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Near Miss Information Visualization Application for BIM

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Near Miss Information Visualization Application for BIM

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ABSTRACT

Several improvements have been realized in visualizing construction project information through Building Information Modeling (BIM). The objective of this research is to provide a framework for near miss data collection and visualization within a BIM platform. A near miss database was created in commercially-available BIM design software to allow construction site personnel to report near misses and visualize them within an existing BIM. Algorithms were created to enable filtering for visualization based on user input properties of each near miss. A feasibility study for the created tool was conducted with an expert review panel of experienced safety managers. Contributions of this research include a near miss visualization user-interface allowing construction personnel to view near misses throughout a construction project to identify hazardous areas and frequency of near misses as well as a feasibility study data of the created tool.

KEY FINDINGS

- Current practices in construction safety data visualization are inadequate
- A near miss data visualization tool was created and linked to a BIM
- The created safety data visualization tool was implemented into an active BIM for evaluation
- Surveyed safety professionals realize the benefits of visualizing near miss reports
- By utilizing the created tool, hazardous situations and conditions can be reported as near misses and visualized by anyone accessing the BIM

INTRODUCTION

Although the construction industry accounts for 4% of the total U.S. employed workforce, the industry experienced 19% of the fatalities (BLS 2012). This disproportionately high number of fatalities indicates the dangers associated with working in the construction industry. Even though the number of fatalities on construction sites has decreased over time, the rate of workplace fatalities has stagnated in recent years (OSHA 2011a). This research visualizes construction site safety data to equip safety managers to view the location and frequency of hazardous conditions and events.

Building Information Modeling (BIM) has been described as one of the most promising recent developments in the construction industry because of its ability to provide a design, communication and project monitoring platform throughout the lifecycle of a project (Azhar 2011, Eastman et al. 2011). Construction project stakeholders are using Building Information Modeling (BIM) to integrate many aspects of a project including building life cycle, designing (Penttila 2007), planning, construction (Kymmell 2008) and operation (Akcamete et al. 2010). Due to the hazardous nature of construction sites, safety management is a critical component to a successful project. By visualizing hazardous situations and conditions, BIM provides a platform to aid in safety management and eventually enhance safety performance of construction site personnel. The growing use and implementation of BIM within the construction industry is transforming the way safety data management can be approached, specifically by visualizing safety data including near miss reports.

The Occupational Safety and Health Administration (OSHA) defines a near miss as “an incident where no property was damaged and no personal injury sustained, but where, given a slight shift in time or position, damage and/or injury easily could have occurred” (OSHA 2002b). OSHA currently does not require construction companies to record or report near misses (OSHA 2011b). Near misses are categorized as safety leading indicators because they are measurements of processes, activities and conditions that define performance and can predict future accidents (Hallowell et al. 2013). Safety leading indicators, including near miss reporting and analysis, provide an additional metric of employee safety performance without requiring an illness, injury or fatality event.

A near miss reporting program was created and implemented by members of the Construction Industry Institute (CII) (Marks et al. 2014). A complete reporting system with worker feedback was established to collect, process and disseminate near miss information for construction sites in various parts of the world. Other efforts to implement and encourage near miss reporting include governmental standards for near miss reporting (HSE 2015) and strategies for increasing quality and quantity of near miss reports (Cambraia et al. 2010). This additional element of an existing company safety program allowed safety managers to pro-actively identify and mitigate hazardous conditions and situations based on near miss reports received from site personnel. To complement near miss reporting, the construction industry needs a data visualization strategy for near miss reports. Similarly to hazard identification and site layout safety planning, near miss reporting information would be greatly enhanced through visualization (Hallowell et al. 2013, Elbeltagi et al. 2004). Because an interactive visualization and communication platform already exists in BIM, a database and user-interface are required to visualize and analyze near miss reports.

The scope of this research is limited to near miss information collected by construction site personnel. User-interfaces of the created tool are focused towards use by safety managers and other management personnel in the construction industry. The selected communication and data analysis platform is limited to commercially-available BIM software. The use of automated data analysis systems provides more accurate data than manual collection and analysis systems and inevitably increases communication about safety across all construction project stakeholders accessing the BIM. Other industrial sectors in the U.S. (e.g. manufacturing) that record safety data (including near misses) could use this visualization concept and proposed methodology for their specific safety program.

