CONSTRUCTION WORKER HEALTH:
A WEB-BASED APPROACH TO SELECTING ALTERNATIVES TO HAZARDOUS PROCEDURES

By

EILEEN ROSA PESANTES-TAVARES

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2011

To my husband and kids

ACKNOWLEDGMENTS

I thank my committee, Dr. Charles Glagola, Dr. Ronald Cook and Dr. Jimmie Hinze, for sharing their knowledge and experience. I especially thank my chair committee, Dr. Ralph D. Ellis, for his encouragement and guidance, and for always being willing to share his vast experience and knowledge; his contribution to my years at The University of Florida is invaluable. I will also like to thank Ms. Pam Susi and the people from The Center for Construction Research and Training (CPWR), who have been constant sources of information.

Special thanks go to my parents, Neida and Hipólito, and siblings, Rosalía, Hugo and Natacha, who unconditionally believe in me and encourage me to aim higher each time. I am deeply grateful to my husband, Miguel, who supports me in all my endeavors, without his companionship and love this road would have been more difficult and less enjoyable. I am also grateful for my kids, Esteban and Elisa, for their patience and understanding even at their early age, as they are my inspiration and my reason to keep on going every day. Last, but not least, I would like to thank my friends, especially those in Gainesville, for being the best support group anyone could ask for.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
API	Application Programming Interface
ASCE	American Society of Civil Engineers
BIM	Building Information Modeling
BREEAM	Building Research Establishment Environmental Assessment Method
CASBEE	Comprehensive System for Building Environmental Efficiency
CECA	Civil Engineering Contractors Association
CMU	Concrete Masonry Unit
CPWR	The Center for Construction Research and Training. Formerly known as The Center to Protect Workers' Rights.
CSI	Construction Specification Institute
DGNB	German Sustainable Building Council
ECI	European Construction Institute
FBGC	Florida Green Building Coalition
FCAW	Flux-cored Arc Welding
GMAW	Gas Metal Arc Welding
GP	General Practitioner
GTAW	Gas Tungsten Arc Welding
GV	General Ventilation
HAVS	Hand Arm Vibration Syndrome
HEPA	High Efficiency Particulate Air
LEED	Leadership in Energy and Environmental Design
LEV	Local Exhaust Ventilation

LTCR	Lost Time Case Rate
Mg/m^3	Milligrams per cubic meter
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
RFID	Radio-Frequency Identification
RSP	Respirable Suspended Particles
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc Welding
SS	Stainless Steel
TLV	Tolerance Level Values
TWA	Time Weighted Average
VOC	Volatile Organic Compound
WMSD	Work Related Musculoskeletal Disorders
XML	Extensible Markup Language

Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

A WEB-BASED APPROACH TO SELECTING ALTERNATIVES TO HAZARDOUS PROCEDURES

By

Eileen Rosa Pesantes-Tavares

December 2011

Chair: Ralph D. Ellis
Major: Civil Engineering

Construction workers health has been studied mostly under occupational health environments. Most studies examine the effects that exposure to harmful substances and procedures can have. Other studies refer to changes that can be made to procedures to avoid hazardous situations and to safeguard the health of the construction workers. Some recommendations have been adopted by the Occupational Safety and Health Administration (OSHA) and others are the result of and the efforts of other agencies such as the American Conference of Governmental Industrial Hygienists (ACGIH) and its maximum exposure values and how to minimize exposure. Unfortunately, health issues are largely disregarded by different construction stakeholders such as owners, designers and construction managers, primarily because of the latency period from the time and length of exposure to the onset of the effects of that exposure.

Safety has been given considerable attention because the cause and effect lag time is minimal, as a worker who has an accident, usually sees the effects at the same moment the accident happens. The adoption of safety regulations by OSHA to prevent injuries and the importance given to safety by construction professionals makes safety

an important issue in construction. Jobsites have safety training and safety talks to avoid accidents, but health issues are rarely addressed in these talks. Besides putting together the different substitutions in procedures and materials, this study aims to present it in a way accessible to construction managers and other construction stakeholders to ensure their adoption. A web-based database, organized using Construction Specification Institute (CSI) Masterformat 1995, has been developed to provide easy access to the different substitutions that can be made to safeguard the health of the construction worker. Furthermore, the database can be access from design software programs like Sketchup through an application programming interface programmed in Ruby. It can also be accessed from Excel, a common tool use by estimators to do their project estimate, via an add-in programmed in Visual Basic. Moreover, it translates to Extensible Markup Language (XML) that later can be integrated to design software and other tools to provide the information at the planning and design stages of the project.

This study does not include all divisions of the CSI Masterformat as it only covers divisions 2 through 5 which are: Sitework, Concrete, Masonry and Metals divisions. It will cover issues that affect long term such as respiratory illnesses, ergonomics, and cancer related agents. Items that require special training, such as dealing with asbestos, will not be covered. Furthermore, this research does not include the different requirements for safety and health protection that manufacturers of construction materials need to provide for their workers. Only construction site issues will be addressed.

CHAPTER 1
INTRODUCTION

Health and Safety in Construction

When describing health in construction it is important to differentiate between the distinctly different issues of health and safety. Konz and Johnson (2000) provided the following explanation: “Toxicology deals with long-term effects of foreign chemicals upon the body-it considers health. Safety deals with the short term effects of physical agents upon the body-it considers accidents.” Health issues incorporate agents that can cause long-term harm to a worker which includes chemicals that act over time to take effect on the body. It might also include cumulative trauma caused by repetitive strain. Konz and Johnson (2000) include in their discussion the reasons why it may take a long time to address a health issue:

- long lag between exposure/dose and response
- ignorance of the effect due to lack of information,
- ignoring the effect due to long latency period,
- companies benefit from ignoring long-term health issues as health costs may be paid by individuals.

Safety and health of construction workers have been of great concern in construction, with safety being given greater attention than health due to its immediate and observable consequences. Hallowell and Gambatese (2009) in their study of safety programs prepared a classification system of 10 construction specific accident types that included only three related to health, including overexertion, repetitive motion, and exposure to harmful substances. These three classifications refer primarily to long term effects which take away their urgency. The CPWR - The Center for Construction Research and Training Chart Book (2008) presents overexertion as the third leading

cause of injuries, constituting 18% of non-fatal injuries with lost time recorded, with contact with objects and falls having a higher non-fatal injury rate with reported lost time. In the data presented in the Chart Book, illnesses (long term and short term) reported with lost time represent about 2.5% of all non-fatal injuries. Even so, the long term consequences of some of these illnesses need to be taken into account when deciding what materials or procedures are to be used on the construction site.

Problem Statement

Although there are numerous studies on different issues concerning the long term health of construction workers, there is no clear evidence of solution implementation in the construction industry. Furthermore, most of the studies are made by occupational health experts and very little has been transferred to the construction management and engineering parties. In the US there is no clear guidance on what to do to safeguard the long term health of the construction worker; however, there are more clear regulations and recommendations on what to do regarding the safety of workers. The ever changing environment of construction projects and the lack of continuity of projects, jobs and workers negatively contribute to health implementation plans in the construction industry. Moreover, the absence of immediate negative effects of material exposures makes the situation even harder to manage.

Overview of Solution

The solution to be presented in this thesis is to assemble a database that, in a user-friendly manner and in a web-based environment, can present changes, modifications and additions that can be made to day-to-day operations on a construction project. The database present the different recommendations organized using the CSI Masterformat version 1995 (CSI, 1995). For the purposes of this report,

the database will only address divisions 2 through 5. Future research may complete the database and incorporate all divisions. The database can also be viewed as an XML document which can allow the user to incorporate it into other applications that can extend the use of the database.

The changes, modifications and additions recommended will come from previous research recommendations found through the literature review. Furthermore, it will include cost data for the different items which is not normally found in the current research. Besides the cost data, if the alternative requires a change in schedule, it will be included in the output along with any recommendations for training and certifications.

The web-based application will work in the following manner: The user will first select a division; in the next step the user will select a subdivision and then a procedure that will be performed at the jobsite. After selecting the procedure, the application will give the user the best method to protect the workers, either an alternative to the procedure or extra protection and any cost or schedule changes that need to be accounted for when selecting the alternative. The database also has the alternative of adding divisions, subdivisions, procedures and other information. This is to make it easier to update and to add new information as it becomes available. Figure 1-1 shows how the user will navigate the database to find the applicable information for the activity to be performed.

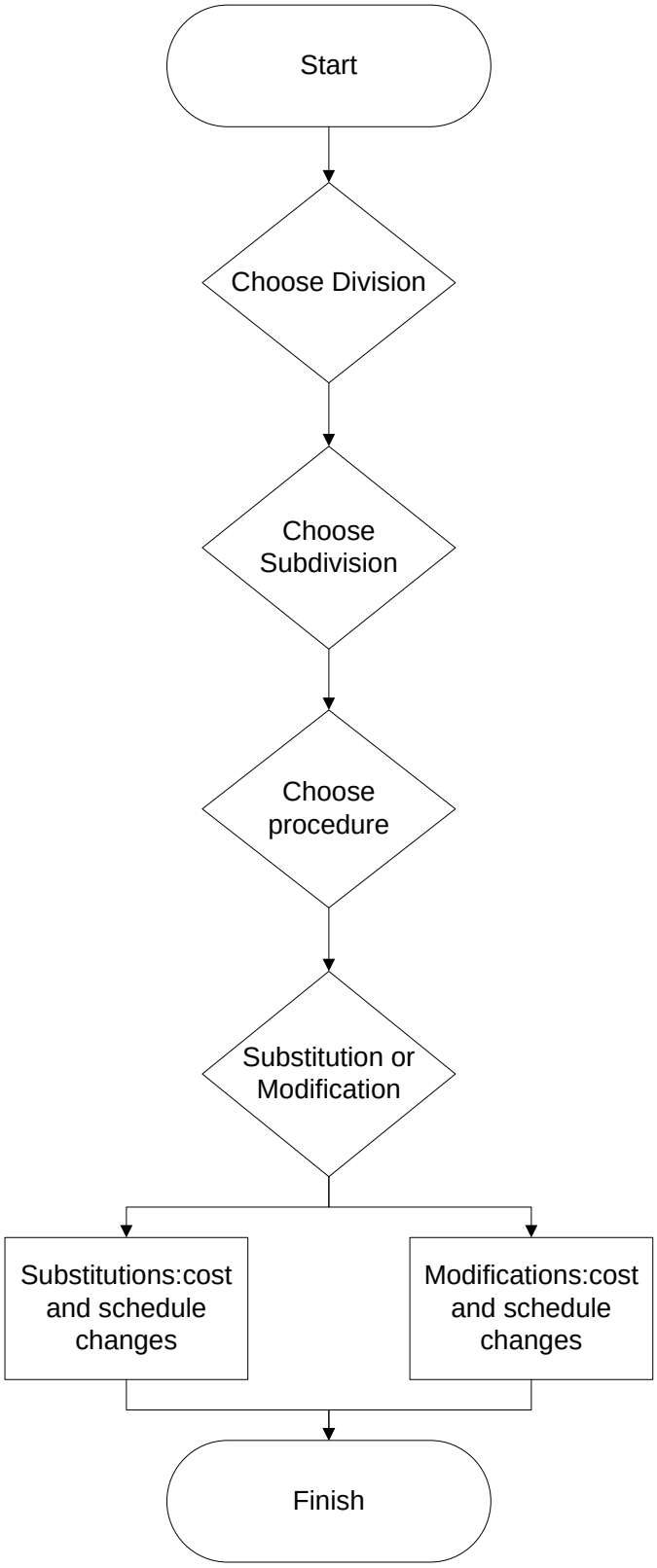

Figure 1-1. Database output

CHAPTER 2
LITERATURE REVIEW

Opening Remarks

There are different specializations that study health issues in construction. Occupational health experts comprise the bulk of those studying the effects of hazards that can be encountered on construction sites. Although agencies such as NIOSH and centers such as CPWR and AGCIH do extensive studies on health issues, on the construction engineering and management side there is less recognition of the importance of this topic. This chapter will present the main health issues that concern this dissertation, the relationship between sustainability and safety and health in construction, and the design for safety and health concept. Moreover, different management systems will be reviewed.

Health Issues in Construction

Health issues are not as notorious or dramatic as injuries, mainly due to the time that the effects take to manifest themselves (Konz & Johnson, 2000). Furthermore, most are not reported which makes them impossible to track (Gyi, Gibb & Haslam, 1999). Also, most contractors usually do not perform health evaluations on their employees and less attention is given to subcontractors. Figure 2-1 shows compiled information from the U.S. Bureau of Labor Statistics on illnesses cases reported between 1995-2009 (BLS, n.d.).

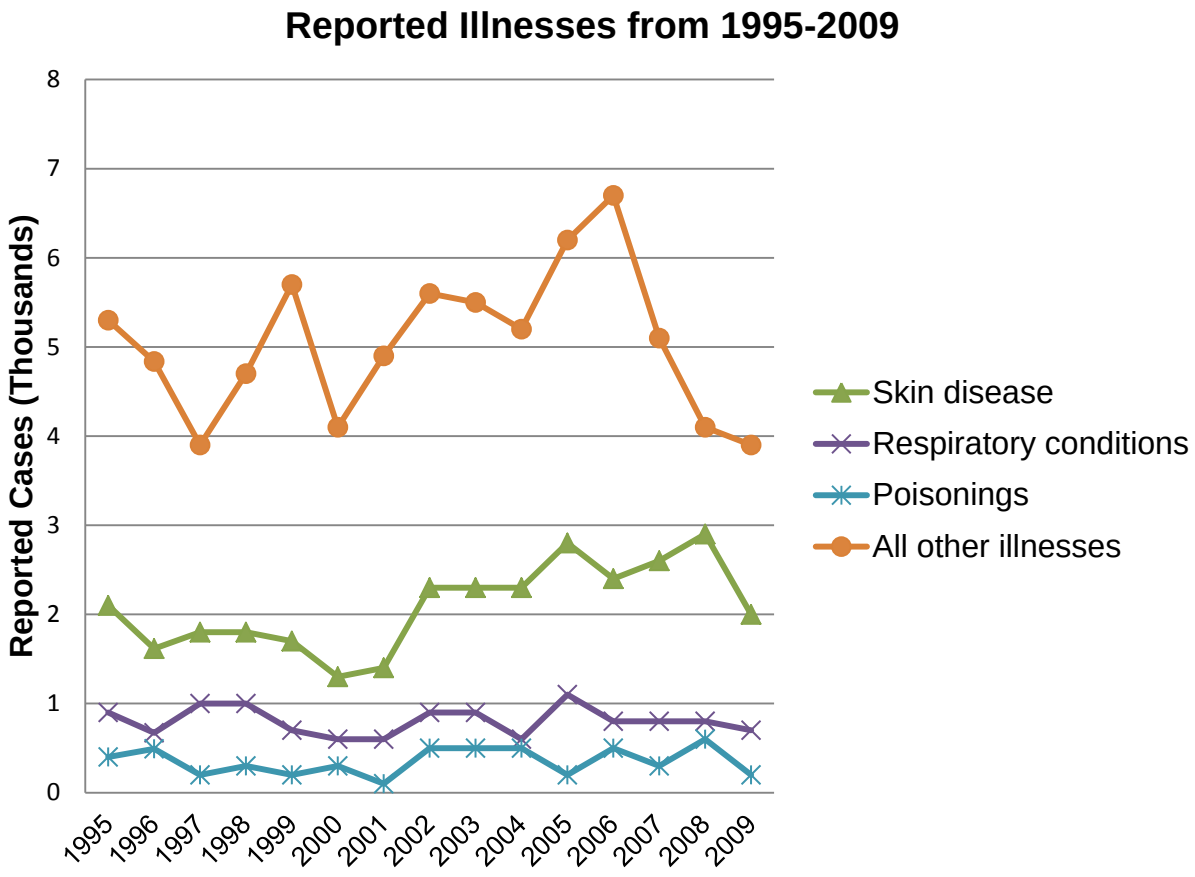

Figure 2-1. Reported illnesses between 1995-2009.

Skin Diseases

From the reported cases, skin diseases are the most commonly reported. Different causes can be attributed to skin diseases such as dermatitis due to dusts, chemicals, contaminants and sun damage (European Construction Institute, ECI, 1999), that primarily affect concrete workers, brick layers, painters, plasters, cleaners, insulators, and other workers that may come in direct contact with different substances that may be harmful to the skin.

Respiratory Conditions

From the CPWR chart book 2008 the following are the most common hazards identified with respiratory use, are shown in Figure 2-2.

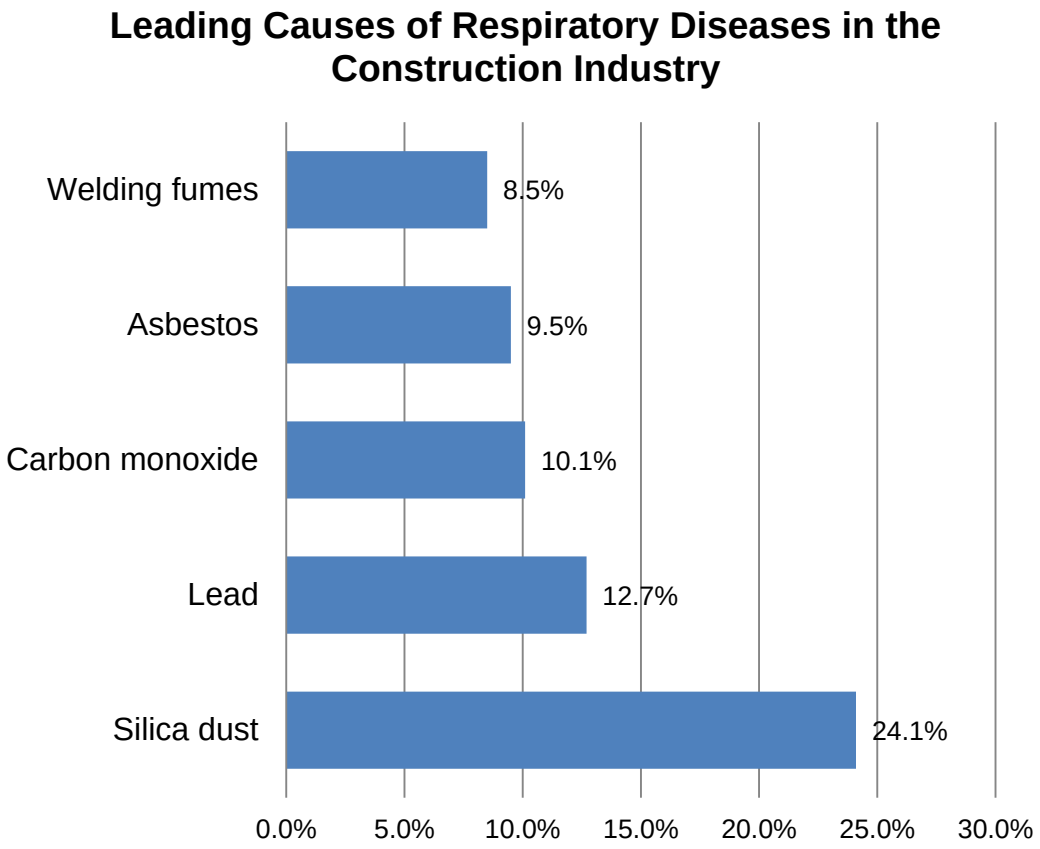

Figure 2-2. Leading causes of respiratory diseases in the construction industry in 2001 (adapted from CPWR Chartbook, 2008)

The focus of the CPWR investigation related more to silica dust (concrete work, sand blasting, grinding, among others), lead and asbestos (demolition work), carbon monoxide (operating engineers and labors in general) and welding fumes (steel trades). Although the BLS reports that the cases of respiratory diseases are under a 1,000 per year as shown Figure 2-1, it is important to understand that this value represents only reported cases. Gyi, Gibb and Haslam (1999) conducted surveys to obtain data on accidents and illnesses in the UK. They acknowledged that health is usually not a major concern and that a very small number of general contractors performed health evaluations of their employees and seldom did this include subcontractors. This was despite the fact that construction workers are in the top five risk groups for contracting

skin diseases, musculoskeletal disorders, lower respiratory diseases, trauma and poisoning, among other illnesses. Regarding health issues, they concluded that there is very little health monitoring and that there is limited meaningful communication between occupational health and health and safety departments that generates a positive or proactive response.

Silica exposure

NIOSH reports that deaths due to silicosis which is caused by exposure to silica, are under reported due to improper diagnosis of the disease. Furthermore, it is believed that the BLS data under-report silicosis related deaths because their data are based on employer reports instead of hospital discharge. Again, the issue of reporting inaccurately on health issues undermines the problem caused by hazardous agents. A study done with data between 1979 and 1995 (Linch, Miller, Althouse, Groce and Hale, 1998) shows that the workers most affected by crystalline silica (the most common type is quartz which comprises 12% of the earth's surface) are construction workers, specifically masonry workers, steel workers and painters. Exposure to construction workers occurs mainly when sandblasting and grinding/cutting metal, masonry or concrete. Per the study, workers in these areas were exposed to at least 10 times the recommended exposure limits as set by NIOSH. They stated that there is not enough done to control crystalline silica exposure.

In another study (Woskie, Kalil, Bello and Virji, 2002), worker exposures to quartz, diesel, dust and welding fumes in the heavy and highway construction segment was researched. The researches argued that in construction, due to the constant change in location which causes changes in duration of tasks and environmental conditions, it is not suitable to apply the same methods to identify hazards as in manufacturing. The

tasks that they studied regarding silica exposure included trenching, excavating and earthmoving, where silica exposure depends on the percentage of quartz in the soil being excavated. Other activities studied included drilling, grinding and cutting of concrete and slurry walls. They found that laborers have the highest mean exposure to respirable dust and quartz followed by operating engineers. Highest exposure of respirable quartz tasks are concrete finishing work and demolition.

A study published regarding excessive silica exposure (Rappaport, Goldberg, Susi and Herrick, 2003) presents the exposures of four groups, namely bricklayers, painters, operating engineers and laborers. They found that the overexposure to silica varied from 64.5% to 100% othe occupational exposure limits as set by NIOSH (value is 0.05 mg/m^3). They also studied dust exposure with overexposure values ranging between 8.2 and 89.2%. They also concluded that better controls are needed to minimize worker exposure to silica and dust.

As the previous studies conclude, other studies concurred that silica exposure on construction sites is high and current controls are not adequate (Flanagan, Seixas, Becker, Takacs and Camp, 2006). Research of controls and what activities produce the most exposure needs to continue to advance the body of knowledge. OSHA in 2009 published a booklet titled “Controlling Silica Exposures in Construction” that presents different ways to minimize silica exposure in different construction tasks.

Welding fumes exposure

Exposure to manganese presumably has neuropsychological effects to welders (Flynn & Susi, 2009). Flynn and Susi (2010) analyzed three databases of welding exposures to manganese, iron and total particulate mass with a focus on neurological outcomes. Their results show a high correlation of manganese with total particulate and

iron (over .7). They also measured the values in front of the welders helmet and behind the helmet. Values of total particulate and iron were usually lower behind helmet than those in front of it. Manganese exposure showed no change due to location. In this study, arc welding was found to result in higher exposure to manganese than the American Conference of Government Industrial Hygienists (ACGIH) tolerance level values (TLV). They recommended the following: use of local ventilation and avoidance of confinement. They also recommended that OSHA measure behind the helmet to assess how well the existing engineering controls work.

Welding fumes are a possible carcinogen according to the International Agency for Research on Cancer (IARC) (1990). While some studies on cancer mortality did not show elevated risks (Steenland, Beaumont and Elliot, 1991), others have shown a significant elevation of risks (Moulin, Wild and Haguenoer, 1993). Sheet metal workers show elevated risk of obstructive lung disease from welding fume exposure (Hunting and Welch, 1993). Woskie et.al. (2002) in their study on heavy and highway construction found that the highest exposure to welding fumes occurs on excavation support operations were overexposure is of 77% of the ACGIH TLV of 5 mg/m^3.

