CREATING A SAFETY DASHBOARD FOR CONSTRUCTION SITE RISK ANALYSIS AND MANAGEMENT

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CHAPTER 1: INTRODUCTION

Identifying, assessing, and prioritizing potential risks is a crucial aspect of success within an organization. Without risk management, organizations could potentially incur losses greater than those caused directly by the risk itself. If safety observations are in an indistinguishable table of data, it can be hard to differentiate between the observations that require immediate attention and those that can be addressed at a later time with a lower priority.

PIMSHQ is a project information management system with various software products to help organizations manage and collect data. Within their scope of products, they handle a software called PIMS Safety. “PIMS Safety is a hosted SaaS (Software as a Service) application created to help clients effectively manage and report on their safety program.” (PIMS Safety, 2022). Currently, PIMS Safety is storing more than a million records involving safety observations around a construction site that may be deemed risky to an organization. This data is stored but not thoroughly analyzed.

Analyzing data associated with risk and observations can help mitigate future occurrences of unsafe events. By building a tool to easily analyze data at a glance, safety personnel can advise their colleagues of potential location of a more severe event to occur. Environmental factors are taken into consideration for extreme conditions that can result in extreme consequences. Prevention and mitigation measures should be taken when there is an anomaly from past trends.

For my capstone project, I determined how the observation data PIMS Safety collects can be leveraged for a company’s construction site in a way that prevents and mitigates risk. The remainder of this document serves as the series of decisions and logical reasoning made to leverage the observation data PIMS Safety collects to prevent and mitigate future risk.

Guiding Project Question: *How can the observation data PIMS Safety collects be leveraged for a company's construction site in a way that prevents and mitigates risk?*

CHAPTER 2: PURPOSE

According to the National Safety Council (NSC) (2020), in 2020 on average, the total cost of work injuries equates to $163.9 billion, and $1.3 million per death. The NSC also reports that if an injury needed to be medically consulted, the average cost comes out to be $44,000 per injury, and a reported 55.4 million injuries. In addition, the National Equipment Register (NER) (2015) reports that the annual “cost of equipment theft vary from $300 million to $1 billion,” and "the average estimated value of a stolen piece of equipment is $26,765.” An analysis of safety data provides monitoring of safety-related data, which allows for prompt identification and response before they escalate into more serious incidents. Examples of such data include:

- incidents - an event that would result in injury, damage, or loss
- injuries - physical harm that occurs as a result of an incident
- near-misses – “a specific unplanned event/s (energy released) or work-related incident that had the potential to cause harm to an individual but no harm to an individual occurred. Potential or actual damage to equipment, environment, or property could/did occur during the event” (Appendix A)
- good catches - “a specific observation and intervention which avoids an event from occurring which could have had the potential to cause incident-harm to an individual, or damage to equipment, environment or property” (Appendix A)

By using data analysis and risk assessment tools, construction sites have the potential to identify potential hazards or areas of concern before they become too late to address. These tools can help construction companies to analyze and assess the risks associated with specific tasks or activities, identify patterns and trends in incidents or injuries, and develop targeted interventions to reduce risks and improve safety outcomes.

For example, predictive analytics can be used to identify potential hazards based on historical data and predict where future incidents are likely to occur. These can be coupled with real-time monitoring systems to provide real-time data on worker behavior, environmental conditions, and other factors that can impact safety. The avoidance of just one injury or theft covers the cost of their PIMS Safety invoice.

Risk can be defined as “someone or something that creates or suggests a hazard” (Risk, 2023). In the context of the data being analyzed, risk would be any observation that has potential to incur a loss in the field. The losses that could occur include financial loss, injury, lost or damaged equipment, or vandalism and trespassers. Safety and operational risks observed on the construction site are the main area of concern that will be addressed by this project. For example, some safety risks might be, workers not wearing hardhats while construction is in progress, or a large piece of debris along a footpath. While an operational risk might be incorrectly securing an object into a crane or leaving unlocked and unmonitored equipment or tools on site. These hazards can lead to a loss if a worker not wearing a hardhat gets hit in the head, or if someone trips over the debris that has fallen on to the walkway. The object incorrectly fastened into the crane could drop leading to loss of the product, and the equipment or tools left on site could end in theft. The preliminary risk might seem small at first, but if not responsibly managed, it can escalate into a much greater risk with potentially grave consequences.

The goal of this project is to leverage the data collected by PIMS Safety to provide a way for someone entering the site to identify the risk within the area and choose a risk mitigation strategy. The goal of this data analysis project is to provide a way for patterns and trends from the data set to become apparent, thus helping the user identify root causes of hazards and develop more effective strategies for prevention.

Areas defined by the user of PIMS Safety as higher risk can be targeted to gain more attention and reduce the level of risk. Workers of the companies implementing the analysis of this data will be held accountable for the actions they take in response to documenting safety observations. By presenting information in an easy-to-read and understandable format, employees can see how their actions and behaviors impact overall safety performance. Construction companies should be taking every possible measure to ensure their team and assets are protected.

As a way to summarize the data analysis performed by this project, PIMS Safety would like to provide the Merck West Point campus and the Merck Durham campus with an interactive dashboard of charts and graphs. A dashboard will help their clients visualize areas of improvement within their construction site and allow PIMS Safety to provide the user with insightful information to mitigate and manage future risks within a construction site. The sites using the software will be able to effectively craft solutions based on an interactive dashboard. By analyzing historical data and trends, organizations can use the information displayed on a risk management dashboard to make informed decisions about future risk management strategies. The dashboard created will be used for future integration within the PIMS Safety website; however, this project's purpose is a proof of concept and exploration of how these solutions can be created.

The PIMS Safety dashboard was created by combining Business Intelligence (BI) and Geographical Information System (GIS) software. BI is a software tool used to analyze and present a graphical representation of data collected for a user to make informed decisions about the steps needed to benefit their output. It is typical for a company to collect data without initially being able to relate and analyze it to increase performance and reduce costs. BI is used to better understand any amount of data and how the data can be used to provide the company with functional information. A GIS is used to create maps based on the relative position of where a data point is collected. With areas of risk outlined and color-coded on the map, the user will be able to identify and prioritize areas of concern. These tools require a significant amount of time, resources, and expertise to develop. Instead of developing my own BI and GIS software, I implemented software that has already been developed. By implementing already existing software, I was able to focus on the data that needed to be analyzed to create a dashboard.

CHAPTER 3: OUTLINE OF COMPLETED PROJECT

The main objective of this project was to examine the data provided by an organization in the PIMS Safety database and use it to compile a dashboard of key performance indicators for effective management. I engaged with data, PIMS employees, and construction site managers for the entirety of the project to ensure I stayed on track with the requirements I was given.

For this project, I used a waterfall method of implementation. This was the most effective way of developing the dashboard as I gathered information, analyzed data, designed the dashboard, constructed the dashboard, then tested it. TechTarget defines the waterfall method as “a linear, sequential approach to the software development lifecycle (SDLC)” (Lutkevich & Lewis, 2022). The waterfall method was also the most beneficial for this project as I have a clear goal and end date defined.

I explored and evaluated the functionality, compatibility, cost, and user-friendliness of various BI software options to determine the best fit for the future integration with PIMS. The selection I choose needed to meet the specific needs and requirements of both PIMS and the user. PIMS had given me the requirements which included creating a dashboard and identifying optimal indicators of risk management to incorporate into charts. User requirements were gathered as I interviewed a construction site manager.

I also researched a GIS best suited for the outlining of buildings and the ability to manipulate what the user sees based off filters and selections. It was important that the software I selected had the ability to seamlessly integrate with PIMS in the future.

As I was new to both the BI software and the GIS, I needed to dedicate time and effort into gaining a full comprehensive understanding of all their features and capabilities. This was crucial in ensuring I was able to maximize their potential and achieve the desired results.

The PIMS Wiki is a document repository used within PIMS to store information that needs to be shared with all developers. Any documentation written for the dashboard will be stored in the PIMS Wiki for future implementation on the PIMS Safety website.

In order to provide the organizations using PIMS with the most valuable information for effective risk management, an evaluation of key performance indicators (KPIs) was conducted. These KPIs will allow organizations to make informed decisions about their practices and determine areas of improvement.

An interview with a site manager was organized to determine the most crucial information to be gathered for the dashboard. The site manager was able to provide perspective into what they think causes the most risk and how to minimize it to benefit their employees. To ensure the site manager’s time is respected and used effectively I will prepare for the interview by researching the organizations and the individual’s role within it and ask open-ended questions to gather the most information from their perspective.

A comprehensive dashboard was created using BI and GIS software by compiling a series of reports that are based on KPIs and information gathered from the site manager. Chartio (2018), a cloud-based business intelligence and analytics solution, conducted a study with over 90,000 dashboards and found “dashboards that are between five and 20 Charts per Dashboard get viewed the most.” Due to time constraints, I generated five charts to achieve an overview of the organization's safety observations and performance. Too many graphs provided can be distracting and can clutter the dashboard with information that may not be useful to the user. The interactive dashboard is easy to use and effective for analyzing trends and historical data to make informed decisions about future risk. The PIMS Safety user will now be able to look at the dashboard and analyze the data that has been collected, instead of spending hours creating their own dashboard.

Table 1: Safety Data

State	ProjectName	ObservationDateTime	Observer	ObserverCompany
COMPLETE	B60 HPV Project Skyline	3/10/21 7:49	Joe Meloscia	IPS
COMPLETE	B71/73 Demo Project	3/10/21 7:49	Gary Plotts	Neuber Environmental Services, Inc.
COMPLETE	B63 Project P	3/10/21 7:55	Jim Roth	Klover Contracting, Inc.

ObservationType	Severity	Priority
Recognition for Safe Acts/Conditions	SAFE	Good Comment, Best Practice, Worth Commenting
Recognition for Safe Acts/Conditions	SAFE	Action Item, Moving forward comment, there is a better way, Help me to understand
Unsafe Acts/Conditions Requiring Correction	UNSAFE	Action Item, Contractor Corrected on the spot

Category	ObservationLocation	CompanyIdentifiedName	Writtenagainst	ObservationName
Pre-Task Planning	B60A outside			
Materials/Tools	WP71 compressor room.			
Materials/Tools	Elevator			

ActsConditions	ImmediateActionTaken
Team meeting with tradesmen	Job site meeting with tradesmen before starting work for today.
Materials stacked causing a trip hazard.	Removed and relocated insulated panels. The stacked steel was too heavy to move. Placed cones to identify hazard.
Needs to be a walkie talkie to call elevator operator	Requested walkie talkie

CHAPTER 4: PROJECT FEATURES

I – Site Manager Interview

To start off this project, I conducted an interview with Art Limper, global construction, and safety leader for Merck, to find out some background information about working on a construction site and what it takes for the site to limit risk as much as possible. The implementation of these processes allows for the root causes of incidents to be investigated to ensure avoidance of similar occurrences. Before the interview process, John Moehnke, Chief Operating Officer (COO) of PIMSHQ, went over the questions I was going to ask to make sure they were meaningful. During the interview I asked a series of six questions:

- How do you stay up to date with the current risks on site?
- How often are you checking PIMS safety observations?
- When a risk is identified, who is responsible for mitigating it?
- Is it possible for a risk to be identified and not entered in PIMS Safety?
- How often is training conducted?
- What is the course of action when an employee identifies something deemed risky?

The following is a summary of the business knowledge and understanding extracted from the results of the interview conducted.

Before any task is started, the employees do something called “pre-task planning.” This involves six questions the worker must ask themselves:

1. Do I understand how to perform this task safely? (Have I received the proper training?) If I do not understand how to perform this task safely, have I contacted my supervisor for further direction?

2. Do I need additional physical assistance to perform any or all aspects of this task?
3. Do I have the proper equipment and/or tools to perform this task safely?
4. Do I have the proper Procedures or SOPs available to perform this task safely?
5. Do I have all the proper Personal Protective Equipment to perform this task safely?
6. If any Safe Work Permits are required to perform this task safely, have the Permits been properly completed, reviewed, and issued?

Next, the employees are asked to complete the following risk assessment tasks:

I – Identify task hazards and hazards in your work area (look for those potential unforeseen hazards).