The following report presents a created user-interface and database for near miss visualization within a BIM and algorithms for data transfers and analysis. The results indicate that safety data including near misses can be assessed and visualized within a BIM. Experimental results are discussed as well as experienced limitations and future research topics extending from near miss visualization.

OBJECTIVES

The current state of near miss reporting requires an automated data visualization method for real-time access to near miss information including location, description of event and mitigation strategies. The goal of this research is to visualize reported near miss data within a BIM. By allowing data visualization capabilities to safety managers, reported unsafe situations and conditions can be addressed before an injury, illness or fatality occurs. The primary objective of this research is to create a tool functional in BIM software to visualize and analyze near miss

information. Sub objectives of this research include creating algorithms and user-interfaces for safety managers to navigate and analyze reported near miss data. A set of best practices for visualizing safety information on construction projects was identified and assembled. The created near miss data visualization tool is intended to visualize near miss information, but any desired categorical safety data including hazard identifications, injuries or illnesses can be viewed within a BIM.

METHODS

A near miss data visualization tool utilizes a methodology of information flow from user input (either by manual input or from an external database) to the near miss database and can be output through three different trajectory: 1) Queried data at the request of the user, 2) visualization within the BIM in 2D or 3D viewpoints and 3) exported to external databases. The user-interface and database communicate via programming codes specifically for near miss data visualization and management. The flowchart for this information is shown in Figure 1.

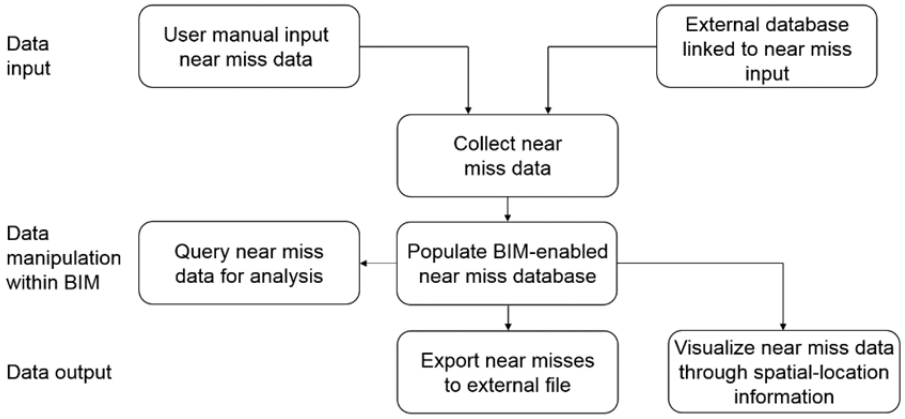


Figure 1: Filtering capabilities of reported near misses

This visualization tool is functional in most commercially-available BIM software. The tool was created using the open Application Programming Interface (API) within a widely used BIM software. The API aided in creating a new set of applications to create and manipulate near miss data including a user-interface (see Figure 2). A commonly-used multi-paradigm programming language was used to create and customize the near miss data visualization tool user interface. The programming language was C#. This coding language is available upon request to the authors. Table 1 displays the functions of the user-interface created by coding and existing algorithms within the API.

Table 1: User Interface Functions

Algorithm	**Description**
Ribbon	Add new applications to the software's original interface
Select	Choose or select the near miss event in 2D or 3D view
TaskDialog	Provide warnings or allow end-users to input information
Event	Enable a function to notify other functions when something of interest occurs (e.g. clicking a tab invokes the function of making a query)

Filtering	Make a query based on a certain criterion
Windows Forms	Create the near miss report

Near Miss Data Visualization Tool for BIM

The near miss data visualization tool was created to improve decision-making for safety managers and other construction project stakeholders by accessing and analyzing near miss information within an active BIM. The usability of the tool was designed for personnel not necessarily familiar with the intricacies of a design model such as BIM. For example, all user-interactions with the tool are simply decision criteria and data entry that require basic computing skills. The following sections describe the functionality of the near miss data visualization tool and discusses specifically how near miss information would be viewed and analyzed with a BIM.

A functional interface for the BIM near miss visualization tool was created for end users to facilitate the input and data analysis of near miss information. The user-interface enables safety managers to do the following functions: 1) create a near miss report, 2) view and edit information for each existing report, 3) visualize the spatial location of a near miss report and 4) filter near misses by various parameters. To create a near miss, the user accesses the “Near Miss” tab with a BIM platform as shown in Figure 2. Using this initial interface, the user can create a near miss report, assign a severity value, access information of previously reported near misses and query near miss information.