Diesel exposure

Diesel fumes include carbon, nitrogen, water, carbon monoxide, aldehydes, nitrogen dioxide, sulphur dioxide, and polycyclic aromatic hydrocarbons (Health and Safety Executive, HSE, 1999). Diesel exposure among laborers is caused by heavy equipment operating on jobsites. A study conducted between 1971 and 1992 revealed that operators of heavy equipment did not show an increase in lung cancer compared to other construction workers (Jarvholm and Silverman, 2003). Other studies (Wong, Morgan, Kheifets, Larson and Whorton, 1985) found that even though lung cancer was

not significantly different, liver cancer had a higher incidence in the operators' population. A third study (Boffetta, Harris and Wynder, 1990) did not show conclusive evidence to support a relationship of lung cancer and diesel exhaust exposure.

Another effect of exposure to diesel fumes is pulmonary function decrease. This can be manifested as asthma and/or chronic bronchitis (Oliver, Miracle-McMahill, Littman, Oakes & Gaita, 2001). It was found that 13% of the laborers and 11.4% of operating engineers presented asthma symptoms while symptomatic chronic bronchitis was present in 6.5% and 1.9%, respectively. CPWR reports that in chest x-rays of different types of construction workers between 1996 and 2006, 15.6% of the laborers and 11.7% of the operating engineers showed abnormal results.

Musculoskeletal Disorders

The CPWR Chart book (2008) presents the data of work-related musculoskeletal disorders (WMSD) showing "overexertion with lifting" at 41.7%, "without lifting" at 33.9%, "bending and twisting" at 17.8% and "repetitive motion" at 6.6%. In general, the Chart Book shows sprains and strains as constituting 34.7% of all non-fatal injuries and illnesses with reported days away from work. Heat and chemicals accounted for 1.3% of the lost workday cases. Data related to age groups also shows that workers in their 40s and 50s have an increased incidence of occupational health problems such as WMSD and lower back disorders (LBD). A study conducted in ergonomics in construction (Hess, Hecker, Weinstein and Lunger, 2004) and CPWR's Chart Book show that it is important to find new ergonomic ways for the construction worker to reduce WMSD. Moreover, ergonomics in construction needs to be studied in greater depth to catch up with other industries such as manufacturing and computers.

Hess et.al. (2004) introduced skid plates attached to concrete filled hoses to measure the risk of LBD on concrete laborers versus no use of the skid plates. They concluded that, although further studies need to be made to account for other concrete laborer activities, such as pulling, the use of skid plates significantly reduces the risk of LBD.

Construction Sustainability

Sustainability has been given an important role in the construction industry. The global warming movement and environmentally-friendly organizations have driven the industry into building green and sustainable. Federal government agencies required that new buildings and building retrofits be certified as green by one of the rating systems available. Private owners are also certifying their new buildings as a way to show their concern for the environment. But, One question that needs to be answered is how safer for construction workers are the regulations for certifying a construction as green. First, let's start by examining some of the most common rating systems available.

Sustainability, a Definition

There are different definitions of what sustainability is but this one goes closer to the topic of this dissertation. This definition comes from the President's Council of Sustainable Development (1998):

> Maintaining economic growth while producing the absolute minimum of pollution, repairing the environmental damages of the past, using far fewer non-renewable resources, producing much less waste, and extending the opportunity to live in a pleasant and healthy environment to the whole population.

Sustainability has three components: environmental equity, economical equity and social equity. Furthermore, sustainability not only refers to green design but also to the social and economical implications of the life cycle of the structure. For something to be

sustainable it has to have more than green products, but its procedures, its methods of producing the structures need to take into account how society is affected, including construction workers and their work environment (Prevention through Design, n.d.).

Rating Systems

Different systems of rating the sustainability of buildings have been developed throughout the years. They are mostly focused on the final occupant well being and on energy savings. Some of them are BREEAM, Green Globes, CASBEE, DGNB, FGBC and LEED.

- Building Research Establishment Environmental Assessment Method (BREEAM) has established benchmarks in the areas of energy, ecology, water use, internal environment, pollution, transport, materials, waste and management processes, that help in the measures of performance of a building's specification, design, construction and use (BREEAM, n.d.).

- Green Globes is the Canadian adaptation of BREEAM that is also used in the United States. The areas of assessment on new buildings and renovations are similar to BREEAM with their attractiveness derived from their online assessment and rating (Green Globes, n.d.).

- Comprehensive System for Building Environmental Efficiency (CASBEE) is a tool developed in Japan to assess environmental performance of buildings (CASBEE, n.d.).

- German Sustainable Building Council (DGNB in German) has as a main goal of promoting the construction of sustainable and economically efficient buildings. Its areas of quality assessment are: ecological, economic, socio-cultural and functional, technical, process and site (German Sustainable Building Council, n.d.).

- Florida Green Building Coalition (FBGC) is a Florida statewide program that aims to provide economic, social and environmental benefits for promoting sustainability. Its assessment areas are: energy, water, site, health, material, disaster mitigation and a general part. Health assessment refers mostly to final building occupant comfort and health, although some points refer to construction workers such as Construction IAQ Management Plan, Before Occupancy and Low Emitting Materials, but most of them are about 1 point from a minimum of 50 points that are needed for certification (Florida Green Building Coalition, n.d.).

Leadership in Energy and Environmental Design (LEED) and the Green Movement

LEED was developed by the US Green Building Council to be used as a rating system that certified buildings as green by providing third party verification in matters such as energy savings, water and air quality and CO_2 emissions reduction (U.S. Green Building Council, USGBC, n.d.). The certifications are point based (up to 100 points plus 10 bonus points) and are divided in Certified (40+ points), Silver (50+ points), Gold (60+ points) and Platinum (80+ points).

LEED and safety

The main question that needs to be answered is how safe are LEED projects vs. non-LEED projects. To assess this, it is imperative to check on the different requirements that LEED has to certify a building and see how they can affect the safety of the construction worker. Some of the credits affect indirectly the safety of the construction worker (U.S. Green Building Council, USGBC, n.d). In regards to recycling and separating the scraps and waste from recyclable material, this may have good and bad effects. On the positive side, if the site is maintained by segregating all the waste into recyclable and non-recyclable categories, the site will be easier to manage. On the other hand, workers now need to spend time separating materials that otherwise would have gone into just one container. Workers are now spending additional time on chores that probably were not originally scheduled which take time from other construction activities. Separating recyclable material from scrap can cause minor injuries. For example, separating nails from wood to recycle both may result in an increased risk of injury. Another point that can cause an unsafe site can be seen in the design itself. A design that is trying to get points by using daylight might have a high atrium that requires workers to be on high cherry pickers or work at elevation in the structure. This

situation can make a job riskier as falls can occur if proper safeguards are not implemented.

A study done by comparing LEED projects to non-LEED projects showed that the RIR was slightly higher on LEED projects than on non-LEED projects (Rajendran, Gambatese & Behm, 2009). In regards to the lost time case rate (LTCR) there was no significant difference shown between the two types of projects. Some comparison limitations make this study one that needs to be used with caution. For example, it was difficult to divide the data by types of projects (e.g. commercial, institutional, and residential) due to not having sufficient projects of each type. Also, there were different contractors involved with different safety records; one project can have lower rates just because the contractor has a better safety management and will not have anything to do with the project being LEED or not. Moreover, the owner's requirements can have an effect on the LTRC. Another point of comparison could have been between different levels of certification. The data available, within levels, was not sufficient to make an accurate test. Other limitations refer to ownership, location, facility type and number of projects.

LEED and health

There are two credit-earning areas (U.S. Green Building Council, USGBC, n.d) that promote the health of the construction worker. Both are under Indoor environmental quality, namely construction indoor air quality management plan and low emitting materials. The first one, which gives 2 credits, affects directly the worker's health as it refers to maintaining high air quality standards during construction. The second point, which gives 4 credits, indirectly affects the constructionworker as low emitting materials are part of assuring the well being of the final occupants. These products that are also

called low volatile organic compounds (VOC) materials have fewer emissions during and after application helping with the health of the installers as well as the final occupants.

Designing for Safety

The designing for safety concept has been widely studied in the US since the 1990's. The first studies were surveys conducted that created a baseline that reflected what designers were doing to safeguard the construction workers and their worries and limitations. Recent surveys can show the changes, if any in the way designers see safety and health in construction.

The Early Years

The first of these surveys (Hinze & Wiegand, 1992) presented the disconnect between designers and contractors by noting that 70% of the design firms that were interviewed did not address construction worker safety and health in their designs. Other design firms, in contrast, mentioned that they not only did constructability reviews of the plans but that they also made decisions taking into account the safety of workers. In this first survey the authors made a list of examples of different design aspects that can positively affect construction worker safety and health. Among the ones that may affect their health are: substitution of hazardous materials for less hazardous materials, noise emissions from installed equipment, and methods for the removal of polychlorinated biphenyl (PCB). From the designer respondents that were not willing to get involved in safety, the responses included that they do not get involved in those decisions, they consider those decisions as means and methods of construction which is the responsibility of the contractor, and that their lawyers recommended them to not get involved to avoid any liability issue.

Contractors were also interviewed and, although the majority did constructability reviews, only a couple had safety personnel in the constructability reviews and mainly to insure compliance with OSHA regulations. They also provided examples of safety provisions that they saw in the design and provided others that could be added to the list. They all referred to safety issues.

Gambatese and Hinze (1999) conducted research to create a design tool that could be used as a resource for designing for safety concepts. They conducted a survey to accumulate existing design solutions to safety issues with the idea of updating as new concepts arise. They not only interviewed companies, but also reviewed manuals and check lists. Liability issues and lack of knowledge were identified as the major obstacles of implementation. Their main idea was to fill the gap between design standards and construction worker safety.

One of the major obstacles in regards to addressing safety and health during design is the liability issue. Gambatese (1998) proposed that there should not be a conflict for the designer to take worker safety into account when designing a project. Furthermore, by citing the fundamental canons of the National Society of Professional Engineers which states that “(Engineers shall) hold paramount the safety, health and welfare of the public”, he questioned if it is ethical and moral to exclude construction workers from design decisions. From court cases involving injuries to construction workers, Gambatese (1998) stated that designers are expected to do what any reasonable designer would have done, and presently, that does not include safety features in the design. He argued that if clients insist that designers incorporate worker

safety concerns in their designs there may be a change and designing for safety may become a standard practice.

Designing for safety available software tools

The Construction Industry Institute (CII) in 1996 funded research to create a list of design suggestions that incorporate safety-in-design concepts. This research, conducted by Gambatese with Dr. Hinze's guidance (1996), included a software tool that compiles over 400 safety-in-design suggestions. This software tool was designed with the main objective to make the design suggestions available for designers. The resulting tool, although functional, was not easy to use or update, making difficult to assess the usefulness of the software (Marini, 2007).

In 2007, as part of his master's degree requirements, James Marini Jr. developed a more user-friendly software tool that incorporates safety-in-design suggestions available and also has an easier platform to update and add newer suggestions.

Designing for Safety and Health in the United Kingdom

In 1994 the Construction Design and Management (CDM) regulations came into effect in the United Kingdom. These regulations obligate designers to address safety and health management in the planning and design stages. Therefore, designers share the responsibility of safety and health of the construction workers with the contractors (Baxendale & Jones, 2000). The main points of the requirements are: the appointment of a planning supervisor by the owner to ensure that safety is taken into account during planning and design; the designer has to eliminate or minimize safety hazards; and the creation of a health and safety file to record details of the construction. Regarding designers, the main idea of the CDM regulations is to incorporate safety and health in the whole development process from conception to construction.

Prevention through Design

The Center to Protect Workers' Rights (CPWR) funded research to conduct a study on the viability of designing for safety (Gambatese, Behm & Hinze, 2005). Through this study they found that not only do designers need to have the knowledge of what to do but they must also accept it as part of the design process. Although more than a decade has passed between that study and the Hinze & Wiegand (1992) study, not many changes can be seen. Almost half of the respondents did not want to accept the concept of designing for safety. Most respondents still mentioned that this was part of means and methods in construction and will interfere with the contractor's responsibility and that their liability could increase. Designers were also asked to rank different aspects of a project with quality and end-user safety receiving the highest priority while construction safety had the lowest. Other negative impacts perceived by respondents included cost, schedule and productivity. The authors concluded the following keys for implementation:

- Change in the designer mindset toward safety
- Establishment of a motivational force to promote designing for safety
- Increase designer knowledge of the concept
- Incorporate construction safety knowledge in the design phase
- Utilize designers knowledgeable about design-for-safety modifications
- Make design for safety tools and guidelines available for use and reference
- Mitigate designers liability exposure

Designing for safety is also known about as prevention through design (PtD). Toole and Gambatese (2008) identify four trajectories for PtD to progress. They are:

- Facilitating prefabrication
- Designers choosing materials and systems that are safer
- Designers performing construction engineering
- Designers considering the construction space to reduce hazards

Prefabrication will bring the preparation of construction components into a controlled factory setting. Some added costs will also be incurred due to the costs of transportation of the components due to the increasing oil prices and the wear and tear on the transportation vehicles.

Materials and systems that are safer are usually study with the end user in mind. However, occupational safety and health research can study the effects of new materials and systems to construction workers.

When designers perform construction engineering, the end result should be a better application of design by more knowledgeable individuals. Problems can arise regarding who the designers are contracting with for this service, whether it is the owner or the contractor. Although designers may take into account the existing hazards that can occur on a construction site, there may be miscommunications with contractors. Designers should stipulate in the construction documents where hazards exist so the contractors will be aware of them.

The OSHA Alliance Program Construction Roundtable has a workgroup on designing for construction safety. The NIOSH National Occupational Research Agenda (NORA) Construction Sector Council also has a workgroup on construction hazards prevention through design. This two work groups in conjunction with Professor Mike Toole from Bucknell University, maintain the Prevention through Design website which provides information on designing for safety, including the history of the PtD to recent studies, challenges and future goals (Prevention through Design, n.d.).

Management of Health in Construction

European Construction Institute

The European Construction Institute (ECI) in 1999 published a book titled “The ECI Guide to Managing Health in Construction.” This book presents strategies on how to plan construction operations to guard the health of the construction workers. Each section is divided by a health issue presenting the risk indicators, high risk activities and health risk management before and during employment.

Civil Engineering Contractors Association

In Europe, the Civil Engineering Contractors Association (CECA) of the United Kingdom, commissioned Loughborough University to develop a health management toolkit to address the large numbers of poor health issues of construction workers (Brace and Gibb 2004.) The study consisted on different questionnaires to assess the key health issues in construction, which are: hand arm vibration syndrome (HAVS), muscular problems, dermatitis, hand injuries, noise induced deafness, and respiratory problems. The toolkit was divided into 5 areas: health reporting, a questionnaire to help in the reporting of ill health issues; health questionnaire, to be completed by new employees and to be updated every year; General Practitioner (GP) registration; and key health problems, including toolbox talks and how to do self checks. In 2008 Bust, Gibb and Brace (2004) evaluated in a study the implementation of the toolkit and found that 11 respondents used parts of it, but none use it in its entirety. One respondent only used the health reporting information, and the ones that already had a health questionnaire used theirs in place of the toolkit. Incomplete questionnaires were common and some others answered no to the questions. On GP registration, eight of the companies recommended that workers register if they had not. The key health

issues portion was the most frequently used showing hand vibration with the highest rank followed by noise induced deafness and muscular problems.

United States Department of Labor

OSHA has created a cooperative program called Alliance with its main objective being to work with different organizations to prevent worker injuries and illnesses. Alliance not only involves construction organizations, but also includes general industries, immigrant workers, small business and transportation organizations, among others. Organizations that are partners with OSHA through Alliance are not exempt from OSHA inspections or citations, if required. OSHA also has a site where their safety and health regulations are available to companies. These regulations not only present the required controls and protections to apply for different tasks, but they also describe how to record and report incidents, training and education, first aid and medical attention, and inspections, among others.

CHAPTER 3
SUBSTITUTIONS AND MODIFICATIONS

Opening Remarks

This chapter covers the different recommendations for changes, mostly in procedures, that can be done to help safeguard the health of construction workers. It covers divisions 2 through 5 of the CSI Masterformat 1995. These divisions are: sitework, concrete, masonry and steel. This list is not all inclusive, as many different procedures are either still in development or have not been studied. Furthermore, not all tasks covered in the divisions studied necessitated a change or warranted substitutions, either because one is not available or the activity does not present a serious health risk. The different changes presented here reflect what is available currently and how it can be used to minimize health hazards for construction workers performing their tasks and those around them who might also be affected by the activity. A preliminary survey conducted gave us a starting point on what issues are most important per division.

Survey Demographics

The survey was done to get a preliminary idea of what issues professionals involved with construction workers believe are the most important. 29 responses were received. Three demographic questions were asked to understand the sample population that answered the survey. The first question asks if the respondent has worked or is currently working in the construction industry. From the 29 respondents 22 answered yes to this questions while 7 answered no. The second question refers to in what capacity they have or are working in the construction industry while the third question refers to for how long. Figures 3.1 and 3.2 sumarize the answers to questions 2 and 3 respectively.

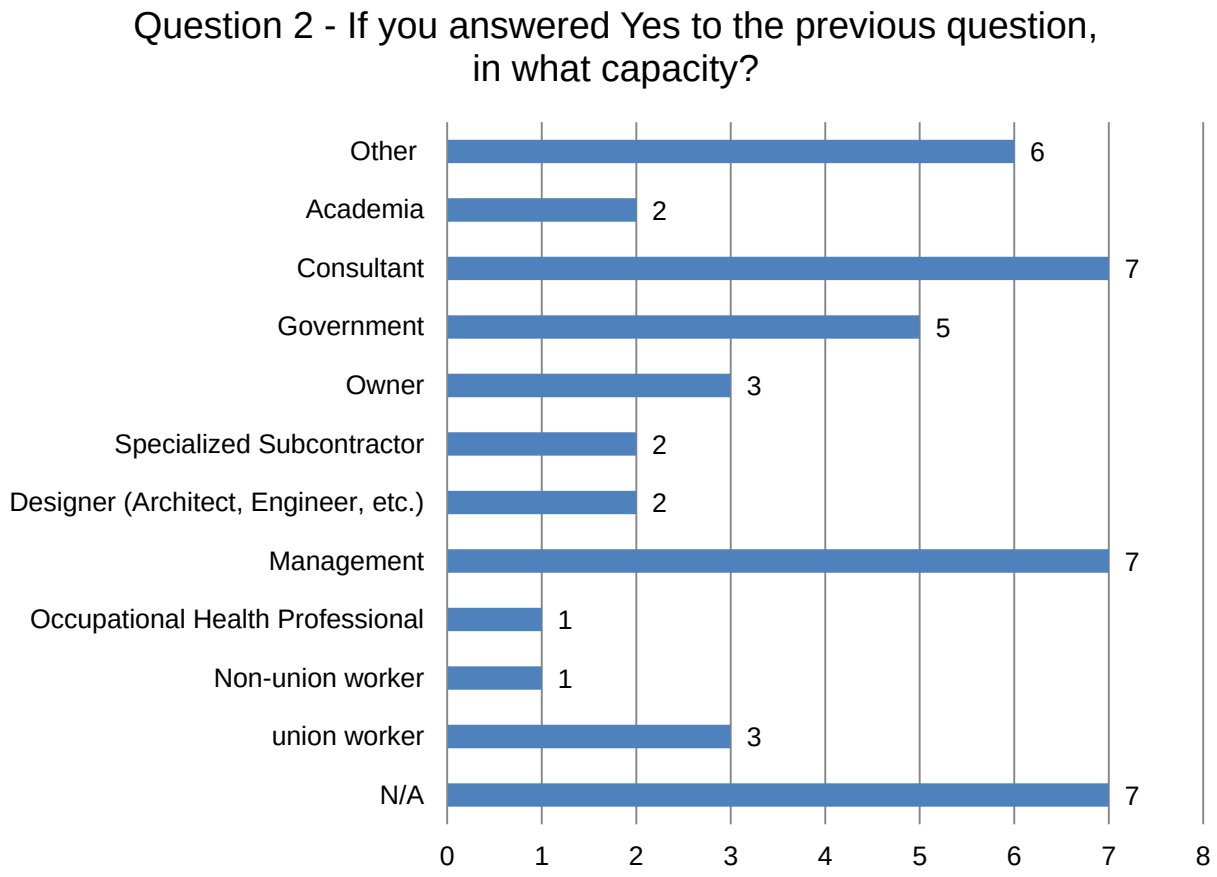

Figure 3-1. Survey demographics question 2

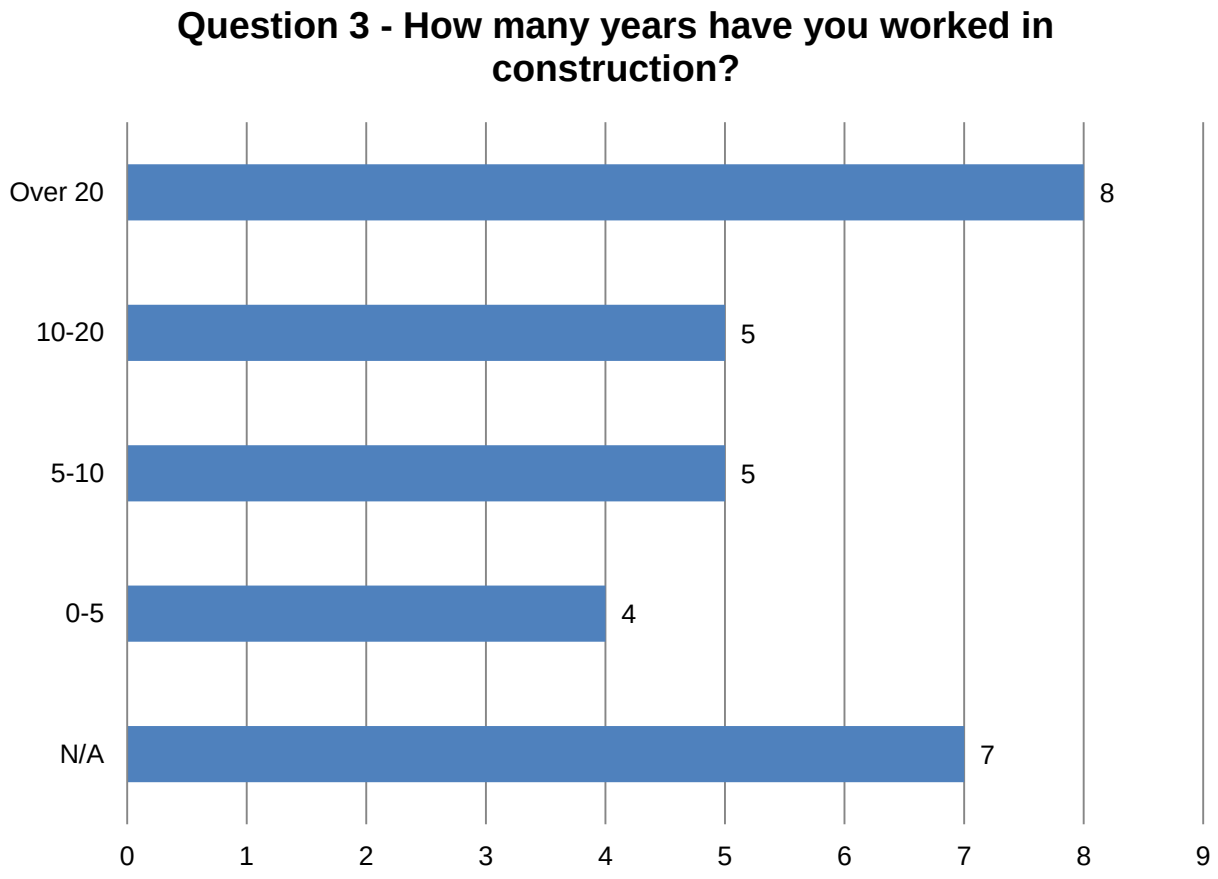

Figure 3-2. Survey demographics question 3.