P – Predict how you will interact with those hazards; that is, anticipate, "what if?" scenarios.

D – Decide how you are going to effectively deal with the hazards to avoid undesired consequences and injury.

E – Execute your preventive or corrective action decisions.

Mr. Limper stated that, "Individuals from other sites come do a safety audit on a project to give another view on the project safety. These Peer Audits are also documented, and lessons learned are shared from these Peer Audits with all the region safety councils." Peer Reviews are also conducted to gain insight from an alternate perspective to identify issues and areas of improvement. The reviews involve the objective review of safety from construction engineers and the oversight from the safety council. Reviews are targeted to be completed within the first 20-50% of the project completion. Each project is expected to have at least one peer review. For each year that goes by during the completion of a project, at least one safety peer review is expected. With smaller construction projects, peer reviews can be combined. The review is conducted in four steps:

1) Project Orientation

Project Orientation will familiarize the reviewing engineers with the project team, the scope of work, and the various subcontractors on the site. The reviewing engineers will be given the same orientation that would be given to new contractors on the project site.

2) Administration Safety Assessment

During the Administration Safety Assessment, the reviewing engineers will assess the safety program and field safety conditions/process using the Construction Area Safety Checklist (Appendix B). As appropriate, a review of the SOR program may be included.

3) Field Safety Review

To perform the Field Safety Review, the reviewing engineers will take a tour of the project site accompanied by the Merck Engineer and Construction and Safety Representatives, as appropriate. During this tour the reviewing engineers will assess the safety standards maintained at the site. They will also use this opportunity to learn from the experiences of the project team and contractors in the use of safety procedures and techniques at the site.

4) Review and Discussion

The fourth and final step of the review is the Review and Discussion session, called by the reviewing engineers. This discussion is meant to generate both positive and creative comments regarding the current safety performance on the project. The construction engineer then goes through 7 page "Construction Area Safety Checklist."

Regular walkthroughs are performed on site to identify risks. Once a day, contractors are on site doing a written evaluation of their areas. Anyone and everyone is responsible for stopping an unsafe act. "If you see something say something."

To make sure every unsafe act is documented, workers are continually being trained on the importance of documenting observations. That being said, it is natural for an unsafe action to have the potential of being corrected on the spot and not recorded.

Before an employee touches a construction site, they must complete a series of training. First, they must complete a 2-hour online orientation comprised of four modules. After the online portion of orientation is completed, they must complete an on-site orientation. Depending on the scope of the work, additional training is required. For example, a forklift requires a license to operate in the state of North Carolina. For all entry-level workers, the Occupational Safety and Hazard Administration (OSHA) 10-hour training is required. For all construction supervisors and foreman, it is customary to complete the OSHA 30-hour training. Once these training courses are completed, the worker is ready to work on site. There is then a yearly refresher course for employees to stay up to date on the risk involved in their area of work.

If an employee displays unsafe acts, there are consequences. It is believed that the disciplinary actions exhibited receive fair and balanced consequences. After their first unsafe act, the employee is given a warning. After a second unsafe act, the employee must complete retraining. After the third unsafe act, the employee is let go. On the other hand, if the employee is belligerent, they are promptly let go of.

When something is deemed risky and cannot be mitigated immediately, the main course of action is to first stop the job. From there it is the observer's responsibility to get a hold of the supervisor. The supervisor will then contact their safety person and figure out a plan. Depending on the scale of the risk, the crew might be put on an alternate task for the day.

Mr. Limper was also able to provide several documents about safety policies and procedures that are observed on the construction site to reduce risk. Some of which are mentioned later in this paper and shown in the appendices. With over 33 years of extensive knowledge and experience in safety management, Mr. Limper was able to help me gain a better understanding of the safety culture within the organization, including the attitudes and behaviors of employees towards safety, as well as the effectiveness of safety policies and procedures. Interviewing with Art Limper helped to establish clear goals and objectives for the safety dashboard, as well as determine the appropriate metrics to track.

II – Business Intelligence Software Selection

To find the most suitable business intelligence (BI) software that would align with the goals and requirements of Art Limper and myself, I researched different applications. This included looking at the websites for each respective software, comparative lists, and community forums. With no experience in BI software, I needed to find one that was going to be easy to use and intuitive. If this project is to be implemented in the PIMS Safety environment, I also wanted this software to work with a SQL Database Management System to update when a user adds a new record to the observation list. The dashboard created within the software also needed to be integrable into a webpage via iFrame or by other means. The last requirement I had for finding BI software for this project was that it needed to be interactable once integrated within a webpage. I compared three different software often used for BI: Power BI, Tableau, and Excel.

The first I looked at was Power BI. The reason I looked at this software to begin with was because it is easily accessible through the Microsoft 365 suite provided to all UNCW students, and my coworker had worked with it for a previous project. As Power BI is a Microsoft application, it can be easily integrated with other Microsoft products like Excel, SQL Server, and Visual Studio. To embed reports into a webpage, Power BI provides the HTML code for an iFrame. When embedding the Power BI report, it is possible to apply filters automatically during the loading phase or include a filters pane to change the filters dynamically after the report has loaded. One of its features includes displaying a map created in ArcGIS, which is helpful when needing to implement a geographical information system. Power BI offers a 60-day free trial, and then can cost up to $20 per user per month. While researching, I found that the desktop version of Power BI is only available for Microsoft compatible computers. While my personal computer is a Mac, I downloaded and used the desktop version on my work laptop and was then able to work on the reports through the online version. Another drawback I found was that Power BI has a data limit of 10GB, but I did not see this as much of an issue as the amount of data being analyzed amounted to 2MB. If this dashboard is to be used in the future with the millions of records stored within PIMS Safety, switching to Tableau may be necessary.

The next contender was Tableau, another BI software I had previously heard about through other students at UNCW. While Power BI is only compatible with Microsoft operating systems, Tableau is available on all operating systems. According to BI Connector (2023), Tableau is also able to handle “billions of data without any requirement for cloud services," unlike Power BI. They also mention that Tableau is best suited for "seasoned data analysts." As this is my first time using BI software, I did not want to overwhelm myself with the complex details of Tableau. Tableau offers a free trial for students for up to a year. While this is an advantage for my personal use, the price of Tableau can get up to $70 per user for a month for the most advanced license. Tableau utilizes JavaScript API code to embed a dashboard. While JavaScript allows more customization, it also requires basic knowledge of JavaScript. Even though Tableau provides mapping functionality, it is not as detailed as what is available within a separate and integrated GIS.

With a lot of previous experience with Excel and creating charts within the application I decided to checkout its use of dashboards. Excel allows for embedding via iFrame as well as Power BI. Filtering and sorting are also functionalities it can provide when embedding into a webpage. As with Power BI, Excel is also part of the Microsoft 365 Suite. While Excel allows for the development of a dashboard, it is more focused on the organization, transformation, and mathematical analysis of data. Their visuals tend to be outdated and limited. Excel has limited slicers to make the dashboard interactive for the user, but they are not available for cross filtering. "Slicers provide buttons that you can click to filter tables, or PivotTables." Slicers are also available in PowerBI and Tableau.

Excel is recognized for its ability to perform calculations using a wide range of input parameters through its formula functions. Since Power BI does not have a function to calculate the R-squared value and I found a quick 11-minute tutorial on how to calculate the outliers with the use of Excel's scatter plot graphing tool and its equations to calculate the R-squared value in Excel, I used Excel and its equations as part of my regression analysis (Low, 2015).

Out of these three options, I chose to go with Power BI based off its ease of use, integration options, cost effectiveness, live data compatibility, and data visualizations.

Table 2: BI Software Comparison

	Power BI	Tableau	Excel
Cost	$20 per user per month.	$70 per user per month.	Free to use with Microsoft 365.
Ease of use	Easy to use.	For experienced data analysts.	Easy to use.
Compatibility	Desktop app not available for use on Mac. Online version available to computers with internet access.	Desktop and online version available to Windows, and Mac.	Desktop and online version available to Windows, and Mac.
Data Source	Multiple ways of providing data, including Excel and SQL Server.	Multiple ways of providing data, including Excel and SQL Server.	Multiple ways of providing data including SQL Server.
Style	Multiple ways of coloring and customizing visuals.	Multiple ways of coloring and customizing visuals.	Outdated and limited visuals.
Integration	iFrame.	Tableau Embedding API.	iFrame.
Interactivity	Filter pane automatically added when integrating into webpage.	Filter pane automatically added when integrating into webpage.	Need to add to iFrame code to allow for interaction with slicers.

III– Charts and KPIs

“Dashboards provide visual displays of important information that is consolidated and arranged on a single screen so that information can be digested at a single glance and easily drilled in and further explored” (Sharda et al., 2018).

Upon analyzing the safety observation data provided to me by PIMSHQ, I determined several Key Performance Indicators (KPI), one of them being the severity of the observations. Severity refers to the extent or degree to which an issue or problem impacts a particular process or outcome. In the context of performance measurement, the severity of observations can be used to assess the overall effectiveness of a system or process by identifying areas that require improvement. By tracking the severity of observations, a clear idea of the most significant issues that are impacting a process or outcome is apparent. By focusing on the most severe issues, the user can prioritize their efforts and resources to address the most pressing problems first, which can lead to significant improvements in overall performance. Another benefit of tracking severity is that it can help identify trends over time. By monitoring the severity of observations over time, the user can see whether the severity of issues is increasing or decreasing and make adjustments accordingly. While analyzing the data I noticed that one out of the total 116, 056 records did not include a severity type, which is a required field when entering the data on the PIMS Safety website. I excluded this record to mitigate anomalies within the charts.

Another KPI being the status of observations. Two-factors make up the state of each observation, pending and complete. Knowing which observations are pending lets the user know that there is something that needs to be done to enter the status of complete. Safety managers are able to prioritize observations based on the status at a glance.

In this dashboard, four types of graphs are utilized to compare different variables within the observation list: pie charts, donut charts, line charts, and clustered bar charts, and a fifth, scatter plot which is mentioned in a later section. “Pie charts should only be used to illustrate relative proportions of a specific measure” (Sharda et al., 2018). Each wedge of a pie chart represents a percentage of the whole, and all the wedges combined equal 100%. They are easy to interpret when there are only a few slices and when the sizes of the slices differ from each other.

Donut charts are similar to pie charts but have a hole in the middle. They can be used to show the same information as pie charts, but the empty space in the center of the chart can be used for additional information or annotations.

Line charts, on the other hand, “sequentially connect individual data points to help infer changing trends over a period of time” (Sharda et al., 2018). They are useful for tracking changes over time and identifying patterns or trends within the data. Line charts can also be split categorically to compare the performance of different groups over time. This feature allows for easy comparison between different categories and can help identify trends or patterns within each group.

Bar charts are another type of graph that is “often used to compare data across multiple categories” (Sharda et al., 2018). Similar to line charts, bar charts can also be split into separate groups for each category, known as clustered bar charts. In clustered bar charts, the differences in the sizes of bars represent the amounts of different groups, making it easy to compare them visually.

To display the quantity of different severity types in the data, I opted to create a donut chart. The donut chart allows for an easy comparison between the number of safe, unsafe, near miss, and good catch observations and communicates the proportion of severity types. By comparing the number of safe observations to the number of unsafe, near miss, and good catch observations, it becomes easier to identify areas where safety procedures need to be reviewed and strengthened.

The pie chart was used to show the number of observations pending, and the number of observations completed. The chart is divided into two segments, one for observations pending and one for observations completed. The size of each segment represents the percentage of the total number of observations. By using a pie chart, the dashboard is able to show the balance between number of pending and completed observations. This information can be used to determine if there are any pending observations that need to be addressed. Using this chart in the dashboard allows other tables and graphs to be filtered by whether or not an observation is pending or complete.

A line chart was used in the dashboard to show the amount of each severity type over time. By understanding trends in our data between time and count of each severity type, safety contractors can identify why observations might be increasing at a continuous rate or dropping in rate. Monthly intervals were chosen over day intervals due to the work week and not having to work some days. A yearly interval would not be significant enough since I am only working with a couple years of data and quarter intervals were too large to compare a significant difference between the current and previous quarter.

