instances where fly ash had caused the need for rework.

6. *Indoor Environmental Quality Credit 4.1: The use of low emitting adhesives*- The low emitting adhesives are not as high quality and don't stick as well. This creates the need for more prep and rework than normal. This increases man-hours and in turn exposure time.
7. *Indoor Environmental Quality Credit 5: Exhaust system in copy rooms and custodial storage closets to minimize indoor contaminants*- This requires the installation of an extra duct and an extra fan for these room, which increases exposure time for the workers.
8. *Indoor Environmental Quality Credit 6.1 and 6.2: Use of sensors to help control indoor lighting and temperature*- This requires extra wiring to install the sensors and occasionally additional time spent on ladders for the electricians. This creates an extra fall hazard and increase exposure time to other hazards.

Both an Increase and Decrease in Hazards

1. *Indoor Environmental Quality Credit 3.1: Indoor site management during the construction phase*- This requires more man hours spent keeping the site clean, therefore increasing the total exposure time for the project. The cleaner site however, decreases the hazards faced by workers in two ways. First, having a clean site means that the workers are exposed to less trip and fall hazards then they traditionally would. Second, the clean site meant that workers could be more productive because they would be less likely to lose track of items needed to complete their work and would spend less time avoiding construction debris. This increased productivity should theoretically decrease the number of hours the workers are exposed to construction site hazards.

Miscellaneous Findings

Overall the contractor felt that LEED project require a significant number of additional man-hours as compared to traditional non-LEED projects. This increases the overall exposure time to construction site hazards. Many of these hours are reflected in additional physical labor hours as well as administrative time. These additional hours are reflected in a majority of the credits that were found to increase the hazards faced by workers.

The designer made two comments discussing the inconsistency of LEED requirements. The first point made was that the low VOCs requirement is only for interior spaces and that the credit could still be attained if higher VOC materials were used on the exterior, for example coatings on MEP roof units. Second, the designer pointed out that no credits were available for using less materials, for example leaving finished concrete floors as opposed to tiles or carpeting. In terms of safety this would create less exposure for the workers constructing the design.

Project E

Project Introduction

Project E is a 131,000 square foot student housing facility located on a large university campus in Boulder, CO. The building is five stories tall and contains housing for approximately 500 students as well as larger common spaces. A large national construction company delivered the project through a design-build process. The construction company subcontracted the design out to a medium sized local design firm. The contract was a guaranteed maximum price contract worth approximately $51 million. At the time the case study was completed (September 2010) the project was under construction and estimated to be 60% complete by the parties interviewed. The project's expected LEED certification level is either Gold or Platinum with the building attempting to achieve 53 of 69 available credits using the LEED New Construction and Major Renovations V2.2 scoring system.

Case Findings

Ultimately, the project aimed to achieve a total of 53 credits, while meeting the additional 7 pre-requisites for LEED certification. After examination of the credits that were achieved the researcher determined that after combining similar credits there were 45 credits to examine for this case. The additional 7 pre-requisites to created a data set of 52 credits for this study. Thirty-three of the 52 credits (63%) were found to have no impact on the hazards the construction workers faced while installing and constructing the facility. Those interviewed stated that there were 7 primary reasons for no change in the workers safety between the LEED and traditional non-LEED design elements.

1. The contractor has a policy of using work methods that meet the LEED requirements.

    a. The contractor uses a storm water and site management plan that meets LEED requirements on all projects.
2. The scope of the project ensured the project would achieve the credit due to its location.
    a. The project is within the university property and therefore on developed land.
    b. The project is located near to public transportation.
    c. Because the project is located centrally within the campus the building does not create any additional light pollution.
3. The installation or construction process of an element was the same
    a. Site water runoff plan
    b. The selection of native and low water use plants.
    c. Low flush water closets and urinals
    d. All recycled, regional and certified materials
    e. Installation of signage throughout the facility
4. Achievement of the credit had no impact on the construction phase of the project.
    a. No additional parking was added
    b. University manages the purchase of green space collectively and not from project to project.
    c. Thermal comfort survey of final occupants
    d. LEED AP certified team members
    e. Monitoring of building energy output after completion.
    f. Purchasing of green energy credits
    g. Building flush out process of mechanical systems
5. The project owner has policies that meet the requirements of LEED.

a. Baseline level building commissioning is completed on all campus facilities.

b. No CFC refrigerants used on the project.

c. Integrated pest management plan

6. Designing to the LEED specifications have become a standard practice for the designer.

a. Building meets ASHRAE standards for energy performance

b. Building temperature and humidity controls

c. Building ventilation system.

7. Smoking regulations in the state of Colorado and the University require that new construction meet standards that also meet LEED standards.

The final nineteen credits (37%) that the project was attempting to achieve did have an impact on the safety and hazards encountered by the workers. According to the contractor, of these nineteen credits, fifteen exposed the workers to additional hazards on the job site and four decreased the hazards that the workers faced.

Increase in Hazards

These credits were cited by the contractor as increasing the hazard faced by the workers as compared to the traditional design alternative. An increased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard.

1. *Sustainable Sites Credit 4.2: Construction of a bike shelter for all of the bike racks that were constructed*- The construction of this hazard requires additional time for workers to at an elevated height, creating a new fall hazard for this project.
2. *Sustainable Sites Credit 4.3: Installation of signage to designate parking spaces for low emitting vehicles*- Because the project is located near to other university facilities this

process was done in an active parking lot and required some light traffic control. The workers were exposed to being struck-by non-construction vehicles during the installation of these signs.

3. *Sustainable Sites Credit 7.2: Use of clay tiles as a roofing material*- The clay tiles are heavier than more traditional asphalt tiles that could have been used on the project. This increased the severity of overexertion injuries for the roofers.
4. *Water Efficiency Credit 2: Use of a dual wastewater system*- The dual waste water system uses water from sinks and showers and then dyes and reuses it as water for the water closets. This dual wastewater system requires significantly more piping; therefore increasing man-hours and exposure time. In addition before the water is sent to the toilets it undergoes a filtration and chlorination process, which exposes the workers to the chlorine while installing the system.
5. *Energy and Atmosphere Credit 1: Use of heavier insulation and an empathy wheel to treat incoming air*- The heavier insulation on the shell of the building increases the severity of potential overexertion injury as well as increasing the severity of a fall incident because these materials are handled at height. The empathy wheel causes the Energy and Heat Recovery Ventilators (ERV) to be heavier, which must be considered during crane picks of these units. For workers directing these units into place the severity of the pre-existing struck-by hazard is increased.
6. *Energy and Atmosphere Credit 2: Use of a passive solar hot water system*- This creates an additional fall hazard as it requires a new trade to work on the sloped roof of the facility.

7. *Energy and Atmosphere Credit 3: Enhanced building commissioning*- This level of commissioning goes above and beyond what would normally be done for a facility of this type. Therefore this is increased exposure time to construction site hazards for the commissioning agent.
8. *Materials and Resources Credit 2: The recycling and diversion of construction waste throughout the project achieved these credits* - On this project waste was being sorted into a separate dumpsters which is placed on the site by the tower crane. This extra dumpster increases the frequency of crane picks on the site and the hazards that exist with this activity. This occasionally required workers to "dumpster dive" in order to sort materials that were not disposed of properly. This activity exposes the workers to scrapes, abrasions and puncture injuries.
9. *Indoor Environmental Quality Credits 1 and 6.1*: *Installation of CO2 monitoring system and occupancy sensors in larger occupancy spaces*- This requires electricians to spend additional time wiring and up on a ladder, increasing their exposure time.
10. *Indoor Environmental Quality Credit 2*: *Larger ventilation system than typically required for a facility of this size*- The larger system requires the installation of heavier and more cumbersome ducts increase the severity of potential overexertion injuries.
11. *Indoor Environmental Quality Credit 3.1: Indoor environmental quality plan during the construction phase*- Workers spend additional time covering the ends of the ducts, climbing up ladders to complete this work, increasing worker exposure time.
12. *Indoor Environmental Quality Credit 8.1 and 8.2: Use of larger windows on in order to ensure building receives enough daylight and views*- According to the contractor the

larger windows are harder to lift into place and increase the chance of an overexertion injury to the workers.

13. *Innovation in Design Credit 1.4: Electric subpanels in the facility*- The subpanels allow occupants to see which portions of the building are using the most energy, and will allow different wings of the dormitory to compete for lowest power use. The additional subpanels require additional wiring and increase exposure time for the electricians.

Decrease in Hazards

These credits were cited by the contractor as decreasing the hazard faced by the workers as compared to the traditional design alternative. A decreased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard.

1. *Indoor Environmental Quality Credits 4.1, 4.2, 4.3, and 4.4: Use of low VOC adhesives, sealants, paints, carpets, composite wood and agrifiber products*- Workers are exposed to lower VOC levels during the installation and construction of these products, therefore decreasing the severity of this hazard.

Miscellaneous Findings

The designer had several relevant comments to make about LEED and construction worker safety after the formal data collection process. They noted that the indoor air quality guidelines during the construction phase are stricter than those set forth by OSHA. Also the increase in availability of low VOC materials has brought down the costs of some of these materials and therefore made their use nearly standard practice. The designer felt that these low VOC materials should have health benefits to the workers. In further discussion about LEED in general the designer felt that the overall impact had been positive, as it had helped to quantify good green building practices. However, they stated there was still a significant premium that was being paid on LEED projects in order to obtain certification. These costs lie in items such as the cost to track and document everything as well additional time spent in meetings discussing LEED and costs to bring in consultants. The designer estimated that for a facility of the size of this case study LEED created an additional cost of $75,000 to $100,000 in fees and additional time spent by professionals such as the designers, consultants and project managers.

