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Using Building Information Modeling for Job Hazard Analysis of Renovating Residential Buildings

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Abstract

Research studies have shown the potential benefits of using Building Information Modeling (BIM) for preventing and reducing safety and health hazards in construction through the Prevention through Design (PtD) approach. However, most of these studies focus on new or large-scale construction projects that have the resources to identify and mitigate hazards. Smaller construction companies involved in renovating residential buildings, however, typically lack the resources to do the same. To address that gap, this research focused on residential renovation projects carried out by smaller contractors. It included laser scanning a typical rowhouse to create a 3-D model, developing a risk assessment database that analyzed the frequency and severity of hazards associated with renovation activities, and integrating the demolition and renovation activities schedule into the 3-D model to generate a 4-D model. The 4-D model allows for easy and precise identification of hazards as part of conducting Job Hazard Analysis (JHA). Overall, the study aims to improve safety and health outcomes in the construction industry, especially for smaller contractors involved in residential renovations.

Key Findings

Outcomes from this research study were the development of:

- A safety database spreadsheet identifying the most common hazards in rowhouse renovation projects.
- BIM models from laser scans (point cloud data) enriched with the identified hazards and their mitigation plans as new attributes and properties of the developed BIM.
- A framework that maps inputs and processes essential for creating a JHA reporting tool.

Specific key findings of this study are:

1. Hazards in residential renovation projects and their consequences appeared most frequently in demolition and construction activities in the following order: 1) eye injury, 2) lifting and carrying, 3) falls from heights, 4) overhead work, 5) stressful hand and wrist activity, 6) cuts and punctures from tools and materials, and 7) kneeling and squatting.
2. Fourteen hazards were identified by safety professionals as having either a *critical* or *a crisis*-level impact on the project. *Gas Meter Relocation* was considered to have a *crisis*-level impact but because of the *low* probability of this hazard, the overall risk was determined as only moderate.
3. A few specific hazards, not as prevalent in other construction work but warranting additional attention in renovation are: exposure to lead, asbestos and mold; stooped postures; and musculoskeletal disorders due to manual lifting and carrying.
4. Laser scanning of the residential buildings to be renovated is a technically viable option to prepare as-built drawings for the purpose of safety planning and communication, among many other functions. However, the cost of using precise laser scanners such as the one in this study, along with the BIM expertise needed in creating a 4D model for safety planning, does not seem to be financially within the reach of many smaller contractors. Nonetheless, if investments in technology and expertise are made with a long-term utilization plan for repeat projects, then they may become financially viable too.

Table of Contents

Introduction

BIM presents an enormous opportunity to improve safety in construction projects. Dodge Data and Analytics' report "Safety Management in the Construction Industry 2017" showed that the use of BIM has a significant positive impact on construction safety compared to traditional safety planning (Smart Market Report, 2017). In the study, contractors who were surveyed on the impact of BIM reported a significant positive impact on safety, from 42% in 2012 to 69%. Contractors who consistently use BIM, the report noted, have more safety practices and gain more benefits from their safety investments.

A 2015 report by Shen and Marks titled "Near Miss Information Visualization Application for BIM" found that the then-current practices in construction safety data visualization were inadequate. However, studies of the utilization of 3-D and 4-D models in new construction projects, particularly for safety hazard identification, have become quite common more recently (Pham et al., 2020). The identification of hazards is the first step in risk management, and BIM has been utilized as a tool for safety planning and monitoring in new construction (Webb & Langar, 2019). Other research studies have combined schedule, BIM, and simulation to develop a tool capable of predicting risks to minimize conflicts at the workplace, as well as something to be used as an active schedule management tool (Kim & Teizer, 2014; Moon et al., 2014a, 2014b). In research supported by CPWR, there have been efforts to explore the use of BIM in hazard identification, training, and mitigation (Shen & Marks, 2015; Gheisari & Esmaeili; 2019; Lee et al., 2020; Gheisari et al., 2020; Din et al, 2022).

Most BIM researchers have targeted commercial and larger construction projects, and there are significant variations between residential and nonresidential construction in building materials, construction methods, equipment, safety monitoring, and work organization (Choi & Carlson, 2014). Residential projects therefore require special attention and tailored research. The National Institute for Occupational Safety and Health (NIOSH) and the U.S. Occupational Safety and Health Administration (OSHA) have recognized residential construction as a dangerous industry largely due to the hazards employees face while working at heights (Choi & Carlson, 2014). Specifically, small construction companies often lack information on hazard recognition, which was the focus of NIOSH in its "Small Business Safety & Health Resource Guide."

Researchers at University of Wisconsin-Whitewater found similar conditions, noting "One-third of residential construction contractors who participated in a recent study said their firms lacked written safety programs." Forty-eight percent of workers said their firms provided safety communication daily or weekly, compared with those who said they receive communication monthly (14 percent) or annually (10 percent). The remainder were unsure. Researchers also gathered data on injuries and illnesses as part of the study, which included 21 residential construction contractors based in Wisconsin. The most common types of injuries occurred because of slips, trips, and falls (36 percent), while other injuries resulted from cuts and lacerations (33 percent), hand tools (13 percent), overexertion (8 percent), being struck by objects (8 percent), and powered equipment (3 percent). The majority of participants who experienced falls were not wearing fall protection equipment (Choi & Carlson, 2014).

Although there has been a substantial effort by both researchers and practitioners to harness BIM for construction safety management of larger, commercial construction projects, there is very limited literature on how BIM has been used for construction and renovation of smaller residential projects. The uniqueness of the residential buildings that are the focus of this research and the hazards associated with their functional transformations pose safety management challenges that deserve a closer look. Because of the nature of the project discussed in this research--the renovation of an old, underused building--this study took a slightly different approach than typical "BIM for safety" research and instead explored the application of "Scan-to-BIM" (Esfahani et al., 2021; Skrzypczak et al., 2022; Son & Han, 2023) technology to enhance the precision and transparency of as-built information. When a more accurate as-built 3-D model of the building is captured, safe demolition and subsequent renovation activities can be chalked out more clearly and methodically.

This study begins to fill the gap of research on the often-neglected topic of residential renovation, in particular of rowhouses, work that is usually performed by contractors with fewer resources to invest in safety, The deliverable of the research would empower these resource-constrained smaller contractors with a better safety hazard identification and prevention system. Superintendents in these renovation projects often have to wear different hats, including that of safety personnel. However, they do not have the time to gather project specific Job Hazard Analysis (JHA) information due to the complexity and length of the JHA procedure (Zhang et al., 2015). Therefore, they rely on generic, paper-based JHA, thus missing an opportunity to incorporate project-specific interventions. This is where the role of BIM in hazard identification, safety planning, and hazard mitigation and communication comes into play. Activity-based hazard identification and prevention is an efficient method to minimize potential safety hazards during project front-end planning (Zhang, 2014) and is the approach taken in this study.

The specific type of residential buildings considered in this research are rowhouses. As the name suggests, a rowhouse is one of many houses in a row. It is primarily found in densely populated urban areas on the East Coast, such as New York, Philadelphia, Baltimore, and Washington, DC. Over 140,000 rowhouses line the streets of Baltimore City today, some dating back as far as the eighteenth century (Husain, 2008). As of January 28, 2022, there were 15,032 vacant properties in Baltimore City, most of which are attached rowhouses. As categorized by Baltimore City Mayor's Office, vacant properties are "unoccupied structures that are unsafe or unfit for human habitation or other authorized use" (Lewis, 2022). Research conducted by Live Baltimore (2020) on the Baltimore City residential market estimates that there are 44,335 households, on average, that represent the potential market for existing and new homes in Baltimore each year over the next five years. Rehabilitating these vacant rowhouses would provide home-owning opportunities for many of these city residents.

It is relevant here to distinguish between refurbishment, renovation, and retrofit with these types of buildings, as the terms are often used interchangeably. Figure 1 outlines the difference in scope among these terms. This research includes activities pertaining to all three types of projects.

Figure 1: Difference between Refurbishment, Renovation, and Retrofit Terms (Source: Che et al., 2019; Hyde et al., 2013)

Refurbishment	Renovation	Retrofit
A process of returning the building, or its systems, to their original condition, addressing the forces of physical obsolescence.	A process of taking refurbishment as one step onwards by integrating changes to physical parameters of the building	A process of replacing and upgrading systems and technology in existing building to address its technological or environmental obsolescence.

Renovation of rowhouses has many challenges, with safety being a major one during the demolition and reconstruction phase. The building units being renovated are old, and their structural components may have been damaged due to external forces during occupancy or compromised due to unintended consequences of modifications over the years. The structural weaknesses could also be due to the less stringent building codes when they were built. Renovation activities involve maneuvering through tight working spaces and site access and are complicated by existing plumbing, electrical, and other utilities. Moreover, there are concerns about biohazards such as molds and mildews, asbestos, chemical hazards such as welding vapor, poisonous gas emanating from carpets, lead-based paint, etc., during demolition. In addition to the hazards of working in a confined environment, the construction durations of such renovation projects are relatively short. Hence, safety is often overlooked or compromised, with meager cost and time invested in safety planning.

The Occupational Safety and Health Administration's (OSHA) interpretation of residential construction combines two elements: (1) the end-use of the structure must be as a home (i.e., a dwelling), and (2) the structure must be constructed using traditional wood framing materials and methods. The limited use of structural steel in a predominantly wood-framed home, such as a steel I-beam to support wood framing, does not disqualify a structure from being considered residential construction. Traditional wood frame materials and methods will be characterized by: wood (or equivalent cold-formed sheet metal stud) framing, not steel or concrete; wooden floor joists; and wooden roof structures. Exterior wall structures are composed of wood (or equivalent cold-formed sheet metal stud) framing or masonry brick or block (OSHA, 2011).

In this study, hazards that are unique to old, vacant buildings that are usually not within the purview of traditional construction are identified and analyzed. The use of BIM in the safety planning process, discussed here, will assist smaller, resource-starved contractors in not only increasing their productivity and labor savings but also standardize the safety planning process through the BIM-enabled JHA procedure.

Objectives

The primary objective of the research is to investigate how Building Information Modeling (BIM) can assist in hazard identification and safety communication during the renovation of a residential rowhouse. The study aims to develop a BIM-based Job Hazard Analysis (JHA) system that connects building elements with potential hazards and provides mitigation strategies for each identified hazard. The research aims to answer the following questions:

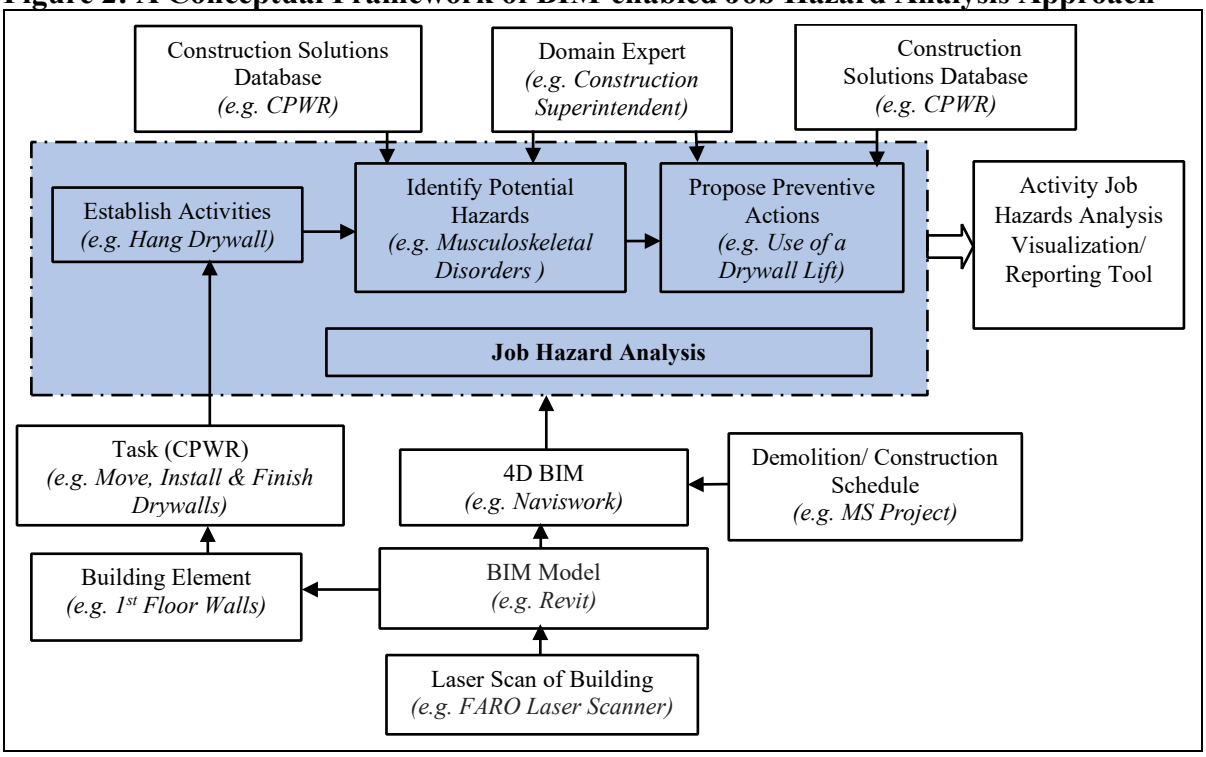
- How can a 3-D as-built model obtained from laser scanning of the existing rowhouse aid in hazard identification and detection?
- What are the most common risks contributing to injuries in rowhouse renovation and reconstruction projects, and how should they be represented in BIM applications to support hazard identification?
- What are the mitigation strategies for each hazard identified during the JHA process?

The ultimate goal of the research is to enhance the safety practices of building renovation contractors by proactively identifying and mitigating safety hazards and communicating these hazards to frontline workers to promote safety awareness.

Method

The selected methodology for the study involved conducting a comprehensive study of Job Hazard Analysis (JHA) during the demolition and construction phase to assess the associated risks of the activities involved. The approach is illustrated in Figure 2, which outlines the framework. The backbone of this framework is the Job Hazard Analysis (JHA), which comprises three generic critical steps: 1) establishing activities, 2) identifying potential hazards, and 3) proposing preventive actions. All other inputs and sources of information linked directly or indirectly to these three fundamental functions of JHA, represented by nodes in Figure 2, are customized for the specificity of this project for conducting a thorough Job Hazard Analysis.

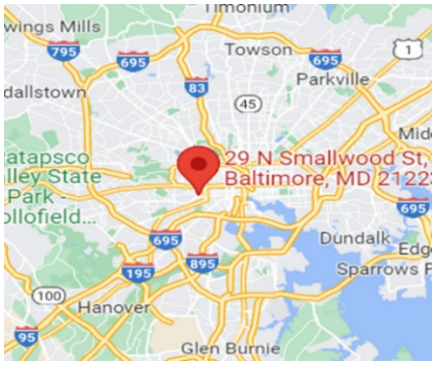
Figure 2: A Conceptual Framework of BIM-enabled Job Hazard Analysis Approach



The research had three specific objectives:
Objective 1: To establish a sequence of tasks and activities involved in the demolition and construction of structural/non-structural components of a vacant rowhouse.

The researchers began by surveying multiple vacant or underused buildings in neighborhoods within the Health Enterprise Zones (HEZ) of Baltimore City. A HEZ is a state-designated community that experiences documented poverty, health disparities, and/or poor health outcomes. The purpose of the survey was to select a case study building representative of the typical renovation project. The researchers conducted preliminary surveys of all the buildings from outside and then contacted the owners/residents to allow for a more detailed survey, which included a laser scanning of the building to generate a 3D model. Eventually, a rowhouse located at 29 N. Smallwood St., Baltimore, MD 21223 (shown in Figure 3) was selected as the case study building for this research project.