A clustered column chart was made with the dependent variable being the category and the count of severity being the independent variable. I was then able to categorize the types of severity for each category creating the clusters. With this chart, not only can the different categories be compared, but the different severity types within a category can be compared with the clustering capability.

Currently, the aforementioned charts are used with static data. In the future, the charts will change dynamically based on current data when an observation is added to the observation list on the website and converted to the safety database. The charts will provide safety managers with up-to-date information about safety incidents and trends, helping them identify potential risks and hold them accountable for addressing them quickly, reducing the likelihood of accidents or injury.

The live data would then be used in a keyword analysis. Keywords from the ActsConditions column in the observation list would be extracted to perform a sentiment analysis to understand a word and its correlation between a safe or unsafe condition. For example, if the name of a piece of equipment is heavily associated with unsafe observations, the safety contractor should be concerned about why it is underperforming. A categorical graph would be used to represent the data from the keyword analysis, such as a bar chart.

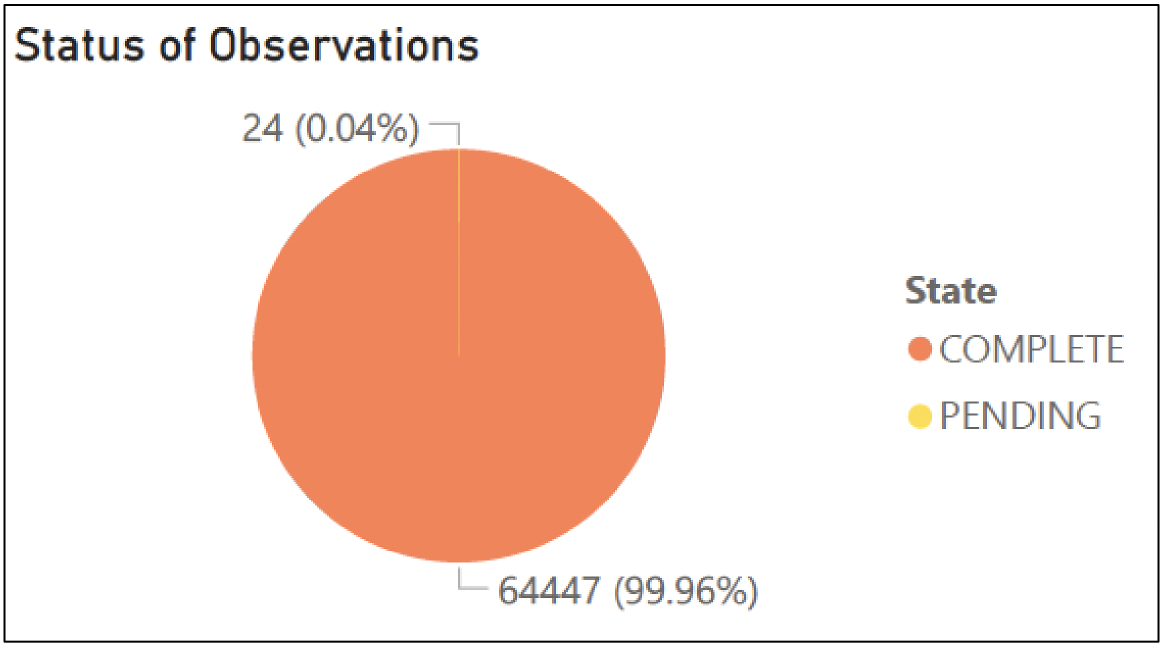

Figure 1: Pie Chart - Status of Observations

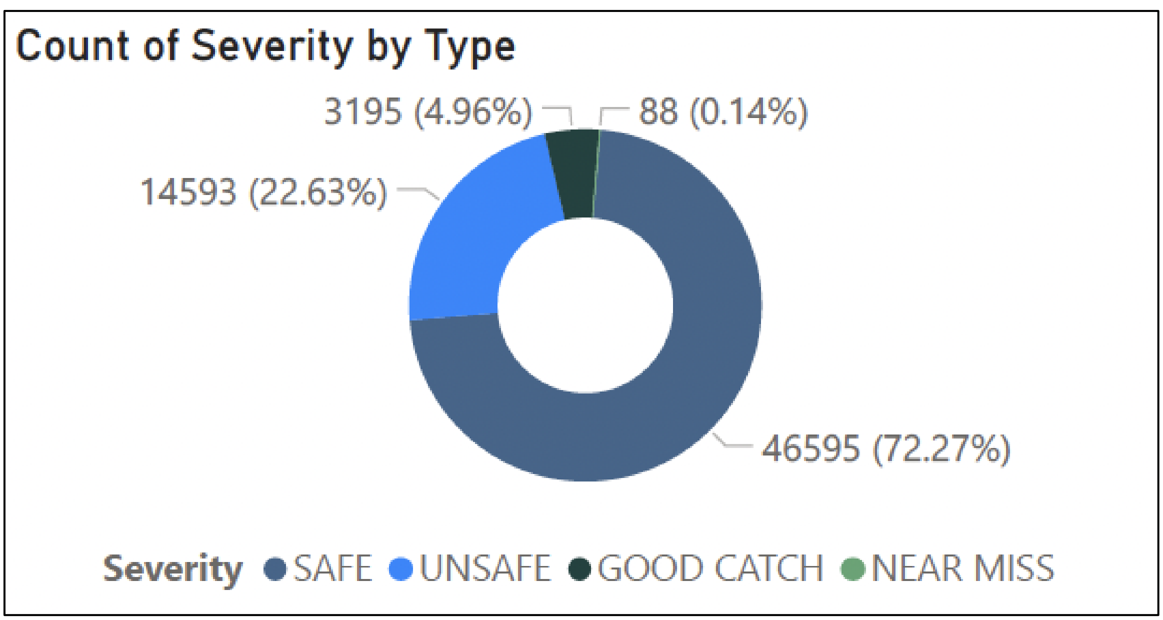

Figure 2: Donut Chart - Count of Severity Type

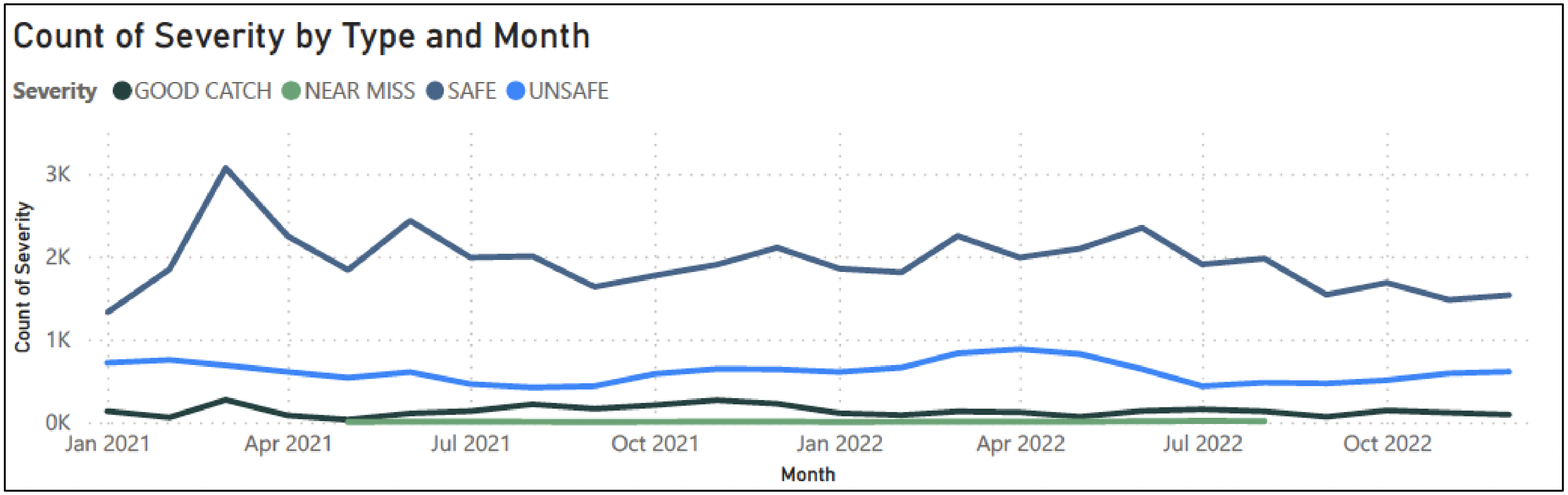

Figure 3: Line Chart - Count of Severity by Type and Month

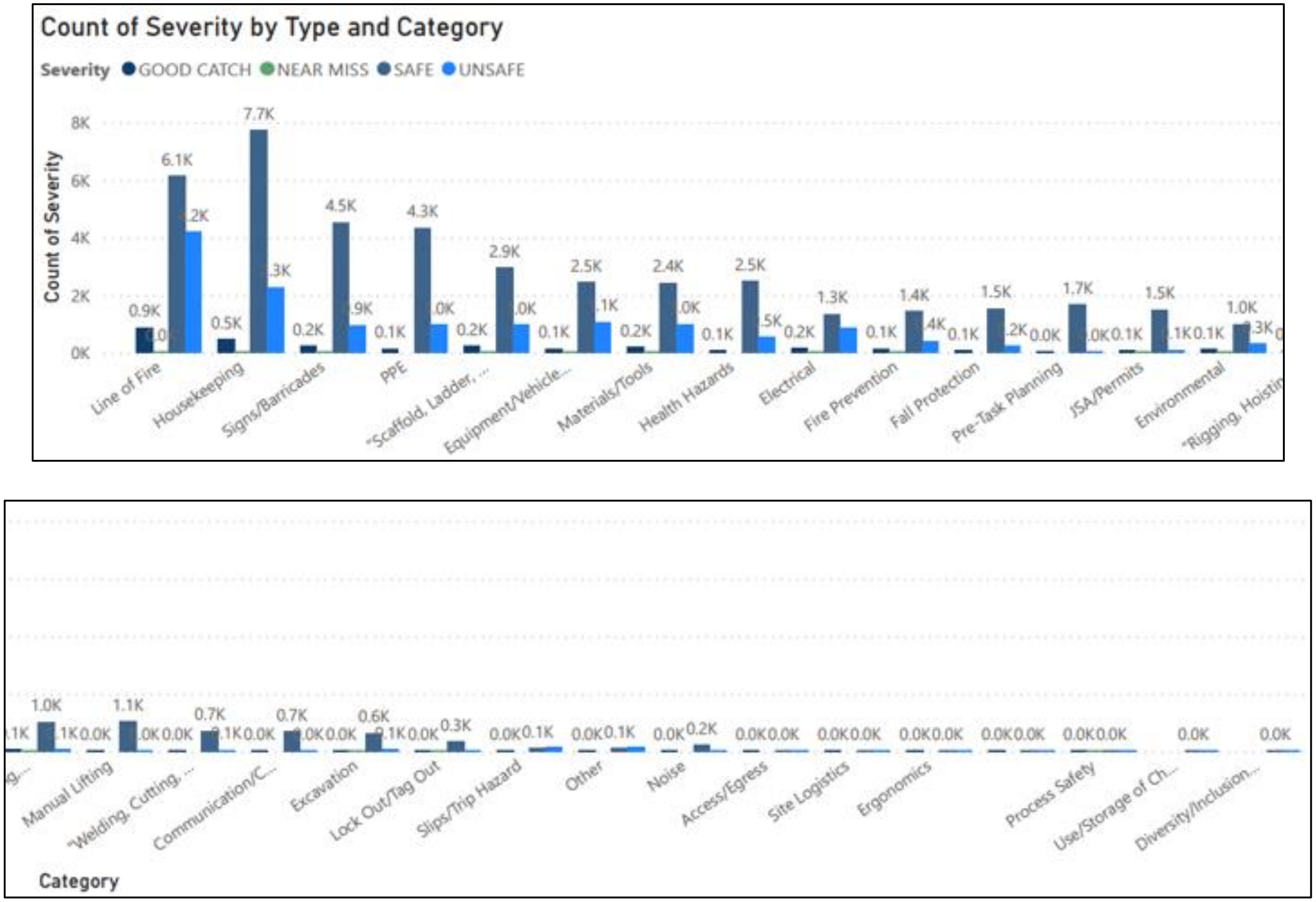

Figure 4: Clustered Bar Chart - Count of Severity by Type and Category

IV – Geographical Information System Selection

As well as the BI software, I also needed to choose a Geographical Information System (GIS). Websites of different GIS software was used to gather information. To start this process, I needed to make a list of requirements. A large requirement I had was ease of use, GIS software as well as BI software is new to me, so I needed to make sure it was easy to learn in the time frame I was given. I also need this software to take a data source input and display information based on the data given. To reflect risk level, the buildings also needed to change color based on the data given. These colors are discussed later when introducing the risk matrix and reviewing the maps created. Because the company construction site does not have an address for each of their buildings rather one address for the whole campus, I needed to customize and map out the buildings that I wanted to change color and display information. As with the BI software I chose, the GIS software needed to provide a way to embed the map to the same webpage as the BI dashboard. Compatibility with a Mac was also a factor I considered but was not as important as I could use my Microsoft computer provided for work. I considered three different mapping software ArcGIS, QGIS, and Google Maps API.