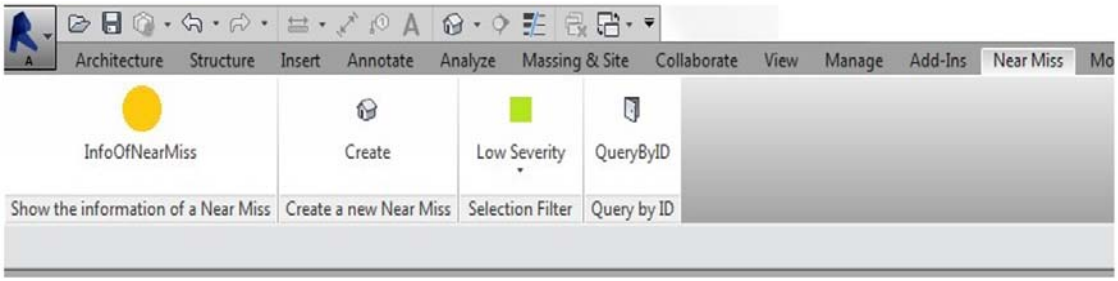


Figure 2: User-interface initial screen for the near miss visualization tool

In total, 22 different categories are available for data entry including the following: Date and time of the near miss, a unique near miss identification number, project name, company name, crew involved, employees involved, event description, associated tasks and reviewer names and dates reviewed. Other available input categories are described in Table 2.

Table 2: Select Categories for Near Miss Data Input

Category	Description
Identification Classification and Category	Near misses can be classified based on their cause using the Eindhoven classification technique that was adopted for the construction industry (Marks et al. 2014, Kaplan et al. 1998, McKay 2013)
Investigative Team	Record the members of the near miss investigative team for each near miss reported and investigated
Severity	User ranks the severity of a near miss on a company-specific scale or using relative measures to historical near misses. The scale allows for a range of 3 different severity scoring options.
Root Cause	The "chain-of-events" that led to the reported near miss
Contributing Cause	Any other events or set of conditions that led to the reported near miss that were not identified as the root cause
Resolution Description	A summary of the mitigation strategy developed by the investigative team to be implemented and observed
Picture	Users can upload a picture taken of the location of the near miss to observe existing and surrounding conditions

These categories are assembled in a similar database template created by the Construction Industry Institute (Marks et al. 2014). Information within this template for each near miss can be viewed and manipulated within a BIM at the near miss location. This near miss template is shown in Figure 3.