Figure 3: Case Study of the Selected Row home (Left: Location; Right: Building Front)



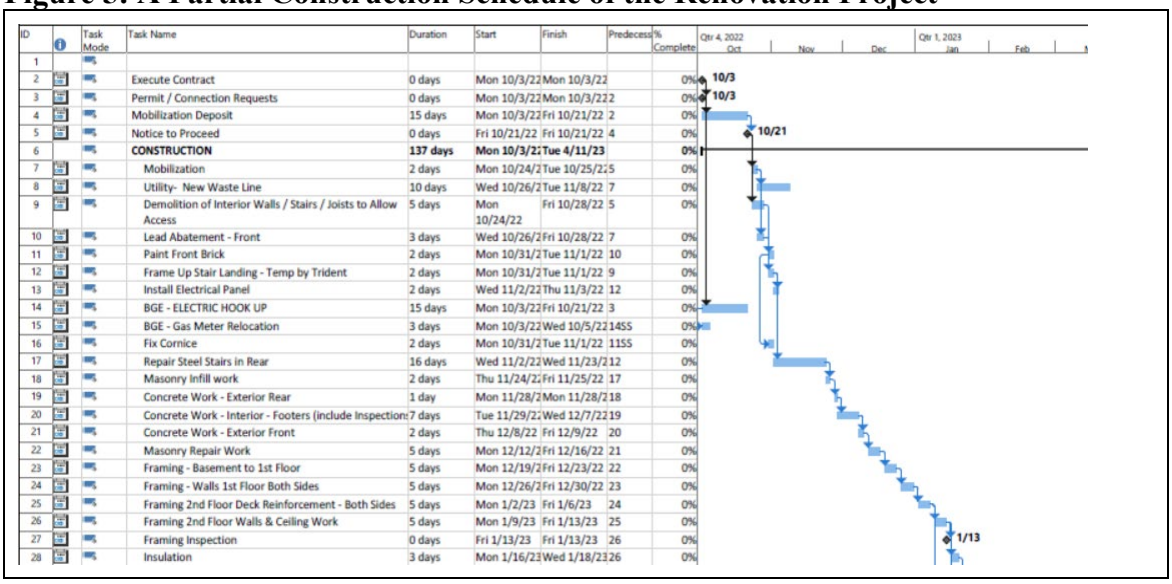
The owner/occupant of the building expressed the desire to renovate the rowhouse to provide additional space for their existing faith-based outreach organization office in the adjacent rowhouse. To facilitate this project, the contractor, who had previously renovated the current office unit, was requested to provide all construction-related information for the rowhouse, including a 3-D laser scan. The contractor had extensive experience in renovating similar buildings, and their superintendents and project engineers acted as the domain safety experts for this study, as they were knowledgeable in both residential renovation and safety.

The Job Hazard Analysis procedure described in this study is based on a Revit-generated 3-D model of the case study building. The process first developed a precise representation of the existing structure by laser scanning its exterior and interior. The FARO Laser Scanner, model Focus 3D X 130, used for this purpose is a "Class 1" device that poses no harm to people or buildings. As there were no architectural/structural drawings of the building available, the scanning depicted the unit in its current state. The laser scan mapped the interior and exterior at all floor levels and generated millions of Point Cloud Data (PCD), resulting in an as-built 3-D model, as depicted in Figure 4. The laser scanning process took approximately 4 hours.

Figure 4: As-built 3-D Model of exterior (left) and interior(right) from Point Cloud Data of the Building

To accomplish the renovation, the contractor created a schedule based on the scope of work provided by the building owner. The schedule was developed according to the building's main elements and systems: footings and foundations, structural framing, roofing, exterior enclosure, and interior construction. The contractor and building owner determined that not all systems required renovation, and so activities related to roofing demolition and construction were not included. The contractor provided the schedule through Microsoft Project, a partial screenshot of which is shown in Figure 5, which includes the total scope of the renovation project. This construction schedule acts as a starting point for activity-based JHA. The planned duration of the project was 137 days, with a total of 44 activities. However, six of these activities either were inspection-related or milestones, so only 38 activities required a hazard analysis.

Figure 5: A Partial Construction Schedule of the Renovation Project

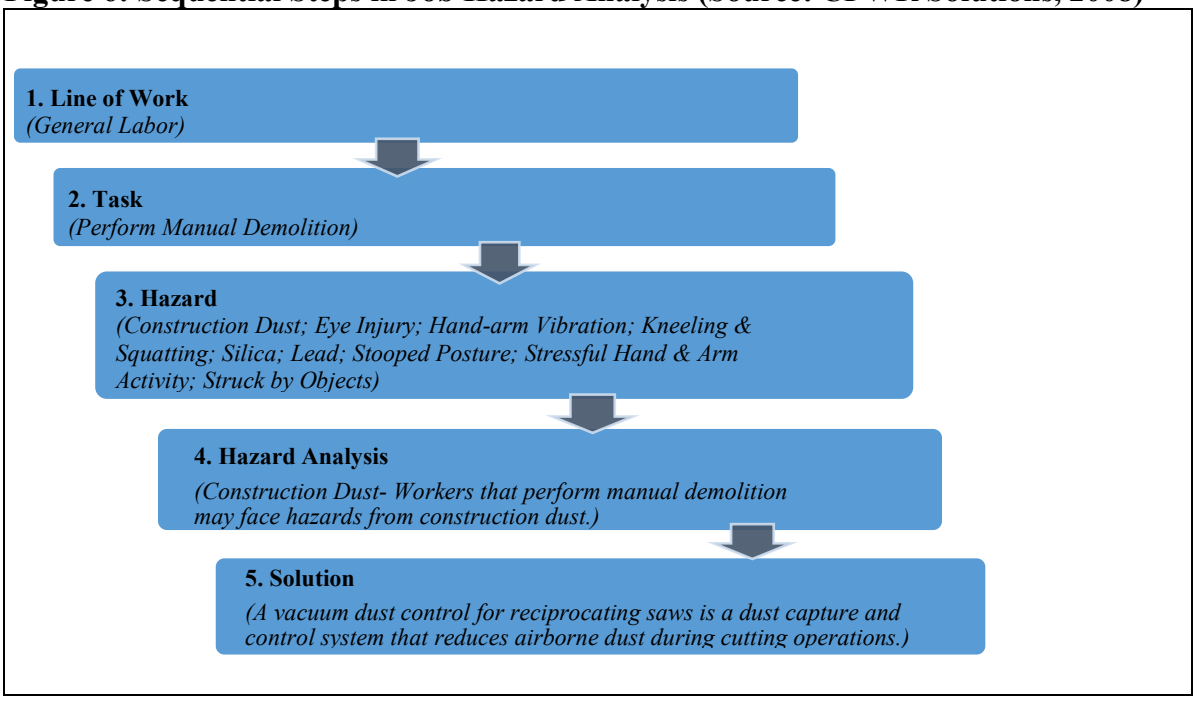


ID	Task Mode	Task Name	Duration	Start	Finish	Predecess	% Complete
1							
2		Execute Contract	0 days	Mon 10/3/22	Mon 10/3/22		0%
3		Permit / Connection Requests	0 days	Mon 10/3/22	Mon 10/3/22	2	0%
4		Mobilization Deposit	15 days	Mon 10/3/22	Fri 10/21/22	2	0%
5		Notice to Proceed	0 days	Fri 10/21/22	Fri 10/21/22	4	0%
6		**CONSTRUCTION**	**137 days**	**Mon 10/3/22**	**Tue 4/11/23**		0%
7		Mobilization	2 days	Mon 10/24/22	Tue 10/25/22	5	0%
8		Utility- New Waste Line	10 days	Wed 10/26/22	Tue 11/8/22	7	0%
9		Demolition of Interior Walls / Stairs / Joists to Allow Access	5 days	Mon 10/24/22	Fri 10/28/22	5	0%
10		Lead Abatement - Front	3 days	Wed 10/26/22	Fri 10/28/22	7	0%
11		Paint Front Brick	2 days	Mon 10/31/22	Tue 11/1/22	10	0%
12		Frame Up Stair Landing - Temp by Trident	2 days	Mon 10/31/22	Tue 11/1/22	9	0%
13		Install Electrical Panel	2 days	Wed 11/2/22	Thu 11/3/22	12	0%
14		BGE - ELECTRIC HOOK UP	15 days	Mon 10/3/22	Fri 10/21/22	3	0%
15		BGE - Gas Meter Relocation	3 days	Mon 10/3/22	Wed 10/5/22	14SS	0%
16		Fix Cornice	2 days	Mon 10/31/22	Tue 11/1/22	11SS	0%
17		Repair Steel Stairs in Rear	16 days	Wed 11/2/22	Wed 11/23/22	12	0%
18		Masonry Infill work	2 days	Thu 11/24/22	Fri 11/25/22	17	0%
19		Concrete Work - Exterior Rear	1 day	Mon 11/28/22	Mon 11/28/22	18	0%
20		Concrete Work - Interior - Footers (include Inspection	7 days	Tue 11/29/22	Wed 12/7/22	19	0%
21		Concrete Work - Exterior Front	2 days	Thu 12/8/22	Fri 12/9/22	20	0%
22		Masonry Repair Work	5 days	Mon 12/12/22	Fri 12/16/22	21	0%
23		Framing - Basement to 1st Floor	5 days	Mon 12/19/22	Fri 12/23/22	22	0%
24		Framing - Walls 1st Floor Both Sides	5 days	Mon 12/26/22	Fri 12/30/22	23	0%
25		Framing 2nd Floor Deck Reinforcement - Both Sides	5 days	Mon 1/2/23	Fri 1/6/23	24	0%
26		Framing 2nd Floor Walls & Ceiling Work	5 days	Mon 1/9/23	Fri 1/13/23	25	0%
27		Framing Inspection	0 days	Fri 1/13/23	Fri 1/13/23	26	0%
28		Insulation	3 days	Mon 1/16/23	Wed 1/18/23	26	0%

Objective 2: Identify potential hazards

The next step in developing the JHA tool was the identification of activity hazards. Two sources of information were CPWR's Construction Solutions Database and a team of safety professionals--construction superintendents and project engineers--from the contractor. The Construction Solutions Database was used to create a spreadsheet of all the hazards for each demolition and construction activity. Meanwhile, the safety professionals were consulted to provide expert opinion on rating the hazards identified and were given an opportunity to add or remove any new hazard in the database. The sequence of identifying hazards and their mitigation techniques from the CPWR Construction Solutions Database is illustrated in Figure 6, with the example of *Manual Demolition Activity*.

Figure 6: Sequential Steps in Job Hazard Analysis (Source: CPWR Solutions, 2008)



The process of creating a Job Hazard Analysis report starts from the very first activity in the project schedule. However, for illustration purpose, the following example is *Activity ID 09 - Demolition of Interior Walls/Stairs/Joists to Allow Access*. The corresponding task that is most similar in the CPWR Construction Solutions database website is *Perform Manual Demolition*. There are several hazards associated with this task: *Construction Dust, Eye Injury, Hand-arm Vibration, Kneeling & Squatting, Silica, Lead, Stooped Posture, Stressful Hand & Arm Activity, and Struck by Objects.* The next step is *Hazard Analysis* where a more detailed description of the hazard is provided. The hazard description aids construction safety professionals to be more cognizant of all the nuances of the hazard, thus helping them to rate these hazards more precisely. For each of the identified hazards, the CPWR Construction Solutions website lists possible solutions. These solutions are categorized under *Engineering Control, Administrative Control, Personal Protective Equipment (PPE) and Work Practice.* However, for this JHA, Administrative Control strategies were not included in the mitigation strategy plan because they are general and apply to all the scheduled activities. *Construction Dust* is one of the many hazards emanating from the construction activity *Demolition of Interior Walls/Stairs/Joists.* Mitigation strategy plan for this hazard includes *using a vacuum dust control for reciprocating saws that reduce airborne dust during cutting operations.* The sequence of steps of hazard analysis (listed from 1 to 5 in Figure 6) is performed for all the activities. This creates a safety database which is ultimately used in the BIM-enabled JHA tool. Figure 7 shows such a safety database based on *Demolition of Interior Walls/Stairs/Joists.*

Figure 7: An Activity Hazard Database for Activity Demolition of Interior Walls/Stairs/Joists

Task Identified	Activity ID	Activity	Hazards Identified	Detailed Description Describe the cause, uncertain event, or potential deviation from plans and the consequences	Likelihood	Crisis	Risk Level	Strategy	Mitigation Strategy Plan
Perform manual demolition	09	Demolition of Interior Walls/Stairs/ Joists	Construction dust	Cutting boards and panels to required size can generate construction dust which can cause chronic bronchitis and emphysema. Wood dust is	Likely	Significant	Moderate	Mitigate	A vacuum dust control for reciprocating saws is a dust capture and control system that reduces airborne dust during cutting
			Eye injury	Welding and plasma, air-arc and	Likely	Significant	Moderate	Mitigate	Auto-darkening welding helmets
			Hand-Arm Vibration	Repetitive use of power tools when chipping, breaking and recycling concrete exposes workers to hand-arm vibration, and is a risk factor for hand-arm vibration syndrome and carpal tunnel syndrome.	Unlikely	Marginal	Low	Mitigate	1. Ergonomic hand tools are designe to minimize awkward and forceful hand exertions. 2. User vibration protection is a built in safety feature designed for some construction power tools to protect workers against fatigue and overexertion by absorbing a significant amount of the tool's vibration.
			Kneeling & Squatting	Workers that perform manual demolition may face hazards from kneeling & squatting.	Very Unlikely	Negligible	Low	Mitigate	Demolition Bars: A demolition bar is designed to allow easy removal of roofing, decking, or subfloor while th worker is standing in an upright position.
			Silica	Workers that perform manual demolition may face hazards from silica.	Likely	Significant	Moderate	Mitigate	Hand-held masonry saws with LEV capture airborne contaminants at th source by drawing the dust into a vacuum receptacle.

Objective 3: Propose Preventive Actions and Prepare JHA Report

The third and the ultimate objective is to propose preventive actions and prepare a Job Hazard Analysis (JHA) report using the hazard database developed in Objective 2. However, not all the hazard solutions listed in the CPWR Construction Solutions Database appear in the database created in this model because they were deemed irrelevant for the project being undertaken. The contractor's team of safety-related professionals involved in the renovation project reviewed the list, finalizing it so that only those hazards that pertain to the type of construction under consideration were included in the database.

Another essential step in developing the Hazard Database shown in Figure 7 is the safety professionals' rating of the likelihood and severity of each hazard, a common risk analysis procedure. Frijters and Swuste (2008) determined the risk of construction activities using probability and severity. Gangolells et al. (2010) used probability and severity to determine the significance of risk to shortlist high-risk activities. Input from safety professionals is vital to determining which of the potential hazards are relevant and considered to be of high risk to the type of construction project under consideration. The severity levels were categorized based on the worker's ability to return to regular work (Hallowell & Gambatese, 2008), and the probability (frequency) levels of the hazard were adopted from Dharmapalan (2011) and modified in the context of the type of project considered in this research. The resulting Risk Matrix is shown in Figure 8. Based on the safety professionals' input in determining the risk level of construction activity, all the associated hazards are rated as high, moderate, and low risks. Only those hazards identified as high risks in JHA report are discussed in detail in the toolbox talk for each day's activity Other moderate-level risks could also be brought up in these safety toolbox meetings as deemed appropriate by the construction superintendents. The report can be printed in color-coded format or displayed in digital format to communicate the hazards and their interventions to the frontline workers.