Questions 4 through 7 refer to each of the five divisions included in this research: Sitework, Concrete, Masonry and Metals. The results of those questions are included in each division section. The survey questions are included in Appendix A

Construction Specification Institute MASTERFORMAT 1995

The Masterformat is a list for organizing tasks classifying them by related areas of work. It serves to organize specifications, accounting and other project information so all project participants can communicate using the same system. The Masterformat is mostly used on commercial projects; it is not used widely on transportation or industrial projects (Construction Specification Institute, CSI, 1995).

There have been different editions of the Masterformat. The latest edition is from 2004, but the 1995 edition is still more commonly used. The 1995 Masterformat has 16 divisions and each division has different tasks to subdivide the bigger items into smaller packages. This thesis will concentrate on divisions 2 through 5 which are: Sitework, Concrete, Masonry and Steel, respectively.

Division 2- Site Construction

Activities Covered by this Division

Each division has different main subdivisions that are subsequently divided into smaller work packages. To examine a complete list of CSI Masterformat 1995, see Appendix B. Table 3-1 includes the subdivisions on division 2.

Table 3-1. Division 2 subdivisions

Code	Subdivision
02050	Basic Site Materials and Methods
02100	Site Remediation
02200	Site Preparation
02300	Earthwork
02400	Tunneling, Boring and Jacking
02450	Foundation and Load-Bearing Elements
02500	Utility Services
02600	Drainage and Containment
02700	Bases, Ballasts, Pavements and Appurtenances
02800	Site Improvements and Amenities
02900	Planting
02950	Site Restoration and Rehabilitation

Survey Results

The results of the survey of the survey for this division are shown in figure 3-3 below:

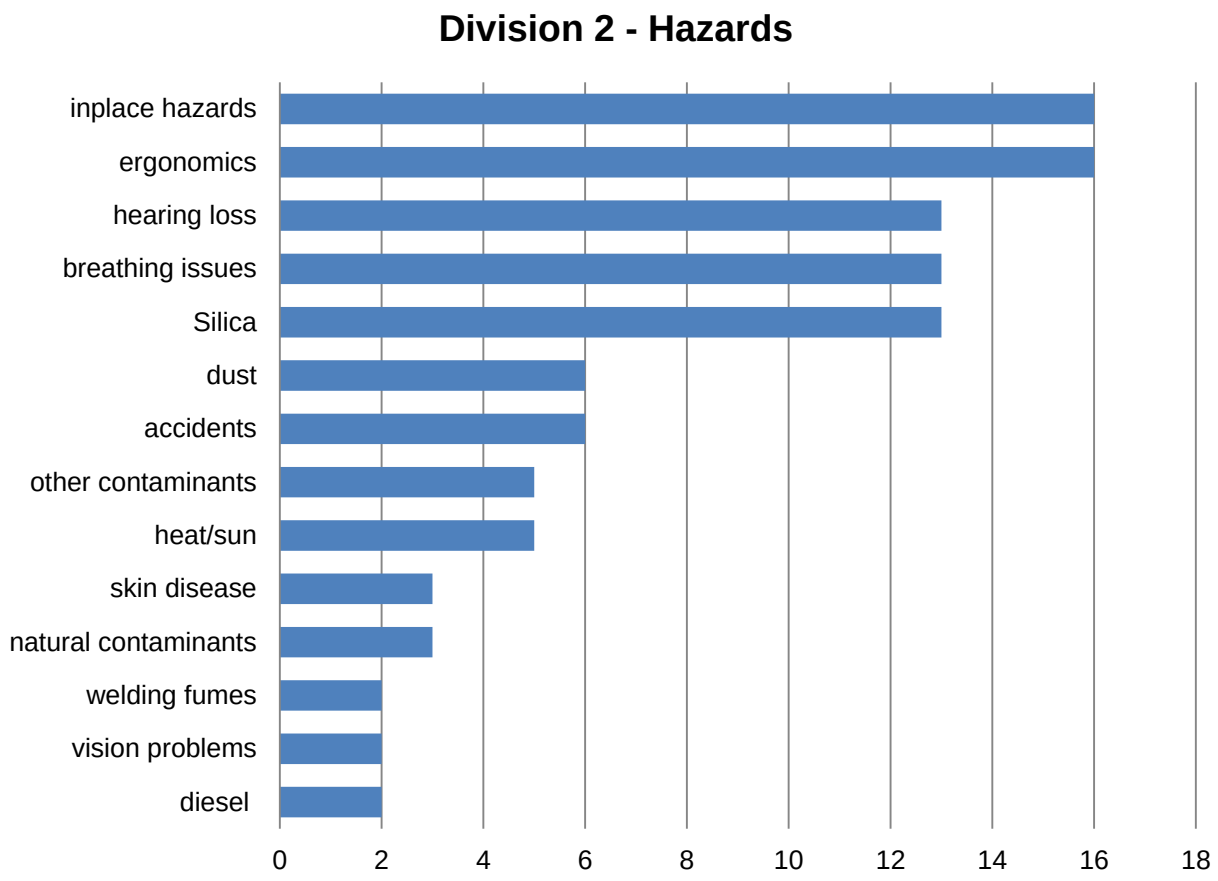

Figure 3-3. Survey results of hazards for division 2

Each respondent was asked to list at most five hazards for the work done in this division. For division 2 we had 105 responses when we add the responses from each individual respondent. In place hazards include asbestos, lead and similar materials that are considered hazardous to any person disturbing them. Ergonomics include back problems, vibration due to equipment use, muscle problems, lifting, and repetitive motion. Hearing loss refer to noise issues. Silica and dust are related to breathing issues. If we combine the numbers of those three we obtained 32 which is the highest

concern among respondents in regards to workers hazards in division 2. Demolition and trenching can be contributors to these hazards.

Demolition

Demolition is under subdivision 02200 that refers to Site Preparation. Demolition itself, under subdivision 02200, has code number 02220. During demolition activities, different types of substances are released into the air. The most widely known substance associated with demolition, especially in older buildings is asbestos. Long term exposure to asbestos is associated with lung, peritoneal and abdominal cancers, and also with respiratory diseases (EPA, 2011). In the case of a known human carcinogen as asbestos, remediation companies with expertise of dealing with this type of material perform the work. It is important to make an assessment of the demolition project to provide the extra cost and time needed to perform this part of the demolition work in a safe way. Because the requirements for demolishing asbestos are so specialized and require expert companies, it is not included in this database.

Regular demolition activities can produce high levels of dust that come in contact with the worker's skin. Even though construction companies need to have dust control procedures, the continuous skin contact with debris can cause dermatitis and other related skin diseases that can be avoided by the use of simple protective gear. During demolition activities the ECI (1999) recommends that workers that might be affected should cover themselves to avoid direct contact with harmful substances and to minimize cold, hot and wind exposure that can leave skin unprotected. Gloves, protective clothing and the use of waterproof dressings to protect cuts and other injuries are highly recommended.

Open Trench vs. Trenchless Methods for Pipe Installation or Replacement

Utilities installation is contemplated under subdivision 02500, Utilities Services, which is divided into the different utilities. Replacement of existing pipes can be found under subdivision 02950, Site Restoration and Rehabilitation, with code 02955, Underground Pipe Restoration. Another subdivision that can be used for this work is 02400 Tunneling, Boring and Jacking that has code 02441 for Microtunneling, and 02445 for Boring and Jacking Conduits. To maintain everything under one subdivision, both new installations and replacements are shown in subdivision 02500 in the database.

Underground utility replacement has been a major problem because most U.S. cities have old and deteriorated systems. ASCE's infrastructure's report card contemplates that the majority of the systems have reached their useful life and are in need of replacement. Replacement of pipes can be done by an open trench or by using newer trenchless methods. Trenchless methods are mostly used in urban areas were space is limited and traffic congestion is a problem. Another issue is pavements cuts that alter the integrity of the pavement and can reduce its life up to 40% (Jung and Sinha, 2007). Moreover, trenchless technology not only serves to substitute existing pipes for new ones but it can install a replacement pipe with an increase in diameter size of up to 300% of the original (Lueke and Ariaratnam, 2001).

New installation by open cut or trenching methods presents most of the same problems as replacements. Among these are the following (Myers, Stickrod, Abraham and Iseley, 1999; Woodroffe and Ariaratnam, 2008):

- Soil Disposal- Contaminated material that is dug out can result in costly disposal.

- Water pollution- Water systems can be polluted during excavation due to soil erosion and contaminated particulates traveling to different bodies of water.
- Air pollution- Airborne particulates can cause pollution of air, not only from the soil, but from the equipment used during excavation (Ariaratnam and Sihabuddin, 2009)
- Impact to roadways – Cuts reduce pavement life. Reconstruction of roadways and adjacent structures (sidewalks, driveways, etc) add to the cost of the project. This cost can be of up to 70% of the total project cost, including soil handling.
- Noise pollution – Equipment used for excavation produces high levels of noise and can be a nuance in residential areas.
- Inconvenience to roadway users- Pedestrians, drivers, business owners and patrons are affected adversely when closing roadways and sidewalks.
- Worker safety – Open cut construction was rated between 1999-2000 as the fourth most deadly occupation in the United States.

Another issue that can affect the health of the construction worker when performing open trench activities included the soil which is 12% quartz, the most common type of silica. Respirable dust can contain high amounts of quartz to make the operation unsafe to the operators and workers, necessitating the use of respirators and respirators. The proper safety measures will depend on the percentage of quartz in the soil (Woskie et.al., 2002). Another issue that Woskie et.al. (2002) studied is that excavation support activities include welding of mild steel using manual metal arc. These activities cannot be completely eliminated by using trenchless methods that are performed in the same space.

Open cut method for installation and replacement of pipes

Open cut methods usually require a trench to be excavated along the length of the pipe to be installed or replaced. When replacing pipes, the cut can be conventional or narrow (Selvakumar, Clark and Sivaganesan, 2002). Conventional refers to making a trench as it would have been made for new installation. Narrow refers to keeping the cut

to its absolute minimum possible (Morris, 1996). The trench might be dug with vertical sides, with sloped sides (V-shape) or with stepped or benched sides (Young and Trott, 1984). OSHA require that worker protection be provided in the form of shoring, sloping the trench wall or using a trench shield. Backfill needs to be placed carefully in order to not disturb the pipe alignment. It does not need to be compacted in all cases (Jung and Sinha, 2007).

Trenchless methods for new installation

New installation can be made by the following methods (Abbot, 2005):

- Impact Moling - Small conduit follows non-steerable impact head driven by pneumatic hammer.
- Auger Boring (See Figure 3-4) – For small to medium diameter conduit installed undercrossing or short distances where alignment is not important.

Figure 3-4. Auger boring (Courtesy of Advanced Underground)

- Pipe Ramming – Non-steerable pipe installation technique where a casing or the actual pipe is driven by an impact hammer.
- Horizontal Directional Drilling (HDD) (see Figure 3-5) – A pilot hole is drilled with a steerable drill, used when obstacles are expected. The hole is enlarged as needed and maintenance of alignment is provided by use of slurries, bentonite and polymers.

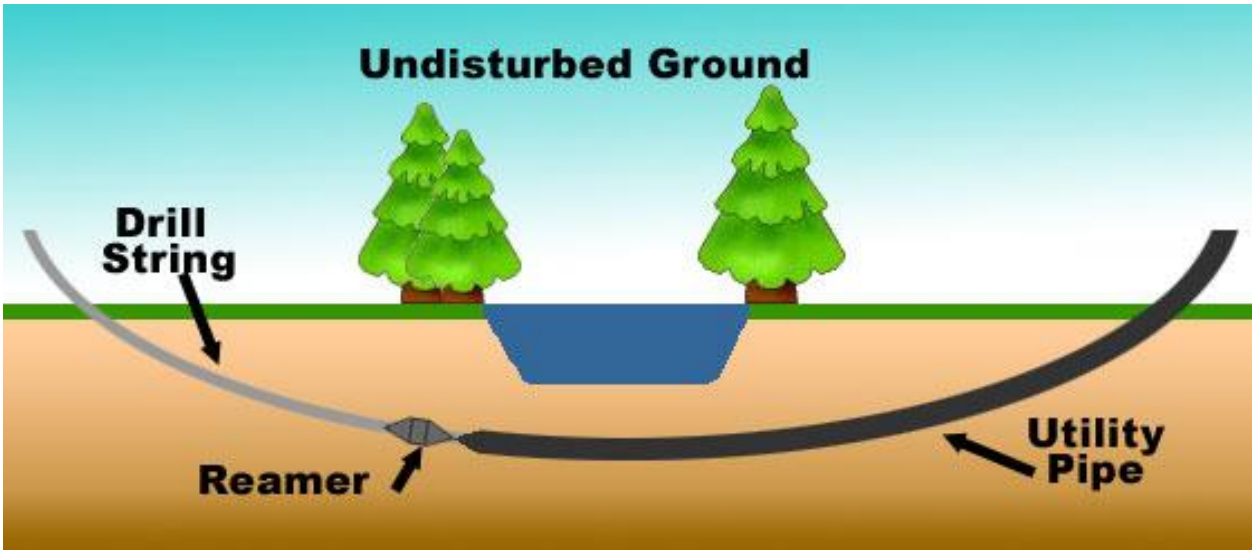

Figure 3-5. Horizontal directional drilling (Courtesy of Advanced Underground)

- Guided drilling systems Mini and Midi HDD – For shorter crossings and locations. Same as HDD but smaller distances and diameters and less powerful equipment.

- Small and medium diameter tunneling and pipe jacking – A tunnel boring machine (TBM) with a cutter wheel may be used to bore the tunnel. Tunnel is supported by ribs and boards or in-situ lining or jacked pipe.

- Microtunneling - Remote controlled steering jacking method of installing pipes.
    - Auger – Large diameter unidirectional auger.
    - Slurry – Used in excavations under groundwater without the need of dewatering. Slurry helps keep constant pressure with the underground pressure and avoid groundwater and soil to fill the new tunnel.
    - EPB – Same as the slurry, only that is uses the recently excavated material to maintain balanced pressure.
    - Pilot pipe method – similar to midi and mini HDD but includes shoe in front that provides 360° rotation.

These methods present different advantages and disadvantages, having in common as main advantage the minimal disturbance to the surface; a major disadvantage for both methods is the high equipment costs (Jung and Sinha, 2007; Woodroffe and Ariaratnam, 2008). Furthermore there is a risk of abandonment due to

unforeseen conditions such as changes in ground, obstructions or equipment failure (Abbott, 2005).

Trenchless methods for pipe replacements

Pipe bursting, Figure 3-6, eliminates the existing pipe and at the same time pulls in the new pipe in the alignment of the original pipe. It can be done with a static, pneumatic or hydraulic bursting head (Selvakumar, et. al., 2002). The burst pipe fragments are pushed to the surrounding soil making pipe removal unnecessary. New pipes can be of a bigger size than existing ones and they can go from 6 inches to 48 inches in diameter.

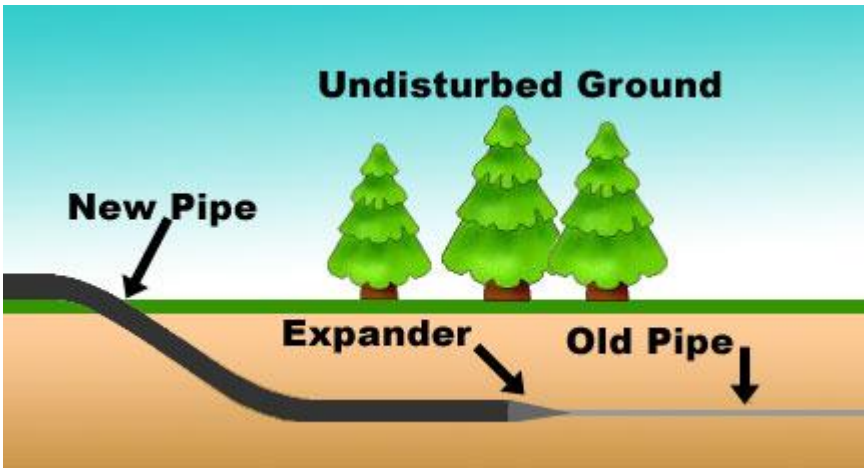

Figure 3-6. Pipe bursting (Courtesy of Advanced Underground)

Emission comparison between open cut and trenchless methods

In a comparison study between trenchless pipe replacement and open cut methods, the average percentage of reduction in different emissions was found to be 80% when trenchless methods were used instead of open cut methods. The principal difference is that open cut is equipment intensive and time consuming. Trenchless methods usually use only one type of equipment and because there is minimal need of excavating, backfilling time is reduced drastically (Ariaratnam and Sihabuddin, 2009).

The main emissions that were studied are all part of diesel fumes. The percent reductions shown below are the reduction of emissions found when using a trenchless method instead of open cut

- Hydrocarbons (HC) – 75% reduction.
- Carbon dioxide (CO_2) – 74.1% reduction.
- Carbon monoxide (CO) – 78.1% reduction.
- Nitrogen oxide (NO_x) – 82% reduction.
- Total organic compounds (TOC) – 85% reduction.
- Sulfur Oxide (SO_x) –79.9% reduction.

As stated previously, diesel fumes may cause lung cancer and different respiratory disease such as asthma and chronic bronchitis. Reducing these fumes for construction workers may reduce respiratory illnesses among them.

Costs comparison between open cut and trenchless methods

The main difference between open cut and trenchless methods is the amount of excavation needed. Open cut methods require excavations throughout the whole project, while trenchless methods need minimal excavation, usually at the start and finish locations and some in between, depending on the method use. However trenchless methods may have a higher equipment cost as the equipment needed is more specialized and sophisticated than regular trenching equipment (Jung and Sinha, 2007).

From the literature, Table 3-2 presents the costs from different trenching projects. The first column indicates the type of project; the second column refers to the pipe diameter being installed; the last column refers to the unit cost of the installation per inch of diameter per lineal ft of the installation (Jung and Sinha, 2007).

Table 3-2. Project unit cost per type and pipe diameter.

Type of project	Pipe diam (in)	Unit cost $/in diam/ft	
Open cut	7.87	$	16.81
	7.87	$	18.18
	9.84	$	13.06
	7.87	$	18.03
	7.87	$	17.18
	Average	**$**	**16.65**
Trenchless	12.40	$	16.17
	6.89	$	20.69
	Average	**$**	**18.43**

One project was taken out of the list due to a substantial difference in diameter size and unit cost. The percent difference between the average costs of both types of projects is as follows:

$$\%\, difference = \frac{(18.43 - 16.65)}{16.65} \times 100 = \ 10.69\%$$

Other authors (Boyce and Bried, 1998) show a price range of pipe bursting between $7 and $9/ft/in diam., for microtunneling between $17 and $24 and for HDD between $10 and $24, which compares to the ones in Table 3-2. Trenchless method costs average 10% higher than open cut methods. There are other qualitative costs that have been quantified and that add cost to the project. These qualitative costs are based on social costs (traffic delay and loss of income) and environmental costs (noise costs). Social and environmental costs add an average of $314.59/in-diam/ft (Boyce and Bried, 1998) to an open cut project and an average of $22.10 to a trenchless project. The total average cost taking into account the social and environmental costs is $331.25 for open

cut and $40.53 for trenchless methods. Even though social and environmental costs are being quantified, they still depend on the researchers' subjectivity.

Schedule impact to the project

A trenchless project is expected to be completed in less time than an open cut. This is due to not having to excavate before laying the pipe, and backfilling the trench after laying the pipe. From the projects listed in Table 3-2, the average productivity rate for open cut projects was 19.21 ft/day, while the trenchless projects averaged of 68.6 ft/day. Overall daily production is 67 feet for open cut and 18 feet for trenchless projects. A reduction in days can avoid overruns in overhead costs, liability issues and inconveniences to the public in general.

Pavers, Curbs and Sidewalks

Under subdivision 02700 Bases, Ballasts, Pavements and Appurtenances, there are codes for unit pavers (02780), sidewalks (02775) and curbs and gutters (02770). Manual handling of pavers can cause MSDs due to the weight of the pavers and repetitive nature of the work (HSE, 2005). Interpave (2006a), United Kingdom's Precast, Concrete Paving and Kerb Association, provides information on the type of equipment that can be used to install pavers to avoid workers having to carry them. This equipment is shown in Appendix C.

Pavers can also contribute to respirable dust and silica when they are cut prior to installation. It is recommended that designers take into account the type and size of pavers they use when designing a project to avoid or minimize the number of cuts needed (Interpave, 2007). The design should include the specific size and installation design that will avoid cutting of the pavers. If cuts cannot be avoided, wet cutting tools and dust respirators shall be provided to workers.

Cost and schedule impact

The cost and schedule impacts of using pavers instead of asphalt in the case of roads or concrete in the case of sidewalks and curbs, have not been widely studied. Interpave (2006b) provides information that shows the cost of permeable pavers being lower through the whole life of the system than cast-in-place concrete but similar to asphalt when both can be used. They still advised that a serviceable life study of pavers shall be made as it is not clear how long is their useful life, but it is estimated to be between the useful lives of asphalt and concrete (between 10 to 40 years).

Division 3 – Concrete

Activities Covered by this Division

The concrete division refers to all concrete tasks, materials and related materials.

Table 3-3. Division 3 subdivisions

Code	Subdivision
03050	Basic Concrete Materials and Methods
03100	Concrete Forms and Accessories
03200	Concrete Reinforcement
03300	Cast-in-Place Concrete
03400	Precast Concrete
03430	Site Precast Structural Concrete
03500	Cementitious Decks and Underlayment
03600	Grouts
03700	Mass Concrete
03900	Concrete Restoration and Cleaning

The database will concentrate on the following subdivisions: 03300, 03400, 03500 and 03600. Recommendations also apply to Site Precast Structural Concrete (03430) and Concrete Restoration and Cleaning (03900).

Survey Results

The survey results for this division are as shown in figure 3-7:

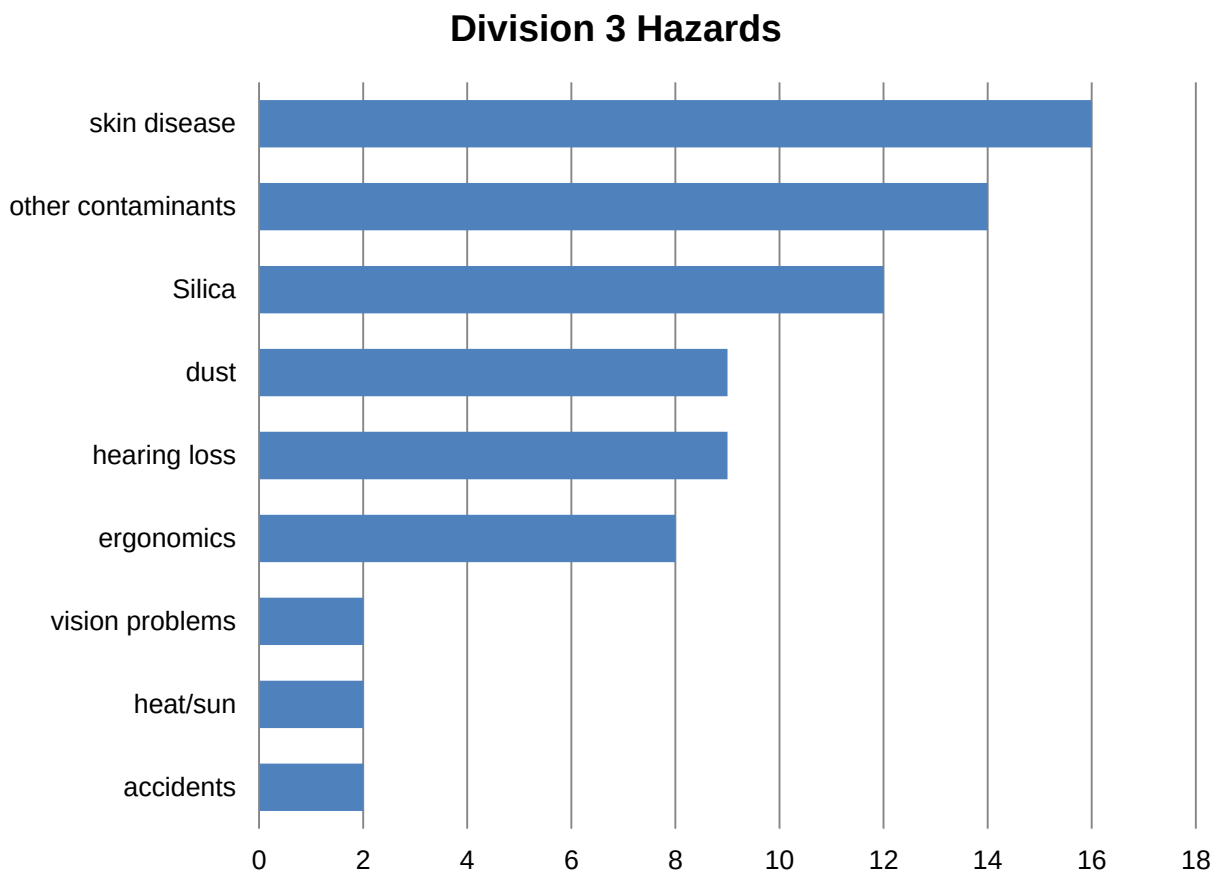

Figure 3-7. Survey results of hazards for division 3

For this division 74 answers were received. The other contaminants relates to components of cement that can cause skin diseases as well as respiratory ones. Silica and dust are primarily related to respiratory diseases and skin diseases.