The contractor stated that safety on the site was not looked at in terms of LEED or non-LEED, instead safety was viewed in terms of different hazards such as falls or struck-by incidents. While safety issues that were related to LEED were discussed during job hazard analyses there were no separate programs or plans to address LEED specific hazards. The contractor also felt that many of the requirements of LEED were becoming standard practice such as workers recycling materials. Other activities that were helping the LEED process were also financially driven (e.g. electricians and plumbers taking all extra copper off the site).

Project F

Project Introduction

Project F is a 92,000 square foot institutional facility located on a large university campus in Fort Collins, CO. The building is four stories tall and contains classroom space, food services, and study lounges on the first floor. Departmental offices are located on the second through fourth floor. A large national construction company delivered the process through a construction manager / general contractor process. A medium sized local design firm, who has significant experience in institutional LEED projects, completed the design. The contract was a guaranteed maximum price contract worth approximately $45 million. At the time the case study was completed (September 2010) the project was completed and recently occupied. The project's expected LEED certification level is Gold, with the building attempting to achieve 43 of 69 available credits using the LEED New Construction and Major Renovations V2.2 scoring system.

Case Findings

Ultimately, the project aimed to achieve a total of 43 credits, while meeting the additional 7 pre-requisites for LEED certification. After examination of the credits that were achieved the researcher determined that after combining similar credits there were 38 credits to examine for this case. The additional 7 pre-requisites to created a data set of 45 credits for this study. Thirty-two of the 45 credits (71%) were found to have no impact on the hazards the construction workers faced while installing and constructing the facility. Those interviewed stated that there were 8 primary reasons for no change in the workers safety between the LEED and traditional non-LEED design elements.

1. The contractor has a policy of using work methods that meet the LEED requirements.

    a. The contractor uses a storm water and site management plan that meets LEED requirements on all projects.
2. The scope of the project ensured the project would achieve the credit due to its location.
    a. The project is within the university property and therefore on developed land.
    b. The project is located near to public transportation.
    c. Because the project is located centrally within the campus the building does not create any additional light pollution.
    d. Campus has a chiller building already meeting requirements.
3. The installation or construction process of an element was the same
    a. Changing rooms and bike racks
    b. Installation of signage in parking lot
    c. Use of light colored concrete
    d. Installation of a TPO roof
    e. Exterior light fixtures
    f. The selection of native and low water use plants.
    g. Low flush water closets and urinals
    h. All recycled, regional and certified materials
4. Achievement of the credit had no impact on the construction phase of the project.
    a. Limited additional parking was added
    b. University manages the purchase of green space collectively and not from project to project.
5. The project owner has policies that meet the requirements of LEED
    a. Baseline level of building commissioning is completed on all campus facilities.

    b. Enhanced commissioning is completed on all facilities of this size and value.
    c. Campus recycling program
6. State and local regulations require this level of performance in the facility.
    a. Smoking regulations
    b. Energy performance of facility meeting ASHRAE
    c. Building ventilation system
7. Achievement of the credit had no impact on the construction phase of the project.
    a. Thermal comfort survey of final occupants
    b. LEED AP certified team members
    c. Monitoring of building energy output after completion.
    d. Purchasing of green energy credits
    e. Green cleaning plan for the maintenance of the facility
    f. Pesticide free landscaping program for the maintenance of the facility
8. Designing to the LEED specifications have become a standard practice for the designer.
    a. Building temperature and humidity controls

The final thirteen credits (29%) that the project was attempting to achieve did have an impact on the safety and hazards encountered by the workers. According to the contractor, of these thirteen credits, six exposed the workers to additional hazards on the job site, four of the credits decreased the hazards and three credits both decreased and increased the hazards that the workers faced.

Increase in Hazards

These credits were cited by the contractor as increasing the hazards faced by the workers as compared to the traditional design alternative. An increased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard.

1. *Sustainable Sites Credit 6.2: The inclusion of a bioswale in order to control storm water*- By including a bioswale in the design of the facility there was a need for additional excavation work by heavy machinery on the site. This heavy machinery increases the worker exposure time to struck-by and struck-against hazards that are created by working around the machinery.
2. *Energy and Atmosphere Credit 2: Use photovoltaic panels so that the facility generated green power*- Installed the PV panels requires that they are lifted onto the roof by the crane on the site. These additional picks increase the frequency which workers are exposed to hazards associated with working around cranes, such as materials falling on them. In addition the PV panels need to be installed by electricians that are do not commonly work on roofs. This creates a fall hazards for the electricians that they were not normally encounter.
3. *Materials and Resources Credit 2: The recycling and diversion of construction waste throughout the project achieved this credit* - This occasionally required workers to "dumpster dive" in order to sort materials that were not disposed of properly. This activity exposes the workers to scrapes, abrasions and puncture injuries. Working on the uneven surfaces can also cause ankle sprains. Using separate dumpsters to sort the materials also increases the frequency with which dumpsters are picked up and dropped off at the site. The hazards associated with the pick up and drop of off the dumpsters are workers being struck-by or struck-against the truck involved in this process.

4. *Materials and Resources Credit 4*: *Use of fly ash in concrete as a recycled material*- Fly ash concrete is more difficult to finish than typical concrete and takes more man-hours, increasing exposure time.
5. *Indoor Environmental Quality Credit 6.1: Use of sensors to help control indoor lighting*- This requires extra wiring to install the sensors and occasionally additional time spent on ladders for the electricians. This creates an extra fall hazard and increase exposure time to other hazards.
6. *Innovation in Design Credit 1.1: Computer system and monitors displaying facility energy use to occupants*- This required the installation of several extra outlets and the installation of the monitors, which increased worker exposure time.

Decrease in Hazards

These credits were cited by the contractor as decreasing the hazard faced by the workers as compared to the traditional design alternative. A decreased hazardous situation was defined as either an increase in frequency, severity, or exposure time to a pre-existing hazard or the creation of a new hazard.

1. *Indoor Environmental Quality Credits 4.2, 4.3, and 4.4: Use of low VOC sealants, paints, carpets, composite wood and agrifiber products*- Workers are exposed to lower VOC levels during the installation and construction of these products, therefore decreasing the severity of this hazard.
2. *Indoor Environmental Quality Credit 6.2: HVAC system that runs under the floors*- Having the HVAC system run under the floors made the installation process easier for the mechanical contractor. It eliminated the need for the workers to climb up ladders and installed the ductwork in the ceilings. This easier installation made the process

faster and decreased the exposure time of the workers. Additionally the occupants manually control many of the controls for the system and fewer thermostats were installed.

Both an Increase and Decrease in Hazards

1. *Energy and Atmosphere Credit 1: Use of continuous exterior insulation, permanent exterior window shades and a mechanical system that runs under the floors to make the building more energy efficient*- The heavier insulation on the shell of the building increases the severity of potential overexertion injury as well as increasing the severity of a fall incident because these materials are handled at height. The exterior window shades created a hazard for construction or later maintenance workers attempting to clean the windows. The permanent shades make it difficult to move from window to window and exposes the workers to fall injuries by extending the time they spend in a scissor lift to clean the windows. Finally, having the HVAC system run under the floors made the installation process easier for the mechanical contractor. It eliminated the need for the workers to climb up ladders and installed the ductwork in the ceilings. This easier installation made the process faster and decreased the exposure time of the workers. Additionally the occupants manually control many of the controls for the system and fewer thermostats were installed.
2. *Indoor Environmental Quality Credit 3.1: Covering of ducts and not running generators inside the facility during the construction phase*- Covering the ends of the duct work increases worker exposure time because it makes the HVAC system installation process longer. However, by not running generators inside the workers are not exposed to the exhaust as directly, decreasing the severity of this hazard.

3. *Indoor Environmental Quality Credit 4.1:* Workers are exposed to a lower VOC level while installing these products therefore decreasing the severity of this hazard. However, because the adhesives are not as effective as the non-LEED materials more time is spent preparing for their application. Occasionally rework was required because of the quality of the adhesives on the roof. This increases the time the roofers are exposed to fall hazards.

Miscellaneous Findings

The designer felt that LEED had served a purpose by bringing building design concepts to the forefront of conversations. It has also made the green building designs accessible and understandable to people. In their opinion though LEED is currently only reiterating what good design practices are and that it will soon be superseded because building codes are adopting many of the standards. To go one step further, if the USGBC and LEED want to continue to be at the forefront of the green building industry, they will need to "up the level of their requirements." In the designers opinion there were few ties to changes in worker safety and LEED designs. One example they stated was the dual four story atriums included in this project. While they did not provide enough light to earn a LEED credit, the designer felt this workspace was more dangerous than a conventional space.

The owner and contractor of the facility echoed the sentiment about the atriums being a more challenging and hazardous workspace. They felt that there were more fall hazards on the project because of this design. The owner discussed two other key green features of the facility while touring the facility that he felt had long-term safety consequences. The first was the patio space on the fourth floor; they had noticed students sitting on the ledge. The owner felt that if a student were to fall the space would have to be closed and feature which was there solely in the spirit of green design would be rendered useless. Second, many of the interior walls carried the stone finish of the exterior of the building. This feature would require no maintenance such as paint for as long as the facility was in use.

The only consideration that the contractor said was different when pre-planning for a LEED project was the space for the dumpsters. When there is limited lay down space on LEED sites and they need to have multiple dumpsters to sort materials this can created problems and hazards on the site.

APPENDIX C: PROJECT DATA CHARTS

Project A

LEED CREDIT	LEED DESIGN ELEMENT	TRADITIONAL DESIGN OPTION	ADDITIONAL HAZARDS	MITIGATED HAZARDS
LEED C&S V2.1				
Sustainable Sites				
SS - Prereq 1	Erosion and Sedimentation Control Plans to be followed throughout Construction. As well as seeding and watering of disturbed soil to control dust.	The state and city regulations are followed which meet this requirement.	None	None
SS - 4.1	Close proximity to RTD bus stop (1/4 mile)	No change	None	None
SS - 4.2	Inclusion of showers and changing facilities on the first floor as well 38 bike lockers located around the facility.	Would not be included in the design	None	None
SS - 4.3	53 parking spaces located close to the main entrances are dedicated as fuel efficient vehicle spaces	Parking spaces would still exist just would not be designated. Signage would not have to be installed.	This creates the hazard that power lines could be hit with the concrete poles are set into the group risking electrocution for the workers.	None
SS - 4.4	1.5% Less parking spaces are available for the building (1003 total)	A larger parking lot area would need to be built to meet the city requirement of 1017 for the facility.	None	Less exposure time for workers to heavy equipment. This protects them from several different injury times most notably struck-by or struck-against incidents.