Figure 8: Risk Matrix with Clear Metrics for Categorizing Different Levels of Severity and Probability

		Probability (Frequency)				
		Very Unlikely Perhaps 1 occurrence every 50	**Unlikely** 1 Occurrence every 5-10 yrs	**Likely** 1 Occurrence twice year to 1 yr	**Very Likely** 1 Occurrence every 1 week to 1 month	**Extremely Likely** 1 Occurrence every 1 hr to 1 day
Severity		*1*	*2*	*3*	*4*	*5*
Crisis (Incident that results in atleast one death)	*5*	Moderate	Moderate	High	High	High
Critical (Incident that results in permanent disablement-worker does not return to work at all)	*4*	Low	Moderate	High	High	High
Significant (Incident that results in lost work time or hospitalized injury-worker does not return to regular work within 1 day)	*3*	Low	Moderate	Moderate	High	High
Marginal (Incident that results in pain, discomfort,or requires first aid treatment- worker returns to regular work within 1 day)	*2*	Low	Low	Moderate	Moderate	Moderate
Negligible (Incident does not result in harm to the worker-no impact on work time)	*1*	Low	Low	Low	Low	Moderate

Low Risk

Medium (Moderate) Risk

High Risk

BIM-enabled Job Analysis Reporting and Visualization Tool: Case Study Implementation

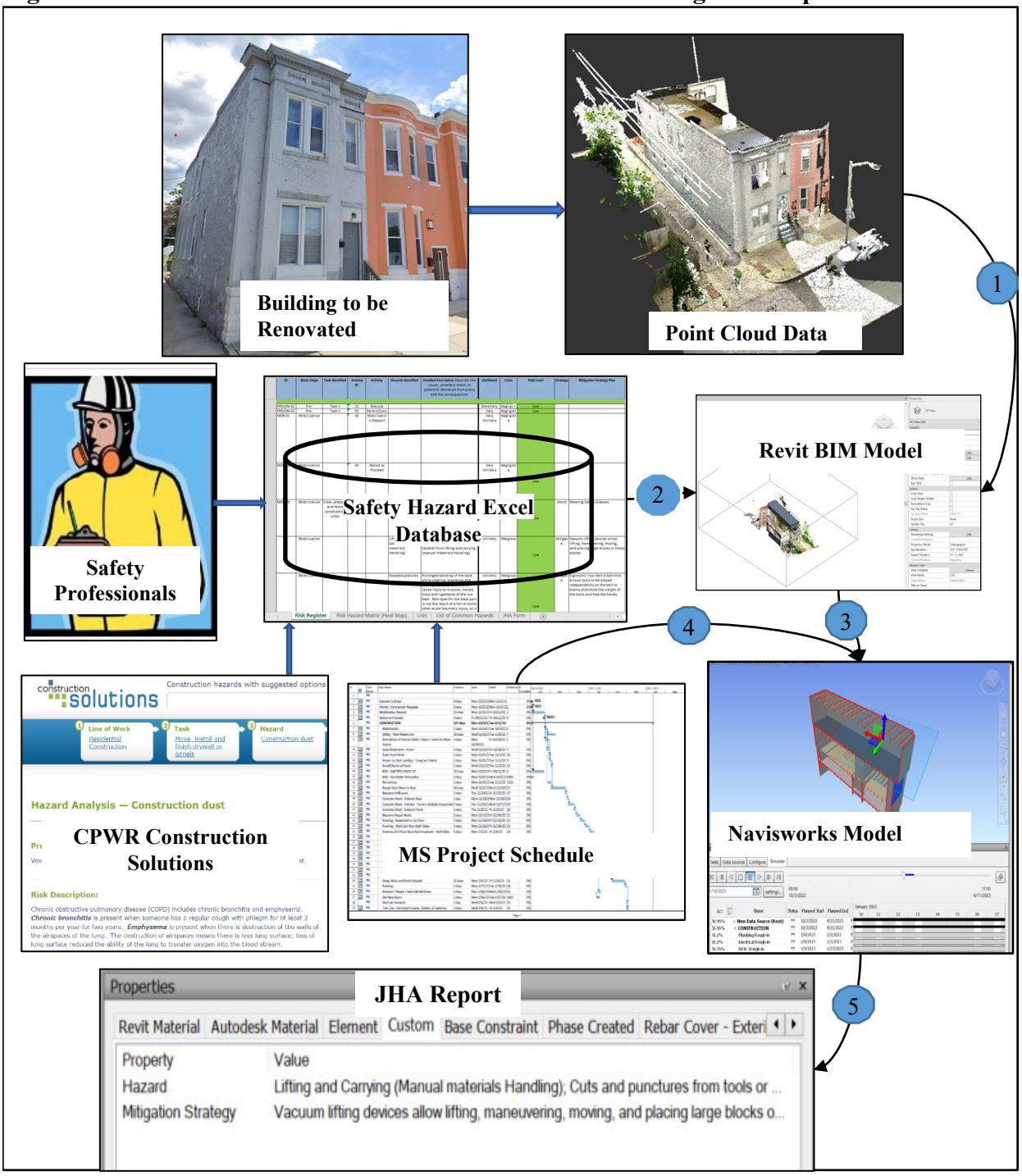
The process outlined below illustrates the implementation of the proposed framework, incorporating information from the CPWR Construction Solutions Database, safety professionals representing the contractor, and 3-D laser scans of the building. All provide input to the JHA Reporting and Visualization Tool. Each step is represented by respective numbers (1 through 5) in Figure 9:

1. **Point Cloud Data Conversion**: The first step involves using the point cloud data obtained from the 3-D laser scans of the building to create a Building Information Modeling (BIM) model. This is done using Revit software, which processes the point cloud data and generates a digital representation of the building with accurate dimensions, geometry, and spatial information. It took about 3 weeks for the research team to incorporate scans from ReCap model into Revit BIM model.

2. **Integration of Safety Database**: Safety professionals representing the contractor contribute their expertise by providing a safety database of relevant information such as hazard identification, mitigation plans, and safety procedures. This safety database, typically stored in Excel format, is then incorporated into the Revit BIM model.
3. **Revit Model Integration with Navisworks**: The next step involves integrating the Revit BIM model, now enriched with safety data, into the Navisworks software. Navisworks is a popular tool for coordination, analysis, and visualization of construction projects. This integration enables stakeholders to collaborate and review the BIM model, including safety information, in the Navisworks environment. It took about 2 weeks to incorporate Revit BIM model into Navisworks Model.
4. **Integration of MS Project Construction Schedule**: In this step, the construction schedule created using Microsoft Project (MS Project) software is integrated into the Navisworks Model. By combining the project schedule with the BIM model, project managers and stakeholders can visualize the construction progress and identify potential hazards associated with specific activities and building elements at each stage of the project.
5. **Retrieval of Activity Job Hazard Data**: Once the Revit BIM model and the construction schedule are integrated into the Navisworks Model, the JHA Reporting and Visualization Tool allows users to retrieve activity-specific job hazard data. This involves selecting the corresponding element or activity and viewing their property within the Navisworks Model.

Overall, this process integrates various data sources, including laser scan data, safety databases, BIM models, construction schedules, and visualization tools, to enhance safety analysis and reporting in construction projects. It enables safety professionals and project stakeholders to collaborate effectively, identify potential hazards, and develop mitigation strategies within a coordinated and visualized environment, ultimately improving overall project safety. It is to be noted that these specialized software packages demand anywhere from 30 to 60 hours of training, depending on the skill level needed, to use them for developing a JHA tool such as the one presented here.

Figure 9: Information Flowchart of the Process for Generating JHA Report



Accomplishments, Results, Conclusions and Recommendations

A framework for developing a BIM-enabled JHA reporting tool has been presented and its functions are demonstrated with a case study project. The results of this research include quantifying the risk for the 36 demolition and construction activities involved in renovating a rowhouse. Job Hazard Analysis of all the

activities involved in the renovation of a rowhouse was performed. As a result, twelve hazards were deemed high risk for the project. These hazards emanated from seven activities of the project. These activities are 1) Masonry repair work, 2) Framing of basement to first floor, 3) Framing of 1st floor walls, 4) Framing of 2nd floor deck, 5) Framing of 2nd floor walls and ceiling, 6) Painting interior and exterior walls, ceilings, trim, etc., and 7) Installing flooring. The associated hazards are:

1. Masonry repair work
    a. Fall from heights--Workers who lay or set brick, block, or stone may fall from heights. Falls from heights include workers falling to a lower level, resulting in injury on impact against an object or the ground.
2. Framing-Basement to first floor; 1st floor walls; 2nd floor deck; 2nd floor walls and ceiling
    a. Fall from heights--Workers working above ground level may pose a safety hazard and be at risk of falling from heights. The result of such a fall can cause fractures, sprains, strains, contusions, severe damage to internal organs, and even death.
    b. Struck-by objects--Workers framing floors, walls, ceilings, stairs, and roofs using wood and/or metal studs and door bucks may face injuries from being struck by objects.
3. Paint interior and exterior walls, ceilings, trim, etc.
    a. Fall from heights--Workers that paint interior and exterior walls, ceilings, trim, etc. may face injuries from falling from heights.
4. Install flooring
    a. Kneeling and Squatting--Workers who install floor coverings and carpets may face injuries from kneeling and squatting.
    b. Stooped postures--Workers who install floor coverings and carpet may face injuries from stooped postures.

An activity that was rated as highly unlikely yet would create a crisis-level impact if it occurs is *Gas Meter Relocation.* Vehicular accidents and knocking out of gas pipes and meters may cause a gas leak, explosion, and catch fire, but because of the highly unlikely nature of this event, this hazard was rated as moderate risk. A risk analysis that incorporates only high-severity, low-probability data ignores a significant portion of the risk, namely high-probability, low-severity events (Hallowell & Gambatese, 2008). These are especially important in the context of smaller construction projects such as the one described here. However, no extremely likely risks (that is, high-probability events) were identified for this project. A comprehensive and formal risk analysis such as the one performed here should include all types of risks.

A contractor involved in residential construction (specifically row homes and even townhomes) may utilize the tool developed in this study during pre-task safety plan meetings or toolbox meetings at their job sites. Contractors may caution the workers regarding the high-risk activities and injury severity during construction of a building element. Moreover, they can train the crews on high-risk activities. For example, when the workers are roofing the building, falling from heights is a major hazard. Therefore, adequate safety resources (e.g., PPE such as safety harnesses) could be allocated to the roofing activity. In addition, contractors could use the results from the assessment to re-sequence high-risk activities that fall on the critical path of the project schedule so that risks are not concentrated during certain periods. Ideally, if there are safer, alternate means and methods of construction for high-risk tasks, they can be adopted as the primary means to avoid the risks altogether. Contractors can also utilize the 4D Model to conduct safety training, as it provides a better means of risk visualization and communicates better with subcontractors regarding the hazards to expect on the job site.

One of the major assumptions made at the proposal stage for this study was that the scan-to-BIM technologies would be relatively low cost, even compared to the cost involved in such residential renovation projects. However, as the implementation progressed, it became evident that the cost of implementing the scan-to-BIM process for these projects was higher than anticipated. Just 3-D scanning for the case study project was about $6,000, and the BIM development and risk analysis would be additional cost. A relatively

small interior renovation of the building finishes could cost upwards of $80,000-100,000, so 3D scanning would account for about 6% to 10% of the total renovation cost. This investment in safety hazard analysis using BIM is a little cost prohibitive for most small contractors.

One potential way to make the investment more viable could be to use the 3D scan for purposes beyond safety planning. For example, using the scan for design and planning would spread its cost across multiple areas and make the investment more cost-effective overall. Its use could improve accuracy in measuring and modeling the existing conditions of the building, which could help minimize errors and reduce costs in other areas of the renovation project. Ultimately, it is up to the contractor to weigh the costs and benefits of 3D scanning in the context of their specific renovation project. By carefully considering the potential uses and benefits of the scan, one can make a more informed decision about whether it is a worthwhile investment.

The research team recommends that the future research and effort related to this project be directed towards providing a user-interface for a JHA reporting tool. This would allow a construction superintendent to print automated JHA reports for the demolition/construction activities from 4-D BIM, customize them as necessary, and use it to plan and communicate safety hazards specific to the activity and the building element. The user-interface (UI) of the JHA Reporting and Visualization Tool is a crucial aspect that can greatly enhance its usability and effectiveness. A well-designed UI can make the tool more intuitive, user-friendly, and efficient, enabling construction superintendents to produce JHA reports easily and effectively. Here are some key considerations for improving the user-interface of the tool:

1. *Clear and Intuitive Navigation*: The UI should provide clear and intuitive navigation options, allowing users to easily access different features and functionalities of the tool. A well-organized menu structure, easily identifiable icons or buttons, and logical workflows can help streamline the user experience.
2. *User-Friendly Data Input*: The tool should provide an intuitive interface for entering and managing data. This can include forms, dropdown menus, checkboxes, and other input elements that facilitate efficient data entry. Clear instructions and tooltips can also assist users in providing accurate and relevant information.
3. *Interactive 3D Visualization*: Since the tool integrates 3D laser scans and BIM models, the UI should include interactive 3D visualization capabilities. Users should be able to navigate the model, zoom in and out, rotate, and interact with different elements to identify hazards and review mitigation plans. This can be achieved through a user-friendly interface that allows easy manipulation of the 3D view.
4. *Customization Options*: The tool should provide customization options to accommodate different project requirements and user preferences. This can include the ability to customize the layout, color schemes, and views within the tool. Users may also benefit from the ability to personalize the interface by saving custom settings or creating templates for repetitive tasks.
5. *Real-Time Feedback and Validation*: The UI should provide real-time feedback to users, such as highlighting potential hazards or displaying warnings when incomplete or incorrect data is entered. This can help ensure the accuracy and completeness of the JHA reports and promote a proactive safety planning process.
6. *Reporting and Exporting*: The UI should include features for generating comprehensive JHA reports based on the input data. Users should have the ability to customize report templates, select the desired information to include, and generate professional-looking reports in various formats (e.g., PDF, Word, Excel). Additionally, the tool could offer the option to export data for further analysis or integration with other software systems.
7. *Mobile-Friendly Design*: Considering that construction superintendents often work on-site, a mobile-friendly UI can be beneficial. Allowing access to the tool from mobile devices such as tablets or smartphones would enable real-time hazard identification and report generation even when away from a desktop computer.

By incorporating these user-interface improvements, the JHA Reporting and Visualization Tool can enhance its usability, making it more accessible and efficient for construction superintendents. A well-designed UI can significantly improve the user experience, increase adoption rates, and ultimately contribute to improved safety planning and hazard communication with frontline workers.

Changes/Problems

The research project experienced some challenges related to timeline and personnel changes, as well as external factors such as COVID-related restrictions. Specifically, the delay in obtaining access to the building in the specified HEZ for laser scanning pushed back the project timeline by about five months. Additionally, one of the project's principal investigators moved to another institution, which affected the project. Finally, COVID-related restrictions were still in effect during this research period, slowing the project's progress.

Future Funding Plans

This research was proposed first with an aim of developing a user-friendly JHA reporting tool that could be used by project superintendents and engineers from small contractors. A framework for developing such a tool has been provided. However, due to limitations of time and resources, the user-interface portion of the application tool was not developed. The future plan is to create a user interface for the JHA tool with the assistance from an application developer. An effort will be made to secure additional funding from public (HUD, NIOSH) or even private resources to refine the tool and develop a user-interface for the JHA tool. The researchers are also looking at ways to expand the scope of work to include modular renovations and energy retrofit of these rowhouses and townhouses to develop a similar JHA Reporting tool to apply for funding from agencies such as NIOSH and HUD.

List of Presentations/Publications

The journal targeted for the research publication is *The Journal of Safety Research*. The findings will be presented at the Associated School of Construction Conference and at other avenues.

Dissemination

The dissemination plan focuses on sharing the research findings, technologies, and applications related to the Scan to BIM technology and visual JHA reporting tool. This could involve tailored outreach efforts, such as training workshops (OSHA 10/30 hrs. training) to construction management students and other industry professionals in the Industry Advisory Board at Morgan State University, webinars, and industry-specific conferences, to ensure the tool's adoption and usage among the intended end-users who will primarily be small contractors and subcontractors, and municipal, state, and federal HUD agencies.

The results will also be shared with other researchers in academic conferences. The paper will be presented at the Associated School of Construction (ASC) Conference in 2024. The researchers recommend that CPWR publish the results of the research in a CPWR Update newsletter. The BIM-enabled reporting tool for row homes could be made available by CPWR to smaller construction companies and trade contractors for their day-to-day JHA exercise.