Crystalline Silica

Crystalline silica can be found in three different forms: quartz, the most common type, cristobalite and tridymite. All these forms can be found in respirable size particles (Occupational Safety and Health Administration, OSHA, n.d.). The main illness cause by silica exposure is silicosis which refers to scar tissue formed in the lungs due to silica dust inhalation that reduces the lungs ability to take up oxygen. Also, lung cancer has been associated with crystalline silica exposure (Steenland, 2005). Silica dust can also

cause dermatitis, as workers need to be protected to avoid skin contact as stated in the demolition section.

There are different agencies that have determined the maximum values of exposure of crystalline silica for workers. OSHA calls for a benchmark of 0.1 mg/m^3 for an 8 hour TWA; NIOSH recommends it to be only 0.05 mg/m^3 for a 10-hour TWA, while the ACGIH recommends the exposure to be limited to 0.025 mg/m^3 for an 8-hour TWA (OSHA, 2009; Flynn and Susi, 2003). Values are shown in Table 3-4.

Table 3-4. Recommended limit values of crystalline silica

Agency	Limit (mg/m3)
OSHA	0.1 for Quartz, 0.05 for Cristobalite and Tridymite (8-hr TWA)
NIOSH	0.05 for all three types (10-hr TWA)
ACGIH	0.025 for all three types (8-hr TWA)

Concrete Activities that Generate Silica Dust

There are different activities related to concrete work that generate respirable silica dust: concrete grinding for finishing and polishing concrete, cutting, chipping and drilling (Flynn and Susi, 2003; Meeker, Cooper, Leftkowitz and Susi, 2009). Concrete grinding due to decorative concrete work is fast growing and requires workers to work in poor ventilated areas (Akbar-Khanzadeh et.al. 2010).

General grinding equipment

For grinding equipment OSHA offers two types of recommendations: wet grinding and equipment with vacuum dust collection (VDC) (OSHA, 2009). One study, performed in laboratory conditions, was done by comparing uncontrolled conventional grinding, wet grinding and local exhaust ventilation (LEV) non HEPA grinding. The test was done first without general ventilation and repeated with general ventilation (GV). The results showed that the best way to perform grinding is by having general ventilation (GV) and

a grinder with an LEV system (Akbar-Khanzadeh et.al., 2007). Although the results show a reduction of dust from uncontrolled conventional grinding to LEV grinding is of 99.2%, the actual value measured using a LEV with the grinder was 0.132 mg/m^3, which is still higher than the values recommended by the different agencies.

Another laboratory study was performed by comparing uncontrolled grinding, shop vacuuming, wet grinding and HEPA LEV systems under general ventilation and non-general ventilation configurations (Akbar-Khanzadeh et.al., 2010). In that study the use of a HEPA LEV with general ventilation produced the lowest reading at 0.11 mg/m^3, still higher than the recommended limits, but showed a reduction of 99%from uncontrolled conventional grinding. Because the values are still higher than the lowest recommended limits of 0.025 mg/m^3 by the ACGIH, the authors recommended that workers use a respirator with a factor protection of 10. On the other hand, the value obtained with LEV systems is similar to OSHA's PEL, thus avoiding the need for any type of respirator. The authors also recommended that if any of the other methods were used for grinding that a respirator should be used. For wet grinding and shop vacuum methods, they recommend the use of a half respirator respirator, and for uncontrolled grinding the use of a full face respirator was recommended as long as the general ventilator was on. In the case of no general ventilation, the use of a half respirator respirator was recommended for shop vacuum, full respirator for wet grinding and powered air-purifying respirator for uncontrolled grinding. However, these dust respirators and respirators are only for use by the worker performing the task and do not protect the workers performing other tasks nearby. Appendix C shows examples of equipment used in the different studies.

Table 3-5 shows some advantages and disadvantages of the different equipment that can be used to minimize silica dust.

Table 3-5. Equipment requirements for controlling silica dust when grinding (Akbar-Khanzadeh, 2010)

Equipment	Extras with GV (Per OSHA PELs)	Advantages	Disadvantages
HEPA LEV	None	No need of extra equipment	Not a standard equipment Training may be required Needs regular cleaning to be effective Cost may be an issue
Shop vaccum	Half mask	Standard Equipment on jobsite	Needs regular cleaning to be effective Half respirator needed Workers may stop using respirator May not protect adequately even with the respirator
Wet grinding	Half mask	Standard Equipment on jobsite	Half respirator needed Operator controls water flow Workers may stop using respirator May not protect adequately even with the respirator
Uncontrolled grinding	Full respirator	Standard Equipment on jobsite	Needs full respirator Workers may stop using respirator May not protect adequately even with the respirator

Cost considerations

Most of the equipment recommended is already part of the equipment used for concrete grinding; however, HEPA filters might be an addition that also comes with training issues to ensure proper equipment and handling. The cost of a new LEV-HEPA is around $2,000 but its motor has a life of 1,400 hours when the equipment is maintained properly. See Apendix B for example of LEV HEPA.

Schedule considerations

Because the main equipment in use is basic for grinding, there should not be any impact on the schedule. On the other hand, the use of HEPA filters may require extra time for training and, depending on the use, time for filter changing. An extra task that the safety personnel of the project need to keep track of is the cleaning of the equipment and changing of the filter to ensure that the respirable silica is maintained to a minimum. Each piece of equipment needs to have a maintenance log to ensure proper maintenance is given to the equipment. A radio-frequency identification (RFID) tag can be used to house the needed information including maintenance logs and user's manual.

Other concrete activities

Other activities such as concrete drilling and cutting, present the same problems as concrete grinding. Recommendations are similar such as the use of HEPA filters and/or dust respirators and respirators. OSHA recommendations present wet cutting as most effective to reduce silica dust (OSHA, 2009). If the recommendations of the previous referenced study is followed (Akbar-Khanzadeh, 2010), then a full face respirator may be needed to minimize the silica dust particles per OSHA's PELs when there is no general ventilation and half face respirator when there is general ventilation. Table 3-5 can be used as a reference for these tasks.

Precast vs. Cast in Place Concrete

Precast concrete usually needs the same type of activities as cast-in-place with some exceptions and modifications. When precast members are required on a project, they are fabricated in a plant that will cast them, usually in reusable metal forms and in more controllable conditions. Not only quality can be controlled, but if prestressed is

combined with precast concrete up to 60% savings on the amount of concrete can be achieved (Yee, 2001a; Yee, 2001b). Precast pieces can also be finished in the precast plant including painting them; this can save time and will also reduce the exposure of other workers to the finishing and painting activities of concrete. The main disadvantage that precast concrete can have is the distance from the plant to the project. If there is no plant near to the project, transportation costs may not be offset with savings in materials and time. Another major disadvantage is the precast members may need to be transported through crowded and narrow streets. Busy and crowded streets can be avoided by scheduling deliveries during off peak hours, while narrow streets are more difficult to avoid if that is the only way to the construction site.

A more extensive study of precast plant configurations, emissions, and other health and safety issues need to be performed to get a better comparison between precast and cast-in-place concrete. The studies that were evaluated for concrete grinding, cutting, etc, refer to cast-in-place concrete, entailing work that were performed on the project site. The expected results on a precast plant are lower emissions, resulting in a healthier workplace.

Division 4- Masonry

Activities Covered by this Division

Division four covers activities that deal with bricks, stone, concrete blocks or CMUs, other masonry units and their related materials and tasks.

Table 3-6. Division 4 subdivisions

Code	Subdivision
04050	Basic Masonry Materials and Methods
04200	Masonry Units
04400	Stone
04500	Refractories
04600	Corrosion Resistant Masonry
04700	Simulated Masonry
04800	Masonry Assemblies
04900	Masonry Restoration and Cleaning

Because the basic material is the actual masonry unit and stone, most of the recommendations refer to most of the subdivisions. Still, in the database, they are under 04200 Masonry Units. The recommendations also apply to 04400 Stone, 04600 Corrosion Resistant Masonry and 04900 Masonry Restoration and Cleaning.

Survey results

Survey results for division 4 are shown in figure 3-8 below:

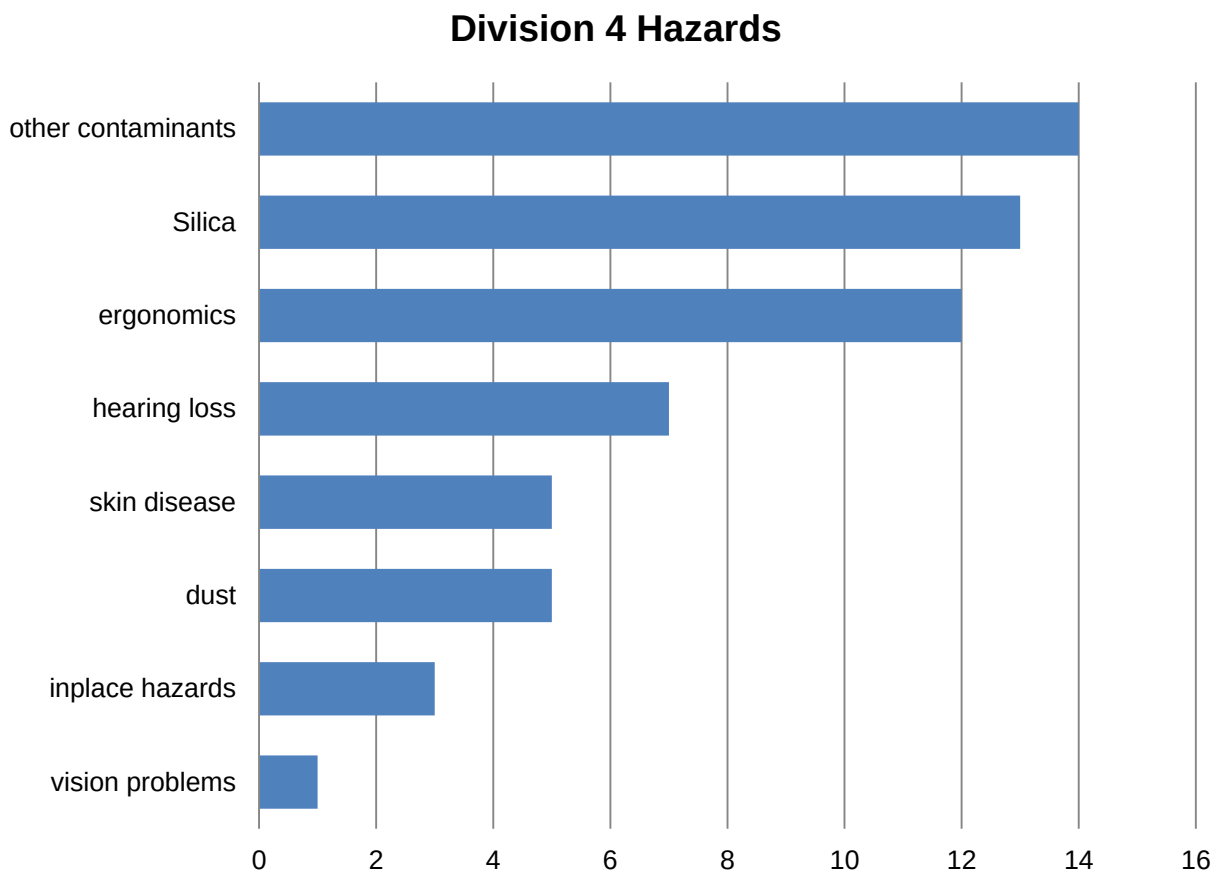

Figure 3-8. Survey results of hazards for division 4

For this division 60 responses were received. Other contaminants, as in division 3, also refer to cement related components. Ergonomics issues refer to vibration, muscle and back problems, lifting, repetitive motion and upper extremities issues such as carpal tunnel.

Hazardous Conditions

Most of the same hazardous conditions that affect concrete, also affect masonry construction. Crystalline silica and respirable suspended particles are the main hazardous agents encountered by workers in common masonry operations such as grinding, cutting and tuckpointing.

To reduce respirable silica dust due to masonry grinding, the same type of equipment and configurations as recommended for concrete can be used here. The use of a LEV HEPA vacuums in the same manner that it is recommended for concrete can minimize the silica dust during masonry grinding.

Cutting masonry can be done in the same manner as concrete cutting, but there is an advantage of masonry operations that most concrete operations do not have, namely that masonry can be cut using stationary saws instead of handheld equipment. The main advantages of using stationary saws are not only for dust control considerations but also ergonomic and safety considerations (Meeker et.al, 2009). These are:

- Workers do not have to bear the weight of the tool
- Avoidance of accidental cuts and amputations
- Stationary saws can use a wet cutting method which minimizes the exposure to respirable silica dust
- Handheld tools generate higher dust levels
- Gasoline-powered equipment is prohibited on scaffoldings
- The main advantage that contractors see in the use of handheld equipment in general is that workers do not have to stop the activity to go to a cutting station saves time (Meeker et.al, 2009).

The best way to reduce silica dust due to cutting is the use of a wet stationary saw and general ventilation. The use of a full face respirator with tank is highly recommended (OSHA, 2009). If the use of a handheld tool is to be considered, an LEV vacuum should be attached to the tool to minimize dust; water cutting is also possible when using hand held tools.

Tuck pointing operations require the use of handheld equipment due to the nature of the operation. The use of a wet grinder is not advisable as the mortar becomes a

paste that can adhere to the surface and block the work being done (Flanigan et.al., 2006). It is advisable to use a LEV system or vacuum dust collector (VDC) system (OSHA, 2009; Meeker et.al, 2009).

Division 5- Metals

Activities Covered by this Division

This division refers to all metal work, from structural steel to ornamental metal work. It also includes new and restoration work as well as cleaning procedures. The main subdivisions are shown in Table 3-7.

Table 3-7. Division 5 subdivisions

Code	Subdivision
05050	Basic Metal Materials and Methods
05100	Structural Metal Framing
05200	Metal Joists
05300	Metal Deck
05400	Cold-Formed Metal Framing
05500	Metal Fabrications
05600	Hydraulic Fabrications
05700	Ornamental Metal
05800	Expansion Control
05900	Metal Restoration and Cleaning

Survey results

The survey results for division 5 are shown in figure 3-9 below:

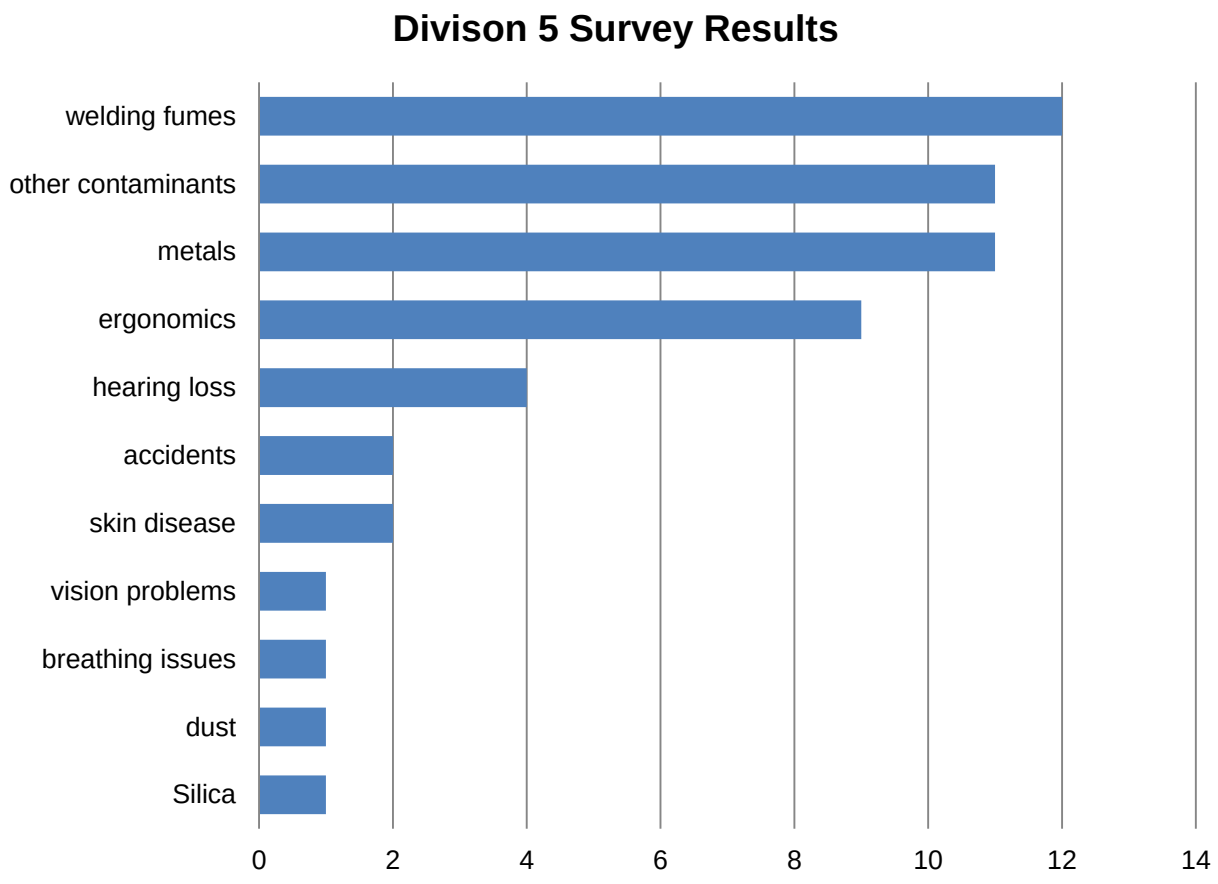

Figure 3-9. Survey results of hazards for division 5

Other contaminants refer to related materials to welding such as lead, chromium and radiation. Ergonomics includes vibration, lifting and repetitive motion. Most ergonomics problems are related to musculoskeletal disorders, MSDs.

Hazardous Conditions Encountered when Working with Metals

The most common and hazardous condition encountered when working with metals is welding. Welding is used in structural steel, in HVAC piping, as well as in industrial duct work, mechanical components such as boilers, chillers, etc, and in ornamental components (Meeker, Susi, & Flynn, 2007). There are over 80 different types of welding for commercial applications (Antonini, Taylor, Zimmer & Roberts, 2004), with arc welding being in the most common use for structural steel welding. Arc

welding is the process where an electric arc is produced between an electrode and a metal object to melt them together. Some electrodes are consumed during the process and some are not (Cary, 1979). The following are the most common arc welding types (Cary, 1979; Tamboli, 1999):

- Shielded Metal Arc Welding, SMAW - The shield is produced by the decomposition of the electrode. Used mainly for miscellaneous components and repairs.
- Flux-cored Arc Welding, FCAW – The electrode is consumed during this type of welding; the shield is produced by a flux inside the electrode. Most popular in structural steel fabrication and erection.
- Submerged Arc Welding, SAW – The flux produced covers the arc providing for a smoke and spatter free weld. The main disadvantage is that the weld is not visible requiring an experienced welder or an automatic welding machine. Because the arc is hidden, multiples welds can be done in a confined space.
- Gas Metal Arc Welding, GMAW – Similar to FCAW but with the advantage of not leaving residual slag and the disadvantage of being sensitive to rust. Not typically used in structural steel fabrication or erection.
- Gas Tungsten Arc Welding, GTAW – The electrode is made out of tungsten and the gas is usually argon. It is commonly used in aluminum and stainless steel (SS) applications.

Some of the effects that long exposures to welding fumes can have in welders is presented in Table 3-8.

Table 3-8. Hazardous welding fume constituents (copy with permission from Antonini, Lewis, Roberts, & Whaley, 2003).

Fume	Uses	Potential hazard concern
Aluminum	Alloy and filler metal	Conducive to ozone production
Barium	Fluxing agent	Eye, nose and throat irritant
Cadmium	Plating and brazing alloy	Respiratory irritant, metal fume fever
Chromium	Stainless steel alloy	Lung carcinogen
Copper	Alloy and coating material	Respiratory irritant, metal fume fever
Fluorine	Fluxing agent	Respiratory irritant
Iron	Most common fume component when welding steel	Siderosis
Lead	Brass, bronze, and steel alloy	Nervous system and kidney effects
Magnesium	Light metal alloy	Respiratory irritant, metal fume fever
Manganese	Steel alloy	Nervous system effects, respiratory irritant
Molybdenum	Steel alloy	
Nickel	Stainless steel alloy	Lung carcinogen
Silicon	Fluxing agent	
Tin	Bronze and solder alloy	Metal fume fever
Titanium	Fluxing agent	
Zinc	Galvanized steel, paint coatings	Metal fume fever

The ACGIH TLV for welding fume particulates is 5 mg/m^3; for manganese it is 0.2 mg/m^3. Previous studies have shown that without any LEV the exposure levels can have a mean value of over 9 mg/m^3 and manganese exposure of 0.100 mg/m^3 (Woskie, et.al, 2002). Furthermore, experimental studies have shown that a significant reduction can be made when an LEV is used during welding. Field experiments have shown reductions on the mean values of welding fumes and manganese exposure, but they have not shown a significant reduction for welding fumes. Manganese readings obtained after adding the use of a LEV did not exceed the ACGIH TLV, the OSHA PEL or the NIOSH REL (Meeker, et.al, 2007).

Recommendations

From the literature it was found that welding processes such as GMAW and GTAW generate a lower manganese exposure than that of FCAW, which is the most common welding used in structural steel. If substitution of FCAW by either GTAW or GMAW was possible, a significant reduction of manganese exposure can be achieved (Meeker, et.al, 2007). The processes and the different materials used in each type of welding, make it difficult to substitute one with the other. The main recommendation for welding operations is the use of an LEV. HEPA LEVs for grinding equipment can also be used for welding operations.

CHAPTER 4
DATABASE CONFIGURATION

Opening Remarks

The presentation of the recommendations is the most important aspect of this study. Most of the discussion on different solutions presented in the previous chapters has being presented before. The main problem that previous studies have is the audience they can reach. The main focus of this dissertation is to make the information readily available and easily understood by construction managers and other construction project stakeholders that may need to alter their activities in order to accommodate features presented in this database.