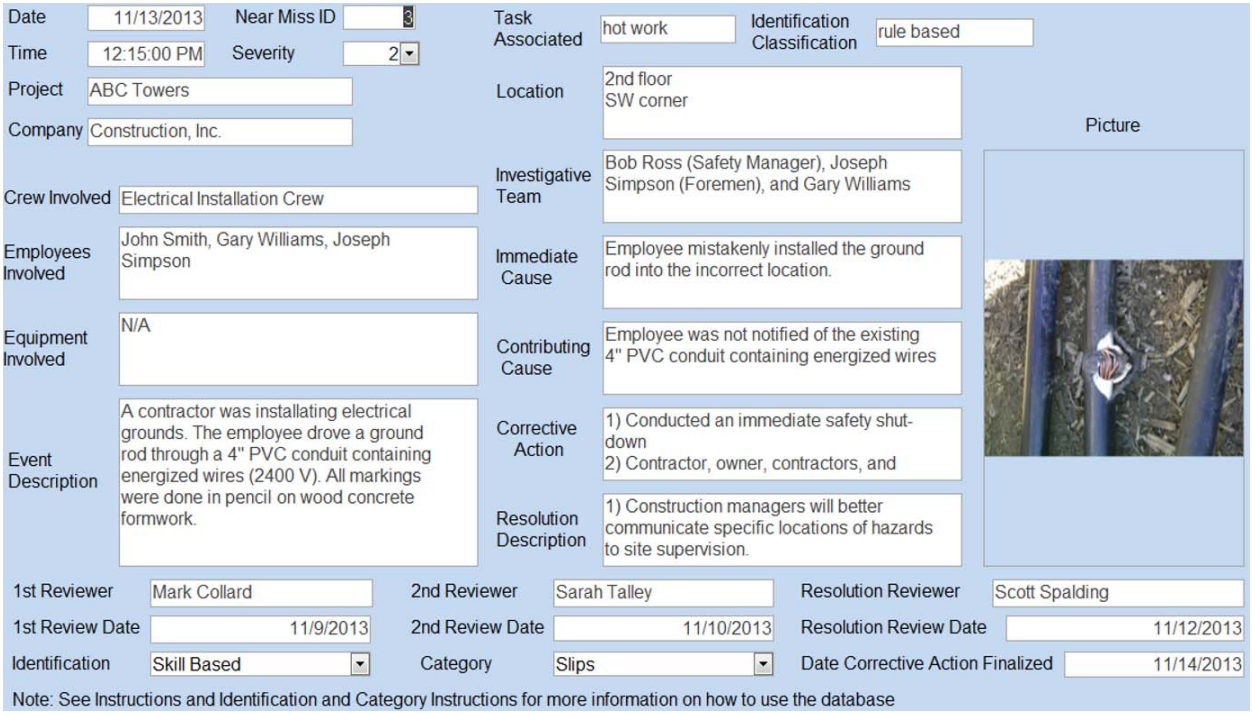
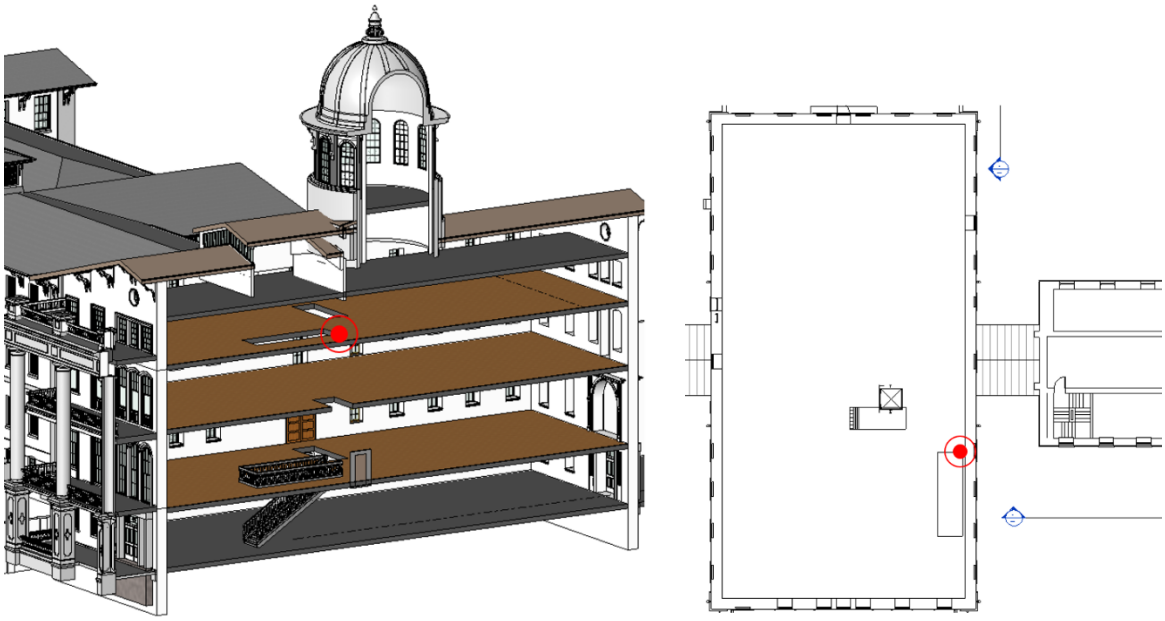


Figure 3: Information template for reported near misses within BIM

The created tool allows for near misses to be reported through a few different methods. The user can input near miss information manually as previously described. Another option, and probably the most preferred, users can identify a location within a BIM and start the information input process based on location-based data of the individual near miss. This location-based data entry within a BIM can be achieved in both 3-dimensional (3D) and 2-dimensional (2D) views. In the prototype shown in Figure 4, a small red sphere represents the location of the near miss. Figure 4 shows the location of a near miss report shown in both 3D and 2D viewpoints.



