Paper ID #17935

Developing and Assessing a Safety Training Module to Reduce the Risk of Cave-ins in the Construction Industry

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Abstract

The construction industry is one of the most dangerous industries with a disproportionate number of fatalities when compared to most other industries. According to the Occupational Safety and Health Administration (OSHA), the majority of construction fatalities happen due to the following four types of construction hazards: falls, caught-in or between, struck-by, or electrocution. To reduce the risk of fatalities among construction workers due to the lack of safety training, the authors conducted research to investigate safety training needs in the construction industry in Puerto Rico. The authors developed a structured interview questionnaire that was administered to construction safety professionals and Puerto Rico OSHA specialists to identify major construction safety concerns and training deficiencies. The authors also administered a survey to construction workers to investigate their safety training and risk perception in the construction industry. Based on the results of the interviews and surveys, the authors concluded that the two hazards where the workers need to receive training more urgently are falls and excavation cave-ins. Since falls has been the priority of OSHA for a long time, there are is significantly more training material available on this topic when compared to excavation cave-ins. Therefore, the authors decided to focus the BIM-enabled training module on excavation. The main objective of the training module is to provide general knowledge so that it can be used in commercial, heavy civil and residential projects to reduce the risk of cave-in fatalities. The authors will present the module to safety experts and to a group of students at the University of Puerto Rico at Mayaguez to make an assessment and validate the learning outcomes of the module prior to implementation with construction workers. This paper presents an overview of the results of the interviews and surveys, and focuses on the development of the safety training module that will be completed by the students and construction workers in Puerto Rico. This paper contributes to the body of knowledge by increasing the understanding regarding the current construction safety training needs in Puerto Rico and the development of a training module to make the construction industry in Puerto Rico safer for construction engineering and management students who will work in the construction industry and construction workers.

Introduction

In 1970 the United States Congress passed the Occupation Safety and Health Act (OSHA). Ever since the act was passed the construction safety management practices and techniques have been continuously improving. Safety planning and management efforts increased because the responsibility was placed on the employer (OSHA 1970). The construction industry is constantly

changing and projects are very dynamic therefore the training and education approach also needs to be constantly evolving to meet the industry needs (Hallowell and Gambatese 2009). Providing adequate training to on-site workers can help reduce the accidents since many of them can be attributed to the lack of it (Rodríguez-Garzón et al. 2015).

The construction industry in Puerto Rico decreased in recent years and with it the rates of injuries and fatalities. But as the industry starts to rise again both non-fatal and fatal injuries have started to increase. With an anticipated high addition of jobs in the next five years the construction industry is expected to have an increase of nearly 5% (Bureau of Labor Statistics 2012). Professionals in the health and safety field need to have the necessary tools to supply the demand in the industry and maintain a safe work environment.

BIM-enabled technologies have made their way into the construction industry to assist in health and safety issues. An interactive BIM-enabled safety training module was developed and administered to a group of 50 students at Colorado State University. The module consisted of two parts of interactive training which included animations and illustrations of proper scaffolding uses. The training also included an integrated user evaluation. The students completed the training module and were given an evaluation form. The results suggested that the training module was effective as the students' performance and interest in safety issues increased. (Clevenger et al. 2015)

Balfour Beatty Construction, a construction management and general contracting firm in the United States developed an initiative called BIM for Zero Harm. They also developed a series of training modules using BIM to visually explain hazards in different situations and scenarios to eliminate or control those risks. Their safety models consider four stages; existing needs, before construction, during construction and following construction. They used SketchUp software to develop 3D models and use them for the training modules. They believe that these interactive modules can capture the audience attention and enhance their understanding as they are currently implementing them in their firm. (Balfour Beatty 2015).

Throughout this research the authors developed an intervention plan to address the current safety culture and training needs of construction workers in Puerto Rico. The authors identified current strengths and deficiencies on training and education of construction workers. An interactive training module is currently under development integrating the use of Building Information Modeling techniques (BIM). Three dimensional models can be used to demonstrate virtual scenarios in construction. These scenarios are used in training modules to increase training effectiveness by better communicating means and methods in construction sites. This educational tool will contribute to the utmost goal of creating a safe work environment for construction students, construction professionals and construction workers.

Research Methodology

To develop an interactive training module tailored for the needs of the construction industry in Puerto Rico the authors used a four-phase plan. It was critical to gather information from both health and safety experts and construction workers who face health and safety hazards continuously. In the first phase the authors conducted a series of interviews to construction safety

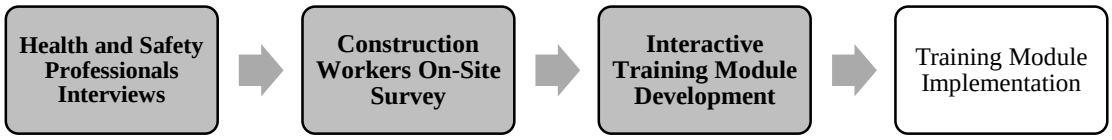

Figure 1: Research Methodology Phases(Rivera Olivencia and Lopez del Puerto 2016)

professionals. Once the interviews phase was completed and the data gathered was analyzed the authors went on the field and conducted a survey to construction workers in different sites around the island. These results assisted the authors on the development of the training module.