When first researching GIS software it was apparent that ArcGIS had increased popularity compared to the other software I researched as they were on the top of most lists of "best GIS Software" I looked at, such as "30 Best GIS Software Applications [Rankings]" (GISGeography, 2015). While looking at their website, I found images of previous maps that had been made by users that looked similar to what I wanted to do; that is, a bird's-eye view map with buildings outlined and color-coded based on a statistic in their dataset. Maps are customizable to outline the exact areas that need to be analyzed and add data based on what has been outlined. SQL server databases are importable allowing the information to change the buildings to a color based on the risk matrix that will be introduced in the next section. ArcGIS provides iFrame code to copy and paste into a webpage to show the map created. While I was originally researching this software, I thought that I would have to pay their $100/year fee to use their software, but upon further research and contact with the head of the Geographical Information Services department at UNCW, I found that the school provides free licensure for students. ArcGIS is not available for Macs, but they do provide an online version as well as a desktop version. ArcGIS is not the easiest software to learn but with the variety of tutorials and examples available online, it was not hard to find exactly what I was looking to do.

The next software I looked at was QGIS. This software is open source meaning its code is being constantly modified and changed by its users. It is also free to use, and usable on Macs. Based on examples found online, it seems I would be able to create a map based on the information I need to display. I also read multiple reviews that told me that QGIS was easy to use and had multiple tutorials for reference. It does provide some complications when it comes to embedding onto a webpage as there is no iFrame code provided by the software. I would need to download a plugin called “QGIS2Web,” which would add multiple unnecessary steps to the development of my map.

The last software I explored was Google Maps API. Each month you are given $200 monthly credit which you are only charged for if the features added to the map exceed the usage limits. This might seem like a benefit for the Google Maps API, but I am not sure how much I would be able to do before I start getting charged for every detail I add to the map, especially with the large amount of data I would need to import to have the buildings change color. Google Maps API are prepackaged chunks of code which allow you to add maps to your website and apps. With these chunks of code, it is required to have experience with JavaScript to be able to add layers and style the map in the way that is required. I am also not familiar with implementing APIs into a website. The Google Maps API Data Layer allows for the user to add arbitrary geospatial data and choose how that data is represented, but again this requires knowledge JavaScript as there is no user interface to customize the maps. Google Maps API is not able to import SQL server data and is also not able to color buildings based off certain parameters specified.

After researching and considering multiple options for a GIS software, I ultimately chose ArcGIS for my project due to several reasons. First and foremost, ArcGIS had a high level of popularity and was consistently ranked as one of the best GIS software options in various lists and reviews. This gave me confidence in its reliability and effectiveness for my project. Additionally, while exploring the ArcGIS website, I found examples of maps that had been created by other users that closely matched the requirements of my project. These examples showcased the ability to create customizable maps with building outlines and the ability to color buildings based on data from a dataset. This demonstrated that ArcGIS had the capability to meet my specific needs. Another factor that influenced my decision was the availability of an iFrame code provided by ArcGIS, which would allow me to easily embed the map onto the same webpage as my BI dashboard. This seamless integration was important to me as it would provide a cohesive user experience for my end users. Furthermore, although ArcGIS is not typically free to use, I was able to obtain a free license through my school, which made it accessible for me to use on my work-provided Microsoft computer. Although ArcGIS may not be the easiest software to learn, I found that the availability of tutorials and examples online would provide me with the necessary resources to quickly grasp the software and implement it for my project. Overall, based on its popularity, ability to meet my specific requirements, integration capabilities, and accessibility through my school, I chose ArcGIS as my GIS software for my project.

Table 3: GIS Software Comparison

	ArcGIS	QGIS	Google Maps API
Cost	Free to use with student account.	Free to use.	$200 credit each month, start to pay after usage has been exceeded.
Ease of use	Not easy to use. Involves some research.	Easy to learn.	Requires experience with JavaScript.
Compatibility	Desktop app not available for use on Mac. Online version available to computers with internet access.	Desktop and online version available to Windows, MacOS, Linux, Android, and iOS.	Available to Chrome, Firefox, Edge, and Safari.
Data Source	Multiple ways of providing data, including Excel and SQL Server.	Multiple ways of providing data to the map including .csv and SQL Server.	Data layer in JSON or GeoJSON.
Style	Colors can change based on data.	Colors can change based on data.	Colors can change based on data.
Map	Buildings can be define using ArcGIS user interface.	Buildings can be defined using ArcGIS user interface.	Buildings can be defined by the coordinates.

V – Risk Matrix and Maps

Once I knew which software to use for building the map, I needed a way to determine the amount of risk a building poses. To do this, I used a risk matrix with a scoring system.

To color the buildings on the GIS map, I needed to make a risk matrix to compare the severity of a risk and the probability of it happening. Depending on the color of the building, the user will be able to prioritize and isolate areas of risk.

Safety observations, provided by the user, have four categories of severity they can fall under. They are “Safe”, “Good Catch”, “Near Miss”, and “Unsafe”. While a good catch prevents the incident from happening, a near miss observation is something that happens that could have resulted in injury but did not. For example, if a piece of wood is left on the edge of a catwalk, someone who moves the piece of wood before it falls would consider that observation a good catch. If that piece of wood were to be left untouched and fell, but did not hit anyone causing injury, that would be considered a near miss observation.

The risk matrix made for this project is not a typical risk matrix. Typically, a risk matrix uses a scale of different types of risk from low risk to high risk. While unsafe, good catch, and near miss are levels of risk, a safe observation is considered good and commends the work observed on the construction site if very likely to happen, the opposite of an unsafe observation and not considered a risk at all. With this in mind, I created a 4x4 risk matrix with the four categories of risk and four categories of probability, very likely, likely, unlikely, and very unlikely. The probability factors are calculated using a formula (Jenn, 2020):

$$P(A) = \frac{n}{N} = \frac{\#\,outcomes\ in\ A}{\#\,outcomes\ in\ Sample\ Space}$$

Figure 5: Probability Equation

The “# outcomes in sample space” is the total amount of observations in a building and the “# outcomes in A” is the level of severity observed in that building. I then multiplied the ratio by 100 to gain the percentage. < 25% would be considered very unlikely, 25% to 50% would be considered unlikely, 51% to 75% would be considered likely, and > 75% would be considered very likely (Wilson, 2022). A standard risk matrix employs four colors based on the calculation of severity combined with probability. Red is given to very high-risk level, orange is given to high risk level, yellow is given to moderate risk level and green is given to low risk level.

Figure 6: Typical Risk Matrix (Levels of a Risk Matrix, 2019)

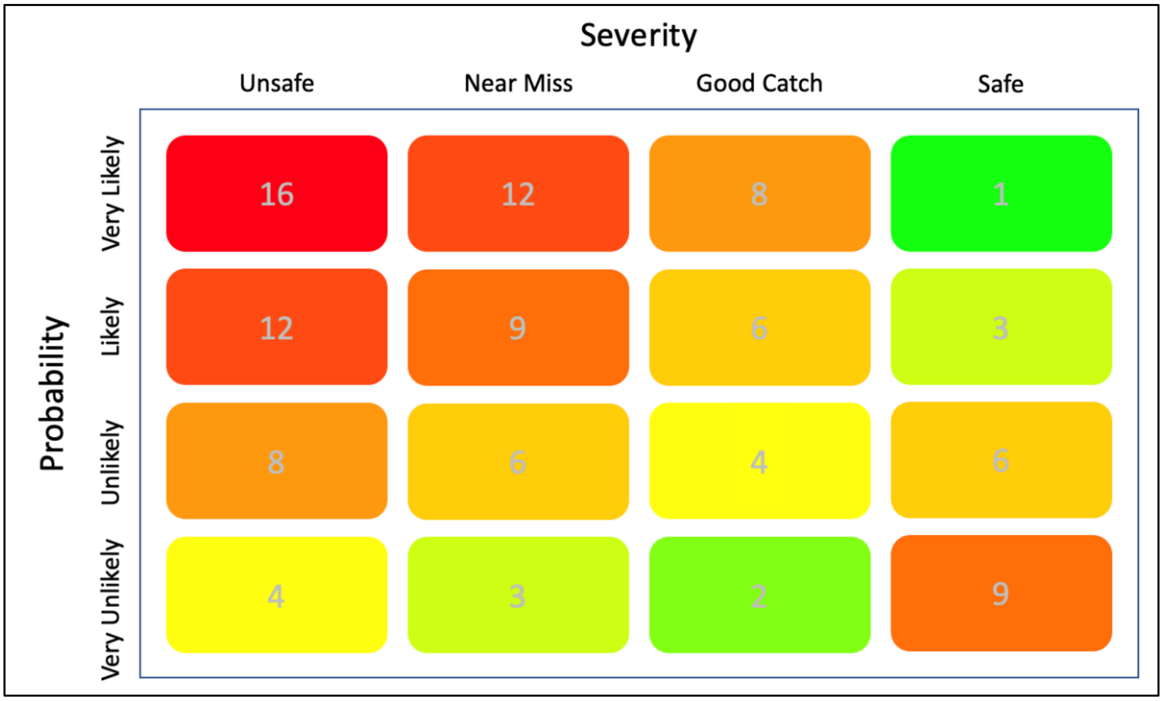

Figure 7: Risk Matrix Made for this Project

Using the same scoring system for my matrix as the sample matrix, I am able to translate the matrix to the map. Safe observations would be given a score of 1, near miss and good catch observations are given a score of 8, and unsafe observations are given a score of 16. When scoring near misses and good catch observations we must take into consideration the rule of three that states "Three Ambers = Red" (Appendix C). With this rule, the total amount of near miss and good catch observations for a building will be divided by three and given a score of 16 and the remainder will be given a score of 8. The total number of good catch and near miss observations would then be the number divided by three plus the remaining. The average is then taken of the score calculated and the total number of observations and rounded up to the nearest number on the risk matrix because it is better to be overly cautious than under cautious.

For example, building D2 has 162 safe, 28 unsafe, 4 good catch, and 1 near miss observations for a total of 195 total observations.

162 x 1 = 162

28 x 16 = 448

4 + 1 = 5 / 3 = 1 with a remainder of 2

1 x 16 = 16

2 x 8 = 16

The adjusted total is now 193 with 3 good catch and near miss observations being counted towards an unsafe observation. The total value is 642. The risk matrix score for building D2 is 642 / 193 = 3.33 which would be rounded up to have a risk matrix score of 4.