The database interface was created to be user friendly. Because it is a web based application, portability is possible in different devices. Future configurations can be made to present it as an application for smart phones and similar devices. Even so, the work presented here can be used in any type of device. Another possibility is the connection of the database with design and BIM software such as Google SketchUp and Autodesk Revit.

Database Language

The application is written in ruby-on-rails version 3.0.8. Ruby-on-rails is an open source framework, built on top of the Ruby language, to create web based data-centric applications (rubyonrails.org). For the development of the application and code structure, examples from different sources were used as a base for implementation (Ruby, 2011; Hartl, 2010; Thomas, 2009). These examples are covered under open source licenses, which allows re-use in any sort of code. A copy of the code can be found in Appendix D.

Available Information

The information that is available for the users for this work is limited to Divisions 2-5 of the CSI Masterformat 1995. These divisions are 2-Sitework, 3-Concrete, 4-Masonry, and 5-Metals, see Figure 4-1. Under each division, the user can find the applicable subdivision. These subdivisions can be found in Appendix B.

Because of the limits of this investigation, only some subdivisions have information on what can be done to make it safer for the construction worker. See Table 4-1 for a sample of the sitework information, Table 4-2 for sample of concrete, Table 4-3 for a sample of masonry and Table 4-4 for a sample of Metals.

Table 4-1. Division 2 - Sitework available information

Subdivision	Activity	Recommendations	Cost Impact	Schedule Impact	Protects Against
02200 Site Preparation	Demolition	Protective clothing, gloves, Full respirator	$200-$300	None	Dermatitis, Respiratory Illnesses
02500 Utility Services	New Utilities	microtunneling	+10% Open Trench	30% of Open Trench	Respiratory Illnesses
		horizontal directional drilling	+10% Open Trench	30% of Open Trench	Respiratory Illnesses
		impact moling	+10% Open Trench	30% of Open Trench	Respiratory Illnesses
		auger moling	+10% Open Trench	30% of Open Trench	Respiratory Illnesses
		pipe ramming	+10% Open Trench	30% of Open Trench	Respiratory Illnesses
	Pipe Replacement	pipe bursting	+10% Open Trench	30% of Open Trench	Respiratory Illnesses
02700 Pavements	Unit pavers	Use mechanical installation and avoid cutting	N/A	N/A	MSDs, Respiratory Illnesses

Table 4-2. Division 3- Concrete available information

Subdivision	Activity	Recommendations	Cost Impact	Schedule Impact	Protects Against
03300 Cast-In-Place Concrete	Concrete grinding	LEV-HEPA	$2,000	None	All items protect against respiratory illnesses. LEV HEPA and shop vacuum will also protect surrounding workers.
		ShopVacuum + half respirator	$200-$300	None	
		Wet grinding tool + half respirator	$200-$300	None	
		Full respirator	$200-$300	None	
	concrete cutting	LEV-HEPA	$2,000	None	
		ShopVacuum + half face respirator	$200-$300	None	
		Wet cutting tool + half face respirator	$200-$300	None	
		Full face respirator	$200-$300	None	
03400 Precast Concrete	Concrete grinding	LEV-HEPA	$2,000	None	
		ShopVacuum +half face respirator	$200-$300	None	
		Wet grinding tool + half face respirator	$200-$300	None	
		Full face respirator	$200-$300	None	
	concrete cutting	LEV-HEPA	$2,000	None	
		ShopVacuum + half respirator	$200-$300	None	
		Wet cutting tool + half face respirator	$200-$300	None	
		Full face respirator	$200-$300	None	
03600 Grouts	tuckpointing	LEV-HEPA	$2,000	None	
		ShopVacuum +half respirator	$200-$300	None	
		Wet tool + half face respirator	$200-$300	None	
		Full face respirator	$200-$300	None	

Table 4-3. Division 4- Masonry available information

Subdivision	Activity	Recommendations	Cost Impact	Schedule Impact	Protects Against
04200 Masonry Units	Grinding	LEV-HEPA	$2,000	None	All items protect against respiratory illnesses such as silicosis. LEV HEPA and shop vacuum will also protect surrounding workers.
		ShopVacuum +half face respirator	$200-$300	None	
		Wet grinding equpment + half face respirator	$200-$300	None	
		Full face respirator	$200-$300	None	
	cutting	LEV-HEPA	$2,000	None	
		ShopVacuum +half face respirator	$200-$300	None	
		Wet cutting equpment + half face respirator	$200-$300	None	
		Full face respirator	$200-$300	None	
	tuckpointing	LEV-HEPA	$2,000	None	
		ShopVacuum +half face respirator	$200-$300	None	
		Wet equpment + half face respirator	$200-$300	None	
		Full face respirator	$200-$300	None	

Table 4-4. Division 5 – Metals available information

Subdivision	Activity	Recommendations	Cost impact	Schedule Impact	Protect Against
05100 Structural Metal Framing	welding	LEV	$1,000	None	All items protect against respiratory illnesses such as silicosis. LEV HEPA and shop vacuum will also protect surrounding workers.
05200 Metal Joists	welding	LEV	$1,000	None	
05300 Metal Deck	welding	LEV	$1,000	None	
05500 Metal Fabrications	welding	LEV	$1,000	None	
05700 Ornamental Metal	welding	LEV	$1,000	None	

Additional Information

Additional information provided to users is necessary for them to make a more informed decision. The database includes information regarding what disease can be avoided or minimized by taking the recommended precautions and a description of the disease. It also includes a link to what are the OSHA minimum requirements for the different tasks in the database.

The recommendations included in the database can be from OSHA minimum requirements, if additional safeguards have not been developed for the task. When additional recommendations are found, they are added to the database even if they go beyond OSHA requirements. The database is not only trying to provide for a simpler way to access information, but to provide additional information than what is readily available such as that provided by OSHA and other similar entities.

Using the Application

Accessing Existing Information

The application allows the user to choose the division, subdivision, and activity for their project. It then shows a list of recommendations for this activity, and the cost and schedule impact for the chosen recommendation. For example: If installing new underground utility piping, the first screen is shown in Figure 4-1.

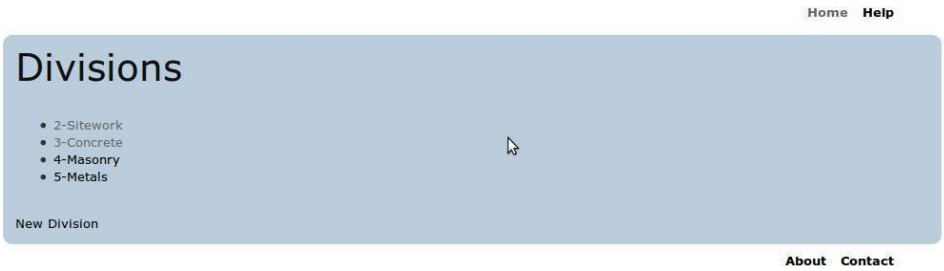

Figure 4-1. Divisions screen

After choosing the Division 2- for Sitework, the next screen shows the subdivisions , see figure 4-2.

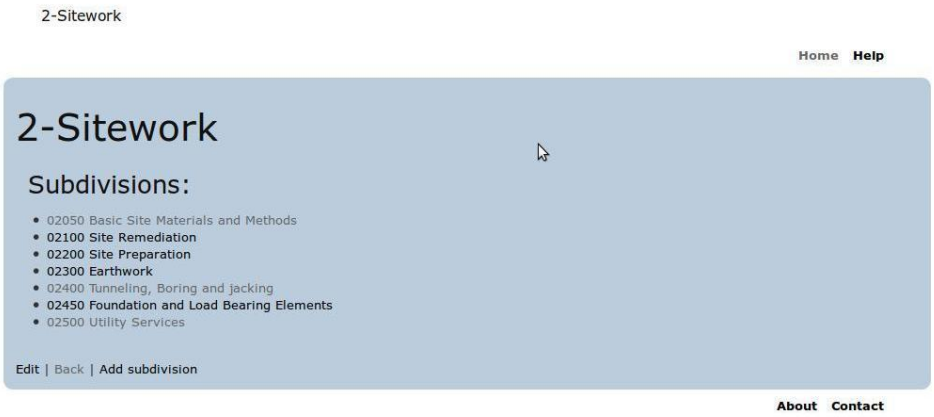

Figure 4-2. Subdivisions screen for division 2- Sitework

After a subdivision is selected, in this example 02500-Utility Services, the next screen presents a list of different activities that the user can choose from.

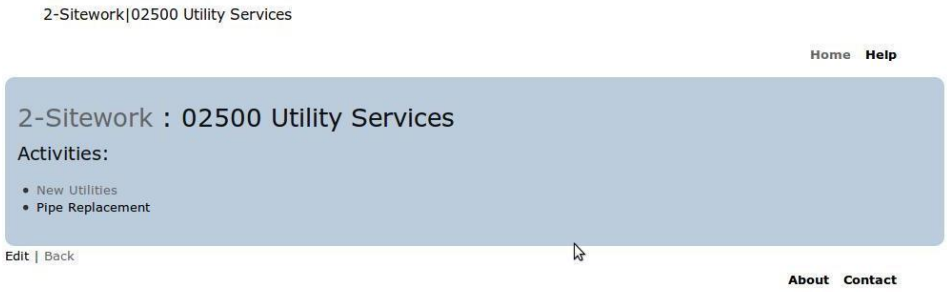

Figure 4-3. Subdivision activities

After an activity is chosen, the next screen presents different recommendations that will help safeguard the health of the construction worker (see Figure 4-4).

Figure 4-4. Recommendations under activities

In Figure 4-5 the user can find information regarding cost and schedule impact of the selected recommendation. It also provides information on the health issues that can be mitigated when adopting the recommendation and a website to find more information on the illness.

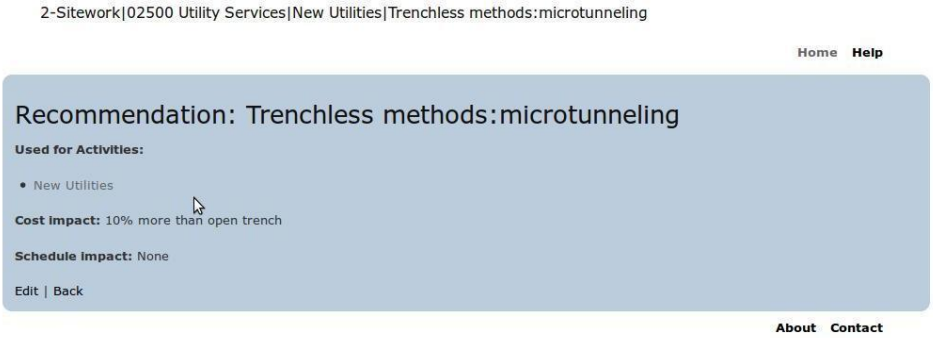

Figure 4-5. Recommendations cost and schedule impact

After choosing the recommendation, the budget and schedule can be adjusted according to the information given by the database.

The database can be used in most browsers including Google Chrome, Internet Explorer, Mozzilla Firefox, and Safari.

Entering New Information

The database lets the user enter new information for future projects and it incorporates it to the main database following these steps:

1. Create a new division – If the activity belongs to a division that has not been defined, the database lets you create a new division, see Figure 4-6. If the Division exists, the user will choose the corresponding one from the home menu, see Figure 4-1.

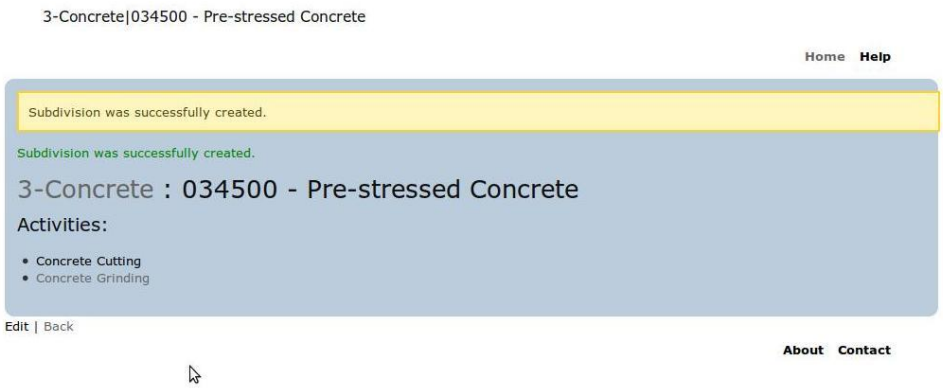

Figure 4-6. Create a new division

2. Create a new subdivision – After either creating a new division or selecting from the list, the user can create or select and existing subdivision where the activity to be added belongs. See Figure 4-7.

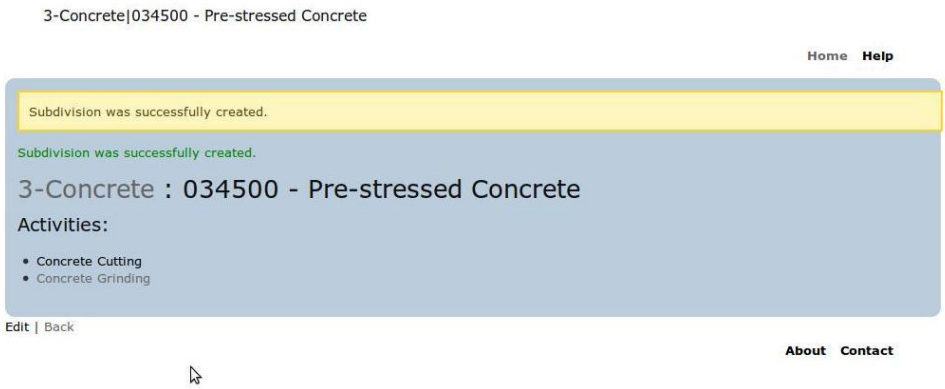

Figure 4-7. Create new subdivision

3. Create a new activity – The activities can be selected from a drop down menu depending on the division. Each activity is linked to a cost and schedule impact. See Figure 4-8.

Figure 4-8. New subdivision with activities

4. Activities can also be added and from the dropdown menu, different recommendations can be added to the activity. See Figure 4-9.

Figure 4-9. New activity with recommendations

5. Recommendations can also be added and the following information is needed to complete the recommendation information: recommendation, cost impact, schedule impact, protect against, url with more information. See Figure 4-10.

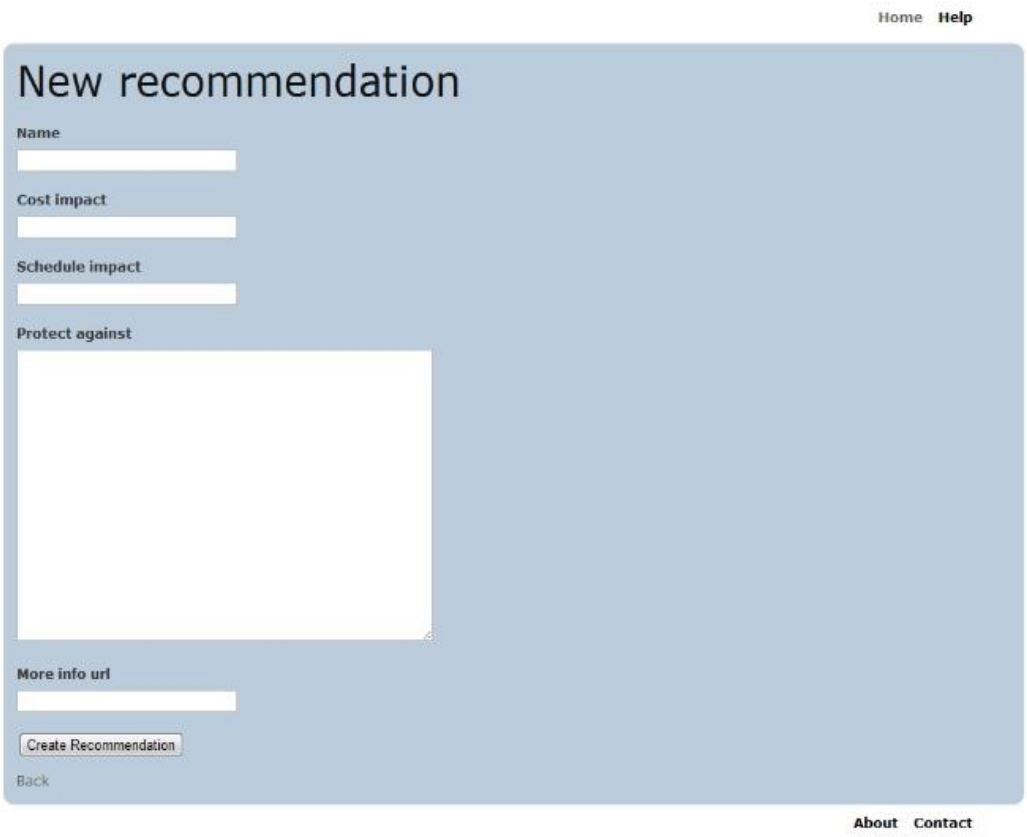

Figure 4-10. New recommendation screen

Translating to Extensible Markup Language (XML)

One of the capabilities added to the application is that it translates the code into XML. The main idea behind XML is its simplicity so it can be generally applied and used over the internet. Figure 4-11 presents the database screen that is visible. Figure 4-12 presents the XML code that applies to it.

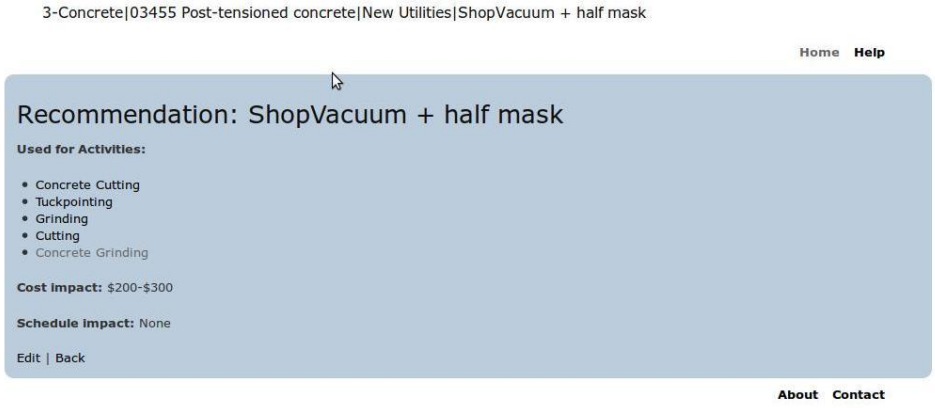

Figure 4-11. Users' screen view

This XML file does not appear to have any style information associated with it. The document tree is shown below.

```
−<recommendation>
    <name>ShopVacuum + half mask</name>
    <created-at type="datetime">2011-06-11T23:56:42Z</created-at>
    <updated-at type="datetime">2011-06-12T00:02:14Z</updated-at>
    <cost-impact>$200-$300</cost-impact>
    <id type="integer">8</id>
    <schedule-impact/>
  </recommendation>
```


Figure 4-12. XML code for screen view on figure 4-9.

Ruby and Sketchup

Google SketchUp is a drawing tool that lets the user do 3-D designs of structures and their surrounding neighborhoods and cities. It also lets the user animate the design to show it from the perspective of someone walking on the streets. It is a useful tool to visualize a design from the end user's perspective making it a tool attractive for designers to show their work to owners. SketchUp also has a free version that has most of the capabilities that the professional version has, including the ability to translate to and from AutoCad programs such as Architecture Revit.

Google SketchUp lets its users create Application Programming interfaces (APIs) to customize their SketchUp environment. These APIs are created in ruby-on-rails and are added to the menus. A new button is created that connects to the application that is added. The database that was created and presented in this chapter was made on ruby-on-rails and will be adapted to work on SketchUp. The tool will identify the materials used in the design and connect it to the alternatives provided in it. For example: If the design calls for a steel structure, the API will open the web-based database in the division 5 page. Then, the user will go to the structural steel subdivision and see the different recommendations, the cost and schedule changes and the illness that using this alternative will protect against. The API code will be made available in

the website for those users that will like to add it to their Sketchup copy. See Appendix E for the API code.

Estimates in Excel

There are different tools that can be used to create estimates. But, a basic tool that is still widely used when preparing estimates is Excel. To make the database accessible from Excel, a Macros created using Visual Basic applications was done. When the Macro is run in an Excel workbook, it will attach a hyperlink to the task name that will open the database in the corresponding division. The website will have the VBA code so it can be copied to Excel. See Appendix F for the VBA code.

CHAPTER 5
CONCLUSIONS AND FUTURE RESEARCH

The database created through this research will provide easily accessible information of construction materials and procedures that may be replaced or modified to make them safer for the construction worker. Designers can look through the database for replacements to incorporate them in their specifications and material schedules. Contractors can also use the database to modify or change procedures during the construction process. Furthermore, OSHA has historically addressed only reportable and immediate causation injuries and illnesses, not taking into account long term effect of hazardous materials and procedures. This database will give the user information on how to protect the construction worker from these hazards.

This research seeks to provide a point of reference for designers and all parties involved in the construction process of what materials and procedures can be changed or modified to improve the long term health of the construction worker. It will also bring awareness of the importance of the health of the construction worker that is commonly overlooked due to its long delay in effects because of the accumulative effect. Because the database works in almost any browser, the user has the flexibility to use the environment that is available and more comfortable to them. Furthermore, having the database web-based, gives the user the opportunity to use it without having to depend of a specific device. It also helps on maintaining the information current by having only one place were the information needs to be updated.

Accomplishments

The following points have been accomplished in this dissertation:

- Extensive study of the major hazards encountered in the first 4 divisions of the CSI masterformat which are:

    - Heavy equipment emissions
    - Crystalline silica
    - Dust effects both on skin and respiratory system
    - Comparison between precast and cast-in-place concrete
    - Welding fumes
    - Noise

- The creation of a web based environment that presents this information in a user friendly manner that is also:

    - Accessible from any web browser
    - Centralized for easy and instantaneous updates
    - Portable and not dependant on one specific device

- Database is accessible from Sketchup through an application that reviews the materials used for the design and opens the database in the corresponding divisions.

- The Database is also accessible from Excel through macros that can be used when using Excel for an estimate. It will evaluate the estimate items and add a hyperlink to the corresponding materials that will connect the database to the estimate.

- Translate to xml language that makes it easier to adapt to other programs for incorporation on design and preconstruction phases.

Future Research

BIM softwares, such as AutoDesk's Revit, store data of materials used for the design of a structure. This tool can process, generate and manage building data throughout its life cycle. This data includes geographical information, component properties and quantities, spatial relations and building geometry. The design created by Revit is graphical, dynamic and in real time which provides designers and builders with the latest information of the building. Furthermore, Autodesk Revit has Take-off, MEP coordination and environmental analysis tools that can help a contractor during the construction process. As a future research, a tool that interacts with BIM software and provides alternatives for materials that are harmful to the construction workers can be

created. This tool will use the database created with the proposed research and connect it with the building data generated by BIM software.

Other issues that need to be further researched are:

- Precast advantages over cast-in-place concrete on respirable particle emissions.
- Precast pavers' cost and schedule impact on a project and respirable particle emissions when compared to the use of cast-in-place concrete or asphalt.
- Other divisions of the CSI Masterformat to include materials and procedures for any type of project.
- The development of applications that can be downloaded to smart phones and similar devices to make the search through the database easier when using this type of devices.
- Creation of a Macros that can be used in Microsoft Project to connect the database to the project schedule.
- RFID tags to hold the information of how to install materials in a safely manner and for tools to provide information of what extra equipment or precautions, if necessary, need to be taken into account when using them for specific tasks that can contribute in unhealthy conditions for the workers.
- The development of specifications that relate to the database use to make it part of the construction process.