SS - 5.2	56 parking spaces were built below the building and compact car spaces were created 25% more open landscaped space than required by the city	The underground parking structure would not have been included and all the parking spaces would be standard size increasing the lot size. Having climate controlled parking is a requirement for a Class A office building	None	None
SS - 7.2	Roof has a highly reflective energy star white roof which reflects sunlight decreases the heat island affect on the surrounding area and decreasing building cooling costs	Same HQ TPO roof membrane would have been used just colored black	None	None
		A lower quality black EPDM roof could have been installed.	TPO roof is slightly more labor intensive, materials are heavier. This increases the severity of a overexertion injury	None
SS - 8	Outside light fixtures were selected to minimize the distance of nighttime light that left the site	Different light fixtures may have been chosen. All the light fixtures function at the same low voltage level therefore there is no change in the hazards for installing them.	None	None
SS - 9	Booklet created to help tenants understand the LEED design elements included in their structure	Booklet would not have been created by the Architect	None	None
Water Efficiency				
WE - 1.1	Plants were chosen that tolerated less water and were regionally appropriate most specifically bluegrass was used instead of a fescue turf.	Fescue turf would have been installed around the facility as specified for the office building complex.	None	None
WE - 1.2	An irrigation system was design to use non-potable water to water the landscape.	Already in place at the complex site.	None	None

WE - 3	Low flush urinals and dual flush water closets were chosen	Standard water closets and urinals would have been selected	None	None
Energy & Atmosphere				
EA - Prereq 1	Training of the facilities management & testing of the HVAC & Electrical systems were conducted to ensure that they were operating at optimum design levels	Due to the size of the project this building would have been commissioned at this level, therefore there is no change in the hazard level.	None	None
EA - Prereq 2	Energy systems comply with ASHRAE Standards to ensure that the building meets certain energy performance levels.	More efficient fans, boilers and other mechanical equipment were specified over cheaper less efficient units. Contractor however, matches the ASHRAE standards on all projects.	None	None
EA - Prereq 3	Refrigerant meets 1990 Clean Air act agreement.	Office complex already has chiller facility that meets the requirements	None	None
EA - 1	Core and Shell of the building consume 17% less than the U.S. baseline and 70% of the energy consumption has been purchased as renewable	More efficient fans, boilers and other mechanical equipment were specified over cheaper less efficient units. Contractor however, matches the ASHRAE standards on all projects.	None	None
EA - 4	This credit is also met by the design elements in EA Prereq 3	This credit is also met by the design elements in EA Prereq 3	None	None
EA - 5.2	Each tenant space as two feeds so that energy consumption can be monitored for each unit.	Entire building would have only one meter and far less wiring throughout.	This required additional wiring, piping, and rough ins throughout the facility. None of this work is done with live electricity so the primary hazards are the additional exposure time.	None

EA - 6	70% of the buildings energy consumption is purchased from a renewable source	Energy would be purchased from the cheapest vendor available	None	None
Materials & Resources				
MR - Prereq 1	Separate recycling dumpsters are also including the dumpster area in the parking garage	Regular dumpsters would have been installed	Additional exposure time installing the dumpsters	None
MR - 2	95% of construction waste is to be diverted from landfill	Additional laborers are needed to sort and direct the sorting of the waste throughout the project	More labor during the collecting of waste and recyclables, increasing exposure time. One specific danger was the additional time spent recycling drywall, which exposes workers to inhalation of the gypsum. A new hazard is that workers sometimes have to enter dumpsters which exposes them to small first aid injuries such as cuts and punctures. The last additional hazard created is that the dumpsters are more frequently brought to and from the site increasing the risk of a worker being struck-by or against the truck.	None
MR - 4	10% of materials used were recycled	Done because the majority of steel in Colorado is recycled	None	None
MR - 5	10% of materials used were regionally extracted	Achieved through the concrete and asphalt that was used.	None	None
MR - 6	50% of the wood materials used were certified wood	FCS certified doors and millwork was specified for the facility	None	None
Indoor Env. Quality				

IEQ - Prereq 1	Indoor Air Quality meets ASHRAE standards	Standard design for designer	None	None
IEQ - Prereq 2	Colorado State law prohibits indoor smoking	Automatically met	None	None
IEQ - 1	Monitors were included in the design that check CO2 and outdoor air levels and have an alarm if they vary by 10% of set levels	Standard design for designer	None	None
IEQ - 2	Ventilation systems delivers > 30% more outdoor air than ASHRAE requirements	Standard design for designer	None	None
IEQ - 3.1	A construction indoor air quality management plan was created before construction began and followed throughout the construction process	The main method is achieved is by covering ducts while construction is going on. Contractor however considers this an industry best practice and enforces it on every job site	None	None
IEQ - 4.1	Low emitting adhesives and sealants were selected	Standard design for designer	None	None
IEQ - 4.2	Low emitting paints and coatings were selected	Standard design for designer	None	None
IEQ - 5	Entranceways have walk off carpet tiles and the building has exhaust systems in all areas that could have harmful chemicals such as janitor's closets.	Standard design for designer	None	None
IEQ - 7	Building Automation Systems ensure that 80% of the occupants have a comfortable space based on temperature, humidity, etc.	Standard design for designer	None	None
IEQ 8.2	Tenant spaces are laid out to ensure that 90% of the spaces have daylight views, this is achieved by not having all the tenant spaces laid out the same and the use of lower partitions	Tenant spaces are unfinished and it is up the to tenant to have the individual spaces LEED certified, therefore under the C&S Program this credit becomes easier.	None	None

	between spaces			
Innovation & Design				
ID - 1.1	70% of power purchased is renewable	Energy would be purchased from the cheapest vendor available	None	None
ID - 1.2	95% of waste is being diverted from landfills	Additional laborers are needed to sort and direct the sorting of the waste throughout the project	See credits MR - Prereq 1 and MR - 2	None
ID - 1.3	Media about the LEED credits is being distributed to the tenants and being made available to the public	Media would not normally be created by the Architect	None	None
ID - 1.4	Over 40% less water is being used in the structure by the inclusion of the dual flush water closets and low flush urinals	Standard toilets and urinals would have been chosen	None	None
ID - 2	Both design and construction teams have a LEED AP	None	None	None

Project B

LEED CREDIT	LEED DESIGN ELEMENT	TRADITIONAL DESIGN OPTION	ADDITIONAL HAZARDS	MITIGATED HAZARDS
LEED N.C. V2.2				
Sustainable Sites				
SS - Prereq 1	Stormwater management plan was put in place that included silt fence and soil dampening to reduce dust	The stormwater management plan is a contractor standard to qualify for this pre-requisite	None	None
SS - 1	The project qualified for this credit because the project was on the developed Campus	No change	None	None
SS - 2	The project qualified for this credit because the project was on the developed Campus	No change	None	None
SS - 4.1	The entire campus has close proximity to public transportations	No change	None	None
SS - 4.2	6 showers and changing rooms were included in the design as well as dozens of racks for bicycles outside of the building	The shower and changing rooms would not have been included and less bike racks would have been installed.	None	None
SS - 4.3	Parking spaces located near to the building are designated for low emitting vehicles	Signage would not have needed to be installed	None	None

SS - 4.4	The multi level underground parking structure minimizes the area taken up by the parking spaces	The facility could have no additional parking associated with it or parking could have been a flat ground level parking lot.	Shoring activities, excavation, 400 plus trucks per day going in and out, traffic control on the roads, small open holes from shoring, lots of welding. Protection of fall hazard for the enormous hole, dedicated carpenter to make sure fall hazard railing was in place for a month and half. To not count wood for LEED the wood for the shoring had to be removed and there as trench work associated with this.	None
SS - 5.1	University purchases open space and restores habitats as a collective entity and does not manage this project to project, therefore this was not managed by the design team	No change	None	None
SS - 5.2	University purchases open space and restores habitats as a collective entity and does not manage this project to project, therefore this was not managed by the design team	No change	None	None
SS- 6.2	On site detention water running through site and pervious pavers and underground detention	The water detention system would have been designed for a lower capacity.	The additional work creates additional exposure time, in this case the detention system was located in an area that trucks or other machinery could have fallen into the holes and constant awareness reminders were needed	None
SS - 7.1	The light colored concrete around the site qualified for this credit.	No change	None	None

SS - 7.2	Standard campus roof tiles were used, however a different color mix was used. In addition the flat roof areas were painted white.	The standard campus roofing color mix would have been used and roof would have been the standard black.	None	None
SS - 8	The campus standard is to use a LED wing light on exteriors, which qualifies. Additionally because the building is centrally located within campus there is no light pollution spill boundary.	No change	None	None
Water Efficiency				
WE - 1.1	Low water use and native plants were selected for around the site. Reclaimed and non-potable water for watering plants is a campus standard	No change	None	None
WE - 3	Low flush water closets and urinals were used as well low flow strainers and motion sensors on faucets	Low flush water closets are standard. The low flow strainers and motions sensors would not necessarily have been chosen	None	None
Energy & Atmosphere				
EA - Prereq 1	Testing of the HVAC & Electrical systems were conducted to ensure that they were operating at optimum design levels	This level of commissioning is standard for a facility of this type.	None	None
EA - Prereq 2	Energy systems comply with ASHRAE Standards to ensure that the building meets certain energy performance levels.	More efficient fans, boilers and other mechanical equipment was specified over cheaper less efficient units	Economizers on the system that have extra piping for hot water heating, and hoods send air through another piece that removes greases, etc and allows it to be reused in the facility. The additional time spent installing the extra pipe and processes is more exposure time for injury.	None