The following query is used within ArcGIS to calculate the risk matrix score for each building and the probability that each safety observation type will happen.

```sql
SELECT
    BuildingID,
    Building,
    [Region],
    [Safe],
    [Unsafe],
    [Good Catch],
    [Near Miss],
    [TotalGCNM],
    ([Safe]+[Unsafe]+[Good Catch]+[Near Miss]) AS [TotalCount],
    CAST(([Safe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 AS [SafePercent],
    CASE WHEN CAST(([Safe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 25 THEN 'Very Unlikely'
         WHEN CAST(([Safe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 25
           AND CAST(([Safe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 50 THEN 'Unlikely'
         WHEN CAST(([Safe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 50
           AND CAST(([Safe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 75 THEN 'Likely'
         WHEN CAST(([Safe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 75 THEN 'Very Likely'
         ELSE 'invalid'
         END AS SafeDeclaration,
    CAST(([Unsafe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 AS [UnsafePercent],
    CASE WHEN CAST(([Unsafe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 25 THEN 'Very Unlikely'
         WHEN CAST(([Unsafe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 25
           AND CAST(([UNSAFE])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 50 THEN 'Unlikely'
         WHEN CAST(([Unsafe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 50
           AND CAST(([UNSAFE])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 75 THEN 'Likely'
         WHEN CAST(([Unsafe])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 75 THEN 'Very Likely'
         ELSE 'invalid'
         END AS UnsafeDeclaration,
    CAST(([GOOD CATCH])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 AS [GoodCatchPercent],
    CASE WHEN CAST(([GOOD CATCH])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 25 THEN 'Very Unlikely'
         WHEN CAST(([GOOD CATCH])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 25
           AND CAST(([GOOD CATCH])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 50 THEN 'Unlikely'
         WHEN CAST(([GOOD CATCH])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 50
           AND CAST(([GOOD CATCH])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 75 THEN 'Likely'
         WHEN CAST(([GOOD CATCH])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 75 THEN 'Very Likely'
         ELSE 'invalid'
         END AS GoodCatchDeclaration,
    CAST(([NEAR MISS])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 AS [NearMissPercent],
    CASE WHEN CAST(([NEAR MISS])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 25 THEN 'Very Unlikely'
         WHEN CAST(([NEAR MISS])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 25
           AND CAST(([NEAR MISS])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 50 THEN 'Unlikely'
         WHEN CAST(([NEAR MISS])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 50
           AND CAST(([NEAR MISS])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 <= 75 THEN 'Likely'
         WHEN CAST(([NEAR MISS])AS FLOAT)/CAST(([Safe]+[Unsafe]+[Good Catch]+[Near Miss])AS FLOAT)*100 > 75 THEN 'Very Likely'
         ELSE 'invalid'
         END AS NearMissDeclaration,
    CAST(([TotalGCNM]/3) AS INT) AS [Divided],
    CAST(([TOTALGCNM]%3) AS INT) AS [Remaining],
    [Unsafe]*16 AS [UnsafeWeight],
    CAST(([TotalGCNM]/3) AS INT)*16 AS [DividedWeight],
    CAST(([TOTALGCNM]%3) AS INT)*8 AS [RemainingWeight],
    [Safe] + ([Unsafe]*16) + (CAST(([TotalGCNM]/3) AS INT)*16) + (CAST(([TOTALGCNM]%3) AS INT)*8) AS [TotalScore],
    [Safe] + [Unsafe] + CAST(([TotalGCNM]/3) AS INT) + CAST(([TOTALGCNM]%3) AS INT) AS [Total],
    CAST(([Safe] + ([Unsafe]*16) + (CAST(([TotalGCNM]/3) AS INT)*16) + (CAST(([TOTALGCNM]%3) AS INT)*8)) AS DECIMAL (10,2)) /
    CAST(([Safe] + [Unsafe] + CAST(([TotalGCNM]/3) AS INT) + CAST(([TOTALGCNM]%3) AS INT)) AS decimal (10,2)) AS [RMScore]
FROM [$SeverityCounts]
```

Figure 8: SQL Query - Calculate Risk Matrix Score

The risk matrix mentioned above played a large part in making a colorful display of information for the user to identify areas most likely to experience safety risks or hazards. By using the risk matrix to assign a risk level to different areas, the map can be color-coded to highlight areas that require increased attention and mitigation efforts. This can help safety managers identify patterns and trends in safety incidents and allocate resources more effectively to reduce the likelihood of accidents or injuries. Additionally, the color-coded map can provide a quick and easy way for users to identify potential risks and hazards, allowing them to take appropriate precautions when working in or traveling through those areas.

The map used for this dashboard was primarily created using ArcGIS Online. The first step in creating the map was to generate a "feature layer" which consisted of different polygons representing the construction site, including the boundary of the construction site and the outlines of five buildings. This feature layer allowed for further customization and styling based on imported data from SQL Server.

Once the feature layer was created, the next step was to style and add colors to the polygons based on the data imported from SQL Server. The colors used on the map were designed to align with a risk matrix that was previously created, which consisted of nine different colors, each corresponding to a different risk score. For example, buildings with a higher risk score were colored in shades of red, indicating that they require more attention, while buildings with a lower risk score were colored in shades of green, indicating that they require less focus.

Figure 9: Map Legend

The map also provides additional information to users when they interact with the buildings. When a user clicks on a building, a short summary is displayed, providing information about the probability of different severity types occurring, categorized as very unlikely, unlikely, likely, or very likely. This information helps users to quickly assess the risk level of each building and make informed decisions on where to allocate resources in order to mitigate risks and bring the area back to a state of ease, represented by yellow or green colors on the map. Before leaving for their daily walkthrough evaluation routine, safety contractors can quickly glance at the map to evaluate areas of increased caution.

Overall, the map created using ArcGIS Online is a powerful tool that allows users to visually understand the risk levels of different buildings within the construction site. By providing color-coded visualizations and additional information on severity probabilities, the map aids in decision-making and resource allocation to effectively manage risks and ensure the safety and success of the construction project.

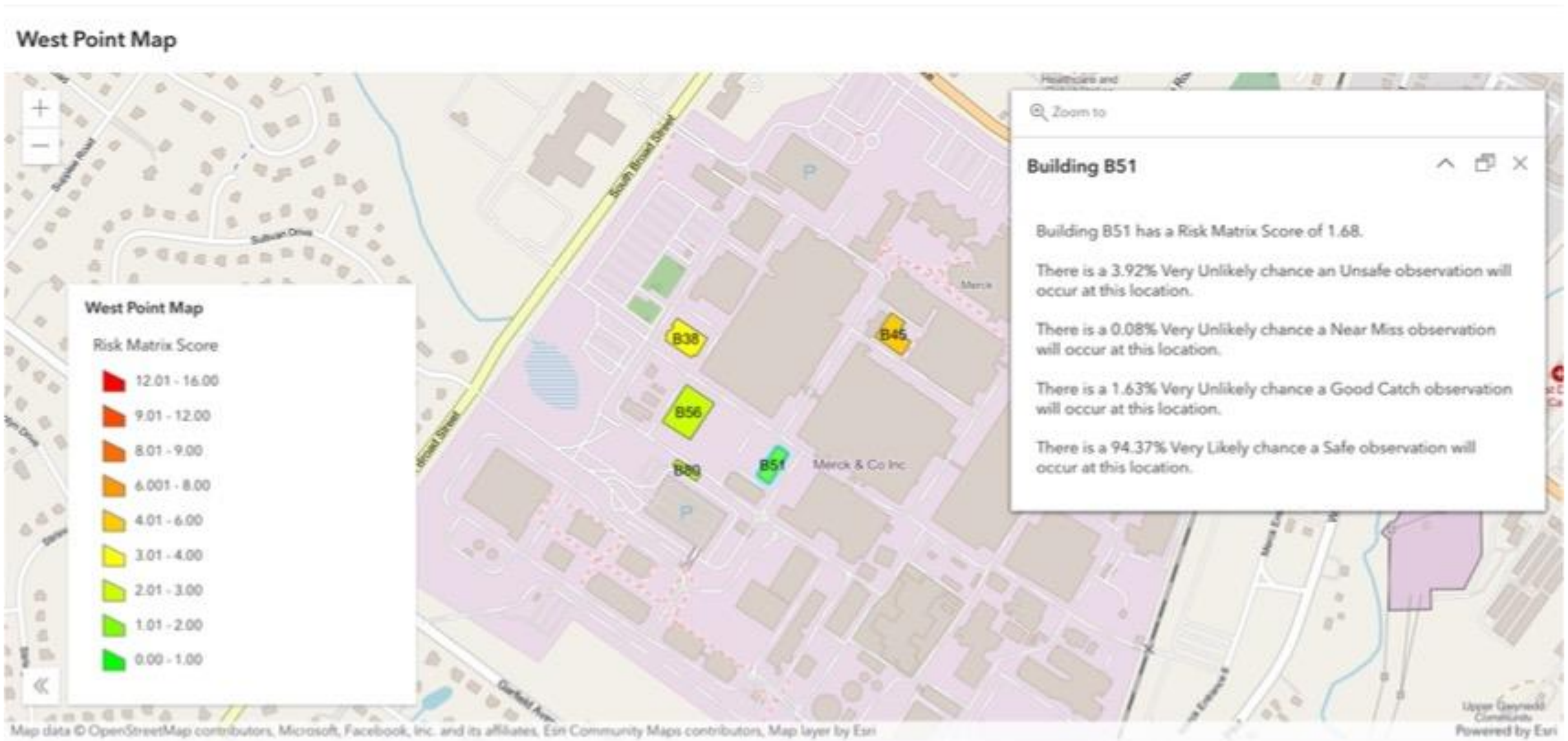

Figure 10: Map

VI – Exploration of Predictive Analytics Possibilities

While the map with a risk matrix and scoring system provides valuable information for predicting the potential risk level of a building or facility, analyzing the impact of various environmental factors can further enhance the predictive capabilities of the dashboard. For instance, a regression analysis on a dependent variable such as precipitation can provide insights into the relationship between rainfall and the frequency and severity of safety observations.

Rain can have significant impacts on construction sites, posing various safety risks such as slips and falls on slippery surfaces, reduced visibility, equipment collisions, and other hazards. It is crucial for construction companies to be aware of the effects of increased rainfall on their construction sites and the potential incidents that can occur due to adverse weather conditions.

One unfortunate example of the risks associated with heavy rainfall on construction sites is an incident that occurred in Oman (2019), where six construction workers suffocated in rainwater and mud while excavating and laying down a pipeline during a heavy rainstorm. The bodies were not recovered until 12 hours after the incident, resulting in a tragic loss of life. In addition to the devastating human toll, the incident likely incurred significant costs for the company, including time delays, expenses related to recovering the bodies, hiring replacement workers, and potential legal and financial liabilities.

This highlights the importance of prioritizing safety during heavy rainfall on construction sites and considering the potential costs and consequences of continuing operations under adverse weather conditions. Conducting regression analysis on the total amount of precipitation in relation to average observations can provide valuable insights into how rainfall impacts different severity types of incidents. By understanding the correlation between rainfall and incident severity, construction companies can make informed decisions on whether to delay work during heavy rainfall to prevent accidents and mitigate potential costs.

It is crucial to prioritize the safety of workers and take necessary precautions to minimize risks associated with adverse weather conditions on construction sites. This may include implementing safety protocols, providing proper training, using appropriate equipment and protective measures, and closely monitoring weather forecasts. Delaying work during heavy rainfall, if feasible, can be a proactive approach to prevent incidents, reduce costs, and prioritize the well-being of workers.

"Regression is a relatively simple statistical technique to model the dependence of a variable (response or output variable) on one (or more) explanatory (input) variable" (Sharda et al,. 2018). Using regression analysis, data scientists can predict events based on independent variables. Since Power BI does not have the functionality to calculate R^2 I needed to find a graphing software, such as Excel, that can calculate an equation for a line of best fit using the least squares method. The least squares method "aims to minimize the sum of squared residuals (squared vertical distances between the observation and the regression point) and leads to a mathematical expression for the estimated value of the regression line" (Sharda et al., 2018). The equation is $y = mx + b$ m being the slope of the line, b being the y intercept, x being your independent variable, and y being the predicted dependent variable. With this equation it is possible to predict and calculate a dependent variable value based on a given independent variable value. To determine if the regression model is well-fitting, something called R-squared is calculated. "The value of R^2 ranges from zero to one (corresponding to the amount of variability explained in percentage) with zero indicating that the relationship and the prediction power of the proposed model is not good, and one indicating that the proposed model is a perfect fit that produces exact predictions (which is almost never the case)" (Sharda et al,. 2018). Excel can calculate both the line of best fit equation and the R^2 values when x and y variable are plotted on a scatter plot and layout 9 is chosen from the "quick layout" menu. The exploration of linear regression as a part of predictive analysis was to show the value of joining data from the observation list with other data in order to find root causes to predict and reduce exposure to unsafe events. When a company reviews this type of predictive analysis, they would consider types of relationships, assumptions, limitations, etc. in a more detailed view that I have done for these explorative purposes.