APPENDIX A
SURVEY QUESTIONS

1. Have you worked or are you currently working in the construction industry?

    a. Yes
    b. No

2. If you answered Yes to the previous question, in what capacity? (Answer N/A if have never worked in construction. You can select more than one answer.)

    a. N/A
    b. Union worker
    c. Non-union worker
    d. Occupational health professional
    e. Management
    f. Designer (Architect, Engineer, etc.)
    g. Specialized subcontractor
    h. Owner
    i. Government
    j. Consultant
    k. Academia
    l. Other

3. How many years have you worked in construction? (Answer N/A if you have never worked in construction)
    a. N/A
    b. 0-5
    c. 5-10
    d. 10-20
    e. Over 20

4. Sitework Health Issues - This section refers to health issues that can arise in sitework. Sitework includes the following subdivision:
    (If you need more clarification of tasks in this division please go to : http://www.mc2ice.com/support/estref/popular_conversion_files/construct_code/Division2.html)

    Division 2 – Sitework
    02050 Basic site materials and methods
    02100 Site remediation
    02200 Site preparation
    02300 Earthwork
    02400 Tunnels, bores and jacks
    02500 Utilities Services

02600 Drainage and containment
02700 Bases, ballasts, pavement and appurtenances
02800 Site improvements and amenities
02900 Planting
02950 Site restoration and rehabilitation

Remember to include only health hazards that can cause short and/or long term illnesses and not safety issues that are mostly related to accidents. For example: If the question refers to building waterproofing a concern regarding roofing installation may be the fumes from the products used and not the possibility of falls. If you don't know the answer, just leave it blank.

Enumerate at most five important health hazards that can affect a construction worker performing a task under this division?

5. Concrete work health issues - This section refers to health issues that can arise in concrete tasks. Concrete includes the following subdivisions:
(If you need more clarification of tasks in this division please go to :
http://www.mc2ice.com/support/estref/popular_conversion_files/construct_code/Division3.html)

Division 3 – Concrete
03050 Basic materials and methods
03100 Forms and accessories
03200 Concrete reinforcing
03300 Cast in place concrete
03400 Precast concrete
03430 Site precast structural concrete
03500 Cementitious decks and underlayment
03600 Grout
03700 Mass concrete
03900 Restoration and cleaning

Remember to include only health hazards that can cause short and/or long term illnesses and not safety issues that are mostly related to accidents. For example: If the question refers to building waterproofing a concern regarding roofing installation may be the fumes from the products used and not the possibility of falls. If you don't know the answer, just leave it blank.

Enumerate at most five important health hazards that can affect a construction worker performing a task under this division?

6. Masonry work health issues - This section refers to health issues that can arise in masonry tasks. Masonry includes the following subdivisions:
(If you need more clarification of tasks in this division please go to :
http://www.mc2ice.com/support/estref/popular_conversion_files/construct_code/Division4.html)

Division 4 – Masonry
04050 Basic materials and methods
04200 Masonry units
04400 Stone
04500 Refractories
04600 Corrosion resistant masonry
04700 Simulated masonry
04800 Masonry assemblies
04900 Restoration and cleaning

Remember to include only health hazards that can cause short and/or long term illnesses and not safety issues that are mostly related to accidents. For example: If the question refers to building waterproofing a concern regarding roofing installation may be the fumes from the products used and not the possibility of falls. If you don't know the answer, just leave it blank.

Enumerate at most five important health hazards that can affect a construction worker performing a task under this division?

7. This section refers to health issues that can arise metals work. Metals includes the following subdivisions:
(If you need more clarification of tasks in this division please go to : http://www.mc2ice.com/support/estref/popular_conversion_files/construct_code/Division5.html)

Division 5- Metals
05050 Basic materials and methods
05100 Structural Metal Framing
05200 Joists
05300 Metal deck
05400 Cold formed metal framing
05500 Metal fabrications
05600 Hydraulic fabrications
05700 Ornamental metal
05800 Expansion control
05900 Metal restoration and cleaning

Remember to include only health hazards that can cause short and/or long term illnesses and not safety issues that are mostly related to accidents. For example: If the question refers to building waterproofing a concern regarding roofing installation may be the fumes from the products used and not the possibility of falls. If you don't know the answer, just leave it blank.

Enumerate at most five important health hazards that can affect a construction worker performing a task under this division?

8. Please use this space to add any comments, concerns and/or questions you may have. Thank you for your participation.

APPENDIX B
CONSTRUCTION SPECIFICATIONS INSTITUTE MASTERFORMAT 1995

Division 1 - General Requirements

01100 Summary
01200 Price and payment procedures
01300 Administrative requirements
01400 Quality requirements
01500 Temporary facilities and controls
01600 Product requirements
01700 Execution requirements
01800 Facility operation
01900 Decommissioning

Division 2 – Sitework

02050 Basic site materials and methods
02100 Site remediation
02200 Site preparation
02300 Earthwork
02400 Tunnels, bores and jacks
02500 Utilities Services
02600 Drainage and containment
02700 Bases, ballasts, pavement and appurtenances
02800 Site improvements and amenities
02900 Planting
02950 Site restoration and rehabilitation

Division 3 – Concrete

03050 Basic materials and methods
03100 Forms and accessories
03200 Concrete reinforcing
03300 Cast in place concrete
03400 Precast concrete
03430 Site precast structural concrete
03500 Cementitious decks and underlayment
03600 Grout
03700 Mass concrete
03900 Restoration and cleaning

Division 4 – Masonry

04050Basic materials and methods
04200Masonry units
04400Stone
04500Refractories
04600Corrosion resistant masonry
04700 Simulated masonry
04800 Masonry assemblies
04900 Restoration and cleaning

Division 5- Metals

05050 Basic materials and methods
05100 Structural Metal Framing
05200 Joists
05300 Metal deck
05400 Cold formed metal framing
05500 Metal fabrications
05600 Hydraulic fabrications
05700 Ornamental metal
05800 Expansion control
05900 Metal restoration and cleaning

Division 6 - Wood and plastics

06050 Basic materials and methods
06100 Rough carpentry
06200 Finish carpentry
06400 Architectural woodwork
06500 Structural plastic
06600 Plastic fabrications
06900 Wood and plastic restoration and cleaning

Division 7 - Thermal and moisture protection

07050 Basic thermal and moisture protection materials and methods
07100 Dampproofing and waterproofing
07200 Thermal protection
07300 Shingles, roof tiles and coverings
07400 Roofing and siding panels
07500 Membrane roofing
07600 Flashing and sheetmetal
07700 Roof specialties and accessories
07800 Fire and smoke protection
07900 Joint sealers

Division 8 - Doors and windows

08050 Basic materials and methods
08100 Metal doors and frames
08200 Wood and plastic doors
08300 Specialty doors
08400 Entrances and storefronts
08500 Windows
08600 Skylights
08700 Hardware
08800 Glazing
08900 Curtainwalls

Division 9 – Finishes

09050 Basic materials and methods
09100 Metal support assemblies
09200 Plaster and gypsum board
09300 Tile
09400 Terrazzo
09500 Ceilings
09600 Flooring
09700 Wall finishes
09800 Acoustical treatment
09900 Paint and coatings

Division 10 – Specialties

10100 Visual display boards
10150 Compartments and cubicles
10200 Louvers and vents
10240 Grilles and screens
10250 Service walls
10260 Wall and corner guards
10270 Access flooring
10290 Pest control
10300 Fireplaces and stoves
10340 Manufactured exterior specialties
10350 Flagpoles
10400 Identification devices
10450 Pedestrian control
10500 Lockers
10520 Fire protection specialties
10530 Identification devices
10550 Post office specialties
10600 Partitions
10670 Storage shelves
10700 Exterior protection
10750 Telephone specialties

10800 Toilet, bath and laundry accessories
10900 Wardrobe and closet specialties

Division 11 – Equipment
11010 Maintenance equipment
11020 Security and vault equipment
11030 Teller and service equipment
11040 Ecclesiastical equipment
11050 Library equipment
11060 Theater and stage equipment
11070 Instrumental and music equipment
11080 Registration equipment
11090 Checkroom equipment
11100 Mercantile equipment
11110 Commercial laundry equipment
11120 Vending equipment
11130 Audiovisual equipment
11140 Vehicle service equipment
11150 Parking control equipment
11160 Loading dock equipment
11170 Solid waste handling equipment
11190 Prison equipment
11200 Water supply and treatment equipment
11280 Hydraulic gates and valves
11300 Fluid waste treatment and disposal equipment
11400 Food service equipment
11450 Residential equipment
11460 Unit kitchens
11470 Darkroom equipment
11480 Athletic, recreational and therapeutic equipment
11500 Industrial and process equipment
11600 Laboratory equipment
11650 Planetarium equipment
11660 Observatory equipment
11680 Office equipment
11700 Medical equipment
11780 Mortuary equipment
11850 Navigation equipment
11870 Agricultural equipment
11900 Exhibit equipment

Division 12 – Furnishings
12050 Fabrics
12100 Art
12300 Manufactured casework

12400 Furnishings and accessories
12500 Furniture
12600 Multiple seating
12700 System furniture
12800 Interior plants and planters
12900 Furnishings restoration and repair

Division 13 - Special construction
13010 Air supported structures
13020 Building modules
13030 Special purpose rooms
13080 Sound, vibration and seismic control
13090 Radiation protection
13100 Lightning protection
13110 Cathodic protection
13120 Preengineered structures
13150 Swimming pools
13160 Aquariums
13165 Aquatic parks
13170 Tubs and pools
13175 Ice rinks
13185 Kennels
13190 Site constructed incinerators
13200 Storage tanks
13220 Filter underdrains and media
13230 Digester covers and appurtenances
13240 Oxygenation systems
13260 Sludge conditioning systems
13280 Hazardous material remedition
13400 Measurement and control instrumentation
13500 Recording instrumentation
13550 Transportation control instrumentation
13600 Solar and wind energy equipment
13700 Security access and surveillance
13800 Building automation and control
13850 Detection and alarm
13900 Fire suppression

Division 14 - Conveying systems
14100 Dumbwaiters
14200 Elevators
14300 Escalators and moving walks
14400 Lifts
14500 Material handling
14600 Hoists and cranes
14700 Turntables

14800 Scaffolds
14900 Transportation

Division 15 – Mechanical
15050 Basic materials and methods
15100 Building services pipe
15200 Process pipe
15300 Fire protection pipe
15400 Plumbing fixtures and equipment
15500 Heat generation equipment
15600 Refrigeration equipment
15700 HVAC equipment
15800 Air distribution
15900 HVAC instrumentation and controls
15950 Testing, adjusting and balancing

Division 16 – Electrical
16050 Basic materials and methods
16100 Wiring methods
16200 Electric power
16300 Transmission and distribution
16400 Low voltage distribution
16500 Lighting
16700 Communications
16800 Sound and video

APPENDIX C
EQUIPMENT EXAMPLES

Hydraulic clamping equipment to install block cluster.

Manual cutter that minimizes the respirable dust and silica released to the air

Wet cutting equipment

Dustcontrol DC 2800c/Auto – LEV HEPA filter with about 1400 hours of motor life. The brushes life is 600-700 hours original brushes, 400 hours first replacement and 300 hours second replacement. Cost is around $1950 new. (Information and figure courtesy of Dustcontrol)