For the first phase the authors targeted safety managers, safety directors, supervisors and coordinators for this phase. Health and Safety Specialists from Puerto Rico OSHA were also contacted to participate in the interviews. The participants were divided in two groups; Construction Company Managers (CCMs) and PR OSHA Specialists. The interview consisted of ten open ended questions in which the researcher gathered general health and safety concerns in the local industry as well as current best practices being implemented. Authors briefed the participants with the project objectives to ensure consistency in the process and that all the participants where in the same context when providing their answers. At the end of each interview the participants were asked to provide feedback specifically for the development of an interactive training module.

On phase two a Safety Culture and Risk Perception Survey was administered to construction workers on site. The survey contained 30 survey questions and although all the data collected was important for the assessment of the safety culture in the industry, not all the questions were relevant for the development of the safety training module as some of them addressed different issues and scenarios. The authors classified the survey questions in three categories; Individual Safety/Risk Perception, Others Safety/Risk Perception and Workplace/Company Environment. Out of these three categories only the questions classified under Individual Safety/Risk Perception were used by the authors as input for the module development. In these questions the participants provided an answer related to their behavior, how they address safety issues and their perception of safety/risk scenarios (E.g. “I know how to do my job safely”). These questions directly addressed the worker’s safety culture and risk perception providing the necessary information and input that allowed the authors to develop the interactive training module.

Based on the results from phases one and two the authors are developing the BIM-enabled training module content. The module currently in development includes two parts, 1) Work site accidents and 2) Excavation Safety. The participants will go over different safety scenarios in a 10-lesson BIM-enabled training module.

Phase 1 - Interviews Overview

The interview phase concluded with the participation of 26 safety professionals. The pool included 19 CCMs and 7 PR OSHA Specialists. Participants were involved in different industry sectors with Commercial and Heavy Civil accounting for 88%. To obtain guidance on where to focus the module the participants were asked what was the most common cause for accidents. Answers included both direct and indirect causes. Table 1 below shows a summary of the causes the authors obtained.

Table 1. Most Common Causes for Accidents According to Participants (Rivera Olivencia and Lopez del Puerto 2016)

Cause	Number of Participants	Percent
Falls/working at heights/scaffolding	13	50.0%
Over confidence	6	23.1%
Lack of training/knowledge/risk identification	5	19.2%
Excavations	4	15.4%
Electrocutions	4	15.4%
Struck by	4	15.4%
Tools and equipment operation	4	15.4%
Lack of supervision/implementation	2	7.7%
Demolitions	1	3.8%
Lack of personal protective equipment	1	3.8%
Lifting loads manually	1	3.8%
Materials management	1	3.8%
Poor equipment maintenance	1	3.8%

Participants were also asked about best practices being currently implemented to increase the knowledge and awareness of health and safety hazards in construction sites. Answers included weekly safety talks, providing safety manuals and protection equipment to workers and OSHA 30-hour course for supervising personnel.

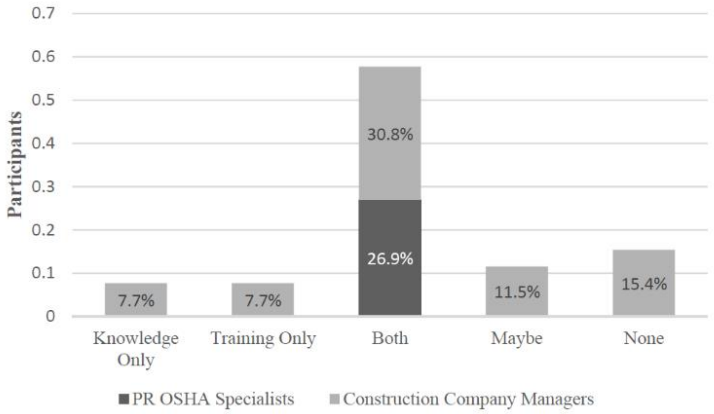

Figure 2. Lack of Knowledge and/or Training according to participants (Rivera Olivencia and Lopez del Puerto 2016)

The authors wanted to know if the experts believe there is a lack of knowledge, training or both among construction workers. Each participant was asked to answer what they believed and the results obtained can be seen in the figure 2.

The last part of the interviews was focused on gathering feedback for the training module development. Most of the participants (88.5%) considered that and interactive training module will be effective while the others weren't sure answering "maybe". Some participants though that workers will engage easily with the use of visual graphics rather than text leaving a lot to the imagination. When giving a recommendation on which are to develop the module all participants included at least one of the four main causes of worker's fatalities in construction (falls, struck-by, electrocutions and caught-in between).

Phase 2 - Workers Survey Overview

The authors went out to the field and surveyed construction workers in six different locations around the island. A total of 96 workers have participated in the survey and the authors are currently in process of gathering more participants to have a more robust sample.