EA - Prereq 3	No CFC refrigerant	Campus standard	None	None
EA - 1	Direct/ indirect evaporative chillers as opposed to a chiller plant, LED lighting fixtures are 40% in the dining area, the entire garage is as well,	Less efficient units could have been installed	Slightly more exposure time to wire the extra controls	None
EA - 3	The enhanced commissioning above and beyond the prerequisites were completed for the project	Commissioning process would not have taken place	Additional time spent on the time by the commissioning contractor which exposes them to number hazards throughout the construction site.	None
EA - 4	Direct and indirect evaporative chiller system qualifies for this credit	Less efficient units could have been installed	Slightly more wiring with controls	None
EA - 5	Measurement and verification of the energy output of the building will go on for a year after construction is complete	No additional hazards created during the construction process	None	None
EA - 6	School is purchasing green power	No change	None	None
Materials & Resources				
MR - Prereq 1	School has the recycling program and this site has it at every entry point and exit point.	No change	None	None
MR - 2	Currently 87% of waste has been diverted	Waste would just be thrown in dumpsters	Dumpsters diving to sort more materials, no injuries on this site but twisting ankles, scrapes punctures etc.	None
MR - 4	21% of project materials are recycled content from the steel, concrete with recycled aggregate and flyash, site furniture, particleboard in the middle of doors, aluminum window extrusions, and glass windows.	Different, likely cheaper materials would have been specified	None	None

MR - 5	The local materials used were the exterior stone, windows, drywall, aggregate, millwork, and concrete	No change	None	None
MR - 7	Doors, backing and blocking, all the decorative timbers and the nailers under the roof tiles are FSC certified wood.	Different, likely cheaper materials would have been specified	None	None
Indoor Env. Quality				
IEQ - Prereq 1	Building design meets all ASHRAE standards	No change as this level of ventilation design was necessary for the industrial kitchen in the facility	None	None
IEQ - Prereq 2	University already has the smoking policies in place	No change	None	None
IEQ - 1	Oudoor air delivery has the alarms if air quality levels are outside of 10% of set point	Alarm system would not have been installed for the CO2	Extra exposure time is created for the workers because they have to wire devices	None
IEQ - 3.1	Duct ends were closed throughout the construction to ensure construction debris did not end up in them.	No change as this is a Standard contractors procedure	None	Different chemicals are used for some processes throughout the site, which have a positive health impact on the workers such as acetones not being used for cleaning and urea formaldehyde in cutting.
IEQ - 3.2	Building flush out after the completion of construction	This process would have been completed as per the specifications of the university	None	None
IEQ - 4.1	Low emitting adhesives and sealants were selected	No change	None	The construction and installation of these materials have lower VOC levels, which is healthier for the workers to not have to breath it in

IEQ - 4.2	Low emitting paints and coatings were selected	No change	None	The construction and installation of these materials have lower VOC levels, which is healthier for the workers to not have to breath it in
IEQ - 4.3	Low emitting carpets were selected	No change	None	The construction and installation of these materials have lower VOC levels, which is healthier for the workers to not have to breath it in
IEQ - 4.4	Low emitting composite wood and agrifiber products were selected	No change	None	The construction and installation of these materials have lower VOC levels, which is healthier for the workers to not have to breath it in
IEQ - 5	Submittals that VOC's aren't entering facility during construction	No change	None	None
IEQ - 6.1	Occupancy sensors in all the offices, parking lot occupancy sensors and hallways.	Less sensors or no sensors would have been installed in the facility	Extra wire and device mounted.	None
IEQ - 6.2	Daylight harvesting in almost every room and most of the offices have an operable window	No change	None	None
IEQ - 7.1	Mechanical systems ensure that 80% of the occupants have a comfortable space based on temperature, humidity, etc.	This level of design was necessary for the project and standard for habitable areas	None	None
IEQ - 7.2	Thermal comfort survey will be conducted with the occupants in the near future	Survey would not be conducted	None	None
Innovation & Design				

ID - 1.1	Glass and the carpet are recycled content and are specially designed to be recycled when it's done.	Different, likely cheaper materials would have been specified	Not on the construction installation but possibly on the manufacturing end.	None
ID -1.2	Organic food program and composting of food waste program. Food waste and water enters a centrifuge and the food is sent to be compost at farms and the water is then reused in various applications	Standard plumbing and food disposals would have been installed, which would normally leave through the building waste water system.	More equipment, more piping, the pulper is a hazardous piece of equipment if not properly used.	None
ID - 1.3	Same as above	Same as above	Same as above	None
ID - 1.4	Same as above	Same as above	Same as above	None
ID - 2	Teams have LEED AP's on them	No change	None	None

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Project C

LEED CREDIT	LEED DESIGN ELEMENT	TRADITIONAL DESIGN OPTION	ADDITIONAL HAZARDS	MITIGATED HAZARDS
LEED NC V2.2				
Sustainable Sites				
SS - Prereq 1	Stormwater management plan was put in place that included silt fence and soil dampening to reduce dust	The stormwater management plan is a contractor standard to qualify for this pre-requisite	None	None
SS - 1	The project qualified for this credit because the project was on the developed campus	No change	None	None
SS - 2	The project qualified for this credit because the project was on the developed campus	No change	None	None
SS - 3	The sight had asbestos on underground pipes that needed to be remediated whether the project was LEED or not.	No change	None	None
SS - 4.1	The campus already has near by public transportation	No change	None	None
SS - 4.2	Changing rooms and dozens of bike racks are included around the facility	The bike racks and the changing rooms would not be included	None	None
SS - 4.3	Additional signage for the low emitting vehicles in pre existing parking structure	The signage would not have to be installed	None	None
SS - 4.4	No additional parking was constructed for this project	No change	None	None
SS - 5.2	The vegetation area around the building was equal to the footprint of the building.	No change	None	None
SS - 7.1	Permanent exterior shades near windows for non roof heat island	This design would not have been incorporated	These create an obstacle for the worker who cleans the windows and forces them to spend additional time in the	None

			lift.	
SS - 7.2	TPO white roof was installed because of its reflectivity	PVC roofing system	The TPO roof is both very bright and a more slippery surface than standard roofs. This increases the danger for workers to slip and fall on the same level or fall from height	None
Water Efficiency				
WE - 1	Low water use and native plants were selected for around the site.	No change	None	None
WE - 3	The urinals, toilets and faucets are low water use.	Low flush water closets and urinals are standard.	None	None
Energy & Atmosphere				
EA - Prereq 1	Fundamental commissioning of the building was completed	This process would have been done because it is a standard for the campus	None	None
EA - Prereq 2	The building complies with ASHRAE requirements	This level of design is standard for the design firm.	None	None
EA - Prereq 3	The building refrigerants have no CFCs	A different refrigerant system could have been chosen	None	None
EA - 1	Building simulation of energy use was completed and then chose variable speed motor controllers, pumps and air handlers	The equipment may not have been specified	None	None
EA - 3	Enhanced commissioning pursued testing the Mechanical systems	This process would not have taken place if the project was not pursuing LEED	None	None
EA - 4	An alternative environmental friendly refrigerant system was chosen	A cheaper refrigerant system would have been selected.	None	The contractor felt that these alternative refrigerant systems are healthier to those installing them.

Materials & Resources				
MR - Prereq 1	There are several recycling centers that are located throughout the facility.	Having these recycling centers available is a campus standard	None	None
MR - 2	Project waste was diverted from the landfill, this was accomplished by hiring a waste disposal company that sorts the materials off site	No change	None	Creating an emphasis on having a clean site causes less debris and makes the workers more productive, decreasing exposure time.
MR - 4	Recycled steel and concrete with flyash were used	Flyash would not be included in the concrete for the project.	None	None
MR - 5	The concrete used on the project was locally derived	No change	None	None
MR - 7	Certified wood was used in the blocking, millwork and doors throughout the facility	Less expensive materials would have been specified	None	None
Indoor Env. Quality				
IEQ - Prereq 1	Facility meetings minimum ASHRAE requirements	This level of design is necessary for the facility because it is a laboratory not just for LEED	None	None
IEQ - Prereq 2	University already has the smoking policies in place	No change	None	None
IEQ - 1	Oudoor air delivery has the alarms if air quality levels are outside of 10% of set point	Alarm system would not have been installed for the CO2	Extra exposure time is created for the workers because they have to wire devices	None
IEQ - 2	Larger ducts and louvers are larger than they would have been	Dictated largely by being a lab building	None	None
IEQ - 3.1	Duct ends were closed throughout the construction process.	This process has become an industry standard for this contractor	None	None
IEQ - 3.2	The mechanical systems are flushed out after the construction is complete.	No change because the time for this was built into the schedule	None	None

IEQ - 4.1	Low emitting adhesives and sealants were selected	No change	The old glues that were used were better and there is more time prep and it can create a hazard because of the silica dust created prepping surfaces.	The construction and installation of these materials have lower VOC levels, which is healthier for the workers to not have to breath it in
IEQ - 4.2	Low emitting paints and coatings were selected	No change	None	The construction and installation of these materials have lower VOC levels, which is healthier for the workers to not have to breath it in
IEQ - 4.3	Low emitting carpets were selected	No change	None	The construction and installation of these materials have lower VOC levels, which is healthier for the workers to not have to breath it in
IEQ - 4.4	Low emitting composite wood and agrifiber products were selected	No change	None	The construction and installation of these materials have lower VOC levels, which is healthier for the workers to not have to breath it in
IEQ - 5	Indoor chemical pollutant source control hard walling in janitors closets and copy machines	Additional duct work and additional gypsum	This required extra time and increased exposure time for the workers	None
IEQ - 6.1	Occupancy sensors were used in most of the inhabited spaces	Less sensors or no sensors would have been installed in the facility	Extra wire and device mounted.	None
IEQ - 7.1	More thermostats were installed than on a building of comparable size	This number of thermostats would have been included as policy of the design firm	None	None
IEQ - 7.2	Thermal comfort survey will be conducted with the occupants in the near future	Survey would not be conducted	None	None