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Appendix A- Photos & BIM Models

Photo 1: Front Brick Façade of the Row House

Photo 2: Basement

Photo 3: Furnace, Stairs to the Basement, and Basement Ceiling

Photo 4: Basement Walls, HVAC, and a Window

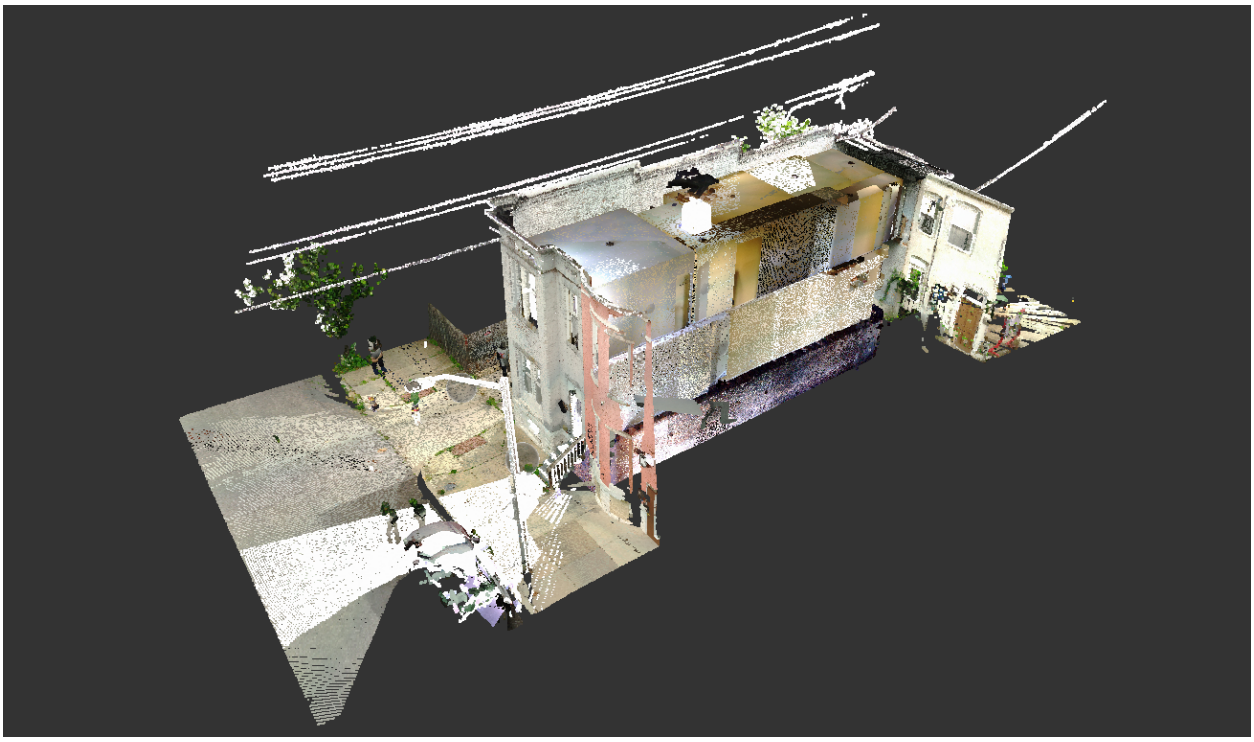
Photo 5: Second Floor Bedroom

Photo 6: Narrow Stair Leading to the Second Floor from the First Floor

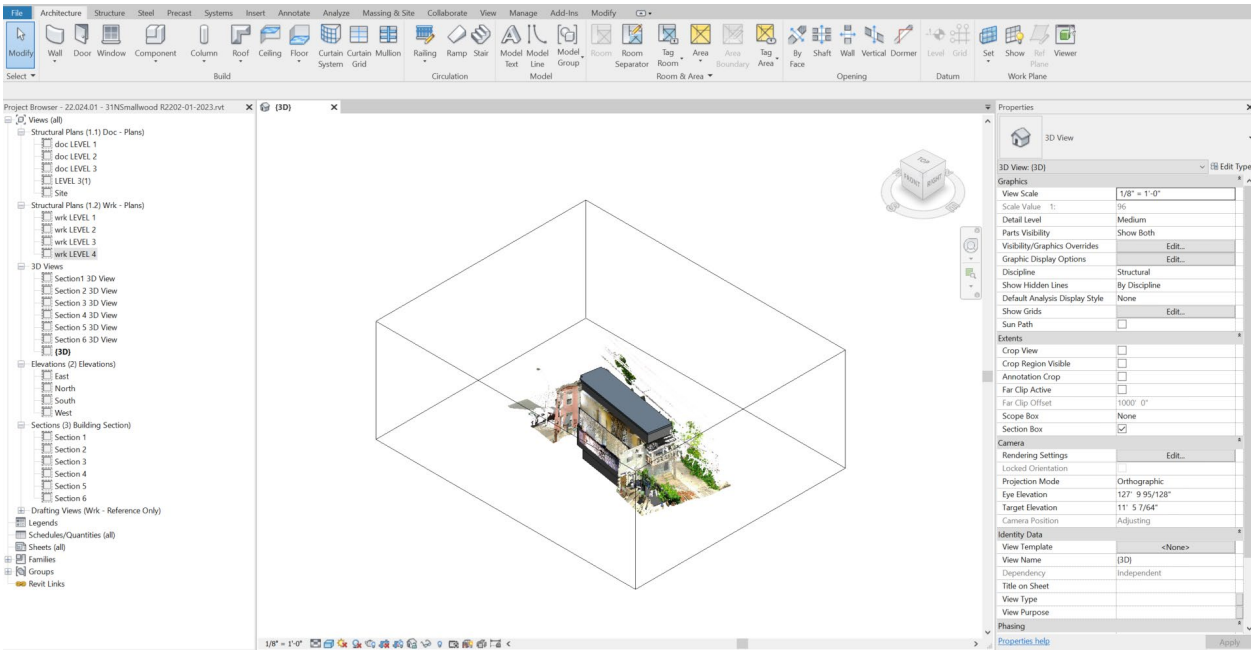
Photo 7: Kitchen

Model 1: Point Cloud Data of the Building from the Front

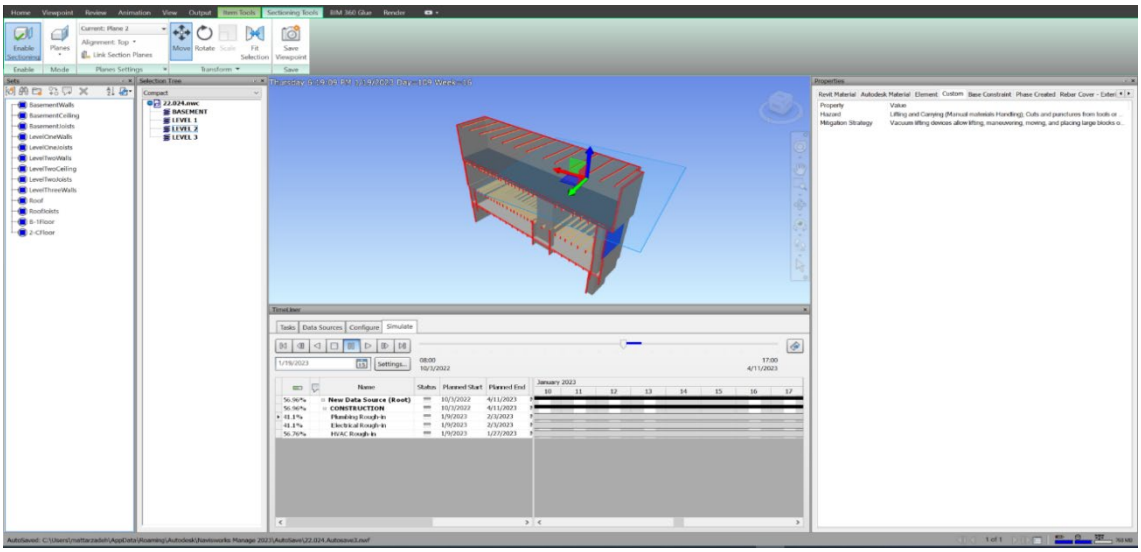
Side



Model 3: Revit BIM Model



Model 4: Navisworks Model with Hazard Analysis Report



Properties

Basic Wall
Stud-04_Type AA

Walls (1) | Edit Type

Unconnected Height	10' 0"
Top Offset	0' 0"
Top is Attached	☑
Top Extension Distance	0' 0"
Room Bounding	☑
Related to Mass	☐
Cross-Section Definition	
Cross-Section	Vertical
Structural	
Structural	☑
Structural Usage	Bearing
Rebar Cover - Exterior Face	Exterior - #3 to #5 <0' - 1 1/2">
Rebar Cover - Interior Face	Interior (slabs, walls, joists) - #3 t...
Rebar Cover - Other Faces	Interior (slabs, walls, joists) - #3 t...
Dimensions	
Length	46' 6 3/16"
Area	441.91 SF
Volume	128.89 CF
Identity Data	
Image	
Comments	
Mark	
Has Association	☐
Phasing	
Phase Created	New Construction
Phase Demolished	None
IFC Parameters	
Export to IFC	By Type
Export to IFC As	
IFC Predefined Type	
IfcGUID	1U53TbkKjE9ROFM2s9zCmg
Data	
Hazard	Lifting and Carrying (Manual ma...
Mitigation Strategy	Vacuum lifting devices allow lifti...

Properties

Revit Material | Autodesk Material | Element | Custom | Base Constraint | Phase Created | Rebar Cover - Exteri

Property	Value
Hazard	Lifting and Carrying (Manual materials Handling); Cuts and punctures from tools or ...
Mitigation Strategy	Vacuum lifting devices allow lifting, maneuvering, moving, and placing large blocks o...

Appendix B – Safety Database

ID	Work Stage	Task Identified	Activity ID	Activity	Hazards Identified	**Detailed Description** Describe the cause, uncertain event, or potential deviation from plans and the consequences	Likelihood	Crisis	Risk Level	Strategy	Mitigation Strategy Plan
PRECON-01	Pre-construction	Task 1	02	Execute			Extremely	Negligible	Low		
PRECON-02	Pre-construction	Task 1	03	Permit/Connec			Very Unlikely	Negligible	Low		
MOB-01	Mobilization		04	Mobilization Deposit			Very Unlikely	Negligible	Low		
MOB-02	Mobilization		05	Notice to Proceed			Very Unlikely	Negligible	Low		
MOB-03	Mobilization	Clear, prepare and fence construction sites	07	Mobilization-Site Safety Fence Installation	Eye injury	Workers who clear, prepare and fence construction sites may face hazards from eye injury.	Unlikely	Marginal	Low	Avoid	Wearing Safety Glasses
	Mobilization				Lifting and Carrying (Manual materials Handling)	Workers who clear, prepare and fence construction sites may face hazards from lifting and carrying (manual materials handling).	Unlikely	Marginal	Low	Mitigate	Vacuum lifting devices allow lifting, maneuvering, moving, and placing large blocks or heavy stones.
	Mobilization				Stooped postures	Prolonged bending of the back while clearing, preparing and fencing construction sites can cause injury to muscles, nerves, discs and ligaments of the low back. Non-specific low back pain is not the result of a fall or some other acute traumatic injury, so it can be difficult to identify a specific event that led to the injury. Continuous work in a 'stooped posture' can lead to low back muscle strain, ligament sprain, a bulging or herniated disc, or other back problems.	Unlikely	Marginal	Low	Mitigate	Ergonomic Tool Belt-A belt that allows tools to be placed independently on the belt to evenly distribute the weight of the tools and free the hands.
	Mobilization			Mobilization-Site toilet installation	Lifting and Carrying (Manual materials Handling)	Lifting heavy materials during the building of forms and reinforcing for footings and foundations can cause injury to muscles, nerves, discs and ligaments of the low back. Non-specific low back pain is not the result of a fall or some other acute traumatic injury, so it can be difficult to identify a specific event that led to the injury. Repetitive lifting can lead to low back strain, ligament sprain, a bulging or herniated disc, or other back problems.	Very Unlikely	Negligible	Low	Mitigate	Vacuum lifting devices allow lifting, maneuvering, moving, and placing large blocks or heavy stones.
	Mobilization			Mobilization-Delivery of machinery	Cuts and punctures from tools or materials	Workers that load, unload or transport construction materials and equipment may face hazards from cuts and punctures from tools or materials	Very Unlikely	Marginal	Low	Mitigate	The shoulder carrying pad improves comfort and stability, and protects from cuts and bruises when carrying objects on the shoulder.
	Mobilization				Lifting and Carrying (Manual materials Handling)	Lifting heavy materials during the manual transporting of materials can cause injury to muscles, nerves, discs and ligaments of the low back. Non-specific low back pain is not the result of a fall or some other acute traumatic injury, so it can be difficult to identify a specific event that led to the injury.	Unlikely	Negligible	Low	Mitigate	Vacuum lifting devices allow lifting, maneuvering, moving, and placing large blocks or heavy stones.
DEMO-06	Demolition	Position and join sewer, water and storm drains	08	Utility-New Waste Line	Lifting and Carrying (Manual materials Handling)	Lifting heavy materials while positioning and joining sewer, water and storm drains can cause injury to muscles, nerves, discs and ligaments of the low back. Non-specific low back pain is not the result of a fall or some other acute traumatic injury, so it can be difficult to identify a specific event	Unlikely	Marginal	Low	Mitigate	Vacuum lifting devices allow lifting, maneuvering, moving, and placing large blocks or heavy stones.
	Demolition				Stooped postures	Prolonged bending of the back while positioning and joining sewer, water and storm drains can cause injury to muscles, nerves, discs and ligaments of the low back. Non-specific low back pain is not the result of a fall or some other acute traumatic injury, so it can be difficult to identify a specific event	Very Unlikely	Marginal	Low	Mitigate	A pipe transport device, pipe dolly, is a mechanical lifting device that can lift and carry heavy pipe(s) or other material.
	Demolition	Perform manual demolition	09	Demolition of Interior Walls/Stairs/ Joists	Construction dust	Cutting boards and panels to required size can generate construction dust which can cause chronic bronchitis and emphysema. Wood dust is another	Likely	Significant	Moderate	Mitigate	A vacuum dust control for reciprocating saws is a dust capture and control system that reduces airborne dust during cutting
	Demolition				Eye injury	Welding and plasma, air-arc and flame	Likely	Significant	Moderate	Mitigate	Auto-darkening welding helmets detect
	Demolition				Hand-Arm Vibration	Repetitive use of power tools when chipping, breaking and recycling concrete exposes workers to hand-arm vibration, and is a risk factor for hand-arm vibration syndrome and carpal tunnel syndrome.	Unlikely	Marginal	Low	Mitigate	1. Ergonomic hand tools are designed to minimize awkward and forceful hand exertions. 2. User vibration protection is a built-in safety feature designed for some construction power tools to protect workers against fatigue and overexertion by absorbing a significant

	Demolition				Kneeling & Squatting	Workers that perform manual demolition may face hazards from kneeling & squatting.	Very Unlikely	Negligible	Low	Mitigate	Demolition Bars: A demolition bar is designed to allow easy removal of roofing, decking, or subfloor while the worker is standing in an upright position.
	Demolition				Silica	Workers that perform manual demolition may face hazards from silica.	Likely	Significant	Moderate	Mitigate	Hand-held masonry saws with LEV capture airborne contaminants at the source by drawing the dust into a vacuum receptacle.
	Demolition				Lead	Sources of lead exposure in the	Likely	Significant	Moderate	Mitigate	Needle guns and needle scalers with
	Demolition				Stooped postures	Workers who perform manual demolition may face hazards from stooped postures.	Unlikely	Marginal	Low	Mitigate	A demolition bar is designed to allow easy removal of roofing, decking, or subfloor while the worker is standing in an upright position.
	Demolition				Stressful hand & wrist activity	Performing stressful hand activities while performing manual demoltion can lead to tendon inflammation (tendonitis) in the hand, wrist, or elbow, or carpal tunnel syndrome.	Very Unlikely	Negligible	Low	Mitigate	1. Extracting pliers feature auto-locking jaws and a curved heel that reduces the gripping force required when extracting nails or staples. 2. Tool-balancing/zero-gravity arms allow workers to maneuver power tools as if the tools were weightless
	Demolition				Struck by Objects	Struck by object injuries are produced by forcible contact or impact between the injured person and an object or piece of equipment. This type of hazard can be categorized by: flying, falling, swinging or, rolling.	Unlikely	Critical	Moderate	Mitigate	Tool-balancing/zero-gravity arms allow workers to maneuver power tools as if the tools were weightless while providing full range of motion.
DEMO-07	Demolition	Identify, control and remove hazardous materials	10	Lead/Asbestos /Mold Remediation	Exposure to Lead, Asbestos, Mold	Occupational exposure to lead comes primarily from inhalation and ingestion of lead dust and fumes. Construction tasks with the highest potential for exposure to lead include abrasive blasting of lead-painted surfaces, welding, and torch cutting. Workers sometimes unintentionally bring lead dust home on their clothing, which can pose a hazard to family members. Children are especially susceptible to lead poisoning. When effective engineering controls are not available, it is important to wear protective clothing and other personal protective equipment, change your clothes and shoes before getting home or entering your car, and launder all lead-contaminated clothing separately.	Likely	Significant	Moderate	Mitigate	Needle guns and needle scalers with vacuum dust control safely remove lead-containing paints and coatings from surfaces.
CON-01	Construction	Paints & Coatings	11	Paint Front Brick	Fall from heights	Workers who inspect and use scaffolds and ladders may fall from heights. Falls from heights include worker falls to a lower level which result in injury on impact against an object or the ground.	Likely	Significant	Moderate	Avoid	1. A ladder leveler is a set of adjustable legs that is attached to the base of an extension ladder that improves stability. 2. Ladder Rung Step- Climbing extension ladders that are unstable can increase the chance of a fall leading to an injury or even death. Fractures are
	Construction				Skin contact with paint-related solvents	Petroleum distillates used in painting tasks may cause skin irritation, a condition also known as irritant contact dermatis (ICD). One of the most commonly used class of paint solvents are aliphatic hydrocarbons, also called petroleum distillates.	Unlikely	Marginal	Low	Mitigate	Protecting Your Skin from Solvents, Adhesives and Other Chemicals- Substitution, wearing PPE and good work practice can help protect your skin from solvents, adhesives and other chemicals.
	Construction				Stressful hand & wrist activity	Stressful hand and wrist activity may be forceful, repetitive, or characterized by extreme postures. Performing stressful hand activities while performing exterior painting with spray guns, brushes or rollers can lead to tendon inflammation (tendonitis) in the hand, wrist, or elbow, or carpal tunnel syndrome.	Very Unlikely	Negligible	Low	Mitigate	1. A bucket dolly is a cart that allows workers to roll buckets and their contents reducing the need to lift and carry. 2. Ergonomic paint applicators are paintbrush and roller handles that are designed to allow painting with a more neutral position of the hand and wrist.
CON-02	Construction	Frame floors, walls, ceiling, stairs and roofs using wood and/or metal studs and door bucks	12	Frame Stairs	Eye injury	Welding and plasma, air-arc and flame cutting metal may expose workers to eye hazards that may include: Eye penetration injury from grinding or chipping welds. Thermal burns Radiation injury to the eyes	Likely	Significant	Moderate	Mitigate	Safety Eye Protection- Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Fall from heights	Workers working above ground level may pose a safety hazard and be at risk of falling from heights. The result of such fall can potentially cause fractures, sprains, strains, contusions, severe damage to internal organs and even death.	Likely	Significant	Moderate	Mitigate	1. Engineering control-Automatic Leveler and Stabilizer Extension Ladder 2. An extension ladder with an automatic leveler and stabilizer requiring only one person to set up. Guardrails-A guardrail with a toprail, midrail, and toeboard, is a fall prevention system that will prevent a worker from falling to a lower level. Ladder Safety Base System-A safety base system that secures an extension ladder up to 60 feet to prevent kick out and reduce lateral movement when used in conjunction with proper ladder techniques. Rolling Ladder- A rolling ladder provides a wider, longer and more stable work platform than a conventional folding ladder.