Jim Frost mentions in his article "R-squared provides the relative measure of the percentage of the dependent variable variance that the model explains. R-squared can range from 0 to 100%." Even if the safety data has a small R-squared value such as a 0.01 or 1%, it is relatively large compared to the other types in it's category. The 1% could be a severe death of multiple employees on a construction site.

To help the user anticipate and plan for the future, regression analysis graphs to show the relationship between the weather and severity of the safety observations were added. By having a better understanding of what is likely to happen in the future, organizations can make proactive decisions that can lead to better outcomes. To do this, I found public data on the historical weather of West Point, PA from Visual Crossing. Example of historical weather recorded:

Table 4: Weather Data

name	datetime	tempmax	tempmin	temp	feelslikemax	feelslikemin	feelslike	dew	humidity	precip
West Point, Philadelphia	1/1/21	37.8	23.1	31.4	34.8	23.1	29	27.6	86.1	0.789
West Point, Philadelphia	1/2/21	50	34.8	41.4	44.9	32.2	38.2	36	82.4	0.068
West Point, Philadelphia	1/3/21	36.4	31.1	34.2	36.2	25.3	30.3	31.7	90.8	0.14

precipprob	precipcover	preciptype	snow	snowdepth	windgust	windspeed	winddir	sealevelpressure	cloudcover	visibility
100	45.83	rain,snow	0	0		6.8	47.9	1028.4	46	8.1
100	20.83	rain	0	0	29.4	17.2	299.5	1013.9	59.7	7.6
100	50	rain,snow	0	0		9.4	37.5	1016.1	74.5	7.5

solarradiation	solarenergy	uvindex	severerisk	sunrise	sunset	moonphase	conditions
76.9	2.8	2		2021-01-01T07:23:51	2021-01-01T16:46:16	0.59	Snow, Rain, Partially cloudy
149.3	5.5	3		2021-01-02T07:23:56	2021-01-02T16:47:07	0.63	Rain, Partially cloudy
38.3	1.5	1		2021-01-03T07:23:59	2021-01-03T16:48:00	0.66	Snow, Rain, Partially cloudy

description	icon	stations
Becoming cloudy in the afternoon with rain or snow.	rain	72510954782,72511354786,72030464752,KPTW,C1648,KLOM,AP069,KDYL
Partly cloudy throughout the day with rain clearing later.	rain	72510954782,72511354786,72030464752,KPTW,C1648,KLOM,KDYL
Partly cloudy throughout the day with rain or snow.	rain	72510954782,72511354786,72030464752,KPTW,C1648,KLOM,AP069,KDYL

I exported the data for 2021 and 2022 to an SQL table and added it to my Power BI report. A scatter plot was used to display the relationship between the two variables. Precipitation in inches being the independent variable, or variable that does not change based on any factor, and average count of severity type being the dependent variable, or variable being predicted. When I first made the graph, I did not separate the severity types, which I quickly realized would not provide useful information if there was no way to tell if the observations recorded were safe, unsafe, good catch, or near miss. Using Power BI's query editor, I was able to input a SQL command to combine the safety data and weather data to calculate the average amount of each severity type recorded per day per precipitation amount. Joining on the date would allow all the observation data to be matched up with the weather based on the dates they were recorded.

The following is the query I used in Power BI to calculate the average amount of a severity type depending on the precipitation.

```
SELECT AVG(count) AS avg_count, w.precip
FROM (
    SELECT COUNT(severity) AS count, CAST(observationDateTime as date) as [date]
    FROM dbo.[$Saferydata]
    WHERE severity = ‘safe’ and region = ‘North East’
    GROUP BY CAST(observationDateTime as date)) sd
JOIN dbo.[$WeatherNE] w
ON sd.[date] = w.dateTime
GROUP BY w.precip;
```

** NOTE: “WHERE severity = ‘safe’ and region = ‘North East’” changed based on which severity type and region I was focused on.*

Figure 11: SQL Query - Join Weather Data and Safety Data

I was then able to use the data calculated from the query to create four separate scatter plots to exhibit the difference between severity types and precipitation. A trendline was also added to the graphs to show how the amount of rainfall affects the amount of severity types recorded in a day.

The data from the calculated average for each severity type was exported to Excel where I was able to use their line of best fit functionality to tell me the equation of the line and the R-squared value, which is not available to Power BI. Using the equation of the line given, I was able to calculate the predicted number of safe, unsafe, near miss, and good catch observations for each of the rainfall amounts. Subtracting the predicted number of observations from the actual number of observations gives us a number called the residual. “Residual is the vertical distance from the line to the point.” The residual is then used to calculate the standard deviation. Standard deviation can be defined as “a measure of how dispersed the data is in relation to the mean.” This number can be calculated by using Excel’s STDEV.P function which will give us the standard deviation of the entire population. Outliers are then determined by multiplying the standard deviation by two. “Use the residuals and compare their absolute values to 2*s* where *s* is the standard deviation of the residuals. If the absolute value of any residual is greater than or equal to 2*s*, then the corresponding point is an outlier.” A new sheet was made to copy the average number of observation severity type and precipitation columns, and any data point with a residual greater than 2s was removed and a new scatter plot within excel was made to show the new equation of best fit line and R squared value. While removing outliers calculated seems like the easiest solution to find a better fit line of regression, it is not always advised. There are a couple ways the outlier should be dropped and that is if there was an error made in the data collection, or if the outlier affects the assumptions made in the analysis. Keep outliers if the assumptions made in the analysis are not affected in the analysis. There is one reason to report with both and that is if the outlier significantly affects the results of the analysis. To know where the outliers fit in these categories I had to compare the dataset with and without outliers. While looking at the West Point data, unsafe, safe, and good catch observations had a positive correlation, or slope, with rainfall, meaning as rainfall increased, the average amount of unsafe, safe, and good catch observations collected in a day increased. Near miss observations had a negative correlation, or slope, meaning as rainfall increased the average amount of near miss observations collected in a day decreased. While looking at the Durham data, all severity types had a negative correlation. Since assumptions and the relationships between the variables do not change when the outliers are removed, I left them in.

Precipitation (inches of rainfall)	Average Unsafe Observations	Predicted Average Unsafe Observations	Residual	Is the Residual Greater Than SD*2?	
0	23	21.825	1.175	Standard D	13.08568
0.001	25	21.82828	3.17172	SD*2	26.17135
0.002	14	21.83156	-7.83156		
0.003	14	21.83484	-7.83484		
0.004	15	21.83812	-6.83812		
0.006	17	21.84468	-4.84468		
0.007	19	21.84796	-2.84796		
0.008	18	21.85124	-3.85124		
0.009	26	21.85452	4.14548		
0.01	28	21.8578	6.1422		
0.011	24	21.86108	2.13892		
0.012	9	21.86436	-12.8644		
0.014	14	21.87092	-7.87092		
0.015	19	21.8742	-2.8742		
0.016	17	21.87748	-4.87748		
0.017	6	21.88076	-15.8808		
0.018	20	21.88404	-1.88404		
0.019	19	21.88732	-2.88732		

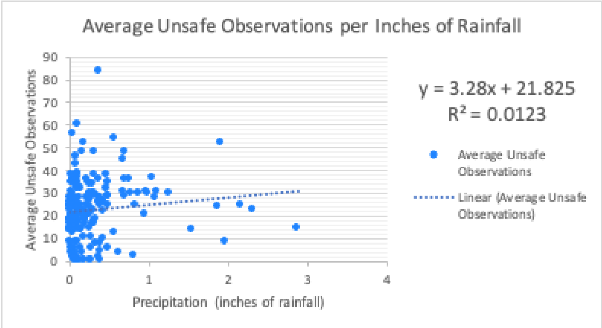

Figure 12: Example of Regression with No Outliers Removed

Precipitation (inches of rainfall)	Average Unsafe Observations
0	23
0.001	25
0.002	14
0.003	14
0.004	15
0.006	17
0.007	19
0.008	18
0.009	26
0.01	28
0.011	24
0.012	9
0.014	14
0.015	19
0.016	17
0.017	6
0.018	20
0.019	19

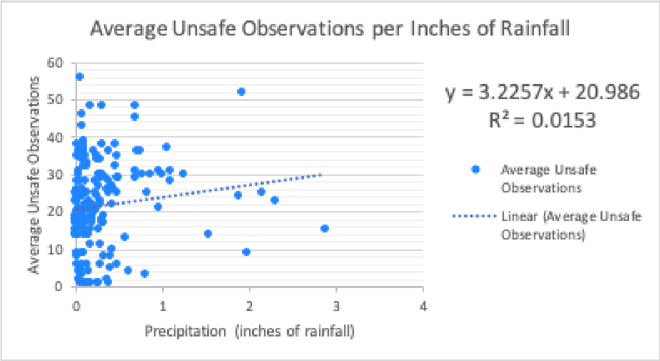

Figure 13: Example of Regression with Outliers Removed

Although the amount of rainfall observed in a day cannot be controlled, safety managers on site can warn their employees of the impact the weather has on the severity of observations and encourage them to take extra precautions to avoid unsafe observations.

Performing a regression analysis between the number of average severity type observations and work man hours could be a useful tool for safety managers to better understand the relationship between these variables. By analyzing the data, safety managers can gain insights into how the amount of work man hours may impact the frequency and severity of safety observations. A regression analysis between another dependent variable such as work man hours, which is collected by PIMS Safety, would be beneficial in the future. Analyzing how many average severity type observations per work hour would provide a safety manager information about how much his employees work and would be able to limit his employee hours depending on the effect it has on the type of safety observations. For example, if the regression analysis shows that there is a positive correlation between work man hours and the number of severity type observations, it may indicate that employees are becoming fatigued or overworked, leading to an increase in safety incidents. In this case, the safety manager may consider limiting employee work hours or implementing additional rest breaks to help reduce the likelihood of accidents or injuries.

VII – Webpage

After everything was researched, created, and assembled, it was time to compile everything together to form a cohesive and usable webpage to display the dashboard.

The webpage created for this project is designed to be hosted locally, as the information it displays is not intended for public access. The webpage was built using the standard web technologies of HTML, CSS, and JavaScript to create a simple yet functional user interface.

One of the key features of the webpage is the inclusion of tabs that allow users to switch between the Southeast and Northeast dashboards. Tabs are commonly used in web design to organize content and provide a visually appealing way to display different sections of information. In this case, the tabs provide an intuitive way for users to access the specific dashboards they are interested in.

To implement the tabs, HTML and CSS were used to create the tab structure and styling. JavaScript was then utilized to handle the tab switching functionality. The JavaScript code defines a function called ‘openTab()’ that is called when a tab is clicked. This function dynamically hides and displays the appropriate content based on the selected tab, using the ‘style.display’ property to control the visibility of the dashboard content associated with each tab.

Additionally, iFrames were added to each of the tabs to display the data analyses created from Power BI and Arc GIS. iFrames are HTML elements that allow external content to be embedded within a webpage. In this case, the iFrames are used to embed the Power BI and ArcGIS data analyses. The iFrames provide a seamless way to display the data analyses within the webpage, allowing users to interact with the dashboards and view the data insights generated from Power BI and ArcGIS.

Overall, the combination of HTML, CSS, JavaScript, and iFrames allows for the creation of a locally hosted webpage with tabs for Southeast and Northeast dashboards, and the ability to display data analyses from Power BI and ArcGIS in a user-friendly manner. This enables the project to securely and efficiently present the data insights to the intended audience.