IEQ 8.2	Views to the outside are available to almost every room of the building, mostly for aesthetic reasons	No change	None	None
Innovation & Design				
ID - 1.1	The facility has exemplary water efficiency	No change	None	None
ID - 1.2	A case study and regular tours will be conducted of the building	No change	None	None
ID -1.3	The facility has adopted a green cleaning policy for the maintenance of the building	No change	None	None
ID - 1.4	Design team complied with many of the design standards of the LABS 21 program, which mostly focuses on the correct sizing and choice of efficient lab equipment	No change	None	None
ID - 2	Teams have LEED AP's on them	No change	None	None

Project D

LEED CREDIT	LEED DESIGN ELEMENT	TRADITIONAL DESIGN OPTION	ADDITIONAL HAZARDS	MITIGATED HAZARDS
LEED NC 2.2				
Sustainable Sites				
SS - Prereq 1	Erosion and Sedimentation Control Plans to be followed throughout Construction. As well as seeding and watering of disturbed soil to control dust.	The contractors standard erosion control plan meets the requirements of LEED	None	None
SS - 1	Project was built on a already established campus	No change	None	None
SS - 2	Project was built on a already established campus	No change	None	None
SS - 3	This credit was achieved because there were old foundations that were found during excavation as unexpected site conditions and this allowed them to achieve the credit	No change	None	None
SS - 4.1	Public transportation was already available on the campus area	No change	None	None
SS - 4.2	Inclusion of showers and changing facilities on the first floor as well bike lockers located around the facility.	Would not be included in the design if the project was not attempting LEED	None	None
SS - 4.3	12 spaces were designated and signage was provided for low emitting vehicles around the site	Signage would not have need to be installed	None	None
SS - 4.4	Achieved because there was no new parking created on the site.	No change	None	None

SS - 5.2	Area around the building was designated as open and green space, this included the detention pond area	No change	None	None
SS - 6.1	Stormwater management plan was created so that there would be limited erosion in the stream channels	Detentions ponds were designed into the open space that would not have normally be included in the design.	The construction of the detention ponds increased equipment hazards and created trenching and standing water hazards.	None
SS- 6.2	Several strategies were used to achieve this credit including using porous rock in the open space, detention ponds and filters were installed to capture particulates before they enter the detention ponds.	Detention ponds, porous rocks and filtration systems would not have been included in the design of the area surrounding the facility.	This credit experiences the same hazards as the previous credit due to the detention ponds	None
SS - 7.1	A light grey concrete was chosen throughout the site to achieve 50% of impervious area to have a certain reflective level.	Concrete still would have been poured in the same manner.	None	None
SS - 8	36 of the exterior fixtures were full cutoff heads to minimize light pollution. On the interior of the building there are occupancy sensors in the rooms to keep lights off as well non-emergency lights are on timers so they shut off during unoccupied hours.	Regular fixtures would have been used on the exterior areas and the interior of the building would not have the sensors and the timers that were installed.	None	None
Water Efficiency				
WE - 3	More efficient plumbing fixtures such as low flush water closets and urinals were installed throughout the building.	Standard water closets and urinals would have been installed.	None	None
Energy & Atmosphere				

EA - Prereq 1	All seven requirements were completed for the commissioning of the building	Commissioning would not have taken place	The commissioning process requires additional man-hours on site and the officers going up down ladders	None
EA - Prereq 2	Mechanical equipment throughout the building was chosen so that it met ASHRAE provisions	Less efficient mechanical equipment would have been chosen for the project.	None	None
EA - Prereq 3	Refrigerant system for the building does not use CFC's	Refrigerant systems are no longer manufactured that use CFC's as far as the designer knows.	None	None
EA - 1	Evaporative chillers, variable air volume hoods were used in the science labs which decreased the energy use of the building to the ASHRAE energy standards	Standard hoods and chillers would have been installed in the science laboratories.	Evaporative coolers are heavier and have a water pipe tied to them which increases overexertion hazard and exposure time	None
EA - 3	The enhanced commissioning above and beyond the prerequisites were completed for the project	Commissioning process would not have taken place	The commissioning process requires additional man-hours on site and the officers going up down ladders	None
EA - 4	The evaporative cooling chillers meet this requirement	Standard chiller units would have been installed in the facility	Same as EA -1	None
EA - 5	Measurement and verification of the energy output of the building will go on for a year after construction is complete	No additional hazards created during the construction process	None	None
EA - 6	The entire campus already purchases 100% green wind energy	No Change	None	None
Materials & Resources				
MR - Prereq 1	Recycling program was already set up throughout campus.	No Change	None	None

MR - 2	75% of construction waste is to be diverted from landfill	Waste would be disposed of in one dumpster without sorting	Additional man-hours and guys going in the dumpsters, cuts, punctures, abrasions in the dumpsters	None
MR - 4	Recycled steel and flyash in the concrete. Agrifiber core doors and casework in the laboratories.	Flyash would not be used in the concrete	The flyash is more difficult to finish, takes longer to finish and increases exposure time	None
MR - 5	Local bricks were used on the project	No Change	None	None
MR - 7	As much of the case work and doors throughout the project were FSC certified wood	No Change	None	None
Indoor Env. Quality				
IEQ - Prereq 1	Indoor Air Quality meets ASHRAE standards	Standard for designer	None	None
IEQ - Prereq 2	Campus had to change the smoking policy	Signage all over the campus had to be changed. This was taken care of by the campus.	None	None
IEQ - 1	Monitors were included to check that CO2 levels stayed within 10% of set level	Because this is a laboratory building this was necessary to included in the design either way.	None	None
IEQ - 2	Ventilation systems delivers > 30% more outdoor air than ASHRAE requirements	Because this is a laboratory building this was necessary to included in the design either way.	None	None
IEQ - 3.1	No running diesel equipment within the building, proper ventilation of the building, dust mitigation and keeping the building clean	Filters would not have been used during the construction phase.	Extra time to keep clean and extra materials	Clean site mitigates a series of hazards
IEQ - 3.2	For approximately the two weeks preceding occupancy the entire mechanical system was run 24 hours a day in order to flush out the entire building	Flush out would not have been done because off the rush to occupy the buildings	None	None

IEQ - 4.1	Low emitting adhesives and sealants were selected	Chosen by designer because there was a desire to have a green building and an additional cost was built in for this credit	More work with the adhesives the glue is not as good and they don't stick as well and there is a lot of rework, especially on the roofing EPDM	None
IEQ - 4.2	Low emitting paints and coatings were selected	Chosen by designer because there was a desire to have a green building and an additional cost was built in for this credit	None	None
IEQ - 4.3	Low emitting carpets were selected	Chosen by designer because there was a desire to have a green building and an additional cost was built in for this credit	None	None
IEQ - 4.4	Low emitting composite wood materials were selected	Chosen by designer because there was a desire to have a green building and an additional cost was built in for this credit	None	None
IEQ - 5	Entranceways have walk off carpet tiles and the building has exhaust systems in all areas that could have harmful chemicals such as janitor's closets.	Entry mats would not have been 6' long in primary travel direction and copy rooms had additional exhaust systems	Installation of an extra duct and an extra fan, which increases worker exposure time	None
IEQ - 6.1	Daylight sensors to control lights inside	Sensors would not have been there to turn lights off and have automatic daylight sunshades that were controlled by sensor.	The sensor replaces the light switch, the motion sensors add extra wiring, increasing exposure time.	None
IEQ - 6.2	Each laboratory has its own thermostat as well.	Would not have had as many temperature control units throughout the facility	Installing extra controls increases exposure time	None
IEQ - 7.1	Mechanical systems ensure that 80% of the occupants have a comfortable space based on temperature, humidity, etc.	This level of design is standard for designer	None	None
IEQ - 7.2	Thermal comfort survey will be conducted with the occupants in the near future	No change in the design of the facility	None	None

IEQ - 8.1	All of the laboratory spaces were located on the perimeter of the building in order to achieve this credit	Did not affect the design of the facility	None	None
IEQ 8.2	Windows were placed between the laboratory spaces and then interior prep and office rooms so that these rooms also have views to the exterior	Additional windows were needed between the spaces throughout the facility.	None	None
Innovation & Design				
ID - 1.1	The high availability of public transportation on the campus achieved this credit	Calculations were performed and this point was attained	None	None
ID - 1.2	Additional fume hood testing and commissioning.	Manufacturer specified that these fume hoods had to be tested to a level that satisfied this credit	None	None
ID - 1.3	20 signs were placed throughout the building educated the occupants on the LEED features of the facility	Signage would not have to be installed, but this is being done by facilities management	None	None
ID - 1.4	Campus is providing 100% green power by the year 2010/2011	No change	None	None
ID - 2	LEED Accredited Professional on the teams	No change	None	None

Project E

LEED CREDIT	LEED DESIGN ELEMENT	TRADITIONAL DESIGN OPTION	ADDITIONAL HAZARDS	MITIGATED HAZARDS
LEED - NC V2.2				
Sustainable Sites				
SS - Prereq 1	Stormwater management plan was put in place that included silt fence and soil dampening to reduce dust	The stormwater management plan is a contractor standard to qualify for this pre-requisite	None	None
SS - 1	The project qualified for this credit because the project was on the developed Campus	No change	None	None
SS - 2	The project qualified for this credit because the project was on the developed Campus	No change	None	None
SS - 4.1	The entire campus has close proximity to public transportation	No change	None	None
SS - 4.2	Bicycle racks and bike shelter, as well as a unisex bathroom and changing room with a shower	The shelter and the unisex changing room would not be included	A fall hazard was created by adding the bike shelter	None
SS - 4.3	Signage was installed to designate parking spaces for low emitting vehicles	The signage would not be installed	Minor traffic control needs to be used in the active lot which creates a struck-by hazard for the workers	None
SS - 4.4	No increase in parking area for the facility	No change	None	None
SS - 5.1	University purchases open space and restores habitats as a collective entity and does not manage this project to project, therefore this was not managed by the design team	No change	None	None