APPENDIX D
WEB-BASED DATABASE CODE

```
========================================
FILE: doc/README_FOR_APP
========================================

= Construction Worker Health:
== Alternatives to Hazardous Materials and Procedures

Application to find and map recommendations for alternative procedures
that will result in reduced negative health impact for construction
workers.

This application is written in ruby on rails (http://rubyonrails.org/)
version 3.0.8. Ruby-on-rails is an open source framework, built on top
of the Ruby language, to create web based data-centric applications.

A list of references for ruby on rails development can be found at:
  * http://rubyonrails.org/documentation

We used version 1.9.2 of the ruby language. References for ruby
language can be found at:
  * http://www.ruby-lang.org/en/documentation/

The following books were heavily used as references during the
development of the application, and code structure and examples from
these books were used to base our implementation (these examples are
covered under open source licenses allowing re-use in any sort of
code):
  * http://pragprog.com/titles/rails4/agile-web-development-with-rails
  * http://ruby.railstutorial.org/ruby-on-rails-tutorial-book
  * http://ruby.railstutorial.org/ruby-on-rails-tutorial-book
  * http://pragprog.com/titles/ruby3/programming-ruby-1-9

The following websites provided hints, and examples used to implement
sections of the code:
  * http://guides.rubyonrails.org/getting_started.html
  * http://railscasts.com/ - rails screen casts
  * http://teachmetocode.com - rails screen casts
  * http://api.rubyonrails.org - Documentation for framework
  * http://stackoverflow.com - question and answer web site

The application allows the user to choose division, subdivision, and
activity for their project. It then shows a list of recommendations
for this activity, and the cost and schedule impact if the
recommendation is followed.
```

```
========================================
FILE: Gemfile
========================================
source 'http://rubygems.org'

gem 'rails', '3.0.8'
gem 'sqlite3-ruby', '1.3.2', :require => 'sqlite3'

group :development do
  gem 'rspec-rails', '2.6.0'
  gem 'annotate-models', '1.0.4'
end

group :test do
  gem 'rspec-rails', '2.6.0'
  gem 'webrat', '0.7.1'
  gem 'spork', '~> 0.9.0.rc5'
  gem 'factory_girl_rails', '1.0'
end


========================================
FILE: config/routes.rb
========================================
Thesis::Application.routes.draw do
  match '/',        :to => 'divisions#index'
  match 'root',     :to => 'divisions#index'
  match '/home',    :to => 'divisions#index'
  root              :to => 'divisions#index'
  resources :recommendations

  resources :activities

  resources :subdivisions
  resources :divisions
  resources :maps

  # The priority is based upon order of creation:
  # first created -> highest priority.

  # Sample of regular route:
  #   match 'products/:id' => 'catalog#view'
  # Keep in mind you can assign values other than :controller and :action
```

```
# Sample of named route:
#   match 'products/:id/purchase' => 'catalog#purchase', :as => :purchase
# This route can be invoked with purchase_url(:id => product.id)

# Sample resource route (maps HTTP verbs to controller actions automatically):
#   resources :products

# Sample resource route with options:
#   resources :products do
#     member do
#       get 'short'
#       post 'toggle'
#     end
#
#     collection do
#       get 'sold'
#     end
#   end

# Sample resource route with sub-resources:
#   resources :products do
#     resources :comments, :sales
#     resource :seller
#   end

# Sample resource route with more complex sub-resources
#   resources :products do
#     resources :comments
#     resources :sales do
#       get 'recent', :on => :collection
#     end
#   end

# Sample resource route within a namespace:
#   namespace :admin do
#     # Directs /admin/products/* to Admin::ProductsController
#     # (app/controllers/admin/products_controller.rb)
#     resources :products
#   end

# You can have the root of your site routed with "root"
# just remember to delete public/index.html.
# root :to => "welcome#index"

# See how all your routes lay out with "rake routes"
```

```
  # This is a legacy wild controller route that's not recommended for RESTful
applications.
  # Note: This route will make all actions in every controller accessible via GET
requests.
  # match ':controller(/:action(/:id(.:format)))'
end


==========================================
FILE: app/controllers/subdivisions_controller.rb
==========================================
class SubdivisionsController < ApplicationController
  # GET /subdivisions
  # GET /subdivisions.xml
  def index
    @subdivisions = Subdivision.all

    respond_to do |format|
      format.html # index.html.erb
      format.xml  { render :xml => @subdivisions }
    end
  end

  # GET /subdivisions/1
  # GET /subdivisions/1.xml
  def show
    @subdivision = Subdivision.find(params[:id])
    session[:subdivision] = @subdivision.name
    @breadcrumb = "#{session[:division]}|#{session[:subdivision]}"

    respond_to do |format|
      format.html # show.html.erb
      format.xml  { render :xml => @subdivision }
    end
  end

  # GET /subdivisions/new
  # GET /subdivisions/new.xml
  def new
    @subdivision = Subdivision.new

    respond_to do |format|
      format.html # new.html.erb
      format.xml  { render :xml => @subdivision }
    end
  end
```

```
  # GET /subdivisions/1/edit
  def edit
    @subdivision = Subdivision.find(params[:id])
  end

  # POST /subdivisions
  # POST /subdivisions.xml
  def create
    map_string_activities_to_object
    @subdivision = Subdivision.new(params[:subdivision])

    respond_to do |format|
      if @subdivision.save
        format.html { redirect_to(@subdivision, :notice => 'Subdivision was
successfully created.') }
        format.xml  { render :xml => @subdivision, :status => :created, :location =>
@subdivision }
      else
        format.html { render :action => "new" }
        format.xml  { render :xml => @subdivision.errors, :status =>
:unprocessable_entity }
      end
    end
  end

  # PUT /subdivisions/1
  # PUT /subdivisions/1.xml
  def update
    @subdivision = Subdivision.find(params[:id])
    map_string_activities_to_object

    respond_to do |format|
      if @subdivision.update_attributes(params[:subdivision])
        format.html { redirect_to(@subdivision, :notice => 'Subdivision was
successfully updated.') }
        format.xml  { head :ok }
      else
        format.html { render :action => "edit" }
        format.xml  { render :xml => @subdivision.errors, :status =>
:unprocessable_entity }
      end
    end
  end

  # DELETE /subdivisions/1
```

```
  # DELETE /subdivisions/1.xml
  def destroy
    @subdivision = Subdivision.find(params[:id])
    @subdivision.destroy

    respond_to do |format|
      format.html { redirect_to(subdivisions_url) }
      format.xml  { head :ok }
    end
  end

  def map_string_activities_to_object
    # Map from string to actual object to insert
    unless params.nil? or params[:subdivision].nil? or
params[:subdivision][:activities].nil?
      params[:subdivision][:activities].collect! { |r|
        unless r.empty?
          Activity.find(r)
        end
      }
      params[:subdivision][:activities].compact!
    end
  end

end


==========================================
FILE: app/controllers/activities_controller.rb
==========================================
class ActivitiesController < ApplicationController
  # GET /activities
  # GET /activities.xml
  def index
    @activities = Activity.all
    respond_to do |format|
      format.html # index.html.erb
      format.xml  { render :xml => @activities }
    end
  end

  # GET /activities/1
  # GET /activities/1.xml
  def show
    @activity = Activity.find(params[:id])
```

```
      @breadcrumb =
"#{session[:division]}|#{session[:subdivision]}|#{@activity.name}"
      session[:activity] = @activity.name

      respond_to do |format|
        format.html # show.html.erb
        format.xml  { render :xml => @activity }
      end
    end

    # GET /activities/new
    # GET /activities/new.xml
    def new
      @activity = Activity.new

      respond_to do |format|
        format.html # new.html.erb
        format.xml  { render :xml => @activity }
      end
    end

    # GET /activities/1/edit
    def edit
      @activity = Activity.find(params[:id])
      logger.debug("AT EDIT with PARAMS: #{@params}") if Rails.env.development?
    end

    # POST /activities
    # POST /activities.xml
    def create
      map_string_recommendations_to_objects

      @activity = Activity.new(params[:activity])

      respond_to do |format|
        if @activity.save
          format.html { redirect_to(@activity, :notice => 'Activity was successfully
created.') }
          format.xml  { render :xml => @activity, :status => :created, :location =>
@activity }
        else
          format.html { render :action => "new" }
          format.xml  { render :xml => @activity.errors, :status =>
:unprocessable_entity }
        end
      end
```

```
  end

  # PUT /activities/1
  # PUT /activities/1.xml
  def update
    @activity = Activity.find(params[:id])
    map_string_recommendations_to_objects

    respond_to do |format|
      if @activity.update_attributes(params[:activity])
        format.html { redirect_to(@activity, :notice => 'Activity was successfully
updated.') }
        format.xml  { head :ok }
      else
        format.html { render :action => "edit" }
        format.xml  { render :xml => @activity.errors, :status =>
:unprocessable_entity }
      end
    end
  end

  # DELETE /activities/1
  # DELETE /activities/1.xml
  def destroy
    @activity = Activity.find(params[:id])
    @activity.destroy

    respond_to do |format|
      format.html { redirect_to(activities_url) }
      format.xml  { head :ok }
    end
  end

  def map_string_recommendations_to_objects
    # Map from string to actual object to insert
    unless params.nil? or params[:activity].nil? or
params[:activity][:recommendations].nil?
      params[:activity][:recommendations].collect! { |r|
        unless r.empty?
          Recommendation.find(r)
        end
      }
      params[:activity][:recommendations].compact!
    end
  end
```

```
end


========================================
FILE: app/controllers/application_controller.rb
========================================
class ApplicationController < ActionController::Base
  protect_from_forgery
end


========================================
FILE: app/controllers/divisions_controller.rb
========================================
class DivisionsController < ApplicationController
  # GET /divisions
  # GET /divisions.xml
  def index
    @divisions = Division.all

    respond_to do |format|
      format.html # index.html.erb
      format.xml  { render :xml => @divisions }
    end
  end

  # GET /divisions/1
  # GET /divisions/1.xml
  def show
    @division = Division.find(params[:id])
    session[:division] = @division.name
    @breadcrumb = "#{session[:division]}"

    respond_to do |format|
      format.html # show.html.erb
      format.xml  { render :xml => @division }
    end
  end

  # GET /divisions/new
  # GET /divisions/new.xml
  def new
    @division = Division.new

    respond_to do |format|
      format.html # new.html.erb
```

```
      format.xml  { render :xml => @division }
    end
  end

  # GET /divisions/1/edit
  def edit
    @division = Division.find(params[:id])
  end

  # POST /divisions
  # POST /divisions.xml
  def create
    @division = Division.new(params[:division])

    respond_to do |format|
      if @division.save
        format.html { redirect_to(@division, :notice => 'Division was successfully
created.') }
        format.xml  { render :xml => @division, :status => :created, :location =>
@division }
      else
        format.html { render :action => "new" }
        format.xml  { render :xml => @division.errors, :status =>
:unprocessable_entity }
      end
    end
  end

  # PUT /divisions/1
  # PUT /divisions/1.xml
  def update
    @division = Division.find(params[:id])

    respond_to do |format|
      if @division.update_attributes(params[:division])
        format.html { redirect_to(@division, :notice => 'Division was successfully
updated.') }
        format.xml  { head :ok }
      else
        format.html { render :action => "edit" }
        format.xml  { render :xml => @division.errors, :status =>
:unprocessable_entity }
      end
    end
  end
```

```
  # DELETE /divisions/1
  # DELETE /divisions/1.xml
  def destroy
    @division = Division.find(params[:id])
    @division.destroy

    respond_to do |format|
      format.html { redirect_to(divisions_url) }
      format.xml  { head :ok }
    end
  end
end


========================================
FILE: app/controllers/recommendations_controller.rb
========================================
class RecommendationsController < ApplicationController
  # GET /recommendations
  # GET /recommendations.xml
  def index
    @recommendations = Recommendation.all

    respond_to do |format|
      format.html # index.html.erb
      format.xml  { render :xml => @recommendations }
    end
  end

  # GET /recommendations/1
  # GET /recommendations/1.xml
  def show
    @recommendation = Recommendation.find(params[:id])
    @breadcrumb =
"#{session[:division]}|#{session[:subdivision]}|#{session[:activity]}|#{@recommendation.
name}"
    session[:recommendation] = @recommendation.name

    respond_to do |format|
      format.html # show.html.erb
      format.xml  { render :xml => @recommendation }
    end
  end

  # GET /recommendations/new
  # GET /recommendations/new.xml
```

```
  def new
    @recommendation = Recommendation.new

    respond_to do |format|
      format.html # new.html.erb
      format.xml  { render :xml => @recommendation }
    end
  end

  # GET /recommendations/1/edit
  def edit
    @recommendation = Recommendation.find(params[:id])
  end

  # POST /recommendations
  # POST /recommendations.xml
  def create
    @recommendation = Recommendation.new(params[:recommendation])

    respond_to do |format|
      if @recommendation.save
        format.html { redirect_to(@recommendation, :notice => 'Recommendation
was successfully created.') }
        format.xml  { render :xml => @recommendation, :status => :created, :location
=> @recommendation }
      else
        format.html { render :action => "new" }
        format.xml  { render :xml => @recommendation.errors, :status =>
:unprocessable_entity }
      end
    end
  end

  # PUT /recommendations/1
  # PUT /recommendations/1.xml
  def update
    @recommendation = Recommendation.find(params[:id])

    respond_to do |format|
      if @recommendation.update_attributes(params[:recommendation])
        format.html { redirect_to(@recommendation, :notice => 'Recommendation
was successfully updated.') }
        format.xml  { head :ok }
      else
        format.html { render :action => "edit" }
```

```
            format.xml  { render :xml => @recommendation.errors, :status =>
:unprocessable_entity }
          end
        end
      end

      # DELETE /recommendations/1
      # DELETE /recommendations/1.xml
      def destroy
        @recommendation = Recommendation.find(params[:id])
        @recommendation.destroy

        respond_to do |format|
          format.html { redirect_to(recommendations_url) }
          format.xml  { head :ok }
        end
      end
    end


    ========================================
    FILE: app/models/activity.rb
    ========================================
    # == Schema Information
    # Schema version: 20110612051555
    #
    # Table name: activities
    #
    #  id         :integer         not null, primary key
    #  name       :string(255)
    #  created_at :datetime
    #  updated_at :datetime
    #

    class Activity < ActiveRecord::Base
      attr_accessible :name, :subdivisions, :recommendations

      has_many :substitutions
      has_many :workcategorizations

      has_many :subdivisions,    :through => :workcategorizations
      has_many :recommendations, :through => :substitutions

      private
      # ensure that there are no recommendations referencing this division
      def ensure_not_referenced_by_any_recommendations
```

```
    if recommendations.empty?
      return true
    else
      errors.add(:base, 'Recommendations present')
      return false
    end
  end

end


========================================
FILE: app/models/substitution.rb
========================================
# == Schema Information
# Schema version: 20110612195636
#
# Table name: substitutions
#
#  id               :integer         not null, primary key
#  activity_id       :integer
#  recommendation_id :integer
#  created_at        :datetime
#  updated_at        :datetime
#

class Substitution < ActiveRecord::Base
  belongs_to :activity
  belongs_to :recommendation
end


========================================
FILE: app/models/recommendation.rb
========================================
# == Schema Information
# Schema version: 20110612210312
#
# Table name: recommendations
#
#  id              :integer         not null, primary key
#  name            :string(255)
#  cost_impact     :string(255)
#  schedule_impact :string(255)
#  created_at      :datetime
#  updated_at      :datetime
```

```
#

class Recommendation < ActiveRecord::Base
  attr_accessible :name, :activities, :me

  has_many :substitutions
  has_many :activities, :through => :substitutions

  validates :name, :presence => true, :uniqueness => true

  def me
    self
  end

  def show_schedule_impact
    if schedule_impact.blank?
      "None"
    else
      schedule_impact
    end
  end

  def show_cost_impact
    if cost_impact.blank?
      "None"
    else
      cost_impact
    end
  end

#  def activity_name
#    if activity.nil?
#      ""
#    else
#      self.activity.name
#    end
#  end
#

end


==========================================
FILE: app/models/subdivision.rb
==========================================
# == Schema Information
```

```
# Schema version: 20110612051555
#
# Table name: subdivisions
#
#  id          :integer         not null, primary key
#  name        :string(255)
#  division_id :integer
#  created_at  :datetime
#  updated_at  :datetime
#

class Subdivision < ActiveRecord::Base
  attr_accessible :name, :division_id, :activities

  belongs_to :division

  has_many   :workcategorizations
  has_many   :activities, :through => :workcategorizations

  validates :division_id, :presence => true
  validates :name,        :presence => true, :uniqueness => true

  before_destroy :ensure_not_referenced_by_any_activities

  def division_name
    self.division.name
  end

  def full_name
    "#{division_name}:#{name}"
  end

  private
  # ensure that there are no activities referencing this division
  def ensure_not_referenced_by_any_activities
    if activities.empty?
      return true
    else
      errors.add(:base, 'Activities present')
      return false
    end
  end

end
```

```
========================================
FILE: app/models/workcategorization.rb
========================================
# == Schema Information
# Schema version: 20110612210312
#
# Table name: workcategorizations
#
#  id             :integer         not null, primary key
#  activity_id    :integer
#  subdivision_id :integer
#  created_at     :datetime
#  updated_at     :datetime
#

class Workcategorization < ActiveRecord::Base
  belongs_to :activity
  belongs_to :subdivision
end


========================================
FILE: app/models/division.rb
========================================
# == Schema Information
# Schema version: 20110612051555
#
# Table name: divisions
#
#  id         :integer         not null, primary key
#  name       :string(255)
#  created_at :datetime
#  updated_at :datetime
#

class Division < ActiveRecord::Base
  has_many :subdivisions
  validates :name, :presence => true, :uniqueness => true

  before_destroy :ensure_not_referenced_by_any_subdivisions

  private
  # ensure that there are no subdivisions referencing this division
  def ensure_not_referenced_by_any_subdivisions
    if subdivisions.empty?
      return true
```

```
    else
      errors.add(:base, 'Subdivisions present')
      return false
    end
  end

end


========================================
FILE: app/views/layouts/application.html.erb
========================================
<!DOCTYPE html>
<html>
<head>
  <title>Thesis</title>
  <%= csrf_meta_tag %>
  <%= render 'layouts/stylesheets' %>
  <%= stylesheet_link_tag :all %>
  <%= javascript_include_tag :defaults %>
</head>
<body>
    <div class="round container">
      <%= render 'layouts/header' %>
      <section class="span-24 content round">
  <% flash.each do |key, value| %>
            <div class="span-24 flash <%= key %>"><%= value %></div>
  <% end %>
  <%= yield %>
      </section>
      <%= render 'layouts/footer' %>
      <%= debug(params) if Rails.env.development? %>
    </div>
</body>
</html>


========================================
FILE: app/views/layouts/_stylesheets.html.erb
========================================
<!--[if lt IE 9]>
    <script src="http://html5shiv.googlecode.com/svn/trunk/html5.js"></script>
<![endif]-->
<%= stylesheet_link_tag 'blueprint/screen', :media => 'screen' %>
<%= stylesheet_link_tag 'blueprint/print',  :media => 'print' %>
<!--[if lt IE 8]><%= stylesheet_link_tag 'blueprint/ie' %><![endif]-->
```

```
<%= javascript_include_tag :defaults %>
<%= stylesheet_link_tag 'custom', :media => 'screen' %>


==========================================
FILE: app/views/layouts/_footer.html.erb
==========================================
<footer class="span-24">
  <nav class="footer round">
    <ul>
      <li><%= link_to "About",   "#" %></li>
      <li><%= link_to "Contact", "#" %></li>
    </ul>
  </nav>
</footer>


==========================================
FILE: app/views/layouts/_header.html.erb
==========================================
<header class="span-24">
  <!-- % logo = image_tag("spectralmd_logo_web.jpg", :alt => "Deepview Image
Visualizer", :class => "round span-7") % -->
  <!-- %= link_to logo, root_path % -->
  <hgroup>
    <h1 class="prepend-1 span-7 append-1"><%= @title %></h1>
    <% unless @breadcrumb.nil? %>
    <h4 class="strong center prepend-1 span-22 append-1"><%= @breadcrumb
%></h4>
    <% end %>
  </hgroup>
  <nav class="round right span-3 last">
    <ul>
      <li><%= link_to "Home",   "/" %></li>
      <li><%= link_to "Help",   "#" %></li>
      <!-- li><%= link_to "Log in", "#" %></li -->
    </ul>
  </nav>
</header>


==========================================
FILE: app/views/activities/show.html.erb
==========================================
<p id="notice"><%= notice %></p>
```

```
<h2><%= @activity.name %></h2>

<section>
  <h3>Recommendations:</h3>
  <ul>
    <% @activity.recommendations.each do |r| %>
    <li><%= link_to r.name, r %></li>
    <% end %>
  </ul>
</section>

<%= link_to 'Update Recommendations', edit_activity_path(@activity) %> |
<%= link_to 'Back', activities_path %> |


========================================
FILE: app/views/activities/new.html.erb
========================================
<h1>New activity</h1>

<%= render 'form' %>

<%= link_to 'Back', activities_path %>


========================================
FILE: app/views/activities/_form.html.erb
========================================
<%= form_for(@activity) do |f| %>
  <% if @activity.errors.any? %>
    <div id="error_explanation">
      <h2><%= pluralize(@activity.errors.count, "error") %> prohibited this activity
from being saved:</h2>

      <ul>
      <% @activity.errors.full_messages.each do |msg| %>
        <li><%= msg %></li>
      <% end %>
      </ul>
    </div>
  <% end %>

  <div class="field">
    <%= f.label :name %><br />
    <%= f.text_field :name %>
  </div>
```

```
  <div class="field">
    Add Recommendation:
    <%= collection_select(:activity, :recommendations, Recommendation.all, :id,
:name, { :prompt => "Select one or more recommendations from list below:", :selected
=> @activity.recommendations.collect { |v| v.id.to_s }}, { :multiple=>true, :size=>6 } ) %>
  </div>

  <div class="actions">
    <%= f.submit %>
  </div>

<% end %>



==========================================
FILE: app/views/activities/index.html.erb
==========================================
<h1>Activities</h1>

<table>
  <tr>
    <th>Name</th>
    <th class="span-2">Number of Recommendations:</th>
    <th class="span-1"></th>
    <th class="span-1"></th>
  </tr>
<% @activities.each do |activity| %>
  <tr>
    <td><%= link_to activity.name, activity %></td>
    <td><%= activity.substitutions.count %></td>
      <td class="span-1"><%= link_to 'Edit', edit_activity_path(activity) %></td>
    <td class="span-1"><%= link_to 'Destroy', activity, :confirm => 'Are you sure?',
:method => :delete %></td>
  </tr>
<% end %>
</table>

<br />

<%= link_to 'New Activity', new_activity_path %>


==========================================
FILE: app/views/activities/edit.html.erb
```

```
========================================
<h1>Editing activity</h1>

<%= render 'form' %>

<%= link_to 'Show', @activity %> |
<%= link_to 'Back', activities_path %>


========================================
FILE: app/views/subdivisions/show.html.erb
========================================
<p id="notice"><%= notice %></p>

  <h2><%= link_to @subdivision.division_name, @subdivision.division %> :   <%=
@subdivision.name %></h2>
  <h3>Activities:</h3>
  <ul>
    <% @subdivision.activities.each do |s| %>
    <li><%= link_to s.name, s %></li>
    <% end %>
  </ul>
</section>


<%= link_to 'Edit', edit_subdivision_path(@subdivision) %> |
<%= link_to 'Back', subdivisions_path %>


========================================
FILE: app/views/subdivisions/new.html.erb
========================================
<h1>New subdivision</h1>

<%= render 'form' %>

<%= link_to 'Back', subdivisions_path %>


========================================
FILE: app/views/subdivisions/_form.html.erb
========================================
<%= form_for(@subdivision) do |f| %>
  <% if @subdivision.errors.any? %>
    <div id="error_explanation">
```

```
        <h2><%= pluralize(@subdivision.errors.count, "error") %> prohibited this
subdivision from being saved:</h2>

        <ul>
        <% @subdivision.errors.full_messages.each do |msg| %>
          <li><%= msg %></li>
        <% end %>
        </ul>
      </div>
    <% end %>

    <div class="field">
      <%= f.label :division %><br />
      <%= collection_select(:subdivision, :division_id, Division.all, :id, :name ) %>
    </div>

    <div class="field">
      <%= f.label :name %><br />
      <%= f.text_field :name %>
    </div>

    <div class="field">
      Add Activities:
      <%= collection_select(:subdivision, :activities, Activity.all, :id, :name, { :prompt
=> "Select one or more activities from list below:", :selected =>
@subdivision.activities.collect { |v| v.id.to_s }}, { :multiple=>true, :size=>6 } ) %>
    </div>

    <div class="actions">
      <%= f.submit %>
    </div>
  <% end %>


  ========================================
  FILE: app/views/subdivisions/index.html.erb
  ========================================
  <h1>Select Subdivision</h1>

  <table>
    <tr>
      <th class="span-3">Division</th>
      <th>Subdivision</th>
      <th class="span-2">Activities with recommendations</th>
      <th class="span-1"></th>
      <th class="span-1"></th>
```

```
  </tr>

<% @subdivisions.each do |subdivision| %>
  <tr>
    <td><%= link_to subdivision.division_name,
division_path(subdivision.division_id) %></td>
    <td><%= link_to subdivision.name, subdivision %></td>
    <td><%= subdivision.activities.count %></td>
    <td><%= link_to 'Edit', edit_subdivision_path(subdivision) %></td>
    <td><%= link_to 'Destroy', subdivision, :confirm => 'Are you sure?', :method =>
:delete %></td>
  </tr>
<% end %>
</table>

<br />

<%= link_to 'New Subdivision', new_subdivision_path %>


========================================
FILE: app/views/subdivisions/edit.html.erb
========================================
<h1>Editing subdivision</h1>

<%= render 'form' %>

<%= link_to 'Show', @subdivision %> |
<%= link_to 'Back', subdivisions_path %>


========================================
FILE: app/views/recommendations/show.html.erb
========================================
<p id="notice"><%= notice %></p>

<h2>Recommendation: <%= @recommendation.name %></h2>


<p>
  <b>Used for Activities:</b>
  <% unless @recommendation.activities.empty? %>
  <ul>
    <% @recommendation.activities.each do |a| %>
    <li><%= link_to a.name, a %></li>
    <% end %>
```

```
  </ul>
  <% end %>
</p>

<p>
  <b>Cost impact:</b>
  <%= @recommendation.show_cost_impact %>
</p>

<p>
  <b>Schedule impact:</b>
  <%= @recommendation.show_schedule_impact %>
</p>


<%= link_to 'Edit', edit_recommendation_path(@recommendation) %> |
<%= link_to 'Back', recommendations_path %>


========================================
FILE: app/views/recommendations/new.html.erb
========================================
<h1>New recommendation</h1>

<%= render 'form' %>

<%= link_to 'Back', recommendations_path %>


========================================
FILE: app/views/recommendations/_form.html.erb
========================================
<%= form_for(@recommendation) do |f| %>
  <% if @recommendation.errors.any? %>
    <div id="error_explanation">
      <h2><%= pluralize(@recommendation.errors.count, "error") %> prohibited this
recommendation from being saved:</h2>

      <ul>
      <% @recommendation.errors.full_messages.each do |msg| %>
        <li><%= msg %></li>
      <% end %>
      </ul>
    </div>
  <% end %>
```

```
  <div class="field">
    <%= f.label :activity_id %><br />
    <%= collection_select(:recommendation, :activity_id, Activity.all, :id, :name ) %>
  </div>

  <div class="field">
    <%= f.label :name %><br />
    <%= f.text_field :name %>
  </div>
  <div class="field">
    <%= f.label :cost_impact %><br />
    <%= f.text_field :cost_impact %>
  </div>
  <div class="field">
    <%= f.label :schedule_impact %><br />
    <%= f.text_field :schedule_impact %>
  </div>
  <div class="actions">
    <%= f.submit %>
  </div>
<% end %>


==========================================
FILE: app/views/recommendations/index.html.erb
==========================================
<h1>Listing recommendations</h1>

<table>
  <tr>
    <th>Name</th>
    <th>Cost impact</th>
    <th>Schedule impact</th>
    <th class="span-1"></th>
    <th class="span-1"></th>
  </tr>

<% @recommendations.each do |recommendation| %>
  <tr>
    <td><%= link_to recommendation.name, recommendation %></td>
    <td><%= recommendation.show_cost_impact %></td>
    <td><%= recommendation.show_schedule_impact %></td>
    <td><%= link_to 'Edit', edit_recommendation_path(recommendation) %></td>
    <td><%= link_to 'Destroy', recommendation, :confirm => 'Are you sure?',
:method => :delete %></td>
  </tr>
```

```
<% end %>
</table>

<br />

<%= link_to 'New Recommendation', new_recommendation_path %>


========================================
FILE: app/views/recommendations/edit.html.erb
========================================
<h1>Editing recommendation</h1>

<%= render 'form' %>

<%= link_to 'Show', @recommendation %> |
<%= link_to 'Back', recommendations_path %>


========================================
FILE: app/views/divisions/show.html.erb
========================================
<p id="notice"><%= notice %></p>
<h1><%= @division.name %></h1>
<section>
  <h2>Subdivisions:</h2>
  <ul>
    <% @division.subdivisions.each do |s| %>
    <li><%= link_to s.name, s %></li>
    <% end %>
  </ul>
</section>

<%= link_to 'Edit', edit_division_path(@division) %> |
<%= link_to 'Back', divisions_path %> |
<%= link_to 'Add subdivision', new_subdivision_path, :division => :id %>


========================================
FILE: app/views/divisions/new.html.erb
========================================
<h1>New division</h1>

<%= render 'form' %>

<%= link_to 'Back', divisions_path %>
```

```
==========================================
FILE: app/views/divisions/_form.html.erb
==========================================
<%= form_for(@division) do |f| %>
  <% if @division.errors.any? %>
    <div id="error_explanation">
      <h2><%= pluralize(@division.errors.count, "error") %> prohibited this division
from being saved:</h2>

      <ul>
      <% @division.errors.full_messages.each do |msg| %>
        <li><%= msg %></li>
      <% end %>
      </ul>
    </div>
  <% end %>

  <div class="field">
    <%= f.label :name %><br />
    <%= f.text_field :name %>
  </div>
  <div class="actions">
    <%= f.submit %>
  </div>
<% end %>


==========================================
FILE: app/views/divisions/index.html.erb
==========================================
<h1>Divisions</h1>
<section class="prepend-1">
  <table>
    <% @divisions.each do |division| %>
    <tr>
      <td><%= link_to division.name, division %></td>
      <td class="span-1"><%= link_to 'Edit', edit_division_path(division) %></td>
      <td class="span-1 append-1"><%= link_to 'Destroy', division, :confirm => 'Are
you sure?', :method => :delete %></td>
    </tr>
    <% end %>
  </table>
</section>
```

```
<br />
<section>
  <%= link_to 'New Division', new_division_path %>
</section>


========================================
FILE: app/views/divisions/edit.html.erb
========================================
<h1>Editing division</h1>

<%= render 'form' %>

<%= link_to 'Show', @division %> |
<%= link_to 'Back', divisions_path %>


========================================
FILE: db/schema.rb
========================================
# This file is auto-generated from the current state of the database. Instead
# of editing this file, please use the migrations feature of Active Record to
# incrementally modify your database, and then regenerate this schema definition.
#
# Note that this schema.rb definition is the authoritative source for your
# database schema. If you need to create the application database on another
# system, you should be using db:schema:load, not running all the migrations
# from scratch. The latter is a flawed and unsustainable approach (the more
migrations
# you'll amass, the slower it'll run and the greater likelihood for issues).
#
# It's strongly recommended to check this file into your version control system.

ActiveRecord::Schema.define(:version => 20110612210312) do

  create_table "activities", :force => true do |t|
    t.string   "name"
    t.datetime "created_at"
    t.datetime "updated_at"
  end

  create_table "activities_recommendations", :id => false, :force => true do |t|
    t.integer "activity_id"
    t.integer "recommendation_id"
  end
```

```
create_table "divisions", :force => true do |t|
  t.string   "name"
  t.datetime "created_at"
  t.datetime "updated_at"
end

create_table "maps", :force => true do |t|
  t.string   "element"
  t.string   "material"
  t.string   "activity"
  t.string   "csi_code"
  t.string   "alternative"
  t.decimal  "extra_cost"
  t.integer  "schedule_impact"
  t.string   "impact_uom"
  t.datetime "created_at"
  t.datetime "updated_at"
end

create_table "recommendations", :force => true do |t|
  t.string   "name"
  t.string   "cost_impact"
  t.string   "schedule_impact"
  t.datetime "created_at"
  t.datetime "updated_at"
end

create_table "subdivisions", :force => true do |t|
  t.string   "name"
  t.integer  "division_id"
  t.datetime "created_at"
  t.datetime "updated_at"
end

create_table "substitutions", :force => true do |t|
  t.integer  "activity_id"
  t.integer  "recommendation_id"
  t.datetime "created_at"
  t.datetime "updated_at"
end

create_table "workcategorizations", :force => true do |t|
  t.integer  "activity_id"
  t.integer  "subdivision_id"
  t.datetime "created_at"
  t.datetime "updated_at"
```

```
  end

end


==========================================
FILE: db/migrate/20110612200706_add_division_id_to_activities.rb
==========================================
class AddDivisionIdToActivities < ActiveRecord::Migration
  def self.up
    add_column :activities, :subdivision_id, :integer
  end

  def self.down
    remove_column :activities, :subdivision_id
  end
end


==========================================
FILE: db/migrate/20110612210312_delete_subdivision_id_from_activities.rb
==========================================
class DeleteSubdivisionIdFromActivities < ActiveRecord::Migration
  def self.up
    remove_column :activities, :subdivision_id
  end

  def self.down
    add_column :activities, :subdivision_id, :integer
  end
end


==========================================
FILE: db/migrate/20110612195636_create_substitutions.rb
==========================================
class CreateSubstitutions < ActiveRecord::Migration
  def self.up
    create_table :substitutions do |t|
      t.integer :activity_id
      t.integer :recommendation_id

      t.timestamps
    end
  end
```

```
  def self.down
    drop_table :substitutions
  end
end


========================================
FILE: db/migrate/20110612051555_create_table_activities_recommendations.rb
========================================
class CreateTableActivitiesRecommendations < ActiveRecord::Migration
  def self.up
    create_table :activities_recommendations, :id => false do |t|
      t.references :activity, :recommendation

      add_index :activities_recommendations, :activity_id
      add_index :activities_recommendations, :recommendation_id

      # TODO: figure out later why the example is doing this:
      #remove_column :activities, :recommendations
    end
  end

  def self.down
    # TODO: figure out later why the example is doing this:
    #add_column :activities, :recommendations
    drop table activities_recommendations
  end
end


========================================
FILE: db/migrate/20110612204936_delete_activity_id_from_recommendations.rb
========================================
class DeleteActivityIdFromRecommendations < ActiveRecord::Migration
  def self.up
    remove_column :recommendations, :activity_id, :integer
  end

  def self.down
    add_column :recommendations, :activity_id, :integer
  end
end


========================================
FILE: db/migrate/20110611212314_create_subdivisions.rb
```

```
========================================
class CreateSubdivisions < ActiveRecord::Migration
  def self.up
    create_table :subdivisions do |t|
      t.string :name
      t.integer :division_id

      t.timestamps
    end
  end

  def self.down
    drop_table :subdivisions
  end
end


========================================
FILE: db/migrate/20110611234119_create_activities.rb
========================================
class CreateActivities < ActiveRecord::Migration
  def self.up
    create_table :activities do |t|
      t.string :name

      t.timestamps
    end
  end

  def self.down
    drop_table :activities
  end
end


========================================
FILE: db/migrate/20110612204949_delete_recommendation_id_from_activities.rb
========================================
class DeleteRecommendationIdFromActivities < ActiveRecord::Migration
  def self.up
    remove_column :activities, :recommendation_id
  end

  def self.down
    add_column :activities, :recommendation_id, :integer
  end
```

```
end


==========================================
FILE: db/migrate/20110611212259_create_divisions.rb
==========================================
class CreateDivisions < ActiveRecord::Migration
  def self.up
    create_table :divisions do |t|
      t.string :name

      t.timestamps
    end
  end

  def self.down
    drop_table :divisions
  end
end


==========================================
FILE: db/migrate/20110611234349_create_recommendations.rb
==========================================
class CreateRecommendations < ActiveRecord::Migration
  def self.up
    create_table :recommendations do |t|
      t.string :name
      t.string :cost_impact
      t.string :schedule_impact
      t.integer :activity_id

      t.timestamps

    end
  end

  def self.down
    drop_table :recommendations
  end
end


==========================================
FILE: db/migrate/20110612205736_create_workcategorizations.rb
==========================================
```

```
class CreateWorkcategorizations < ActiveRecord::Migration
  def self.up
    create_table :workcategorizations do |t|
      t.integer :activity_id
      t.integer :subdivision_id

      t.timestamps
    end
  end

  def self.down
    drop_table :workcategorizations
  end
end
```