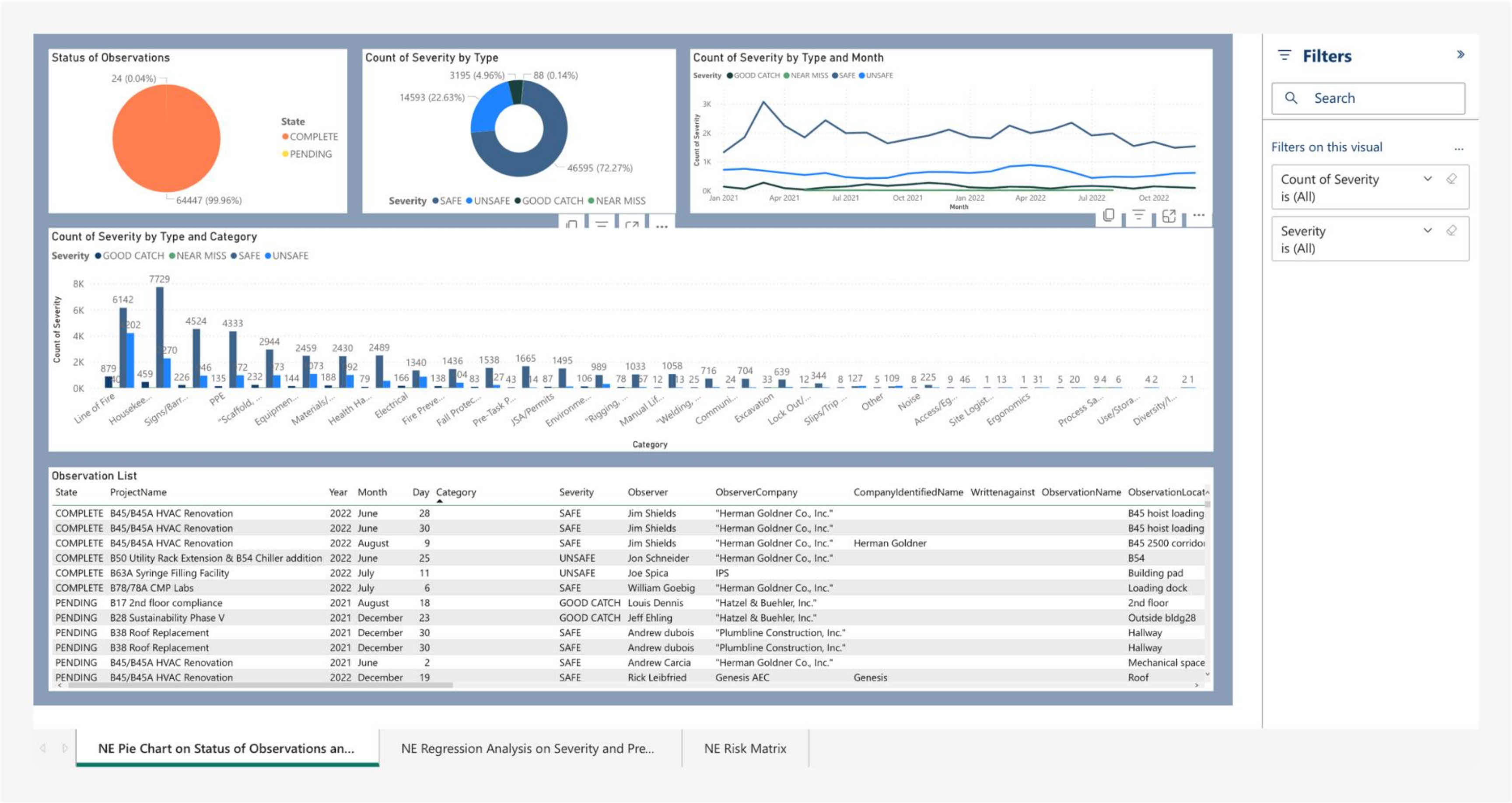

Figure 14: Example of Dashboard on Website

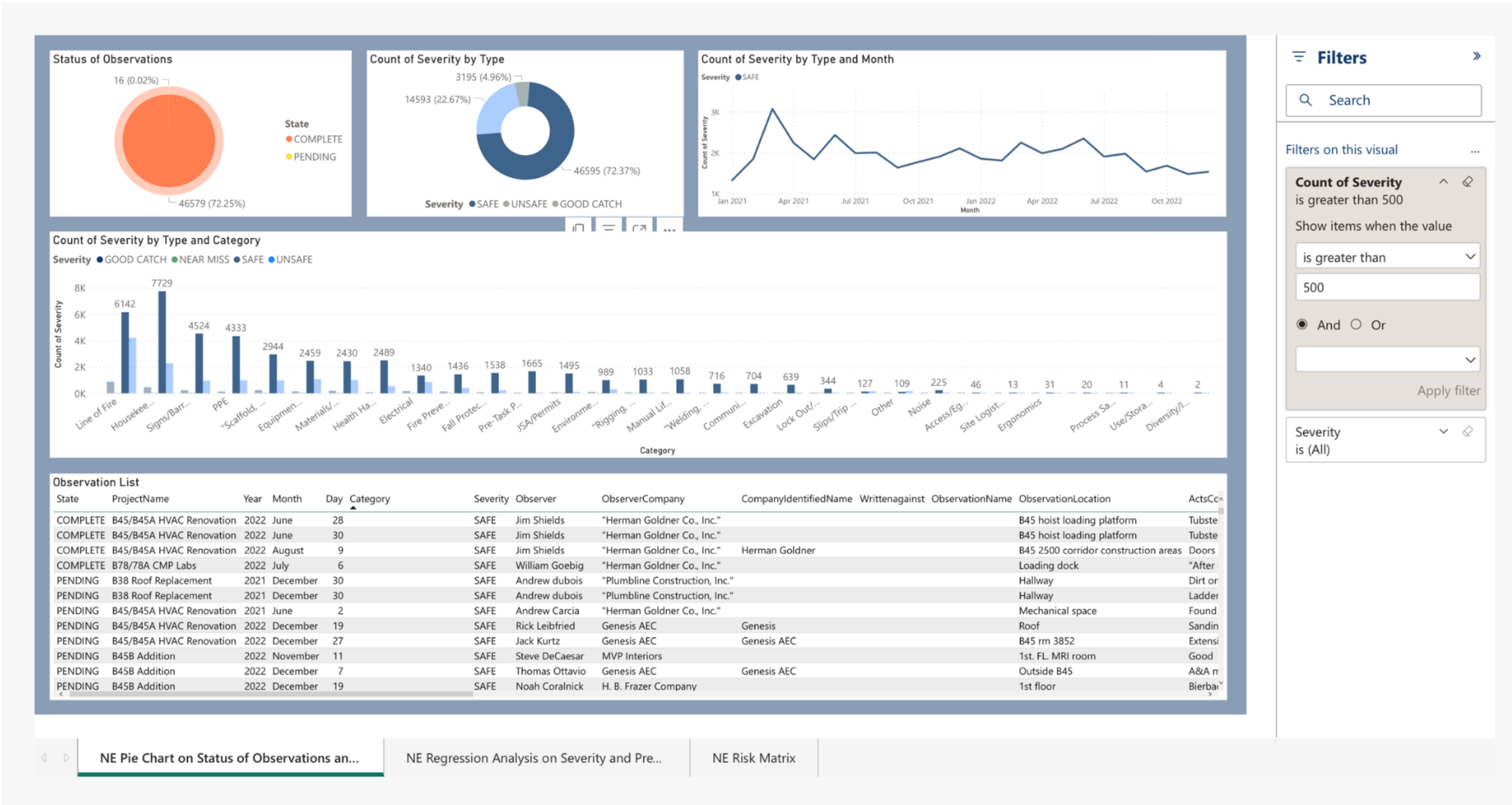

Figure 15: Example of Dashboard on Website with Filters Applied

CHAPTER 5: EXAMPLE OF POSSIBLE USER STORY

To tell exactly how the complete compiled dashboard might be used on a construction site here is a theoretical story of a made-up person, Jim:

Jim, the safety manager on the construction site, relies on the dashboard as a powerful tool to prioritize safety and address areas of concern. He starts his day early, arriving at the office at 6:45AM, before the rest of his personnel. Jim knows that the dashboard provides a visual representation of the site, with buildings color-coded as red, green, orange, or yellow, indicating their safety status.

When Jim sees a building lit up in red on the dashboard, he knows it requires immediate attention and notifies his workers to be cautious in that area. Green buildings are considered safe, and he can reassure his employees about those areas. Orange and yellow buildings fall in between, and Jim takes note of them as potential areas of concern that may require attention in the near future.

Jim also relies on the pie chart of pending and complete observations. If there are any pending observations, he can click on the corresponding part of the pie chart to filter the dashboard content. This helps him quickly identify the category of pending observations and assign the right personnel to address them. For instance, an unsafe electrical observation would be assigned to someone with electrical expertise.

After reviewing the dashboard, Jim conducts debriefings with his employees, informing them about areas to be cautious of, problems that need fixing, and encouraging them to report any unusual activity, whether it's deemed safe or unsafe, no matter how small or significant. Jim understands the importance of accurate documentation and reporting, aligning with OSHA's philosophy of "If it is not documented, it didn't happen."

Jim also keeps an eye on other charts on the dashboard, such as the comparison of safe and unsafe observations and the trend of observations over time. He notices that there are more safe observations than unsafe ones, but overall, the number of recorded observations this month is lower than last month. Jim realizes that this could indicate underreporting of unsafe incidents and takes action to encourage employees to report all observations for more accurate analysis.

Before clocking out, Jim looks at the weather forecast for the next day. He realizes it is a 100% predicted chance that it will rain so he advises his employees to wear the proper clothing and encourages work on indoor projects and prevent slips and falls in wet areas since he can conclude from the regression analysis that unsafe observations are more likely to happen.

With a commitment to prioritizing safety and using the dashboard as a daily tool for identifying and addressing areas of concern, Jim leaves work each day knowing he has taken proactive steps to ensure the well-being of his employees and is prepared to start anew the next day, continuing to prioritize safety on the construction site.

CHAPTER 6: CONCLUSION AND KEY TAKEAWAYS

The dashboard created will play a large part in preventing unsafe events observed on a construction site. A construction site risk management dashboard is an essential tool in preventing unsafe events on construction sites. Safety personnel can take proactive measures to prevent unsafe events. It provides a visual representation of the data, such as graphs and charts, making it easier for project managers to quickly identify trends and patterns in safety performance. By providing real-time information about safety performance and enabling project managers to take proactive steps to prevent accidents, a dashboard can help ensure the safety and well-being of all workers on the site.

During my work on this project, I realized the importance of critical thinking and analysis in making informed decisions and achieving desired outcomes. Starting from selecting the most suitable software to display KPIs in the dashboard and figuring out the best way to present data in charts, every step required thoughtful consideration. Making decisions is crucial when developing projects, and it's okay if the first decision is not the best one. I learned from my mistakes and kept working to improve my approach.

Effective communication with experts in the field was crucial to gain a better understanding of the work, especially when I reached out to Art Limper, the safety manager. Before approaching him, I researched the type of work he did and made sure to ask concise questions to avoid wasting his time. As I had never been to a construction site, I needed to know how the system works in the field and how my dashboard could be useful in future use.

Throughout the project, I faced some challenges that required me to adapt to the situation. For instance, while conducting a regression analysis, I realized that Power BI lacked some formula capabilities that Excel had. As a result, I had to switch between

Power BI and Excel to ensure accurate display. Additionally, the GIS software I chose was challenging to work with, and I had to seek advice from experts to gain a better understanding of how it works.

This project helped teach me to take time when exploring something new. Understanding each part of this dashboard was an important aspect of this project. Through extensive research, I was able to pull together a safety dashboard on a software never used before to create a pie chart that compares pending and completed observations, a donut chart that compares the amount of the different severity types, a time series to analyze the relationship between time and the different severity types, and a clustered bar chart that compares how many of each severity type there have been observed in each category. Regression analysis was also utilized in Power BI to monitor the relationship between heavy rainfall trends and the severity of an observation. A risk matrix was created to tell the user the probability a certain severity type is going to happen in a building. The scores from the risk matrix are used to calculate the color that is used on the map to show the amount of risk in a building.