	Construction				Struck by Objects	Workers that frame floors, walls, ceiling, stairs and roofs using wood and/or metal studs and door bucks may face hazards from struck by objects.	Likely	Significant	Moderate	Mitigate	Engineering control- Magnetic Nail Holder-A magnetic nail holder positions a nail while providing a striking surface to cover the fingers and help prevent struck-by injuries while hammering.
CON-03	Construction	Install and maintain electrical control systems	13	Install Electrical Panel	Electrical shocks, burns and/or electrocution	Workers that install and maintain electrical control systems may face hazards from electrical shocks, burns and/or electrocution.	Unlikely	Critical	Moderate	Avoid	1. Substitution:Absence of Voltage Tester (AVT)- An Absence of Voltage Tester (AVT) is a permanently-mounted test device designed to verify that a circuit is de-energized prior to opening an electrical enclosure containing electrical conductors and circuit parts. 2. Wristband Voltage Sensor-A wrist-worn (wristband) voltage sensor can warn users against impending contact with live equipment.
CON-04	Construction	Install and maintain electrical control systems	14	BGE-Electrical Hook-up	Fall from heights	Workers working above ground level may pose a safety hazard and be at risk of falling from heights. The result of such fall can potentially cause fractures, sprains, strains, contusions, severe damage to internal organs and even death.	Unlikely	Critical	Moderate	Mitigate	1. Engineering control-Ladder Safety Base System. A safety base system that secures an extension ladder up to 60 feet to prevent kick out and reduce lateral movement when used in conjunction with proper ladder techniques.
CON-05	Construction		15	BGE Gas Meter Relocation	Gas Leaks, Explosion and Fire	Vehicular accidents and knocking of gas pipes and meters may cause gas leak, explosion and catch fire.	Unlikely	Crisis	Moderate	Avoid	
CON-06	Construction	Install cabinets, countertops and moldings	16	Fix Cornice	Cuts and punctures from tools or materials	Workers that install cabinets, countertops and moldings may face hazards from cuts and punctures from tools or materials.	Unlikely	Significant	Moderate	Mitigate	1. Engineering control:Sequential Nail Guns-Sequential nail guns are pneumatic guns that require the nose of the gun to be depressed before the trigger can be pulled in order to fire. 2. Twin Blade Circular Saw-A twin blade circular saw uses two counter-rotating blades to reduce kickback.
	Construction				Eye injury	Workers who install cabinets, countertops and moldings may face hazards from eye injury.	Unlikely	Negligible	Low	Mitigate	Safety glasses
	Construction				Hand-Arm Vibration	Workers who install cabinets, countertops and moldings may face hazards from hand-arm vibration.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control Ergonomic Hand Tools Ergonomic hand tools are designed to minimize awkward and forceful hand exertions. 2. Reduced Vibration Power Tools A reduced vibration, or anti-vibration, power tool produces less vibration than conventional tools during construction operations. 3. Tool Handle Wraps A tool handle wrap is a viscoelastic material tape wrapped around a tool handle to damp vibration. 4. User Vibration Protection User vibration protection is a built-in safety feature designed for some construction power tools to protect workers against fatigue and overexertion by absorbing a significant
	Construction				Kneeling & Squatting	Workers that install cabinets, countertops and moldings may face hazards from kneeling & squatting.	Very Unlikely	Negligible	Low	Mitigate	Engineering control:Cabinet Lifting Device-A cabinet lifting device transports and lifts and holds cabinets at various heights for easy installation.
	Construction				Overhead work	Workers who install cabinets, countertops and moldings may face hazards from overhead work.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control-Cabinet Jack A cabinet jack supports materials during installation on walls including cabinets, sink disposals, crown molding, and pipes. 2. Cabinet Lifting Device A cabinet lifting device transports and lifts and holds cabinets at various heights for easy installation. Drywall Jack A drywall jack props and supports drywall sheet panels during ceiling installations. Rolling Ladder A rolling ladder provides a wider, longer and more stable work platform than a conventional folding ladder.

	Construction				Stressful hand & wrist activity	Workers that install cabinets, countertops and moldings may face hazards from stressful hand & wrist activity.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control Compact Circular Saw The compact circular saw is smaller and lighter than a conventional circular saw. 2. Cordless Electric Adhesive Dispenser Cordless electric adhesive dispensers (CEADs) are engineering controls that can mitigate musculoskeletal disorders by minimizing required force and repetition of specific tasks. 3. Granite Countertop Dolly A granite countertop dolly can be used to easily move granite slabs over a variety of surfaces and up stairs. 4. Multiple Panel Slab Cart A multiple panel slab cart can be used to easily transport a variety of slabs at once.
	Construction				Wood dust	Workers who install cabinets, countertops and moldings may be exposed to wood dust.	Likely	Marginal	Moderate	Mitigate	Engineering control Hand-held Wood Routers with Vacuum Dust Control A vacuum dust control for hand-held wood routers is a dust capture device that reduces airborne wood dust during wood routing operations.
CON-07	Construction	Structural Steel	17	Repair Steel Stairs-rear	Fall from heights	Workers who build or erect false work may fall from heights. Falls from heights include worker falls to a lower level which result in injury on impact against an object or the ground.	Unlikely	Significant	Moderate	Mitigate	1. Substitution-Portable Adjustable Stairs Portable adjustable stairs offer the convenience and functionality of permanent stairs to situations where the portability of a ladder is required. 2. Work practice-Using Safety Nets A personnel safety net is a passive fall protection designed to catch a worker after a fall so the worker does not contact the surface below.
	Construction				Welding fumes	Workers who fabricate metal structures in shop and field may be exposed to welding fumes.	Likely	Significant	Moderate	Mitigate	Substitution Selecting Proper Welding Processes to Reduce Fume Exposure When selecting the proper welding process for the task, evaluating the potential for fume generation and the availability of different, lower-fume welding processes may help lower your exposure to harmful compounds in welding fumes. Engineering control Fume Extraction MIG Welding Gun Fume extraction MIG welding guns remove welding fumes at the point of generation. Portable Vacuum Fume Collector without HEPA filtration A portable vacuum fume collector without HEPA filtration is a local exhaust ventilation unit that captures contaminates near the source.
	Construction				Lifting and Carrying (Manual materials Handling)	Workers that hoist and move members and components in shop may face hazards from lifting and carrying (manual materials handling).	Unlikely	Significant	Moderate	Mitigate	1. Engineering control-Air Manipulator Hoist. An air manipulator hoist is a portable and lightweight device that uses compressed air to lift material up to 500 pounds.
CON-08	Construction	Masonry, Tile, Cement & Plaster	18	Masonry Infill Work	Construction dust	Workers who cut bricks, blocks, stone, concrete, tile or terrazzo may be exposed to construction dust.	Likely	Marginal	Moderate	Mitigate	1. Engineering control Stationary Masonry Saws with Wet Dust Suppression-Stationary masonry saws that can be used with water to suppress silica and other construction dust at the source. 2. Brick, Stone and Paver Splitters Mechanical, pneumatic or hydraulic splitters are used to cut, shape or break bricks, concrete block, stone, and pavers. 3. Hand-held Masonry Saws with Vacuum Dust Control Hand-held masonry saws with LEV capture airborne contaminants at the source by drawing the dust into a vacuum receptacle. 4. Hand-held Masonry Saws with Wet Dust Suppression Hand-held masonry saws that can be
	Construction				Eye injury	Workers who cut bricks, blocks, stone, concrete, tile or terrazzo may face hazards from eye injury.	Very Unlikely	Significant	Low	Mitigate	Personal Protective Equipment Safety Eye Protection Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.

	Construction				Silica	Workers that cut bricks, blocks, stone, concrete, tile or terrazzo may face hazards from silica.	Likely	Significant	Moderate	Mitigate	1. Engineering control-Stationary Masonry Saws with Wet Dust Suppression Stationary masonry saws that can be used with water to suppress silica and other construction dust at the source. 2. Brick, Stone and Paver Splitters-Mechanical, pneumatic or hydraulic splitters are used to cut, shape or break bricks, concrete block, stone, and pavers. 3. Hand-held Grinders with Wet Dust Suppression-A hand-held grinder with wet dust suppression delivers water to the surface to reduce airborne contaminants while smoothing masonry surfaces. 4. Hand-held Masonry Saws with Vacuum Dust Control-Hand-held masonry saws with LEV capture
	Construction				Fall from heights	Workers who lay or set brick, block, or stone may fall from heights. Falls from heights include worker falls to a lower level which result in injury on impact against an object or the ground.	Unlikely	Significant	Moderate	Mitigate	1. Engineering control-Automatic Leveler and Stabilizer Extension Ladder 2. An extension ladder with an automatic leveler and stabilizer requiring only one person to set up. 3. Guardrails-A guardrail with a toprail, midrail, and toeboard, is a fall prevention system that will prevent a worker from falling to a lower level. 4. Ladder Safety Base System-A safety base system that secures an extension ladder up to 60 feet to prevent kick out and reduce lateral movement when used in conjunction with proper ladder techniques. 5. Rolling Ladder- A rolling ladder provides a wider, longer and more stable work platform than a conventional folding ladder.
	Construction				Skin contact with Portland cement	Workers who lay or set brick, block, or stone may face hazards from skin contact with portland cement.	Likely	Negligible	Low	Mitigate	1. Work practice-Protecting Your Skin from Solvents, Adhesives and Other Chemicals Substitution, wearing PPE and good work practice can help protect your skin from solvents, adhesives and other chemicals.
	Construction				Hand-Arm Vibration	Workers who pour, pump, vibrate concrete may be exposed to hand-arm vibration.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control: Backpack Concrete Vibrator-Ergonomic backpack concrete vibrator distributes the weight of the engine on the worker's hips during concrete vibration. 2. Ergonomic Hand Tools-Ergonomic hand tools are designed to minimize awkward and forceful hand exertions. 3. Reduced Vibration Power Tools-A reduced vibration, or anti-vibration, power tool produces less vibration than conventional tools during construction operations.
	Construction				Lifting and Carrying (Manual materials Handling)	Workers who pour, pump, vibrate concrete may face hazards from lifting and carrying (manual materials handling).	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control:Powered (Concrete) Buggy-A powered buggy, or concrete buggy, is originally used for transporting, spot pouring and spread dumping concrete. However, these powered buggies are also used for other material handling jobs that can include construction debris removal, landscaping, or on-site tool and equipment transportation. They are typically powered by gas or propane with hydraulic pumps to empty the polythylene tubs and a stand for workers to "ride-on" while operating the equipment. 2. Pre-Blended Mortar and Grout Delivery Equipment-A pre-blended mortar and grout delivery system utilizes gravity to deliver grout into the masonry wall. 3. Remote-Controlled Chute for Concrete Mixer-A concrete chute that moves vertically and horizontally, and
CON-09	Construction	Reinforced Concrete	19	Concrete Work-Exterior Rear	Eye injury	Workers who pour, pump, vibrate concrete may face hazards from eye injury.	Very Unlikely	Negligible	Low	Mitigate	Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Cuts and punctures from tools or materials	Workers that build traditional formwork and lay down decking may face hazards from cuts and punctures from tools or materials.	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Pre-fabricated Slab Formwork System-Using pre-fabricated slab formwork reduces safety risks associated with constructing traditional timber formwork. 2. Pre-fabricated Wall and Column Formwork System-Using pre-fabricated wall and column formwork reduces safety risks associated with constructing traditional timber formwork.
	Construction				Kneeling & Squatting	Working in kneeling or squatting posture while installing and finishing flooring. The cumulative effects of kneeling or squatting may lead to knee injuries such as bursitis or osteoarthritis and in some cases may contribute to low back pain.	Likely	Marginal	Moderate	Mitigate	1. Engineering control:Kneeling Mats-Kneeling mats help displace the pressures and forces when kneeling on the surface. 2. Stake or Post Puller-A stake or post puller removes rebar, stakes, or posts from an upright posture by pushing down on the handle.

CON-10	Construction	Reinforced Concrete	20	Concrete Work-Interior- Footers	Eye injury	Workers who pour, pump, vibrate concrete may face hazards from eye injury.	Unlikely	Significant	Moderate	Mitigate	Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Cuts and punctures from tools or materials	Workers that build traditional formwork and lay down decking may face hazards from cuts and punctures from tools or materials.	Unlikely	Significant	Moderate	Mitigate	1. Engineering control:Pre-fabricated Slab Formwork System-Using pre-fabricated slab formwork reduces safety risks associated with constructing traditional timber formwork. 2. Pre-fabricated Wall and Column Formwork System-Using pre-fabricated wall and column formwork reduces safety risks associated with constructing traditional timber formwork.
	Construction				Kneeling & Squatting	Working in kneeling or squatting posture while installing and finishing flooring. The cumulative effects of kneeling or squatting may lead to knee injuries such as bursitis or osteoarthritis and in some cases may contribute to low back pain.	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Kneeling Mats-Kneeling mats help displace the pressures and forces when kneeling on the surface. 2. Stake or Post Puller-A stake or post puller removes rebar, stakes, or posts from an upright posture by pushing down on the handle.
CON-11	Construction	Reinforced Concrete	21	Concrete Work-Exterior Front	Eye injury	Workers who pour, pump, vibrate concrete may face hazards from eye injury.	Unlikely	Significant	Moderate	Mitigate	Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Cuts and punctures from tools or materials	Workers that build traditional formwork and lay down decking may face hazards from cuts and punctures from tools or materials.	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Pre-fabricated Slab Formwork System-Using pre-fabricated slab formwork reduces safety risks associated with constructing traditional timber formwork. 2. Pre-fabricated Wall and Column Formwork System-Using pre-fabricated wall and column formwork reduces safety risks associated with constructing traditional timber formwork.
	Construction				Kneeling & Squatting	Working in kneeling or squatting posture while installing and finishing flooring. The cumulative effects of kneeling or squatting may lead to knee injuries such as bursitis or osteoarthritis and in some cases may contribute to low back pain.	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Kneeling Mats-Kneeling mats help displace the pressures and forces when kneeling on the surface. 2. Stake or Post Puller-A stake or post puller removes rebar, stakes, or posts from an upright posture by pushing down on the handle.
CON-12	Construction	Masonry, Tile, Cement & Plaster	22	Masonry Repair Work	Fall from heights	Workers who lay or set brick, block, or stone may fall from heights. Falls from heights include worker falls to a lower level which result in injury on impact against an object or the ground.	Likely	Critical	High	Mitigate	1. Engineering control-Automatic Leveler and Stabilizer Extension Ladder. An extension ladder with an automatic leveler and stabilizer requiring only one person to set up. 2. Guardrails-A guardrail with a toprail, midrail, and toeboard, is a fall prevention system that will prevent a worker from falling to a lower level. 3. Ladder Safety Base System-A safety base system that secures an extension ladder up to 60 feet to prevent kick out and reduce lateral movement when used in conjunction with proper ladder techniques. 4. Rolling Ladder- A rolling ladder provides a wider, longer and more stable work platform than a conventional folding ladder.
	Construction				Lifting and Carrying (Manual materials Handling)	Workers who lay or set brick, block, or stone may face hazards from lifting and carrying (manual materials handling).	Unlikely	Marginal	Low	Avoid	1. Substitution-AAC (Aerated Autoclaved Concrete).Aerated autoclaved concrete (AAC) block is a lightweight building material. 2. H-Block-An H-block, or double open-end unit, is open on both ends which increases the space available for rebar and grout. 3. Lightweight Concrete Block,Lightweight concrete blocks are made of expanded aggregate to reduce the density and weight compared to standard concrete blocks.
	Construction				Overhead work	Applying coats of plaster or stucco can lead to shoulder tendonitis and non-specific shoulder pain. Tendonitis occurs when the tendon becomes inflamed. Tension neck syndrome (myofascial pain syndrome) is characterized by pain in the shoulder- neck region along with tenderness over the shoulder-neck muscles. It is one of the most common work-related MSDs of the neck and shoulder.	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Adjustable Tower Scaffold- An adjustable tower scaffold consists of a work platform that moves up and down a vertical truss structure by using a winch drive unit. 2. Aerial and Scissor LiftAn aerial lift, or aerial work platform, is an a mechanical device that provides temporary access to elevated work sites.Bricklaying Robotic System 3. A robotic system that can perform brick- or block-laying operations autonomously. 4. Lift-assist Equipment for Masonry Unit robotic system that aids workers to lift and lay bricks or blocks. 5. Mast Climbing Work Platform-A mast climber consists of a work platform system that moves up and down a vertical truss structure by using a powered drive unit. 6. Rebar Positioning Device-A rebar