SS - 5.2	University purchases open space and restores habitats as a collective entity and does not manage this project to project, therefore this was not managed by the design team	No change	None	None
SS - 6.1	A water runoff plan was created that manages the stormwater	This design was the same as urban drainage guidelines	None	None
SS- 6.2	A water runoff plan was created that manages the stormwater	This design was the same as urban drainage guidelines	None	None
SS - 7.1	The light colored concrete around the site qualified for this credit.	No change	None	None
SS - 7.2	Standard campus roof tiles were used, however a different color mix was used.	An asphalt roof was in the original contract	Clay tiles are heavier than asphalt and more time is spent installing them increase overexertion and exposure hazards	None
SS - 8	The campus standard is to use a LED wing light on exteriors, which qualifies. Additionally because the building is centrally located within campus there is no light pollution spill boundary.	No change	None	None
Water Efficiency				
WE - 1.1	Low water use and native plants were selected for around the site. Reclaimed and non-potable water for watering plants is a campus standard	No change	None	None

WE - 2	Dual waste water system, water comes from showers goes to separate system from toilet	A single traditional waste water system	A lot more piping and a lot more time and the chemicals in the filtration systems that has a chlorination process that works are exposed to and the food coloring	None
WE - 3	Low flush water closets, urinals, shower heads and faucets were installed throughout the facility	No change	None	None
Energy & Atmosphere				
EA - Prereq 1	Testing of the HVAC & Electrical systems were conducted to ensure that they were operating at optimum design levels	This level of commissioning is standard for a facility of this type.	None	None
EA - Prereq 2	Energy systems comply with ASHRAE Standards to ensure that the building meets certain energy performance levels.	Required by ASHRAE and building codes	None	None
EA - Prereq 3	No CFC refrigerants used in the facility	Campus standard	None	None
EA - 1	Empathy wheel that treats some of the air, building envelope has 1.5" insulation outside of metal studs to create insulation plane. Fiberglass windows that have a high efficiency	Empathy wheel would not have been included and lighter insulation would have been chosen.	Heavier material for the insulation in a fall hazard situation. Larger ERV units for the crane to pick that needs to be considered. No change on the fiberglass windows	None
EA - 2	Passive solar domestic hot water system on the roof of the facility	A standard water heating process would have been only chosen	Additional fall hazards because it sends somebody up to the roof and this is a new trade on the roof (sloped)	None
EA - 3	The enhanced commissioning above and beyond the prerequisites were completed for the project	Commissioning process would not have taken place	Additional time spent on the time by the commissioning contractor which exposes them to a number of hazards especially climbing up and down a ladder	None

EA - 5	Measurement and verification of the energy output of the building will go on for a year after construction is complete	No additional hazards created during the construction process	None	None
EA - 6	School is purchasing green power	No change	None	None
Materials & Resources				
MR - Prereq 1	School has the recycling program and this site has it at every entry point and exit point.	No change	None	None
MR - 2	Waste diversion from landfills	Waste would just be thrown in dumpsters	More hazards because there are more dumpsters picks and they take up more space and there is more activity. Laborers have to sort some of the stuff, general garbage getting things that should be recycled.	None
MR - 4	The steel and the concrete used on this project were the major materials used to qualify for this credit	Different, likely cheaper materials would have been specified	None	None
MR - 5	The brick and exterior stone used on this project were the major materials used to qualify for this credit	No change	None	None
MR - 6	ACT with biofibers and wheat board in the substrate of some of the wood was used to qualify for this credit	Different, likely cheaper materials would have been specified	None	None
MR - 7	Blocking, doors and millwork are FSC certified wood	Different, likely cheaper materials would have been specified	None	None
Indoor Env. Quality				
IEQ - Prereq 1	Ventilation system meets ASHRAE and building codes on the front range that require them	No change	None	None

IEQ - Prereq 2	University already has the smoking policies in place	No change	None	None
IEQ - 1	In the higher occupancy rooms there are CO2 monitoring systems installed	These systems would not be installed if the project was not going for LEED	Additional exposure time and frequency of climbing on a ladder for workers	None
IEQ - 2	Large ventilation system with higher rate of air change	Lower level ventilation systems because it makes the building less efficient	Heavier and larger ductwork to handle increases overexertion hazard	None
IEQ - 3.1	Duct ends were closed throughout the construction to ensure construction debris did not end up in them.	These processes would not have been as closely monitored or documented	Additional time covering the ducts and fall hazards because they are up and down the ladder more often	None
IEQ - 3.2	The building will be flushed out before it is occupied	Normally not as large a flush out process	None	None
IEQ - 4.1	Low emitting adhesives and sealants were selected	No change	None	Lower exposure to the chemicals in the standard materials for the workers
IEQ - 4.2	Low emitting paints and coatings were selected	No change	None	Lower exposure to the chemicals in the standard materials for the workers
IEQ - 4.3	Low emitting carpets were selected	No change	None	Lower exposure to the chemicals in the standard materials for the workers
IEQ - 4.4	Low emitting composite wood and agrifiber products were selected	No change	None	Lower exposure to the chemicals in the standard materials for the workers
IEQ - 6.1	Occupancy sensors in the heavily occupied rooms	The sensors would not normally be installed	Additional exposure time and frequency of climbing on a ladder for workers	None
IEQ - 6.2	Most of the occupied spaces have the thermal controls	Becoming standard in new dormitory facilities	None	None
IEQ - 7.1	Mechanical systems ensure that 80% of the occupants have a comfortable space based on temperature, humidity, etc.	This level of design was necessary for the project and standard for habitable areas	None	None
IEQ - 7.2	Thermal comfort survey will be conducted with the occupants in the near future	Survey would not be conducted	None	None

IEQ - 8.1	Three different types and sizes of windows based on where the window is located to ensure the right amount of view and light	Normally one window would have been chosen and installed	3 window sizes and 2 types of glass - the larger windows can be harder to lift increasing overexertion hazard	None
IEQ 8.2	Three different types and sizes of windows based on where the window is located to ensure the right amount of view and light	Normally one window would have been chosen and installed	3 window sizes and 2 types of glass - the larger windows can be harder to lift increasing overexertion hazard	None
Innovation & Design				
ID - 1.1	Education system with signage that educated the users and occupants about the green features of the building	Signage would not be there	None	None
ID - 1.2	Exemplary purchase of green power by the university for the facility	No change	None	None
ID - 1.3	A non vegetation area surrounds the building in order to keep rodents and other pests out of the facility	No change because it is a University policy	None	None
ID - 1.4	Different floors can compete to use the least energy and the sub panels to allow the different floors and wings to see how much energy they are using	The subpanels would not be included in the design	Additional wiring and panel were installed increasing the exposure time for the workers	None
ID – 2	Teams have LEED AP's on them	No change	None	None

Project F

LEED CREDIT	LEED DESIGN ELEMENT	TRADITIONAL DESIGN OPTION	ADDITIONAL HAZARDS	MITIGATED HAZARDS
LEED NC V2.2				
Sustainable Sites				
SS - Prereq 1	Stormwater management plan was put in place that included silt fence and soil dampening to reduce dust	The stormwater management plan is a contractor standard to qualify for this pre-requisite	None	None
SS - 1	The project qualified for this credit because the project was on the developed campus	No change	None	None
SS - 2	The project qualified for this credit because the project was on the developed campus	No change	None	None
SS - 4.1	The entire campus has close proximity to public transpirations	No change	None	None
SS - 4.2	There are many bike racks and some changing rooms available in the building for those commuting by bike.	The changing rooms would not have been included if the project was not attempting LEED certification	None	None
SS - 4.3	Parking spaces located near to the building are designated for low emitting vehicles	Signage would not have need to be installed	None	None
SS - 4.4	The project added less parking than would normally be designed for a facility of this size.	No change	None	None
SS - 5.1	Protection of habitat is done on a campus level and is not managed project to project.	No change	None	None
SS - 5.2	Protection of open space is done on a campus level and is not managed project to project	No change	None	None

SS- 6.2	Pervious pavers with an underdrain were used around the building. Additionally there is a bioswale on the east side of the building to manage water.	Regular pavers would have been used and the bioswale would not have been included.	The inclusion of the bioswale caused the construction workers to spend additional time working among heavy machinery.	None
SS - 7.1	Light colored concrete allowed for this credit to be achieved	No change	None	None
SS - 7.2	A TPO white roof was installed on the facility because of its reflectivity	The traditional design would have been a standard black EPDM roof.	None	None
SS - 8	A standard was writing for the lighting of the facility and different lighting was chosen that limited the light pollution of exterior lights	Different light fixtures would have been chosen for the outside of the facility.	None	None
Water Efficiency				
WE - 1.1	Native, low water use plants were chosen in the landscaping around the facility.	No change	None	None
WE - 3	Low flush water closets, urinals, and faucets were specified.	Normal volume flush units may have been chosen.	None	None
Energy & Atmosphere				
EA - Prereq 1	Fundamental commissioning process	This level of commissioning is standard for all new buildings on the campus.	None	None
EA - Prereq 2	The building meets all the ASHRAE codes to ensure building meets a certain energy performance level. This level of design is part of local building codes.	No change	None	None
EA - Prereq 3	Refrigerant is provided by a central chiller facility that meets the requirements of this credit	No change	None	None