APPENDIX E
SKETCHUP API CODE

```
module EPSTH

  def EPSTH.get_faces(sel)
    list = []
    sel.each { |s|
      if s.is_a? Sketchup::Face
        list << s
      end
    }
    list
  end

  # This breaks *really* easily if we start changing division names;
  # Need to provide a mapping of name to ID; ideally we juts pass the
  # name as part of the url (somethign like:
  #    UI.openURL("http://epesantes-th-2011.heroku.com/divisions/find?name=#{name}")
  # And the rails application does the mapping of name to division

  NAME_TO_ID_MAP = {
    # ID  Type
    # 1 - Sitework
    # 2 - Concrete
    # 3 - Masonry
    # 4 - Metals
    "concrete" => "2",
    "cement"   => "2",
    "masonry"  => "3",
    "brick"    => "3",
    "metal"    => "4",
    "steel"    => "4",
    "iron"     => "4",
    #"Asphalt"  => ??
  }

  def EPSTH.get_material_name(s)
    s.material.display_name unless s.material.nil?
  end

  def EPSTH.map_material_name(name)
    unless name.nil?
      NAME_TO_ID_MAP.each { |key, val|
        if name =~ /#{key}/i
          return val
        end
```

```
    }
    return name
  end
end

def EPSTH.get_unique_material_name_list(faces)
  return if faces.nil?

  nameset = Set.new
  faces.each { |f|
    name = EPSTH.get_material_name(f)
    nameset.insert name unless name.nil?
  }
  nameset
end

def EPSTH.get_selected_faces
  sel = Sketchup.active_model.selection

  unless sel.empty?
    EPSTH.get_faces(sel)
  end
end

def EPSTH.show_selected_faces_material_names
  names = "Nothing selected"
  faces = EPSTH.get_selected_faces
  if faces.nil?
    names = "No selected faces found"
  else
    names = EPSTH.get_unique_material_name_list(faces).to_a.join(';')
  end

  names
end

def EPSTH.add_thesis_submenus
  plug_menu = UI.menu("Plugins")

  return if plug_menu.nil?

  submenu = plug_menu.add_submenu("Eileen Thesis")

  return if submenu.nil?

  submenu.add_item("Show selected materials") {
```

```
    UI.messagebox(EPSTH.show_selected_faces_material_names)
  }

  submenu.add_item("Open recommendations for selected materials") {
    faces = EPSTH.get_selected_faces

    list = EPSTH.get_unique_material_name_list(faces)
    if list.nil? || list.size ==  0
      UI.messagebox("No materials selected")
    else
      list.each { |name|
        UI.openURL("http://epesantes-th-
2011.heroku.com/divisions/#{EPSTH.map_material_name(name)}")
        #UI.messagebox("http://epesantes-th-
2011.heroku.com/divisions/#{EPSTH.map_material_name(name)}")
      }
    end
  }


 end

end

EPSTH.add_thesis_submenus
```

APPENDIX F
EXCEL MACRO CODE

```
Option Compare Text 'to avoid case sensitiveness
'Subroutine
Sub AddHyperlinkFormula()
Dim MyPath As String, MyFile As String, FriendlyName As String, c As Range
'hyperlink location
MyPath = "http://epesantes-th-2011.heroku.com/"
'Evaluation of description cells of estimate
For Each c In [A2:A7]
 'Link to Concrete, Division 3, database
 If c.Value Like "*Concrete*" Then
    MyFile = "divisions/2"
    FriendlyName = c.Value
    c.Formula = "=HYPERLINK(""" & MyPath & MyFile & """,""" & FriendlyName & """)"
 Else
   'Link to Masonry, Division 4, database
 If c.Value Like "*Masonry*" Then
    MyFile = "divisions/3"
    FriendlyName = c.Value
    c.Formula = "=HYPERLINK(""" & MyPath & MyFile & """,""" & FriendlyName & """)"
 Else
 If c.Value Like "*brick*" Then
    MyFile = "divisions/3"
    FriendlyName = c.Value
    c.Formula = "=HYPERLINK(""" & MyPath & MyFile & """,""" & FriendlyName & """)"
Else
If c.Value Like "*stone*" Then
    MyFile = "subdivisions/19"
    FriendlyName = c.Value
    c.Formula = "=HYPERLINK(""" & MyPath & MyFile & """,""" & FriendlyName & """)"
Else
'Link to Metals, Division 5, database
If c.Value Like "*steel*" Then
    MyFile = "divisions/4"
    FriendlyName = c.Value
    c.Formula = "=HYPERLINK(""" & MyPath & MyFile & """,""" & FriendlyName & """)"
Else
If c.Value Like "*metal*" Then
    MyFile = "divisions/4"
    FriendlyName = c.Value
    c.Formula = "=HYPERLINK(""" & MyPath & MyFile & """,""" & FriendlyName & """)"
Else
'Link to Sitework, Division 2, database
If c.Value Like "*demolition*" Then
    MyFile = "divisions/1"
```

```
    FriendlyName = c.Value
    c.Formula = "=HYPERLINK(""" & MyPath & MyFile & """,""" & FriendlyName & """)"
Else
If c.Value Like "*utilit*" Then
    MyFile = "divisions/4"
    FriendlyName = c.Value
    c.Formula = "=HYPERLINK(""" & MyPath & MyFile & """,""" & FriendlyName & """)"
End If
End If
End If
End If
End If
End If
End If
End If
Next
End Sub
```

LIST OF REFERENCES

Abott, D.G., (2005). Practical considerations in the selection and for the use of microtunneling vs other trenchless techniques. *Proceedings Conference on North American Society for Trenchless Technology No-Dig Show*, Orlando Fl, April 24-27, 2005.

Akbar-Khanzadeh, F., Milz, S., Ames, A., Susi, P., Bisesi, M., Khuder, S., & Akbar-Khanzadeh, M. (2007). Crystalline Silica Dust and Respirable Particulate Matter During Indoor Concrete Grinding - Wet Grinding and Ventilated Grinding Compared with Uncontrolled Conventional Grinding. *Journal of Occupational and Environmental Hygiene*, *4*(10), 770-779. doi:10.1080/15459620701569708

Akbar-Khanzadeh, F., Milz, S., Wagner, C., Bisesi, M., Ames, A., Khuder, S., Susi, P., et al. (2010). Effectiveness of Dust Control Methods for Crystalline Silica and Respirable Suspended Particulate Matter Exposure During Manual Concrete Surface Grinding. *Journal of Occupational and Environmental Hygiene*, *7*(12), 700-711. doi:10.1080/15459624.2010.527552

Antonini, J. M., Lewis, A. B., Roberts, J. R., & Whaley, D. A. (2003). Pulmonary effects of welding fumes: Review of worker and experimental animal studies. *American Journal of Industrial Medicine*, 43(4), 350-360. doi:10.1002/ajim.10194

Ariaratnam, S. T., & Sihabuddin, S. S. (2009). Comparison of Emitted Emissions Between Trenchless Pipe Replacement and Open Cut Utility Construction. *Journal of Green Building*, *4*(2), 126-140. doi:10.3992/jgb.4.2.126

ASCE (2009). Report card for America's infrastructure, American Society of Civil Engineers, Reston VA. Retrieved from http://apps.asce.org/reportcard/2009/grades.cfm.

Baxendale, T., & Jones, O. (2000). Construction design and management safety regulations in practice—progress on implementation. *International Journal of Project Management*, *18*(1), 33-40. doi:10.1016/S0263-7863(98)00066-0

Behm, M. (2005). Linking construction fatalities to the design for construction safety concept. *Safety Science*, *43*(8), 589-611. doi:10.1016/j.ssci.2005.04.002

Blanc P. D. (2007), Metal Fume Fever. Olson KR, Poisoning & Drug Overdose (5th edition). Retrieved from http://www.accessmedicine.com/content.aspx?aID=2677865.

Boffetta P., Harris, R.E., & Wynder, E.L., (1990). Case-control study on occupational exposure to diesel exhaust and lung cancer risk. *American Journal of Industrial Medicine*, 17(5), pp.577-591. doi:10.1002/ajim.4700170504

Boyce, G.M., & Bried, E.M. (1998). Social cost accounting for trenchlessprojects. *Proceedings Conference on North American Society for Trenchless Technology No-Dig Show*, Alburquerque, N.M., NASTT, pp. 3-12.

Brace, C.L., & Gibb, A. G. (2004). Health Management in the Construction Industry. *Contemporary Ergonomics*, Boca Raton Fla. pp. 274-279.

Bureau Labor of Statistics, BLS. (n.d.). *Illnesses cases reported between years 1995-2009*. Retrieved from the Bureau Labor of Statics website, http://www.bls.gov/iif/oshsum.htm

Building Research Establishment Environmental Assessment Method, BREEAM (n.d.). About BREEAM. Retrieved on March 12, 2011 from http://www.breeam.org/

Bust, P., Gibb, A.G., & Brace, C. L. (2008). Implementing a Health Management Toolkit in the Construction Industry. *Contemporary Ergonomics*, London: Taylor & Francis, pp. 197-202.

Cary, H. (1979). *Modern welding technology*. Englewood Cliffs N.J.: Prentice-Hall.

Center for Construction Research and Training (CPWR) (2008). *The construction chart book. The US construction industry and its workers*, 4th edition. Silver Spring, MD. Retrieved from http://www.cpwr.com/rp-chartbook.html.

Comprehensive Assessment system for Built environment Efficiency, CASBEE (n.d.). *An Overview of CASBEE*. Retrieved March 12, 2011 from http://www.ibec.or.jp/CASBEE/english/overviewE.htm

Construction Specification Institute, CSI (1995). *CSI Masterformat version 1995*.Retrieved from the construction Specifications Institute Website, http://www.csinet.org/masterformat

Dust Control (2011). *DC 2800c/Auto: Original Instructions*. Retrieved on June 12, 2011, from Dust Control website, http://www.dustcontrol.com/upload/Products/user_instructions/2800c-Auto_94112_94116.pdf

European Construction Institute. (1999). *The ECI guide to managing health in construction. London*: Thomas Telford.

Environmental Protection Agency. (2011, March 7). *Asbestos (CASRN 1332-21-4)*. Retrieved from http://www.epa.gov/iris/subst/0371.htm#I.A.

Flanagan, M. E., Seixas, N., Becker, P., Takacs, B., & Camp, J. (2006). Silica Exposure on Construction Sites: Results of an Exposure Monitoring Data Compilation Project. *Journal of Occupational and Environmental Hygiene*, *3*(3), 144-152. doi:10.1080/15459620500526552

Florida Green Building Coalition, FGBC (n.d.). *FGBC Facts Sheet*. Retrieved March 12, 2011 from http://floridagreenbuilding.org/files/1/File/FGBC_Organizational_Fact_Sheet2011.pdf

Flynn, M. R., & Susi, P. (2003). Engineering Controls for Selected Silica and Dust Exposures in the Construction Industry -- A Review. *Applied Occupational and Environmental Hygiene*, *18*(4), 268-277. doi:10.1080/10473220301406

Flynn, M. R., & Susi, P. (2009). Neurological risks associated with manganese exposure from welding operations – A literature review. *International Journal of Hygiene and Environmental Health*, *212*(5), 459-469. doi:10.1016/j.ijheh.2008.12.003

Flynn, M.R., & Susi, P. (2010). Manganese, Iron, and Total Particulate Exposures to Welders. *Journal of Occupational and Environmental Hygiene*, *7*(2), 115-126. doi:10.1080/15459620903454600

Gambatese, J. (1996). *Addressing Construction Worker Safety in the Project Design*. (Doctoral dissertation, University of Washington, 16 May 1996).

Gambatese, J. A. (1998). Liability in Designing for Construction Worker Safety. *Journal of Architectural Engineering*, *4*(3), 107. doi:10.1061/(ASCE)1076-0431(1998)4:3(107)

Gambatese, J. & Hinze, J. (1999). Addressing construction worker safety in the design phase Designing for construction worker safety. *Automation in Construction*, *8*(6), 643-649. doi:10.1016/S0926-5805(98)00109-5

Gambatese, J. A., Behm, M., & Hinze, J. W. (2005). Viability of Designing for Construction Worker Safety. *Journal of Construction Engineering and Management*, *131*(9), 1029. doi:10.1061/(ASCE)0733-9364(2005)131:9(1029)

German Sustainable Building Council, DGNB (n.d.). *The German Sustainable Building Council*. Retrieved March 12, 2011 from http://www.dgnb.de/_en/about/Portrait/index_portrait.php

Green Globes. (n.d.). What is Green Globes? Retrieved March 12, 2011 from http://greenglobes.com/about.asp

Gyi D.E., Gibb A., Roger A, D. & Haslam, R. (1999). The quality of accident and health data in the construction industry: interviews with senior managers. *Construction Management & Economics*, *17*(2), 197-204. doi:10.1080/014461999371691

Hallowell, M. R., & Gambatese, J. A. (2009). Construction Safety Risk Mitigation. *Journal of Construction Engineering and Management*. doi:10.1061/(ASCE)CO.1943-7862.0000107

Hartl, M. (2010). *Ruby on rails tutorial: learn rails by example*. Retrieved from http://ruby.railstutorial.org/ruby-on-rails-tutorial-book

Health and Safety Executive, HSE (1999). *Diesel Engine Exhaust Emissions*. Retrieved December 7, 2010 from http://www.hse.gov.uk/pubns/indg286.htm

Health and Safety Executive, HSE (2005). *Handling kerbs: reducing the risks of musculoskeletal disorders (MSDs)*. Retrieved April 10, 2010 from http://www.hse.gov.uk/pubns/cis57.pdf

Hess, J., Hecker, S., Weinstein, M., & Lunger M. (2004). A participatory ergonomics intervention to reduce risk factors for low-back disorders in concrete laborers. *Applied Ergonomics*, *35*(5), 427-441. doi:10.1016/j.apergo.2004.04.003

Hinze, J., & Wiegand, F. (1992). Role of Designers in Construction Worker Safety. *Journal of Construction Engineering and Management*, *118*(4), 677. doi:10.1061/(ASCE)0733-9364(1992)118:4(677)

Hunting, K.L., & Welch, L.S. (1993). Occupational exposure to dust and lung disease among welders exposed to aluminum and manganese. *British Journal of Industrial Medicine*, 50:432-442.

International Agency for Research on Cancer (IARC) (1990). *Monographs on the evaluation of carcinogenic risks to humans: chromium, nickel and welding*, IARC, vol. 49, Lyon, France.

Interpave (2006a). *Modern methods of paving: machine installation of concrete paving blocks.* Retrieved April 1, 2010 from http://www.paving.org.uk/downloads.php

Interpave (2006b). *The cost of paving: comparative initial construction and whole life cost analyses for pavements.* Retrieved April 1, 2010 from http://www.paving.org.uk/downloads.php

Interpave (2007). *Cutting paving: cutting precast concrete blocks flags and kerbs-efficient design and managing the risk.* Retrieved April 1, 2010 from http://www.paving.org.uk/downloads.php

Jarvholm, B. (2003). Lung cancer in heavy equipment operators and truck drivers with diesel exhaust exposure in the construction industry. *Occupational and Environmental Medicine*, *60*(7), 516-520. doi:10.1136/oem.60.7.516

Jung, Y. J., & Sinha, S. K. (2007). Evaluation of Trenchless Technology Methods for Municipal Infrastructure System. *Journal of Infrastructure Systems*, *13*(2), 144. doi:10.1061/(ASCE)1076-0342(2007)13:2(144)

Konz, S. (2000). *Work design : industrial ergonomics* (5th ed.). Scottsdale Ariz.: Holcomb Hathaway.

Linch, K. D., Miller, W. E., Althouse, R. B., Groce, D. W., & Hale, J. M. (1998). Surveillance of respirable crystalline silica dust using OSHA compliance data (1979-1995). *American Journal of Industrial Medicine*, *34*(6), 547-558. doi:10.1002/(SICI)1097-0274(199812)34:6<547::AID-AJIM2>3.0.CO;2-B

Lueke, J. S., & Ariaratnam, S. T. (2001). Rehabilitation of Underground Infrastructure Utilizing Trenchless Pipe Replacement. *Practice Periodical on Structural Design and Construction*, *6*(1), 25. doi:10.1061/(ASCE)1084-0680(2001)6:1(25)

Marini, J. (2007). *Designing for construction worker safety: A software tool for designers*. Gainesville, Fla.: University of Florida. http://purl.fcla.edu/fcla/etd/UFE0020222

Meeker, J. D., Cooper, M. R., Leftkowitz, D., & Susi, P. (2009). Engineering Control Technologies to Reduce Occupational Silica Exposures in Masonry Cutting and Tuckpointing. *Public Health Reports*, *124*, 101-111.

Meeker, J., Susi, P., & Flynn, M. (2007). Manganese and Welding Fume Exposure and Control in Construction. *Journal of Occupational and Environmental Hygiene*, 4(12), 943-951. doi:10.1080/15459620701718867

Morris, J. (1996). *Cost effective management of water pipelines and networks*. London.

Moulin, J. J., Wild, P., Haguenoer, J. M., Faucon, D., De Gaudemaris, R., Mur, J. M., Mereau, M., et al. (1993). A mortality study among mild steel and stainless steel welders. *Occupational and Environmental Medicine*, *50*(3), 234-243. doi:10.1136/oem.50.3.234

Myers, M. B., Stickrod, T. W., Abraham, D. M., & Iseley, T. (1999). Microtunneling Technology for Conduit Construction. *Practice Periodical on Structural Design and Construction*, *4*(2), 56. doi:10.1061/(ASCE)1084-0680(1999)4:2(56)

Occupational Safety and Health Administration, OSHA. (2009). *Controlling Silica Exposures in Construction*. Occupational Safety and Health Administration U.S. Department of Labor.

Occupational Safety and Health Administration, OSHA. (n.d.). *Crystalline Silica Exposure Health Hazard Information*. Occupational Safety and Health Administration U.S. Department of Labor.

Oliver, L. C., Miracle-McMahill, H., Littman, A. B., Oakes, J. M., & Gaita, R. R. (2001). Respiratory symptoms and lung function in workers in heavy and highway construction: A cross-sectional study. *American Journal of Industrial Medicine*, *40*(1), 73-86. doi:10.1002/ajim.1073

President's Council on Sustainable Development. (1998). *Sustainable Communities Task Force report*. Washington, DC (730 Jackson Pl., NW, Washington 20503), President's Council on Sustainable Development

Prevention through Design. (n.d.). *Prevention through Design Concept*. Retrieved, march 11, 2011 from www.designforconstructionsafety.org

Rajendran, S., Gambatese, J. A., & Behm, M. G. (2009). Impact of Green Building Design and Construction on Worker Safety and Health. *Journal of Construction Engineering and Management*, *135*(10), 1058. doi:10.1061/(ASCE)0733-9364(2009)135:10(1058)

Rappaport, S. M. (2003). Excessive Exposure to Silica in the US Construction Industry. *Annals of Occupational Hygiene*, *47*(2), 111-122. doi:10.1093/annhyg/meg025

Ruby, S. (2011). *Agile Web development with Rails* (4th ed.). Raleigh, N.C.: Pragmatic Bookshelf.

Schneider, S., & Susi, P. (1993). *Final Report: An Investigation of Health Hazards on a New Construction Project* (No. OSH1-93) (p. 52). Washington, DC: National Institute of Occupational Health (NIOSH), Center to Protect Workers' Right (CPWR).

Selvakumar, A., Clark, R. M., & Sivaganesan, M. (2002). Costs for Water Supply Distribution System Rehabilitation. *Journal of Water Resources Planning and Management*, *128*(4), 303. doi:10.1061/(ASCE)0733-9496(2002)128:4(303)

Steenland, K., Beaumont, J., & Elliot, L. (1991). Lung cancer and mild steel welders. *American Journal of Epidemiology*, 133:220-229.

Steenland, K. (2005). One agent, many diseases: Exposure-response data and comparative risks of different outcomes following silica exposure. *American Journal of Industrial Medicine*, *48*(1), 16-23. doi:10.1002/ajim.20181

Tamboli, A. R. (1999). *Handbook of structural steel connection design and detail*. New York: McGraw Hill.

Thomas, D. (2009). *Programming Ruby 1.9: the pragmatic programmers' guide*. Raleigh, N.C.: Pragmatic Bookshelf.

Toole, T., & Gambatese, J. (2008). The Trajectories of Prevention through Design in Construction. *Journal of Safety Research*, *39*(2), 225-230. doi:10.1016/j.jsr.2008.02.026

U.S. Green Building Council, USGBC (n.d.). *What LEED is*. Retrieved March 12, 2011 from http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1988

Wong, O., Morgan, R. W., Kheifets, L., Larson, S. R., & Whorton, M. D. (1985). Mortality among members of a heavy construction equipment operators union with potential exposure to diesel exhaust emissions. *Occupational and Environmental Medicine*, *42*(7), 435-448. doi:10.1136/oem.42.7.435

Woodroffe, N. J. A., & Ariaratnam, S. T. (2008). Cost and Risk Evaluation for Horizontal Directional Drilling versus Open Cut in an Urban Environment. *Practice Periodical on Structural Design and Construction*, *13*(2), 85. doi:10.1061/(ASCE)1084-0680(2008)13:2(85)

Woskie, S. R., Kalil, A., Bello, D., & Virji, M. A. (2002). Exposures to Quartz, Diesel, Dust, and Welding Fumes During Heavy and Highway Construction. *AIHA Journal*, *63*(4), 447-457. doi:10.1080/15428110208984733

Yee, A.A. (2001a). Social and environmental benefits of precast concrete technology. *PCI Journal*, vol 46, part 3, pp 14-19.

Yee, A.A. (2001b). Structural and economic benefits of precast/prestressed concrete construction. *PCI Journal*, vol 46, part 4 pp 34-43.

Young, O.C., & Trott, J.J. (1984). *Buried rigid pipes: Structure design of pipelines*, New York: Elsevier.

BIOGRAPHICAL SKETCH

Eileen R. Pesantes-Tavares was born in San Juan Puerto Rico on December 1971. She studied civil engineering at the University of Puerto Rico at Mayagüez, graduating Magna cum Laude and second in her class in 1994. After finishing her bachelor's degree, she worked for the United States Army Corp of Engineers at the Engineer Research and Developing Center, formerly known as Waterways Experiment Station in Vicksburg, Mississippi, in the capacity of Research Structural Engineer. In the fall of 1994, she started her master's in civil engineering with a concentration on structural engineering mechanics and materials at the University of California at Berkeley, finishing in December 1995. From 1996 to 1997, she worked as a structural engineer and as a roof field supervisor for various projects in the San Francisco Bay Area. In fall of 1997, she was admitted in the Masters in Science in Civil and Environmental Engineering with a concentration on construction engineering and management at Stanford University, graduating in June of 1998. After graduation, she worked as a project engineer and preconstruction engineer for various companies in the San Francisco Bay Area. In 2002, she returned with her family to Puerto Rico were she started teaching at her Alma Matter, The University of Puerto Rico at Mayagüez, advanced courses in construction engineering and management in the Civil Engineering and Surveying Department. She also taught courses in project management in the General Engineering Department. To keep current with the construction industry, she also worked as a consultant in different projects on the west side of the island. In 2008, the University of Puerto Rico at Mayagüez, offered her the opportunity to pursue a PhD in the construction engineering and management area for which she applied and was accepted at the University of Florida. She received her Ph.D. in the fall of 2011 and

expects to continue teaching, one of her passions, at a higher education institution. Eileen is married to Miguel Sosa, a software engineer, and has two kids, Esteban 11 and Elisa 6.