(a) (b)

Figure 4: 3D (a) and 2D (b) view of near miss sphere in circle

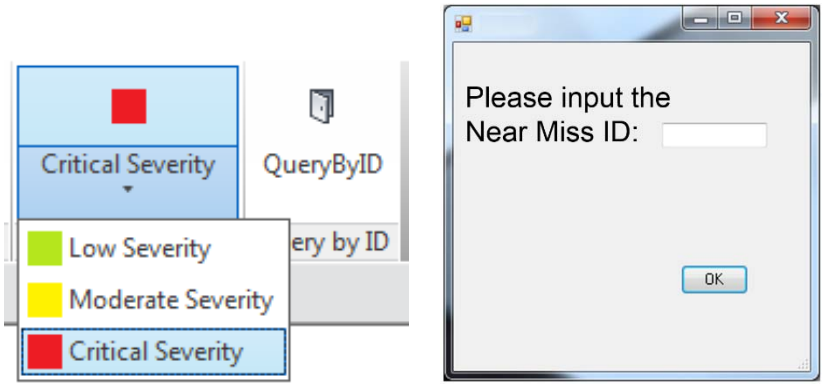
A database linking input information with the existing model is established. Most BIM platforms provide query functions that are accessed by the created visualization tool. The query capabilities can be exported into common file formats for further analysis by other software programs if so desired by the user. Likewise, previously generated databases of near miss information can be uploaded into the BIM platform database for visualization and analysis using the created tool. For this transition to be effective, external input database information should be formatted such that each information category fits with the template within the BIM near miss visualization tool. A sample screenshot of an exported near miss database created using the BIM near miss visualization tool is displayed in Figure 5.

<Near Miss Database>

A	B	C	D	E	F
ID	Date	Time	Severity	Identification	Task Associated
1	10/13/2014	12:15 PM	1	rule based	tripping
2	10/13/2014	2:10 PM	3	skill based	qualification
3	10/14/2014	9:20 AM	2	knowledge bas	slips
4	10/15/2014	10:05 AM	3	skill based	slips
5	10/15/2014	12:10 PM	3	skill based	coordination
6	10/15/2014	3:30 PM	2	rule based	verification
7	10/17/2014	8:20 AM	1	knowledge bas	compliance
8	10/18/2014	9:00 AM	2	knowledge bas	compliance
9	10/18/2014	11:00 AM	1	rule based	monitoring
10	10/19/2014	9:15 AM	1	skill based	knowledge

Figure 5: Exported near miss database

Filtering collected near miss data is an important component to transitioning collected data into usable information for safety managers. The created user-interface allows for user filtering of near miss data by severity level, near miss identification, time of day, equipment involved and other quantifiable project specific parameters input by the user. This data filtering allows safety managers and other project stakeholders to identify only high severity near miss reports for immediate mitigation or group only near misses associated with a particular root cause. Users can also simply search for a specific reported near miss by filtering by identification number. Figure 6 shows the user-interface display when implementing a query for a near miss data set.



(a) (b)

Figure 6: Filtering capabilities of reported near misses by severity (a), searching near miss by unique identification number (b)

ACCOMPLISHMENTS AND RESULTS

A sample BIM was used to test and validate the prototype near miss data visualization tool. The model was used to create a design, facilitate the construction process and maintain the facility during operation of an engineering building on the University of Alabama's campus in Tuscaloosa, Alabama. The BIM software used for both the model and near miss data visualization tool was Revit. A list of 20 randomly generated near miss events was structured for visualization. Information for these near miss events followed the template shown previously in Figure 7 so that each category was populated. The near misses were entered into the visualization tool through both methods:

1) Manual entry through the user-interface (single event entry)
2) Link the external database to the created tool (multiple-event entry)

Each near miss event was verified that it appeared in the BIM and the corresponding near miss information was accessible. Information was also queried based on quantifiable data provided in the created near miss template. The events were queried by severity, data, company, project, task associated and near miss identification number. A similar methodology was used for another BIM used for an engineering building new construction. The resulting near miss visualization within the model is shown in Figure 7.