EA - 1	In order to achieve this credit the facility has a continuous insulation on the outside of the building, optimized the window system, mechanical systems with a more complicated control system, more insulation on the roof, and sun shades on the building to reduce solar heat building (exterior permanent).	The designer would have selected a lighter level of insulation for the outside of the building. Simpler mechanical systems would have been selected that requires fewer controls throughout. Also the permanent exterior sunshades would not have been included.	Additional time was needed in order to install the continuous installation around the building. This required additional time spent on lifts and the heavy insulations increases the overexertion hazard. Finally the exterior shades make the cleaning of the windows difficult, another task done at height.	Having the HVAC system under the floors makes it easier for the mechanical contractor to install the system.
EA - 2	The facility has photovoltaic power generation units on the roof.	These units would have not been chosen or installed if the building was not achieving LEED certification.	Installing the PV panels requires additional lifts by the cranes to put the units on the roof. Also electricians are now exposed to fall hazards that they are not familiar with	None
EA - 3	Enhanced commissioning	This level of commissioning is standard for all new buildings of this size and cost on the campus	None	None
EA - 4	Refrigerant is provided by a central chiller facility that meets the requirements of this credit	No change	None	None
EA - 5	Measurement and verification of the building energy output will go on for one year after the building is complete.	No change	None	None
EA - 6	University agrees to purchase green energy credits for the facility	No change	None	None
Materials & Resources				
MR - Prereq 1	There are several recycling centers that are located throughout the facility.	Having these recycling centers available is a campus standard	None	None

MR - 2	Waste is diverted from landfills by having construction workers sort waste by material type into different dumpsters	Normally waste would just be thrown into a single dumpster	Waste diversion takes more time and increases worker exposure time. Dumpster diving is occasionally needed to sort waste, which exposes workers to abrasions, punctures and sprained ankles. Finally this requires more dumpster removal and delivery increases the frequency workers are exposed to the trucks	None
MR - 4	A majority of the recycled materials in this facility came from the steel and the use of some flyash in the concrete.	Flyash would not be included in the concrete for the project.	The flyash makes finishing the concrete more difficult and increases exposure time for the workers.	None
MR - 5	The stone for the exterior of the building and the concrete were locally obtained materials	No change	None	None
MR - 7	The designer certified that certified would be used for the blocking, millwork and other portions of the facility.	No change	None	None
Indoor Env. Quality				
IEQ - Prereq 1	Indoor air quality meets ASHRAE standards, these codes are adopted by the local building codes	No change	None	None
IEQ - Prereq 2	The smoking requirements of the state of Colorado mandate this credit is achieved	No change	None	None
IEQ - 3.1	A construction indoor air quality management plan that included the covering of ducts and not running machinery inside was followed	These procedures would not have been as closely followed and documented.	This process increased worker exposure time by needing to cover the ducts.	Not running the generators inside created a healthier work environment for the workers.

IEQ - 3.2	An indoor atmospheric quality test was conducted after construction and before occupancy	The test would not have been conducted if the project was not attempting LEED	None	None
IEQ - 4.1	Low emitting adhesives and sealants were selected	A cheaper alternative would have been selected if this building was not looking to achieve LEED	Rework was occasionally required for the roof work because the adhesives were not as good. Exposure time to the fall hazard experienced was increased.	The construction and installation of these materials have lower VOC levels, which is healthier for the workers.
IEQ - 4.2	Low emitting paints and coatings were selected	A cheaper alternative would have been selected if this building was not looking to achieve LEED	None	The construction and installation of these materials have lower VOC levels, which is healthier for the workers.
IEQ - 4.3	Low emitting carpets were selected	A cheaper alternative would have been selected if this building was not looking to achieve LEED	None	The construction and installation of these materials have lower VOC levels, which is healthier for the workers.
IEQ - 4.4	Low emitting composite wood and agrifiber products were selected	A cheaper alternative would have been selected if this building was not looking to achieve LEED	None	The construction and installation of these materials have lower VOC levels, which is healthier for the workers.
IEQ - 6.1	Occupancy sensors and additional lighting controls were added to the rooms	The occupancy sensors would not have been included.	This required a greater frequency of exposure to the workers from falling off ladders.	None
IEQ - 6.2	Mechanical system had under floor air displacement system, which has more air diffusers and more thermostat control points. This requires the use of multi zone air handler units.	A simpler mechanical system would have been designed for the facility and would have allowed for single zone air handlers.	None	Having all of the HVAC running under the floor made the installation process easier and faster for the mechanical contractor, decreasing exposure time.
IEQ - 7.1	Design of building ensures that majority of occupants have thermal comfort	This level of design is standard for the designer	None	None

IEQ - 7.2	Thermal comfort survey will be conducted with the occupants in the near future	Survey would not be conducted	None	None
Innovation & Design				
ID - 1.1	The building has signage and a computer system that is hooked up to the VAS system that informs users of the green building features.	The signage and computer system would not have been included in the facility.	Required the addition of a few display monitors and outlets, increasing worker exposure time.	None
ID - 1.2	A green cleaning plan was created for the maintenance of the building.	This process is for the maintenance of the building after the completion of construction	None	None
ID - 1.3	A pesticide free landscaping program was adopted for the maintenance of the building.	This process is for the maintenance of the building after the completion of construction	None	None
ID - 1.4	The building has exemplary water use reduction, use of FSC wood and an extended contract for the purchase of green power.	Same as credits WE-3, MR- 7 and EA- 6	None	None
ID - 2	Project team included a LEED AP	No change	None	None

APPENDIX D: FINDINGS COMPILATION

LEED CREDIT									
Sustainable Sites	**Projects Attempting Credit (%)**	**Hazard Change**	**Change (%)**	**Project A**	**Project B**	**Project C**	**Project D**	**Project E**	**Project F**
Prereq 1: Construction Activity Pollution Prevention	100	N/A	0						
		No Change	100	x	x	x	x	x	x
		Increase	0						
		Decrease	0						
Credit 1: Site Selection	83	N/A	100		x	x	x	x	x
		No Change	0						
		Increase	0						
		Decrease	0						
Credit 2: Development Density	83	N/A	100		x	x	x	x	x
		No Change	0						
		Increase	0						
		Decrease	0						
Credit 3: Brownfield Redevelopment	33	N/A	0						
		No Change	100			x	x		
		Increase	0						
		Decrease	0						
Credit 4.1: Public Transportation Access	100	N/A	100	x	x	x	x	x	x
		No Change	0						
		Increase	0						
		Decrease	0						
Credit 4.2: Bicycle Storage and Changing Rooms	100	N/A	0						
		No Change	83	x	x	x	x		x
		Increase	17					x	
		Decrease	0						
Credit 4.3: Low Emitting and Fuel Efficient Vehicles	100	N/A	0						
		No Change	67		x	x	x		x
		Increase	33	x				x	

		Decrease	0						
Credit 4.4: Parking Capacity	100	N/A	67			x	x	x	x
		No Change	0						
		Increase	17		x				
		Decrease	17	x					
Credit 5.1: Protect and Restore Habitat	50	N/A	100		x			x	x
		No Change	0						
		Increase	0						
		Decrease	0						
Credit 5.2: Maximize Open Space	100	N/A	50		x			x	x
		No Change	50	x		x	x		
		Increase	0						
		Decrease	0						
Credit 6.1: Stormwater Quantity Control	33	N/A	0						
		No Change	50					x	
		Increase	50				x		
		Decrease	0						
Credit 6.2: Stormwater Quality Control	67	N/A	0						
		No Change	25					x	
		Increase	75		x		x		x
		Decrease	0						
Credit 7.1: Heat Island Effect- Non-roof	83	N/A	0						
		No Change	80		x		x	x	x
		Increase	20			x			
		Decrease	0						
Credit 7.2: Heat Island Effect- Roof	83	N/A	0						
		No Change	40		x				x
		Increase	60	x		x		x	
		Decrease	0						
Credit 8: Light Pollution Reduction	83	N/A	60		x		x	x	
		No Change	40	x					x
		Increase	0						
		Decrease	0						

Credit 9: Tenant Design and Construction Guide (C&S)	17	N/A	100	x					
		No Change	0						
		Increase	0						
		Decrease	0						
Water Efficiency									
Credit 1.1: Water Efficient Landscaping: Reduce by 50%	83	N/A							
		No Change	100	x	x	x		x	x
		Increase	0						
		Decrease	0						
Credit 1.2: Water Efficient Landscaping- No potable water use or no irrigation	17	N/A	100	x					
		No Change	0						
		Increase	0						
		Decrease	0						
Credit 2: Innovate Wastewater Technologies	17	N/A	0						
		No Change	0						
		Increase	100					x	
		Decrease	0						
Credit 3: Water Use Reduction	100	N/A	0						
		No Change	100	x	x	x	x	x	x
		Increase	0						
		Decrease	0						
Energy & Atmosphere									
Prerequisite 1: Fundamental Commissioning of Building Energy Systems	100	N/A	0						
		No Change	83	x	x	x		x	x
		Increase	17				x		
		Decrease	0						
Prerequisite 2: Minimum Energy Performance	100	N/A	0						
		No Change	83	x		x	x	x	x
		Increase	17		x				
		Decrease	0						
Prerequisite 3: Fundamental Refrigerant Management	100	N/A	17	x					
		No Change	83		x	x	x	x	x
		Increase	0						

		Decrease	0						
Credit 1: Optimize Energy Performance	100	N/A	0						
		No Change	33	x		x			
		Increase	67		x		x	x	x
		Decrease	17						x
Credit 2: On-Site Renewable Energy	33	N/A	0						
		No Change	0						
		Increase	100					x	x
		Decrease	0						
Credit 3: Enhanced Commissioning	83	N/A	0						
		No Change	40			x			x
		Increase	60		x		x	x	
		Decrease	0						
Credit 4: Enhanced Refrigerant Management	83	N/A	0						
		No Change	40	x					x
		Increase	40		x		x		
		Decrease	20			x			
Credit 5.1: Measurement and Verification-Base Building	50	N/A	100		x		x	x	x
		No Change	0						
		Increase	0						
		Decrease	0						
Credit 5.2: Measurement and Verification- Tenant Submetering (C & S)	17	N/A	0						
		No Change	0						
		Increase	100	x					
		Decrease	0						
Credit 6: Green Power	83	N/A	100	x	x		x	x	x
		No Change	0						
		Increase	0						
		Decrease	0						
Materials and Resources									
Prerequisite 1: Storage & Collection of Recyclables	100	N/A	0						
		No Change	83		x	x	x	x	x
		Increase	17	x					