	Construction				Skin contact with Portland cement	Workers who lay or set brick, block, or stone may face hazards from skin contact with portland cement.	Likely	Marginal	Moderate	Mitigate	1. Substitution:Mortarless Masonry Wall SystemsA mortarless masonry wall system are made from dry-stacked units that can be subsequently grouted, partially grouted, or surface bonded. 2. Work practice:Protecting Your Skin from Solvents, Adhesives and Other Chemicals 3. Substitution, wearing PPE and good work practice can help protect your skin from solvents, adhesives and other chemicals. 4. Good Work Practices for Working with Cement-Good work practices when working with cement provide tips on how to handle cement.
	Construction				Stressful hand & wrist activity	Workers who lay or set brick, block, or stone may face hazards from stressful hand & wrist activity.	Likely	Marginal	Moderate	Mitigate	1. Substitution:Mortarless Masonry Wall Systems-A mortarless masonry wall system are made from dry-stacked units that can be subsequently grouted, partially grouted, or surface bonded. 2. Engineering control:Bricklaying Robotic System-A robotic system that can perform brick- or block-laying operations autonomously. 3. Ergonomic Hand Tools-Ergonomic hand tools are designed to minimize awkward and forceful hand exertions. 4. Panel Gripper-A panel gripper has two metal plates with rubber grip pads that tighten around the desired material to ease lifting tasks. 5. Lift-assist Equipment for Masonry Unit-A robotic system that aids workers to lift and lay bricks or blocks. 6. Rebar Positioning Device-A rebar positioning device is a precisely shaped wire that allows a bricklayer to place
CON-13	Construction	Frame floors, walls, ceiling, stairs and roofs using wood and/or metal studs and door bucks	23	Framing - Basement to 1st Floor	Eye injury	Welding and plasma, air-arc and flame cutting metal may expose workers to eye hazards that may include: Eye penetration injury from grinding or chipping welds. Thermal burns Radiation injury to the eyes	Likely	Significant	Moderate	Mitigate	Safety Eye Protection- Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Fall from heights	Workers working above ground level may pose a safety hazard and be at risk of falling from heights. The result of such fall can potentially cause fractures, sprains, strains, contusions, severe damage to internal organs and even death.	Likely	Critical	High	Mitigate	1. Engineering control-Automatic Leveler and Stabilizer Extension Ladder 2. An extension ladder with an automatic leveler and stabilizer requiring only one person to set up. 3. Guardrails-A guardrail with a toprail, midrail, and toeboard, is a fall prevention system that will prevent a worker from falling to a lower level. 4.Ladder Safety Base System-A safety base system that secures an extension ladder up to 60 feet to prevent kick out and reduce lateral movement when used in conjunction with proper ladder techniques. 5. Rolling Ladder- A rolling ladder provides a wider, longer and more stable work platform than a conventional folding ladder.
	Construction				Struck by Objects	Workers that frame floors, walls, ceiling, stairs and roofs using wood and/or metal studs and door bucks may face hazards from struck by objects.	Likely	Critical	High	Mitigate	Engineering control- Magnetic Nail Holder-A magnetic nail holder positions a nail while providing a striking surface to cover the fingers and help prevent struck-by injuries while hammering.
CON-14	Construction	Frame floors,	24	Framing -	Eye injury	Welding and plasma, air-arc and flame	Unlikely	Significant	Moderate	Mitigate	Safety Eye Protection- Selecting the
	Construction				Fall from heights	Workers working above ground level may pose a safety hazard and be at risk of falling from heights. The result of such fall can potentially cause fractures, sprains, strains, contusions, severe damage to internal organs and even death.	Likely	Critical	High	Mitigate	1. Engineering control-Automatic Leveler and Stabilizer Extension Ladder 2. An extension ladder with an automatic leveler and stabilizer requiring only one person to set up. 3.Guardrails-A guardrail with a toprail, midrail, and toeboard, is a fall prevention system that will prevent a
	Construction				Struck by Objects	Workers that frame floors, walls, ceiling, stairs and roofs using wood and/or metal studs and door bucks may face hazards from struck by objects.	Likely	Critical	High	Mitigate	1. Engineering control- Magnetic Nail Holder-A magnetic nail holder positions a nail while providing a striking surface to cover the fingers and help prevent struck-by injuries while hammering.
CON-15	Construction	Frame floors, walls, ceiling, stairs and roofs using wood and/or metal studs and door bucks	25	Framing 2nd Floor Deck Reinforcement - Both Sides	Eye injury	Welding and plasma, air-arc and flame cutting metal may expose workers to eye hazards that may include: Eye penetration injury from grinding or chipping welds. Thermal burns Radiation injury to the eyes	Unlikely	Significant	Moderate	Mitigate	Safety Eye Protection- Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Fall from heights	Workers working above ground level may pose a safety hazard and be at risk of falling from heights. The result of such fall can potentially cause fractures, sprains, strains, contusions, severe damage to internal organs and even death.	Likely	Critical	High	Mitigate	1. Engineering control-Automatic Leveler and Stabilizer Extension Ladder 2.An extension ladder with an automatic leveler and stabilizer requiring only one person to set up. 3. Guardrails-A guardrail with a toprail, midrail, and toeboard, is a fall prevention system that will prevent a
	Construction				Struck by Objects	Workers that frame floors, walls, ceiling, stairs and roofs using wood and/or metal studs and door bucks may face hazards from struck by objects.	Likely	Critical	High	Mitigate	Engineering control- Magnetic Nail Holder-A magnetic nail holder positions a nail while providing a striking surface to cover the fingers and help prevent struck-by injuries while hammering.
CON-16	Construction	Frame floors,	26	Framing 2nd	Eye injury	Welding and plasma, air-arc and flame	Likely	Significant	Moderate	Mitigate	Safety Eye Protection- Selecting the

	Construction				Fall from heights	Workers working above ground level may pose a safety hazard and be at risk of falling from heights. The result of such fall can potentially cause fractures, sprains, strains, contusions, severe damage to internal organs and even death.	Likely	Critical	High	Mitigate	1. Engineering control-Automatic Leveler and Stabilizer Extension Ladder 2.An extension ladder with an automatic leveler and stabilizer requiring only one person to set up. 3. Guardrails-A guardrail with a toprail, midrail, and toeboard, is a fall prevention system that will prevent a
	Construction				Struck by Objects	Workers that frame floors, walls, ceiling, stairs and roofs using wood and/or metal studs and door bucks may face hazards from struck by objects.	Likely	Critical	High	Mitigate	Engineering control- Magnetic Nail Holder-A magnetic nail holder positions a nail while providing a striking surface to cover the fingers and help prevent struck-by injuries while hammering.
CON-17	Construction		27	Framing Inspection							
CON-18	Construction	Insulation & Lagging	28	Insulation	Cuts and punctures from tools or materials	Workers that attach insulation with tape, staples, glue, wire and bands may face hazards from cuts and punctures from tools or materials.	Very Unlikely	Negligible	Low	Mitigate	Engineering control:Sequential Nail Guns-Sequential nail guns are pneumatic guns that require the nose of the gun to be depressed before the trigger can be pulled in order to fire.
	Construction				Construction dust	orkers who blow and place insulation may be exposed to construction dust.	Likely	Marginal	Moderate	Mitigate	Personal Protective Equipment:Respiratory Protection Program-A respiratory protection program addresses exposures to airborne dust, engineered nanomaterials, and chemical exposures as well as implementing and evaluating other effective exposure control
	Construction				Exposure to spray polyurethane foam (SPF) chemicals	Workers that blow and place insulation may face hazards from exposure to spray polyurethane foam (spf) chemicals.	Likely	Significant	Moderate	Mitigate	Engineering control:Prototype Spray Polyurethane Foam (SPF) Spraying Booth-The “Prototype SPF spraying booth” reduces exposure to Spray Polyurethane Foam (SPF) by separating the application zone from other parts of the building.
CON-19	Construction		29	Insulation Inspection							
CON-20	Construction	Install plumbing	30	Plumbing Rough-In	Eye injury	Workers who install plumbing may face hazards from eye injury.	Very Unlikely	Marginal	Low	Mitigate	Personal Protective Equipment:Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Kneeling & Squatting	Workers who install plumbing may face hazards from kneeling & squatting.	Very Unlikely	Negligible	Low	Mitigate	Engineering control:Kneeling Mats-Kneeling mats help displace the pressures and forces when kneeling on the surface.
	Construction				Lead	Workers that install plumbing may face hazards from lead.	Unlikely	Significant	Moderate	Mitigate	Lead encapsulating compounds can help prevent lead exposure by sealing the surface of lead-based paint and other coatings.
	Construction				Lifting and Carrying (Manual materials Handling)	Workers who install plumbing may face hazards from lifting and carrying (manual materials handling).	Unlikely	Marginal	Low	Mitigate	Pipe rack carts reduce heavy lifting and carrying by supporting multiple pipes during movement across a variety of surfaces.
	Construction				Overhead work	Workers who install plumbing may face hazards from overhead work.	Likely	Marginal	Moderate	Mitigate	A cabinet jack supports materials during installation on walls including cabinets, sink disposals, crown molding, and pipes.
	Construction				Stressful hand & wrist activity	Workers who install plumbing may face hazards from stressful hand & wrist activity.	Very Unlikely	Marginal	Low	Mitigate	Engineering control:Cordless Electric Adhesive Dispenser-Cordless electric adhesive dispensers (CEADs) are engineering controls that can mitigate musculoskeletal disorders by minimizing required force and repetition of specific tasks.

CON-21	Construction	Install electrical systems	31	Electrical Rough-In	Electrical shocks, burns and/or electrocution	Workers who install electrical systems may be exposed to electrical shocks, burns and/or electrocution.	Likely	Significant	Moderate	Avoid	1. Engineering control:Ground Fault Circuit Interrupter (GFCI)-In case of ground faults on construction sites, GFCIs help reducing electrical accidents and injuries by shutting off electric power immediately. 2. Grounding Mat-Grounding mats, connected to a grounded object, can protect workers from electrocution by providing an equipotential zone. 3. Using Non-conductive Ladders-These ladders prevent the current from the live power lines to reach the worker if the ladder contacts an overhead power line. 4. Ground Ring-To protect buildings and electrical equipment from damages caused by electrical surges, a ring ground could be placed under buildings during construction phase. 6. Surge Protection Device (SPD)-Surge protection devices (when installed properly on power distribution panels)
	Construction				Overhead work	Workers who install electrical systems may face hazards from overhead work.	Likely	Significant	Moderate	Mitigate	Engineering control:Portable Lift Platform-A portable lift platform provides access to elevated worksites and can be transported, assembled, and operated by one person.
	Construction				Stooped postures	Workers who install electrical systems may face hazards from stooped postures.	Very Unlikely	Negligible	Low	Mitigate	Engineering control:Ergonomic Tool Belts-An belt that allows tools to be placed independently on the belt to evenly distribute the weight of the tools and free the hands.
CON-22	Construction	Sheet Metal & HVAC	32	HVAC Rough-In	Eye injury	Workers who install heating and air conditioning duct hangers and ductwork may face hazards from eye injury.	Unlikely	Marginal	Low	Mitigate	Personal Protective Equipment:Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Lifting and Carrying (Manual materials Handling)	Workers who install heating and air conditioning duct hangers and ductwork may face hazards from lifting and carrying (manual materials handling).	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Duct Lift-A duct lift is a lifting device used to raise duct systems to the desired level for installation. 2. Mast Climbing Work Platform-A mast climber consists of a work platform system that moves up and down a vertical truss structure by using a powered drive unit. 3. Vacuum Lifters for Windows and Sheet Materials-A vacuum lifter for windows and sheet materials is a lifting equipment used to handle and position windows and sheet materials. 4. Vacuum Lifting Devices-Vacuum lifting devices allow lifting, maneuvering, moving, and placing large blocks or heavy stones.
	Construction				Overhead work	Workers who install heating and air conditioning duct hangers and ductwork may face hazards from overhead work.	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Aerial and Scissor Lift-An aerial lift, or aerial work platform, is an a mechanical device that provides temporary access to elevated work sites. 2. Drill Bit Extension-Drill bit extensions reduce force at the shoulder and minimizes strain of the arms when drilling overhead. Duct Lift A duct lift is a lifting device used to raise duct systems to the desired level for installation. Ergonomic Hand Tools Ergonomic hand tools are designed to minimize awkward and forceful hand exertions. Extension Poles for Powder-Actuated Tools
	Construction				Welding fumes	Workers who install heating and air conditioning duct hangers and ductwork may be exposed to welding fumes.	Likely	Significant	Moderate	Mitigate	1. Engineering control-Fume Extraction MIG Welding Gun 2. Fume extraction MIG welding guns remove welding fumes at the point of generation. 3. Portable Vacuum Fume Collector without HEPA filtration 4. A portable vacuum fume collector without HEPA filtration is a local exhaust ventilation unit that captures contaminates near the source. 5. Portable Vacuum Fume Collectors with HEPA Filtration-A portable vacuum fume collector with HEPA filtration is a local exhaust ventilation unit that captures contaminants near the source.
CON-23	Construction		33	MEP-Rough-In Inspections							