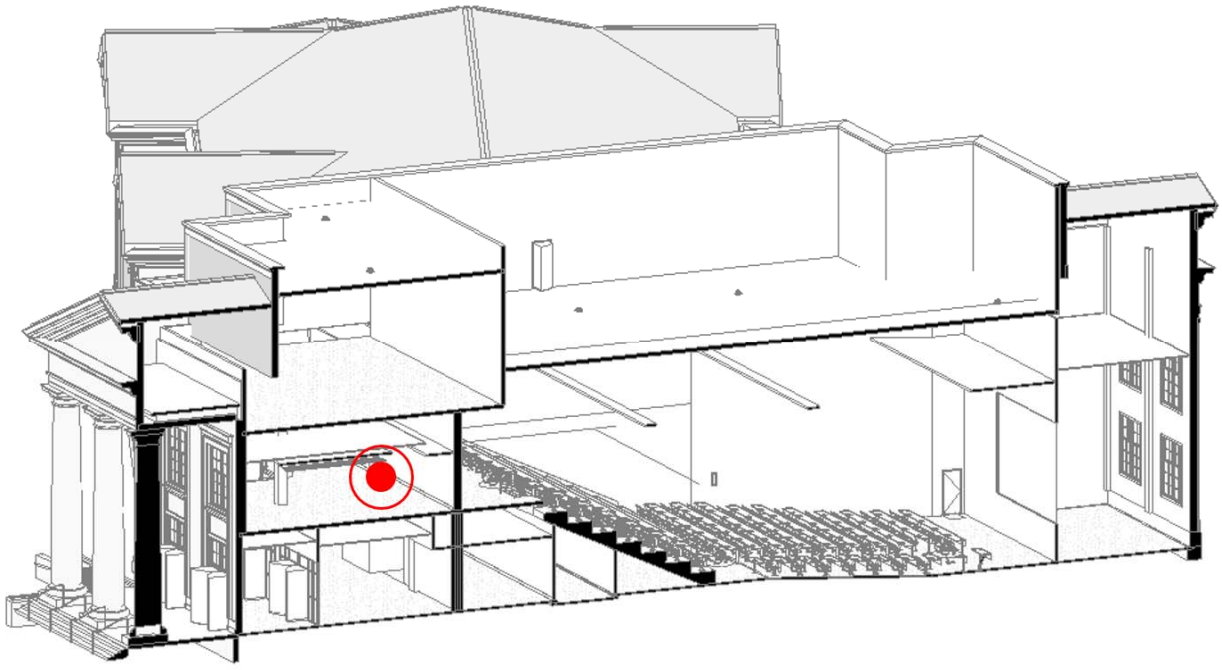


Figure 7: Near miss events visualized within a BIM

Results from the case study indicate that near miss events can be captured and visualized through BIM. New methods were developed to populate and automatically visualize near miss information. The near miss data visualization tool has been successfully implemented on several real project models and all created capabilities were demonstrated. The conducted research

illustrates that collected safety data can be visualized and accessible to all project stakeholders by integrating with BIM.

Expert Review Panel Feasibility Study

Seven safety managers for construction companies were given a demonstration of the created near miss visualization tool. Members of the expert review panel were all Certified Safety Professionals (CSP) and have a minimum of eight years of experience as a safety manager. The safety managers were all employed by construction companies with a minimum of 1,700 employees. The OSHA Total Recordable Incident Rate (TRIR) of these companies ranged from zero to two with an average value of 0.6.

Each participant was provided a description of the study, a description of the created tool and a demonstration of the tool in the BIM shown in Figure 7. The demonstration included instructions and presentations of all available functions of the near miss visualization tool. Additionally, several near miss reports were randomly generated to demonstrate query functions and near miss visualization within the model. After the demonstration, expert review panel members discussed the feasibility and functionality of the tool as well as respond to survey statements about the created tool. Comments from these discussions were recorded and analyzed to identify the content and frequency of each statement. For each statement, panel members were asked to score their perceptions and understanding of the tool based on the following scale: 1 = strongly disagree, 2 = disagree, 3 = unsure/neutral, 4 = agree and 5 = strongly agree. Table 3 provides a statistical analysis of each answered question.