Being unexperienced with the software I was using; this project took a lot of time and deliberation over why each element was chosen. It was important to document every decision made as to why I should include an element in my project. Being able to predict trends and analyze data requires a great amount of knowledge, which is why I have included many sources to back up claims.

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APPENDIX A*

GES Safety Accident/Incident Investigation & Reporting

Definitions:

An incident is an undesired occurrence that results in personal injury/illness and/or potential personal injury/illness, chemical release, business interruption or property damage. An incident can be classified in several types and the most common ones are:

- **Near Miss** – A specific unplanned event/s (energy released) or work-related incident that had the potential to cause harm to an individual but no harm to an individual occurred. Potential or actual damage to equipment, environment, or property could/did occur during the event.
- **Good Catch-** A specific observation and intervention which avoids an event from occurring which could have had the potential to cause incident-harm to an individual, or damage to equipment, environment or property
- **Environmental Incident** - any spill or release that could impact human health, property, and/or the environment (e.g., contaminate soil, water, air or cause significant ecological damage).
- **First Aid** –
- **Recordable Injury** - Any work-related injury that results in death, unconsciousness, days away from work, restricted work, transfer to another job, or requires medical treatment beyond first aid. A case is also recordable if it involves a significant injury, diagnosed by a physician or other licensed health care professional, even though it does not result in death, days away from work, restricted work or job transfer, medical treatment beyond first aid, or loss of consciousness.
- **D.A.R.T. Days Away, Reassignment, Transfer** – OSHA 300 Recordkeeping revisions replaces "Lost Time" terminology with a "Days Away" classification and adds classification of restricted duty and transfer cases. DART is a defined/recognized work-related injury or illness that results in days away from work, reassignment, restricted duty and or transfer to another job

Site Incident Procedure Execution

Once an incident has occurred, Global Engineering Solutions Projects must follow the site procedures for incident investigation and reporting requirements, in addition to the reporting outlined in GES Practice 7.3. If an incident occurs on an isolated GES Project such as a new site or GES stand-alone project, GES incident investigation and reporting requirements shall be used.

Incident Investigation

The Merck Project Manager or designated representative(s) must ensure that all incidents are appropriately. Investigated following the GES Standard. The purpose of this investigation is to determine root cause and appropriate actions (CAPA's) are implemented to avoid any similar incidents. It may be necessary for the project management to designate an incident investigation team to review an incident. This decision should be based on both severity and consequence of the incident or potential incident. The Significant Incident and Fatalities (SIF) Matrix should be reviewed to determine the level of investigation and communication required when working on an established site. The GSE requirements and GES requirements for incident investigation and reporting are combined in the GES flowchart "Detailed Incident Investigation and Management" (appendix F of GES Practice 7.3)

APPENDIX B*

Construction Area Safety Checklist

Merck Global Engineering Services

To be used for weekly documented safety audits and peer safety reviews

Project/Area Inspected: ____________________________________ Time/Date: __________

Inspectors: _______________________________ _______________________________

_______________________________ _______________________________

Description	YES	NO	N/A	Comments
ADMINISTRATION / PROGRAM:				
Workers have attended Safety/cGMP Orientation. (Sub)contractor training verification				
Emergency Response, Evacuation Plans and rescue procedure in place, muster points posted in field.				
First aid trained personnel on project, mutual aid contacted and verified				
Procedure for recording and investigation of incidents, first aid cases and near misses. (Fear Factor of reporting is addressed)				

Incident Log (ie OSHA 300 Log) being maintained Case management and return-to-work process				
Safety bulletin board with safe workdays posted and current safety information				
Contractor Toolbox safety meetings held weekly, with intermittent Merck/CM participation.				
Merck/CM led Town Halls being done.				
(Sub)contractors "competent persons" identified				
CM weekly safety meetings held with (sub) contractors supervision				
MSDSs provided to Merck, maintained in field office				
Job Safety Analyses / Risk assessment /Method Statement completed as needed/required				
Distracted Working and Outside Influences are addressed in planning.				
Daily Task Safety Planning completed, and White Board coordination meetings held.				
Weekly Merck led audits of work area safety done. Audits done with CM/Contractor participation.				
SOR Program in place, & feedback given to craft.				

Emergency phone numbers posted in office areas and field.				
Drinking water & Wash Facilities available				
Toilet facilities available, accessible and clean				

Description	YES	NO	N/A	Comments
HOUSEKEEPING:				
Contractors inspect work areas daily.				
Job site organized, not cluttered				
Walking surfaces clear, clean, trip hazard eliminated				
Trash/construction debris emptied regularly, disposal area neat, receptacles available				
Nails, scrap metal/wood picked up from previous days				
Materials storage, proper segregation, stacked properly, chocked, no danger of falling				
Rodent, insect & vermin control				
Site perimeter maintained				
PPE:				
Hard hats, safety glasses, high visibility vests / clothing and safety footwear worn				

by craft / management meets GES requirements.				
Safety glasses with secure side shields being worn				
Face shields/goggles worn where appropriate				
Hearing protection used where appropriate				
Glove Program in effect & meets GES requirements				
Back injury prevention (material handling)				
Respirators/dust masks worn where appropriate, program in place, fit test, etc. (Fit tests must be completed by contractor not MSD)				
FALL PROTECTION:				
100% Fall protection used above 6 feet (EU 2 m)				
Full body harnesses worn (incl. high reaches). Inspection certificates available				
Fall Protection equipment in good shape and inspected				
Anchorage points for fall arrest meet required ratings				
Lanyards with shock absorbers and double locking clips				
Perimeter guarding provided, perimeter cables or wire rope properly installed				

FIRE SAFETY & EMERGENCY PROCEDURES:				
Proper fire extinguishers available and inspected				
Used rags in labeled metal cans with cover				
All walkways, stars, access, egress free of combustibles				
Trained Fire Watch on duty during Hot Work – Area monitored after hot work completed				
Description	YES	NO	N/ A	Comments
Workers know evacuation alarm signals and evacuation routes				
First Aid Kit policy established and followed (CM or contractor provided)				
Eye wash stations provided in field.				
Sprinkler heads unobstructed				
Temporary heaters, ventilation, dehumidifiers, lighting properly installed				
GENERAL SAFETY:				
Work area barricaded, access limited				
PPE signs posted near access points Safety posters / signage / banners in field				
Flaggers for mobile equipment movements				
Containers, Chemical materials labeled (labels legible)				

Fuels, flammable materials stored properly				
Temporary lights provided where needed. Adequate task lighting provided as appropriate.				
Temporary power provided, in good working order				
Equipment/tools in good working condition				
Equip./Tool Guards in place, where needed				
LADDERS / STAIRS / SCAFFOLDS:				
Proper types of ladders being used				
Ladders in good operating condition, inspected and stored properly				
Conductive (metal) ladders not in use near elec.				
Extension ladders tied off, and/or footed and secure, extended 36” (EU 1 m) above landing, 4/1 slope maintained				
Workers not using top two steps on ladders				
Stairs provided where needed >19" (EU >0.5 m), secured				
Stairs greater than 4 risers equipped with hand rail				
Scaffolds correct and rollers locked when in use, tagged correctly, inspected daily				

Toe boards, railing on scaffolds, where needed				
Scaffold planking overlaps 12" (EU 0.3 m)				
Safe access / egress for scaffolds				
Working platforms at least 2 feet (EU 0.6 m) wide, Safe loading of platform				
Workers protected from falls off scaffold by railing and workers below protected from falling hazards				
Holes/penetrations protected with secured covers labeled "HOLE" or barricaded. Hole Cover removal/replacement procedure in place.				
Description	YES	NO	N/A	Comments
Backup alarms, horns on mechanized equipment				
WELDING, CUTTING:				
Compressed gas cylinders secured with chain or wire				
Cylinders capped when not in use				
Oxygen and flammable gas cylinders kept 20 feet (EU 5 m) apart or approved ½ hour fire wall separation				
Torch, hoses, gages, regulators and cables in good condition. Torch equipped with flash-back regulator				

Hot work permit in use, fire watch established				
No combustible material in vicinity of hot work				
Welding screens used where needed				
LIFTING/RIGGING:				
Lifting and crane area barricaded, no lifting over personnel, rigger and flagger in place				
Crane usage approved, pre-lift checklist completed, operator certification on hand. Daily and annual crane inspection documented				
Tag lines used to control loads				
Rigging equipment used properly, in good condition				
EXCAVATION/CONFINED SPACES:				
Trenches/excavations sloped properly or shored and barricaded				
Adequate access in/out of excavations (max. 25') (EU max 7.5 m)				
Spoils, tools, etc kept 2 feet (EU 0.6 m) back from excavation edge				
Soil classification identified				
Ventilation used for confined spaces				
Confined Space; personnel properly trained				

Confined Space; Retrieval equipment available and used appropriately				
Confined Space; Standby attendant(s) present, communication means available				
Confined Space; Air monitoring (including continuous) performed				
MOTORIZED EQUIPMENT:				
Mechanized equipment used properly				
Proper inspections performed/documented				
Rollover protection in place and maintained				
Seatbelts used by all operators				
Description	YES	NO	N/ A	Comments
ELECTRICAL SAFETY:				
Cords in good condition, no cuts or repairs w/ tape Cables secured and off floor to minimize trip hazard				
All Elec. extension cords inspected within last month (color coding)				
GFCIs used for lead cords, GFCIs tested monthly				
Grounding in working order on power tools, equipment				
Temp electrical panels labeled, grounded				

Conduit tightly connected to junction/outlet box, all breakers labeled and field outlets w/ circuit #				
Adequate illumination				
Temporary wiring; power/lighting isolated from building structure and not presenting trip hazard				
Precautions taken where overhead lines are present, No Work within min 20’ (EU 6 m) clear				
HAZARDOUS WORK (PERMITS):				
Required permits completed properly, posted				
Fire watch present for high energy (Class A) hot work				
Flammable/combustible materials removed from hot work area				
Hazardous energy sources locked out properly				
ENVIRONMENTAL:				
Containment for petroleum products adequate and in good condition (no debris, rainwater accumulated)				
Petroleum tank/containment inspections and inventory adequately documented				
Documentation of asbestos survey with negative results for demolition and renovation				

Storm Sewers protected				
Threading Machine catch box in place				
Drip pans in place for equipment such as generators and welders				
Containers labeled & closed when not in use				
Chemical storage away from storm sewers and on impervious surface				
Appropriate environmental training and documentation				
Erosion and sedimentation control at project site (silt fences, tarps, mulching, as necessary)				
Erosion and sedimentation control in Soil Mgmt Area (silt fences, tarps, mulching, as necessary)				
Erosion and sedimentation control inspections being completed and logged				
Description	YES	NO	N/A	Comments
Environmental excavation permit number on excavation permit				
Roll-offs labeled (contents, date waste first placed in container, designated non-haz or hazardous waste)				
Roll-offs covered and in good condition				
Appropriate residual waste handling, accumulation and disposal				

Appropriate hazardous waste handling				
Ensure all hazardous wastes are removed from site by contractor unless otherwise specified				
Lay down in appropriate areas (not on unimproved landfill)				
Truck/vehicle wash in place. Concrete truck washout procedure followed				
Dust generation minimized / controlled				
OTHER/MISCELLANEOUS:				
Safety Culture Measurement plan in place. (Hearts and Minds)				
Safety Surveys are being done to gain feedback.				
Safety Mentoring program is in place				

Safe/Un-Safe Behaviors Noted & Other comments:

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AUDIT/INSPECTION OVERVIEW:

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Revised 11/05/2010, HH/AFL

APPENDIX C*

Achieving Situation Awareness in Five Minutes

- The idea is simple. We have clear No-Go limits – Reds and marginal conditions – Ambers. If there are no problems we are in the clear – Green. We must always stop if we have a Red, but too many ambers are just as risky.
- The rule says, Three Ambers = Red. When we have too many ambers, we can try to manage some of them back into the green, maintaining control of what might become an escalating situation.
- Analyses of many incidents has shown a relationship between the number of ambers you have and whether the outcome is a near miss or an accident.

*All documents in the appendices are safety documents used on the construction site provided to me by Art Limper