CON-24	Construction	Move, install and finish drywall or panels	34	Install Drywall	Construction dust	Workers who move, install and finish drywall or panels may be exposed to construction dust.	Likely	Marginal	Moderate	Mitigate	1. Substitution: Pre-fabricated Drywall Pieces-Using pre-fabricated drywall pieces reduces health and safety risks associated with installing and finishing drywall. 2. Engineering control: Wet Drywall Sanding Sponge-A wet drywall sanding sponge is a damp sponge used to sand drywalls while wetting dust particles.
	Construction				Cuts and punctures from tools or materials	Workers that move, install and finish drywall or panels may face hazards from cuts and punctures from tools or materials.	Very Unlikely	Negligible	Low	Avoid	1. Substitution: Pre-fabricated Drywall Pieces-Using pre-fabricated drywall pieces reduces health and safety risks associated with installing and finishing drywall. 2. Engineering control:Glass Panel Cart- A glass panel cart can help reduce risks from manual handling glass panels. 3. Sequential Nail Guns:Sequential nail guns are pneumatic guns that require the nose of the gun to be depressed before the trigger can be pulled in order to fire.
	Construction				Eye injury	Workers who move, install and finish drywall or panels may face hazards from eye injury.	Unlikely	Marginal	Low	Mitigate	1. Personal Protective Equipment-Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Lifting and Carrying (Manual materials Handling)	Workers who move, install and finish drywall or panels may face hazards from lifting and carrying (manual materials handling).	Likely	Marginal	Moderate	Mitigate	1. Substitution:Lightweight Drywall Panels-Lightweight drywall panels weigh less than standard panels used in residential and commercial construction. 2. Engineering control-Door Dolly-A door dolly moves doors or other materials around a worksite without
	Construction				Overhead work	Workers who move, install and finish drywall or panels may face hazards from overhead work.	Unlikely	Significant	Moderate	Mitigate	1. Engineering control:Drywall Jack-A drywall jack props and supports drywall sheet panels during ceiling installations. 2. Drywall Lift-A drywall lift is a mobile hoist that lifts and positions sheetrock. 3. Pneumatic Drywall Finishing System 4. A pneumatic drywall finishing system
	Construction				Stooped postures	Workers who move, install and finish drywall or panels may face hazards from stooped postures.	Unlikely	Marginal	Low	Mitigate	Engineering control:Ergonomic Tool Belts-An belt that allows tools to be placed independently on the belt to evenly distribute the weight of the tools and free the hands.
	Construction				Stressful hand & wrist activity	Workers that move, install and finish drywall or panels may face hazards from stressful hand & wrist activity.	Likely	Marginal	Moderate	Mitigate	1. Substitution-Pre-fabricated Drywall Pieces-Using pre-fabricated drywall pieces reduces health and safety risks associated with installing and finishing drywall. 2. Engineering control:Glass Panel Cart-A glass panel cart can help reduce risks from manual handling glass panels.
CON-25	Construction	Paint interior and exterior walls, ceilings, trim, etc.	35	Painting	Fall from heights	Workers that paint interior and exterior walls, ceilings, trim, etc. may face hazards from fall from heights.	Likely	Critical	High	Mitigate	1. Engineering control:Corner Ladder Stabilizer-A corner ladder stabilizer can help improve ladder stability when working on the corner of a building structure. 2. Extension Ladder Securing Device-An extension ladder securing device is an attachment that can help improve
	Construction				Lead	Workers that paint interior and exterior walls, ceilings, trim, etc. may face hazards from lead.	Unlikely	Significant	Moderate	Mitigate	Lead encapsulating compounds can help prevent lead exposure by sealing the surface of lead-based paint and other coatings.
	Construction				Overhead work	Workers who paint interior and exterior walls, ceilings, trim, etc. may face hazards from overhead work.	Unlikely	Significant	Moderate	Mitigate	1. Engineering control:Aerial and Scissor Lift-An aerial lift, or aerial work platform, is an a mechanical device that provides temporary access to elevated work sites. 2. Portable Lift Platform-A portable lift platform provides access to elevated worksites and can be transported,
	Construction				Skin contact with paint-related solvents	Workers who paint interior and exterior walls, ceilings, trim, etc. may face hazards from skin contact with paint-related solvents. Some of the most commonly used solvents for paints are aliphatic hydrocarbons or other petroleum distillates.	Likely	Marginal	Moderate	Mitigate	1. Work practice:Protecting Your Skin from Solvents, Adhesives and Other Chemicals 2. Substitution, wearing PPE and good work practice can help protect your skin from solvents, adhesives and other chemicals.
	Construction				Stressful hand & wrist activity	Workers who paint interior and exterior walls, ceilings, trim, etc. may face hazards from stressful hand & wrist activity.	Likely	Marginal	Moderate	Mitigate	1. Engineering control:Bucket Dolly-A bucket dolly is a cart that allows workers to roll buckets and their contents reducing the need to lift and carry. 2. Ergonomic Hand Tools-Ergonomic hand tools are designed to minimize awkward and forceful hand exertions.
CON-26	Construction	Install doors, windows, attic access and associated hardware	36	Remove/Repair/Reinstall windows	Cuts and punctures from tools or materials	Workers that install doors, windows, attic access and associated hardware may face hazards from cuts and punctures from tools or materials.	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Glass Panel Cart- A glass panel cart can help reduce risks from manual handling glass panels. 2. Sequential Nail Guns-Sequential nail guns are pneumatic guns that require the nose of the gun to be depressed before the trigger can be pulled in order to fire.
	Construction				Eye Injury	Workers who install doors, windows, attic access and associated hardware may face hazards from eye injury.	Unlikely	Significant	Moderate	Mitigate	Personal Protective Equipment-Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.

	Construction				Lifting and Carrying (Manual materials Handling)	Workers who install doors, windows, attic access and associated hardware may face hazards from lifting and carrying (manual materials handling).	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Door Dolly-A door dolly moves doors or other materials around a worksite without lifting and carrying. 2. Door Installation Lever-The door installation lever is a manual lever that lifts doors to a convenient height to insert hinge pins while hanging doors. 3.Door Installation Cart-A door installation cart is a dolly that transports and holds doors in place during door installation. 4.Glass Panel Cart-A glass panel cart can help reduce risks from manual handling glass panels. 5. Window Hoists-Window Hoists are manual lifts that helps hoist windows and frames during installation.
	Construction				Overhead work	Workers that install doors, windows, attic access and associated hardware may face hazards from overhead work.	Likely	Marginal	Moderate	Mitigate	1. Engineering control:Adjustable Work Stand-This functions as a workstation with adjustable legs that improves stability on uneven ground. 2. Portable Lift Platform-A portable lift platform provides access to elevated worksites and can be transported, assembled, and operated by one
	Construction				Wood dust	Workers that install doors, windows, attic access and associated hardware may face hazards from wood dust.	Unlikely	Marginal	Low	Mitigate	Hand-held Wood working tool with Vacuum Dust Control
CON-27	Construction	Install doors, windows, attic access and associated hardware	37	Set New Doors	Cuts and punctures from tools or materials	Workers that install doors, windows, attic access and associated hardware may face hazards from cuts and punctures from tools or materials.	Likely	Significant	Moderate	Mitigate	1. Engineering control:Glass Panel Cart- A glass panel cart can help reduce risks from manual handling glass panels. 2. Sequential Nail Guns-Sequential nail guns are pneumatic guns that require the nose of the gun to be depressed before the trigger can be pulled in order to fire.
	Construction				Eye Injury	Workers who install doors, windows, attic access and associated hardware may face hazards from eye injury.	Likely	Significant	Moderate	Mitigate	Personal Protective Equipment-Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Lifting and Carrying (Manual materials Handling)	Workers who install doors, windows, attic access and associated hardware may face hazards from lifting and carrying (manual materials handling).	Unlikely	Marginal	Low	Mitigate	1.Engineering control:Door Dolly-A door dolly moves doors or other materials around a worksite without lifting and carrying. 2. Door Installation Lever-The door installation lever is a manual lever that lifts doors to a convenient height to insert hinge pins while hanging doors.
	Construction				Overhead work	Workers that install doors, windows, attic access and associated hardware may face hazards from overhead work.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control-Adjustable Work Stand-This functions as a workstation with adjustable legs that improves stability on uneven ground. 2. Portable Lift Platform-A portable lift platform provides access to elevated worksites and can be transported, assembled, and operated by one
	Construction				Wood dust	Workers that install doors, windows, attic access and associated hardware may face hazards from wood dust.	Unlikely	Marginal	Low	Mitigate	Hand-held Wood working tool with Vacuum Dust Control
CON-28	Construction		38	Start-up New Furnaces	Eye injury	Workers who install heating and air conditioning duct hangers and ductwork may face hazards from eye injury.	Very Unlikely	Significant	Low	Mitigate	Personal Protective Equipment Safety Eye Protection Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Lifting and Carrying (Manual materials Handling)	Workers who install heating and air conditioning duct hangers and ductwork may face hazards from lifting and carrying (manual materials handling).	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control: Duct Lift-A duct lift is a lifting device used to raise duct systems to the desired level for installation. 2. Mast Climbing Work Platform-A mast climber consists of a work platform system that moves up and down a vertical truss structure by using a
	Construction				Welding fumes	Workers who install heating and air conditioning duct hangers and ductwork may be exposed to welding fumes.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control-Fume Extraction MIG Welding Gun 2. Fume extraction MIG welding guns remove welding fumes at the point of generation. 3. Portable Vacuum Fume Collector without HEPA filtration-A portable vacuum fume collector without HEPA
CON-29	Construction	Install and maintain fixtures, lights, motors and pumps	39	Trim-work Electrical Fixtures/Outlets	Construction dust	Workers who install and maintain fixtures, lights, motors and pumps may be exposed to construction dust.	Likely	Marginal	Moderate	Mitigate	1. Work Box Cutter Drill Attachment with Vacuum Dust Control- A work box cutter is a drill attachment that cuts square or rectangular openings in drywall for the installation of outlets, light switches, and low voltage mud rings.
	Construction				Cuts and punctures from tools or materials	Workers that install and maintain fixtures, lights, motors and pumps may face hazards from cuts and punctures from tools or materials.	Likely	Marginal	Moderate	Mitigate	1. Engineering control: Dual-trigger Portable Band Saw-A band saw designed with dual triggers to prevent unintended power activation as well as provide ergonomic benefits.

	Construction				Electrical shocks, burns and/or electrocution	Workers that install and maintain fixtures, lights, motors and pumps may face hazards from electrical shocks, burns and/or electrocution.	Unlikely	Significant	Moderate	Avoid	1. Engineering control: Grounding Mat-Grounding mats, connected to a grounded object, can protect workers from electrocution by providing an equipotential zone. 2. Work practice-Lock Out Tag Out-LOTO devices reduce the risk of an unexpected equipment start-up by ensuring that an unauthorized worker cannot energize that equipment.
	Construction				Eye injury	Workers who install and maintain fixtures, lights, motors and pumps may face hazards from eye injury.	Unlikely	Significant	Moderate	Mitigate	1. Personal Protective Equipment:Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Fall from heights	Workers that install and maintain fixtures, lights, motors and pumps may face hazards from fall from heights.	Likely	Significant	Moderate	Mitigate	1. Engineering control: Ladder Safety Base System-A safety base system that secures an extension ladder up to 60 feet to prevent kick out and reduce lateral movement when used in conjunction with proper ladder techniques.
	Construction				Overhead work	Workers who install and maintain fixtures, lights, motors and pumps may face hazards from overhead work.	Unlikely	Marginal	Low	Mitigate	1. Engineering control: Aerial and Scissor Lift-An aerial lift, or aerial work platform, is an a mechanical device that provides temporary access to elevated work sites. 2. Drill Bit Extension-Drill bit extensions reduce force at the shoulder and minimizes strain of the arms when drilling overhead. 3. Overhead Drilling-An overhead drill press allows the upper arms to be held below the shoulder for a more comfortable posture during overhead drilling. 4. Portable Lift Platform-A portable lift platform provides access to elevated worksites and can be transported, assembled, and operated by one person. 5. Puller Attachment for Cordless Drill-Puller attachment for a cordless drill is a hand-held equipment that provides a constant mechanical pulling force for
	Construction				Stressful hand & wrist activity	Workers who install and maintain fixtures, lights, motors and pumps may face hazards from stressful hand & wrist activity.	Unlikely	Negligible	Low	Mitigate	1. Engineering control: Electronic Cable Cutter-An electronic cable cutter is an electronic tool that cuts cables and wires during installation and removal of cable and wire materials. 2. Ergonomic Hand Tools-Ergonomic hand tools are designed to minimize awkward and forceful hand exertions. 3. Puller Attachment for Cordless Drill-Puller attachment for a cordless drill is a hand-held equipment that provides a constant mechanical pulling force for cables and wires. 4. Tool Handle Wraps-A tool handle wrap is a viscoelastic material tape wrapped around a tool handle to damp vibration. 5. Work Box Cutter Drill Attachment with Vacuum Dust Control-A work box cutter is a drill attachment that cuts square or rectangular openings in drywall for the installation of outlets, light switches, and low voltage mud
CON-30	Construction	Install floor coverings and carpet	40	Install Flooring	Cuts and punctures from tools or materials	Workers that install floor coverings and carpet may face hazards from cuts and punctures from tools or materials.	Likely	Marginal	Moderate	Mitigate	1. Sequential nail guns are pneumatic guns that require the nose of the gun to be depressed before the trigger can be pulled in order to fire. 2. A twin blade circular saw uses two counter-rotating blades to reduce kickback.
	Construction				Eye injury	Workers who install floor coverings and carpet may face hazards from eye injury.	Very Unlikely	Negligible	Low	Mitigate	1.Personal Protective Equipment-Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Kneeling & Squatting	Workers who install floor coverings and carpet may face hazards from kneeling & squatting.	Very Likely	Significant	High	Mitigate	1.Engineering control:Kneeling Creepers-A kneeling creeper is a mobile platform that displaces pressure from kneeling and reduces the need for constant kneeling and squatting. 2. Kneeling Mats-Kneeling mats help displace the pressures and forces when kneeling on the surface.
	Construction				Lifting and Carrying (Manual materials Handling)	Workers who install floor coverings and carpet may face hazards from lifting and carrying (manual materials handling).	Likely	Significant	Moderate	Mitigate	1. Engineering control-Powered Hand Trucks-Powered hand trucks enable one or two workers to move heavy loads with minimal effort across worksites and up and down stairs.
	Construction				Stooped postures	Workers who install floor coverings and carpet may face hazards from stooped postures.	Very Likely	Significant	High	Mitigate	1. Engineering control:Ergonomic Tool Belts-An belt that allows tools to be placed independently on the belt to evenly distribute the weight of the tools and free the hands. 2. Standing Fastening Tool-A fastening tool, or power-actuated fastening tool with an extension shaft, allows workers to secure flooring while standing.

	Construction				Stressful hand & wrist activity	Workers who install floor coverings and carpet may face hazards from stressful hand & wrist activity.	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Ergonomic Hand Tools-Ergonomic hand tools are designed to minimize awkward and forceful hand exertions. 2. Fans, Misters and Air Conditioning Units-Fans, misters and air conditioning units are engineering controls that can be used to reduce the incidence of heat-related illnesses by cooling workers while they work or rest. 3. Moldable Tool Grips-A moldable tool grip is a pliable material that can be customized to a tool to decrease the contact stress between the hand and tool.
CON-31	Construction	Install plumbing	41	Install Plumbing fixtures	Eye injury	Workers who install plumbing may face hazards from eye injury.	Very Unlikely	Negligible	Low	Mitigate	1. Personal Protective Equipment-Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Kneeling & Squatting	Workers who install plumbing may face hazards from kneeling & squatting.	Likely	Marginal	Moderate	Mitigate	1. Engineering control: Kneeling Mats-Kneeling mats help displace the pressures and forces when kneeling on the surface.
	Construction				Lead	Workers that install plumbing may face hazards from lead.	Very Unlikely	Negligible	Low	Avoid	Hand-held XRF Analyzers provide real-time estimates of the concentration of lead and other metals in solid materials without the need for scraping, sample collection, or lab analysis.
	Construction				Lifting and Carrying (Manual materials Handling)	Workers who install plumbing may face hazards from lifting and carrying (manual materials handling).	Very Unlikely	Negligible	Low	Mitigate	Pipe rack carts reduce heavy lifting and carrying by supporting multiple pipes during movement across a variety of surfaces.
	Construction				Overhead work	Workers who install plumbing may face hazards from overhead work.	Very Unlikely	Negligible	Low	Mitigate	A cabinet jack supports materials during installation on walls including cabinets, sink disposals, crown molding, and pipes.
	Construction				Stressful hand & wrist activity	Workers who install plumbing may face hazards from stressful hand & wrist activity.	Unlikely	Marginal	Low	Mitigate	1. Engineering control-Cordless Electric Adhesive Dispenser-Cordless electric adhesive dispensers (CEADs) are engineering controls that can mitigate musculoskeletal disorders by minimizing required force and repetition of specific tasks. 2.Ergonomic Hand Tools-Ergonomic hand tools are designed to minimize awkward and forceful hand exertions. 3. Pipe Wrench Stand-A pipe wrench stand is a small vice-like device that holds one pipe wrench firmly in place. 4. Tool Handle Wraps-A tool handle wrap is a viscoelastic material tape wrapped around a tool handle to damp vibration.
CON-32	Construction		42	Trim Install	Cuts and punctures from tools or materials	Workers that install cabinets, countertops and moldings may face hazards from cuts and punctures from tools or materials.	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Sequential Nail Guns-Sequential nail guns are pneumatic guns that require the nose of the gun to be depressed before the trigger can be pulled in order to fire. 2. Twin Blade Circular Saw-A twin blade circular saw uses two counter-rotating blades to reduce kickback.
	Construction				Eye injury	Workers who install cabinets, countertops and moldings may face hazards from eye injury.	Unlikely	Marginal	Low	Mitigate	Personal Protective Equipment:Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Kneeling & Squatting	Workers that install cabinets, countertops and moldings may face hazards from kneeling & squatting.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control: Cabinet Jack-A cabinet jack supports materials during installation on walls including cabinets, sink disposals, crown molding, and pipes. 2. Drywall Jack-A drywall jack props and supports drywall sheet panels during ceiling installations.
	Construction				Lifting and Carrying (Manual materials Handling)	Workers who install cabinets, countertops and moldings may face hazards from lifting and carrying (manual materials handling).	Likely	Marginal	Moderate	Mitigate	1. Engineering control:Cabinet Jack-A cabinet jack supports materials during installation on walls including cabinets, sink disposals, crown molding, and pipes. 2. Cabinet Lifting Device-A cabinet lifting device transports and lifts and holds cabinets at various heights for easy installation. 3. Door Dolly-A door dolly moves doors or other materials around a worksite without lifting and carrying. 4. Drywall Jack-A drywall jack props and supports drywall sheet panels during ceiling installations. 5. Granite Countertop Dolly-A granite countertop dolly can be used to easily move granite slabs over a variety of surfaces and up stairs. 6. Multiple Panel Slab Cart-A multiple panel slab cart can be used to easily transport a variety of slabs at once. 7. Vacuum Lifting Devices-Vacuum