Table 3: Safety Expert Review Panel Responses

Posed Statement Description	Minimum Score	Maximum Score	Average Score
A need exists to integrate safety data in existing project management tools	3	5	4.6
It is useful for safety managers should visualize safety information in 3D models	3	5	4.2
The proposed tool would be easy to use	3	5	3.6
The proposed tool is implementable in my company	3	5	3.8
The proposed tool would enhance near miss reporting	2	5	3.4
The proposed tool would be effective in safety data management	3	5	3.8
The proposed tool would improve safety management	2	5	3.8

Most of the discussions of the safety experts focused on the feasibility and ability to implement the created tool. The safety experts discussed strategies on implementing the tool and specifically cited that existing methods would satisfy all implementation needs. For example, employees would receive training and be educated on the use of the tool as well as the objective of implementing the tool. All agreed that if implemented, the visualization tool would be a useful enhancement to their existing safety program.

A majority of the safety expert review panel members scored favorably (e.g. agreed or strongly agreed) with all posed statements including the proposed tool would improve safety management, the tool is implementable and the tool would be easy to use. One barrier identified by the safety manager is the learning curve and implementation of technology that has proven difficult for this panelists' company. Specifically, this company has historically been slow to implement new technology and innovation due to a resistance to change among employees. This panelist gave the only two scores (e.g. disagree) received in the study. To overcome this barrier, it was suggested by other panelist that an increased time and money investment for the initial training element could be advantageous. One panelist suggested an experiential exercise where employees complete the near miss reporting process through BIM to realize the benefits.

Members of the safety expert review panel also discussed the tool post-demonstration. Statements that were repeated and agreed by a majority of the panel are recorded in the following:

- Members identified the potential promotion of safety across the company by integrating database capabilities of BIM with safety data
- The tool is valuable for promoting safety and could greatly assist companies already doing a satisfactory job of generating and collecting near miss reports to automate their data collection and analysis process
- The tool gives safety managers an simple way to identify locations where the majority of near misses are occurring and reported
- The concept would be beneficial not only to safety professionals, but to anyone associated with project management on construction sites

The implications of this panel indicate an identified industry desire for the created tool. During the interview, many panelist requested a version of the reporting tool and research results when completed indicating the immediate use of the created tool. Other concepts including incorporating other safety data (e.g. hazard identification) into a similar tool were also discussed.

CHANGES/ PROBLEMS

No changes or problems were encountered during the study. The study followed all originally proposed methods.

FUTURE FUNDING PLANS

The research team plans to seek additional funding from select construction companies to further this research. However, no funding currently has been secured.

LIST OF PRESENTATIONS

- "Near Miss Information Visualization Tool in BIM." *Construction Research Congress,* San Juan, Puerto Rico, June 1, 2016.
- "Near Miss Reporting for Construction Companies." *American Contractors Insurance Group,* Indianapolis, IN, September 23, 2016 (scheduled).

LIST OF PUBLICATIONS

- Shen, X. and Marks, E. (2015). "Near-Miss Information Visualization Tool in BIM." *Journal of Construction Engineering and Management,* ASCE, 04015100-1-04015100-10.
- Shen, X. and Marks, E. (2016). "Near Miss Information Visualization Tool for BIM." *Construction Research Congress,* San Juan, Puerto Rico.

DISSEMINATION

A pre-requisite for implementing and maintaining the near miss data visualization tool is a fully integrated and functioning BIM for the design and construction process. Another pre-requisite for experiencing success using the near miss data visualization tool is to have a fully implemented safety program that assesses safety performance based on safety leading indicator metrics including near misses. Without an active and foundational safety program, collecting and analyzing near miss data would be pre-mature. The near miss visualization tool can be linked as an additional component to many commercially-available BIM software and existing database software.

Depending on the company's specific near miss reporting program, the safety personnel and other managers should provide adequate training to all site personnel concerning the near miss reporting process. Training materials and time for the near miss data visualization tool should be limited to personnel with accessibility to BIM. Effort levels of training for the tool can be tailored towards the specific user. For example, crew supervisors collecting near miss reports may not necessarily be interested in how to link external near miss databases to the BIM. Regardless, all site personnel should know managers are able to visualize near miss data. Furthermore, near miss reporters should experience feedback from their near miss report to encourage future reporting.

The created tool enables safety managers and other project stakeholders to visualize and communicate about safety data within a project BIM. Safety managers can download the created near miss visualization tool and follow instructions provided by the user-interface. These instructions explain how users can access, input and analyze near miss data. By utilizing this tool, hazardous situations and conditions can be reported as near misses and visualized by anyone accessing the BIM. This visualization of construction safety data during a project's duration promotes safety within a company and within an active construction site.

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