		Decrease	0						
Credit 1: Building Reuse	0	N/A	0						
		No Change	0						
		Increase	0						
		Decrease	0						
Credit 2: Construction Waste Management	100	N/A	0						
		No Change	0						
		Increase	83	x	x		x	x	x
		Decrease	17			x			
Credit 3: Materials Reuse	0	N/A	0						
		No Change	0						
		Increase	0						
		Decrease	0						
Credit 4: Recycled Content	100	N/A	0						
		No Change	67	x	x	x		x	
		Increase	33				x		x
		Decrease	0						
Credit 5: Regional Materials	100	N/A	0						
		No Change	100	x	x	x	x	x	x
		Increase	0						
		Decrease	0						
Credit 6: Rapidly Renewable Materials	33	N/A	0						
		No Change	100	x				x	
		Increase	0						
		Decrease	0						
Credit 7: Certified Wood	83	N/A	0						
		No Change	100		x	x	x	x	x
		Increase	0						
		Decrease	0						
Indoor Environmental Quality									
Prerequisite 1: Minimum IAQ Performance	100	N/A	0						
		No Change	100	x	x	x	x	x	x
		Increase	0						

		Decrease	0						
Prerequisite 2: Environmental Tobacco Smoke Control	100	N/A	100	x	x	x	x	x	x
		No Change	0						
		Increase	0						
		Decrease	0						
Credit 1: Outdoor Air Delivery Monitoring	83	N/A	0						
		No Change	40	x			x		
		Increase	60		x	x		x	
		Decrease	0						
Credit 2: Increased Ventilation	67	N/A	0						
		No Change	75	x		x	x		
		Increase	25					x	
		Decrease	0						
Credit 3.1: Construction IAQ Management Plan- During Construction	100	N/A	0						
		No Change	33	x		x			
		Increase	50				x	x	x
		Decrease	50		x		x		x
Credit 3.2: Construction IAQ Management Plan - Before Occupancy	83	N/A	0						
		No Change	100		x	x	x	x	x
		Increase	0						
		Decrease	0						
Credit 4.1: Low-Emitting Materials- Adhesives and Sealants	100	N/A	0						
		No Change	17	x					
		Increase	50			x	x		x
		Decrease	67		x	x		x	x
Credit 4.2: Low-Emitting Materials- Paints and Coatings	100	N/A	0						
		No Change	33	x			x		
		Increase	0						
		Decrease	67		x	x		x	x
Credit 4.3: Low-Emitting Materials- Carpets	83	N/A	0						
		No Change	20				x		
		Increase	0						
		Decrease	80		x	x		x	x

Credit 4.4: Low-Emitting Materials- Composite Wood and Agrifiber Products	83	N/A	0						
		No Change	20				x		
		Increase	0						
		Decrease	80		x	x		x	x
Credit 5: Indoor Chemical and Pollutant Source Control	67	N/A	0						
		No Change	50	x	x				
		Increase	50			x	x		
		Decrease	0						
Credit 6.1: Controllability of Systems- Lighting	83	N/A	0						
		No Change	0						
		Increase	100		x	x	x	x	x
		Decrease	0						
Credit 6.2: Controllability of Systems- Thermal Comfort	50	N/A	0						
		No Change	50		x			x	
		Increase	25				x		
		Decrease	25						x
Credit 7.1: Thermal Comfort- Design	100	N/A	0						
		No Change	100	x	x	x	x	x	x
		Increase	0						
		Decrease	0						
Credit 7.2: Thermal Comfort- Verification	83	N/A	100		x	x	x	x	x
		No Change	0						
		Increase	0						
		Decrease	0						
Credit 8.1: Daylight 75% of Spaces	33	N/A	0						
		No Change	50				x		
		Increase	50					x	
		Decrease	0						
Credit 8.2: Views for 90% of Spaces	67	N/A	0						
		No Change	75	x		x	x		
		Increase	25					x	
		Decrease	0						
Innovation in Design									

Credit 1.1: Innovation in Design	100	N/A	0						
		No Change	83	x	x	x	x	x	
		Increase	17						x
		Decrease	0						
Credit 1.2: Innovation in Design	100	N/A	33			x			x
		No Change	33				x	x	
		Increase	33	x	x				
		Decrease	0						
Credit 1.3: Innovation in Design	100	N/A	17						x
		No Change	67	x		x	x	x	
		Increase	17		x				
		Decrease	0						
Credit 1.4: Innovation in Design	100	N/A							
		No Change	67	x		x	x		x
		Increase	33		x			x	
		Decrease	0						
Credit 2: LEED AP	100	N/A	100	x	x	x	x	x	x
		No Change	0						
		Increase	0						
		Decrease	0						

APPENDIX E: CONDENSED FINDINGS

Credit	Projects Attempting Credit	Increase	No Change	Decrease	N/A
Sustainable Sites					
Prereq 1: Construction Activity Pollution Prevention	6	0	6	0	0
Credit 1: Site Selection	5	0	0	0	5
Credit 2: Development Density	5	0	0	0	5
Credit 3: Brownfield Redevelopment	2	0	2	0	0
Credit 4.1: Public Transportation Access	6	0	0	0	6
Credit 4.2: Bicycle Storage and Changing Rooms	6	1	5	0	0
Credit 4.3: Low Emitting and Fuel Efficient Vehicles	6	2	4	0	0
Credit 4.4: Parking Capacity	6	1	0	1	4
Credit 5.1: Protect and Restore Habitat	3	0	0	0	3
Credit 5.2: Maximize Open Space	6	0	3	0	3
Credit 6.1: Stormwater Quantity Control	2	1	1	0	0
Credit 6.2: Stormwater Quality Control	4	3	1	0	0
Credit 7.1: Heat Island Effect- Non-roof	5	1	4	0	0
Credit 7.2: Heat Island Effect- Roof	5	3	2	0	0
Credit 8: Light Pollution Reduction	5	0	2	0	3
Credit 9: Tenant Design and Construction Guide (C&S)	1	0	0	0	1
Water Efficiency					
Credit 1.1: Water Efficient Landscaping: Reduce by 50%	5	0	5	0	0
Credit 1.2: Water Efficient Landscaping- No potable water use or no irrigation	1	0	0	0	1
Credit 2: Innovate Wastewater Technologies	1	1	0	0	0
Credit 3: Water Use Reduction	6	0	6	0	0
Energy & Atmosphere					
Prerequisite 1: Fundamental Commissioning of Building Energy Systems	6	1	5	0	0
Prerequisite 2: Minimum Energy Performance	6	1	5	0	0
Prerequisite 3: Fundamental Refrigerant Management	6	0	5	0	1
Credit 1: Optimize Energy Performance	6	4	2	0	0
Credit 2: On-Site Renewable Energy	2	2	0	0	0

Credit 3: Enhanced Commissioning	5	3	2	0	0
Credit 4: Enhanced Refrigerant Management	5	2	2	1	0
Credit 5.1: Measurement and Verification-Base Building	4	0	0	0	4
Credit 5.2: Measurement and Verification- Tenant Submetering (C & S)	1	1	0	0	0
Credit 6: Green Power	5	0	0	0	5
Materials and Resources					
Prerequisite 1: Storage & Collection of Recyclables	6	1	5	0	0
Credit 1: Building Reuse	0	0	0	0	0
Credit 2: Construction Waste Management	6	5	0	1	0
Credit 3: Materials Reuse	0	0	0	0	0
Credit 4: Recycled Content	6	2	4	0	0
Credit 5: Regional Materials	6	0	6	0	0
Credit 6: Rapidly Renewable Materials	2	0	2	0	0
Credit 7: Certified Wood	5	0	5	0	0
Indoor Environmental Quality					
Prerequisite 1: Minimum IAQ Performance	6	0	6	0	0
Prerequisite 2: Environmental Tobacco Smoke Control	6	0	0	0	6
Credit 1: Outdoor Air Delivery Monitoring	5	3	2	0	0
Credit 2: Increased Ventilation	4	1	3	0	0
Credit 3.1: Construction IAQ Management Plan- During Construction	6	3	2	3	0
Credit 3.2: Construction IAQ Management Plan- Before Occupancy	5	0	5	0	0
Credit 4.1: Low-Emitting Materials- Adhesives and Sealants	6	3	1	4	0
Credit 4.2: Low-Emitting Materials- Paints and Coatings	6	0	2	4	0
Credit 4.3: Low-Emitting Materials- Carpets	5	0	1	4	0
Credit 4.4: Low-Emitting Materials- Composite Wood and Agrifiber Products	5	0	1	4	0
Credit 5: Indoor Chemical and Pollutant Source Control	4	2	2	0	0
Credit 6.1: Controllability of Systems- Lighting	5	5	0	0	0
Credit 6.2: Controllability of Systems- Thermal Comfort	4	1	2	1	0
Credit 7.1: Thermal Comfort- Design	6	0	6	0	0
Credit 7.2: Thermal Comfort- Verification	5	0	0	0	5
Credit 8.1: Daylight 75% of Spaces	2	1	1	0	0
Credit 8.2: Views for 90% of Spaces	4	1	3	0	0
Innovation in Design					

Credit 1.1: Innovation in Design	6	1	5	0	0
Credit 1.2: Innovation in Design	6	2	2	0	2
Credit 1.3: Innovation in Design	6	1	4	0	1
Credit 1.4: Innovation in Design	6	2	4	0	0
Credit 2: LEED AP	6	0	0	0	6