	Construction				Overhead work	Workers who install cabinets, countertops and moldings may face hazards from overhead work.	Likely	Marginal	Moderate	Mitigate	1. Engineering control-Cabinet Jack:A cabinet jack supports materials during installation on walls including cabinets, sink disposals, crown molding, and pipes. 2. Cabinet Lifting Device-A cabinet lifting device transports and lifts and holds cabinets at various heights for easy installation. 3. Drywall Jack-A drywall jack props and supports drywall sheet panels during ceiling installations. 4. Upper Limb Exoskeletons-Upper limb exoskeletons are engineering controls that can reduce musculoskeletal disorders (MSDs) of shoulders and arms by relocating the burden of hand tools on a worker's body in overhead tasks.
	Construction				Stooped postures	Workers who install cabinets, countertops and moldings may face hazards from stooped postures.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control:Cabinet Lifting Device-A cabinet lifting device transports and lifts and holds cabinets at various heights for easy installation. 2. Ergonomic Tool Belts-An belt that allows tools to be placed independently on the belt to evenly distribute the weight of the tools and free the hands.
	Construction				Stressful hand & wrist activity	Workers that install cabinets, countertops and moldings may face hazards from stressful hand & wrist activity.	Unlikely	Negligible	Low	Mitigate	1. Engineering control-Compact Circular Saw-The compact circular saw is smaller and lighter than a conventional circular saw. 2. Cordless Electric Adhesive Dispenser-Cordless electric adhesive dispensers (CEADs) are engineering controls that can mitigate musculoskeletal disorders by minimizing required force and repetition of specific tasks. 3. Granite Countertop Dolly-A granite countertop dolly can be used to easily move granite slabs over a variety of surfaces and up stairs. 4.Multiple Panel Slab Cart-A multiple panel slab cart can be used to easily transport a variety of slabs at once.
	Construction				Wood dust	Workers that install cabinets, countertops and moldings may face hazards from wood dust.	Unlikely	Marginal	Low	Mitigate	1.Engineering control:Hand-held Wood Routers with Vacuum Dust Control-A vacuum dust control for hand-held wood routers is a dust capture device that reduces airborne wood dust during wood routing operations. 2. Reciprocating Saws with Vacuum Dust Control-A vacuum dust control for reciprocating saws is a dust capture and control system that reduces airborne dust during cutting operations.
CON-33	Construction	Paints & Coatings	43	Painting and Finishes Point up	Fall from heights	Workers that paint interior and exterior walls, ceilings, trim, etc. may face hazards from fall from heights.	Unlikely	Significant	Moderate	Mitigate	1. Engineering control:Corner Ladder Stabilizer-A corner ladder stabilizer can help improve ladder stability when working on the corner of a building structure. 2. Extension Ladder Securing Device-An extension ladder securing device is an attachment that can help improve ladder stability by clipping to a variety of surfaces on a stable structure. 3. Ladder Safety Base System-A safety base system that secures an extension ladder up to 60 feet to prevent kick out and reduce lateral movement when used in conjunction with proper ladder techniques. 4. Portable Lift Platform-A portable lift platform provides access to elevated worksites and can be transported, assembled, and operated by one person.
	Construction				Lead	Workers that paint interior and exterior walls, ceilings, trim, etc. may face hazards from lead.	Very Unlikely	Negligible	Low	Mitigate	Lead encapsulating compounds can help prevent lead exposure by sealing the surface of lead-based paint and other coatings.
	Construction				Overhead work	Workers who paint interior and exterior walls, ceilings, trim, etc. may face hazards from overhead work.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control:Aerial and Scissor Lift-An aerial lift, or aerial work platform, is an a mechanical device that provides temporary access to elevated work sites. 2. Portable Lift Platform-A portable lift platform provides access to elevated worksites and can be transported, assembled, and operated by one person. 3. Portable Mini Scaffold-A portable mini scaffold provides painters with a larger elevated base than a conventional stepladder. 4. Upper Limb Exoskeletons-Upper limb exoskeletons are engineering controls that can reduce musculoskeletal disorders (MSDs) of shoulders and arms by relocating the burden of hand tools on a worker's body in overhead tasks.
	Construction				Skin contact with paint-related solvents	Workers who paint interior and exterior walls, ceilings, trim, etc. may face hazards from skin contact with paint-related solvents. Some of the most commonly used solvents for paints are aliphatic hydrocarbons or other petroleum distillates.	Likely	Marginal	Moderate	Mitigate	1. Work practice-Protecting Your Skin from Solvents, Adhesives and Other Chemicals 2. Substitution, wearing PPE and good work practice can help protect your skin from solvents, adhesives and other chemicals.

	Construction				Stressful hand & wrist activity	Workers who paint interior and exterior walls, ceilings, trim, etc. may face hazards from stressful hand & wrist activity.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control-Bucket Dolly-A bucket dolly is a cart that allows workers to roll buckets and their contents reducing the need to lift and carry. 2. Ergonomic Hand Tools-Ergonomic hand tools are designed to minimize awkward and forceful hand exertions. 3. Ergonomic Paint Applicators-Ergonomic paint applicators are paintbrush and roller handles that are designed to allow painting with a more neutral position of the hand and wrist. 4. Tool Handle Wraps-A tool handle wrap is a viscoelastic material tape wrapped around a tool handle to damp vibration.
CON-44	Construction	Apply coats of plaster or stucco	44	Stucco Work	Eye injury	Workers who apply coats of plaster or stucco may face hazards from eye injury.	Very Unlikely	Negligible	Low	Mitigate	Personal Protective Equipment:Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Fall from heights	Workers who apply coats of plaster or stucco, especially while walking on stilts, may fall from heights. Falls from heights include worker falls to a lower level which result in injury on impact against an object or the ground.	Unlikely	Significant	Moderate	Mitigate	Engineering control:Rolling Ladder-A rolling ladder provides a wider, longer and more stable work platform than a conventional folding ladder.
	Construction				Overhead work	Workers who apply coats of plaster or stucco may face hazards from overhead work.	Unlikely	Marginal	Low	Mitigate	1. Engineering control:Adjustable Tower Scaffold-An adjustable tower scaffold consists of a work platform that moves up and down a vertical truss structure by using a winch drive unit. 2. Aerial and Scissor Lift-An aerial lift, or aerial work platform, is an a mechanical device that provides temporary access to elevated work sites. 3. Rolling Ladder-A rolling ladder provides a wider, longer and more stable work platform than a conventional folding ladder. 4. Upper Limb Exoskeletons-Upper limb exoskeletons are engineering controls that can reduce musculoskeletal disorders (MSDs) of shoulders and arms by relocating the burden of hand tools on a worker's body in overhead tasks.
	Construction				Stressful hand & wrist activity	Workers who apply coats of plaster or stucco may face hazards from stressful hand & wrist activity.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control-Easy-Hold Glove for Mud Pans-An easy-hold glove is a tight-fitting glove attached to a mud pan. 2. Ergonomic Hand Tools-Ergonomic hand tools are designed to minimize awkward and forceful hand exertions. 3. Rubberized Handle Trowels-A rubberized handle trowel is a tool with a rubber grip that smooth, spread and finish concrete.
	Construction				Stooped postures	Workers who apply coats of plaster or stucco may face hazards from stooped postures.	Unlikely	Marginal	Low	Mitigate	Engineering control:Mortar Stand-A mortar stand is a base that supports a board or pan to mix mortar at the waist level.
CON-45	Construction	Paints & Coatings	45	Paint Exterior Steel	Eye injury	Workers who paint machinery, piping, signs, etc. may face hazards from eye injury.	Very Unlikely	Negligible	Low	Mitigate	Personal Protective Equipment-Safety Eye Protection-Selecting the appropriate safety eye protection for your environment, the specific type of work and its potential hazards is critical.
	Construction				Fall from heights	Workers that paint machinery, piping, signs, etc. may face hazards from fall from heights.	Unlikely	Significant	Moderate	Mitigate	1. Engineering control:Ladder Safety Base System-A safety base system that secures an extension ladder up to 60 feet to prevent kick out and reduce lateral movement when used in conjunction with proper ladder techniques. 2. Portable Lift Platform-A portable lift platform provides access to elevated worksites and can be transported, assembled, and operated by one person.
	Construction				Kneeling & Squatting	Workers who paint machinery, piping, signs, etc. may face hazards from kneeling & squatting.	Very Unlikely	Negligible	Low	Mitigate	1. Engineering control:Kneeling Creepers-A kneeling creeper is a mobile platform that displaces pressure from kneeling and reduces the need for constant kneeling and squatting. 2. Kneeling Mats-Kneeling mats help displace the pressures and forces when kneeling on the surface.
	Construction				Lead	Workers that paint machinery, piping, signs, etc. may face hazards from lead.	Very Unlikely	Negligible	Low		Lead encapsulating compounds can help prevent lead exposure by sealing the surface of lead-based paint and other coatings.

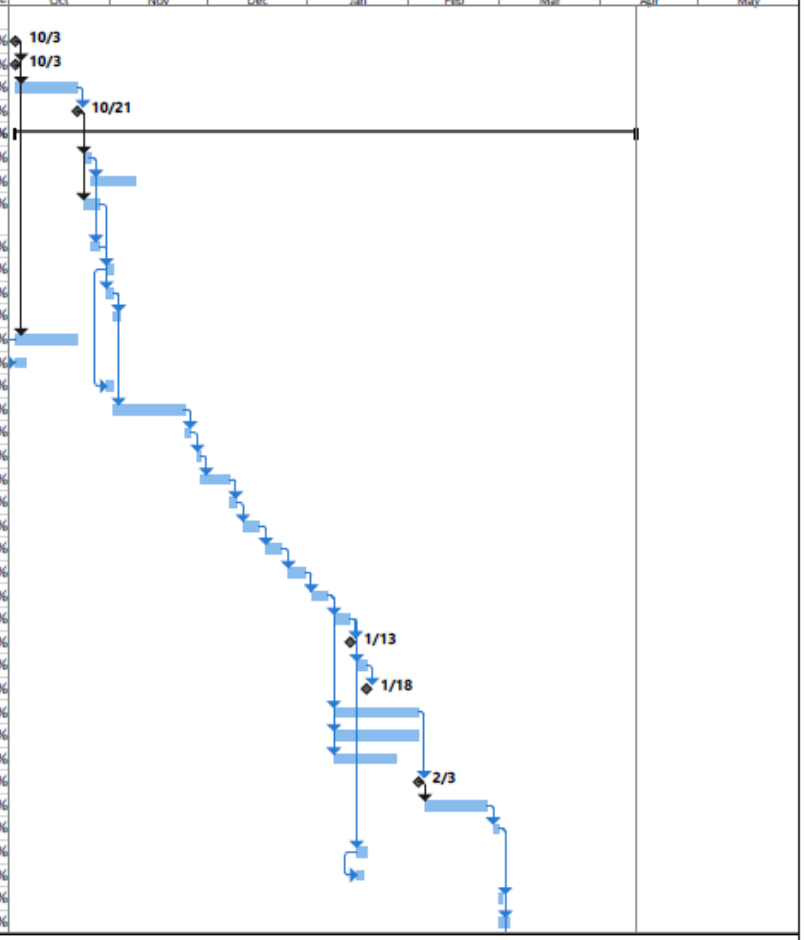
	Construction				Overhead work	Workers who paint machinery, piping, signs, etc. may face hazards from overhead work.	Very Unlikely	Negligible	Low		1. Engineering control:Adjustable Work Stand-This functions as a workstation with adjustable legs that improves stability on uneven ground. 2. Extension Poles for Powder-Actuated Tools-A fixed height or modular extension pole attached to a powder-actuated tool can reduce the risk of serious shoulder, arm, and hand injuries. 3. Portable Lift Platform-A portable lift platform provides access to elevated worksites and can be transported, assembled, and operated by one person.
	Construction				Stressful hand & wrist activity	Workers who paint machinery, piping, signs, etc. may face hazards from stressful hand & wrist activity.	Very Unlikely	Negligible	Low		1. Engineering control:Bucket Dolly-A bucket dolly is a cart that allows workers to roll buckets and their contents reducing the need to lift and carry. 2. Ergonomic Hand Tools-Ergonomic hand tools are designed to minimize awkward and forceful hand exertions. 3. Ergonomic Paint Applicators-Ergonomic paint applicators are paintbrush and roller handles that are designed to allow painting with a more neutral position of the hand and wrist.
CON-46	Construction		46	Punchlist							

Appendix C- MS Project Schedule

22-017 MSU Scan - Hypo Project Schedule FSOO

TRIDENT BUILDERS

ID	Task Mode	Task Name	Duration	Start	Finish	Predecess	% Complete
1							
2		Execute Contract	0 days	Mon 10/3/22	Mon 10/3/22		0%
3		Permit / Connection Requests	0 days	Mon 10/3/22	Mon 10/3/22	2	0%
4		Mobilization Deposit	15 days	Mon 10/3/22	Fri 10/21/22	2	0%
5		Notice to Proceed	0 days	Fri 10/21/22	Fri 10/21/22	4	0%
6		**CONSTRUCTION**	**137 days**	**Mon 10/3/22**	**Tue 4/11/23**		0%
7		Mobilization	2 days	Mon 10/24/2	Tue 10/25/22	5	0%
8		Utility- New Waste Line	10 days	Wed 10/26/2	Tue 11/8/22	7	0%
9		Demolition of Interior Walls / Stairs / Joists to Allow Access	5 days	Mon 10/24/22	Fri 10/28/22	5	0%
10		Lead Abatement - Front	3 days	Wed 10/26/2	Fri 10/28/22	7	0%
11		Paint Front Brick	2 days	Mon 10/31/2	Tue 11/1/22	10	0%
12		Frame Up Stair Landing - Temp by Trident	2 days	Mon 10/31/2	Tue 11/1/22	9	0%
13		Install Electrical Panel	2 days	Wed 11/2/22	Thu 11/3/22	12	0%
14		BGE - ELECTRIC HOOK UP	15 days	Mon 10/3/22	Fri 10/21/22	3	0%
15		BGE - Gas Meter Relocation	3 days	Mon 10/3/22	Wed 10/5/22	14SS	0%
16		Fix Cornice	2 days	Mon 10/31/2	Tue 11/1/22	11SS	0%
17		Repair Steel Stairs in Rear	16 days	Wed 11/2/22	Wed 11/23/2	12	0%
18		Masonry Infill work	2 days	Thu 11/24/22	Fri 11/25/22	17	0%
19		Concrete Work - Exterior Rear	1 day	Mon 11/28/2	Mon 11/28/2	18	0%
20		Concrete Work - Interior - Footers (include Inspections	7 days	Tue 11/29/22	Wed 12/7/22	19	0%
21		Concrete Work - Exterior Front	2 days	Thu 12/8/22	Fri 12/9/22	20	0%
22		Masonry Repair Work	5 days	Mon 12/12/2	Fri 12/16/22	21	0%
23		Framing - Basement to 1st Floor	5 days	Mon 12/19/2	Fri 12/23/22	22	0%
24		Framing - Walls 1st Floor Both Sides	5 days	Mon 12/26/2	Fri 12/30/22	23	0%
25		Framing 2nd Floor Deck Reinforcement - Both Sides	5 days	Mon 1/2/23	Fri 1/6/23	24	0%
26		Framing 2nd Floor Walls & Ceiling Work	5 days	Mon 1/9/23	Fri 1/13/23	25	0%
27		Framing Inspection	0 days	Fri 1/13/23	Fri 1/13/23	26	0%
28		Insulation	3 days	Mon 1/16/23	Wed 1/18/23	26	0%
29		Insulation Inspection	0 days	Wed 1/18/23	Wed 1/18/23	28	0%
30		Plumbing Rough-in	20 days	Mon 1/9/23	Fri 2/3/23	25	0%
31		Electrical Rough-in	20 days	Mon 1/9/23	Fri 2/3/23	25	0%
32		HVAC Rough-in	15 days	Mon 1/9/23	Fri 1/27/23	25	0%
33		MEP Rough-In Inspections	0 days	Fri 2/3/23	Fri 2/3/23	30	0%
34		Hang, Mud, and Finish Drywall	15 days	Mon 2/6/23	Fri 2/24/23	33	0%
35		Painting	2 days	Mon 2/27/23	Tue 2/28/23	34	0%
36		Remove / Repair / Reinstall Windows	3 days	Mon 1/16/23	Wed 1/18/23	26	0%
37		Set New Doors	2 days	Mon 1/16/23	Tue 1/17/23	36SS	0%
38		Start up Furnaces	1 day	Wed 3/1/23	Wed 3/1/23	35	0%
39		Trim Out - Electrical Fixtures, Outlets, & Switches	3 days	Wed 3/1/23	Fri 3/3/23	35	0%



Page 1

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