The first part of the survey gathered demographics from the participants. Like the interviews most of the participants showed involvement in Commercial or Heavy Civil (92.8%). The majority (79.1%) fall in between 31-50 years of age and 84.5% were from Puerto Rico. 66% of the participants had 11 years or more working in the construction industry. Twenty one percent started but not graduated from high school, 33% finished high school, 11.34 had part of college and 17.5% attended a technical school. 90% of the participants said they had at least 5 hours of training in the last year and 29% had sustained an injury at some point at work.

The questions in the survey were classified in three categories with 14 out of the 30 questions in the survey falling under the Individual Safety/Risk Perception category. These questions were directly related to the module development. The participants answered each question using a scale from one (Totally Disagree) to five (Totally Agree). A higher value in most of the questions meant a "best/safer" behavior, attitude or perception by the worker. But for some questions the "best/safer" answer was the lowest value. For example, in the question "I have control over the dangers that I encounter on construction sites" the best answer would be *Totally Disagree* with a value of 1 per the scale. For analysis purposes the values for these questions were inverted from the original scale values, thus normalizing the results.

The results for the 14 Individual Safety/Risk Perception questions are shown in table 2. The mean values are based on a scale from one to five after normalization and are shown in order from lowest to highest. A lower mean value meant most the participants did not answer the question in a safely manner.

Table 2. Individual Safety/Risk Perception Questions and Mean Values

Question	Mean
I have control over the dangers that I encounter on construction sites. *	1.87
Some safety rules and procedures are difficult to understand. *	2.85
The dangers present on construction sites cannot cause my death or the death of others. *	3.05
The risk level of my job concern me quite a bit.	3.31
I am willing to take more risks than my coworkers. *	3.51
I know all the specific risks for each project before I begin to work on them.	4.13
Accidents can happen to anyone. *	4.16
It is the responsibility of each employee to seek out opportunities to prevent injuries.	4.16
I have received adequate job safety training.	4.22
When I see a potential safety hazard (e.g., oil spill), I am willing to correct it myself if possible.	4.30
I always follow the safety rules and procedures when doing my job.	4.32
I have the personal protective equipment that I need to do my job safely.	4.34
I know how to do my job safely.	4.49
I am willing to warn my coworkers about working unsafely.	4.57

* Normalized Value

Out of the 14 questions classified under the Individual Safety/Risk Perception category only five had a mean value lower than four. These questions were the following:

- I have control over the dangers that I encounter on construction sites. *
- Some safety rules and procedures are difficult to understand. *
- The dangers present on construction sites cannot cause my death or the death of others. *
- The risk level of my job concern me quite a bit.
- I am willing to take more risks than my coworkers. *

These questions with low mean value were interpreted as if the participants needed more awareness of the risks they constantly face and that there must be an alternate way of communicating the safety rules and procedures.

Phase 3 - Training Module Development

After conducting both, the interviews and the survey the authors found some key factors to justify the need for the creation of a BIM-enabled training module.

The results from the Health and Safety Professionals Interviews phase showed that the majority (57.7%) of the CCMs and PR OSHA Specialists perceive that there is lack of both knowledge and training among construction workers. Also 23 out of the 26 participants consider that an interactive training module will increase the knowledge and improve the attitude of the workers towards safety.

From the Construction Workers On-Site Survey the data analysis the questions with the lower mean values (<4) can be attributed to the lack of knowledge and or training along with overconfidence. Especially when the results showed that workers consider that some of the safety rules and procedures are difficult to understand.

After analyzing the data from the previous phases, it became clear that the authors should focus the training on at least one of the "Fatal Four" which include falls, struck-by, electrocutions and caught in between. Creating a module that addresses all the mentioned areas in detail can turn out as an overwhelming training for the workers. For that reason, the authors selected one of the leading causes to aim the module. Based on the results from the interview phase the leading cause for accidents was falls and the most recommended focus area was excavation activities. OSHA has emphasized falls protection in many of their training materials available. Therefore, the authors decided to focus the module on excavation safety since there is less training materials available in that topic. Other than falls, excavations were the topic of more concern based on the results of the interviews and surveys.

The authors developed the content of the module which consist of two main parts: 1) Worksite accidents overview and 2) Excavations Safety. Participants will go over 10 lessons to gain a better understanding of the risks related to excavation activities. The module is being developed using Adobe® Captivate® 9 software.

Lesson 1	• Worksite Accidents
Lesson 2	• Competent Person
Lesson 3	• Inspecting Excavations
Lesson 4	• Soil Types
Lesson 5	• Sloping
Lesson 6	• Benching
Lesson 7	• Shoring Systems
Lesson 8	• Trench Shields
Lesson 9	• Ingress and Egress Means
Lesson 10	• Debris Protection and Equipment Use

Figure 1. Training Module Lessons

The authors created a three-dimensional environment using Trimble SketchUp® in which the training module will be based. Participants will have the opportunity to interact with the module with different activities that include: walkthrough, drag and drop selection and user guided placement. Authors used different available materials to develop the scenarios to be evaluated throughout the module. OSHA had developed a fact sheet (OSHA 2014) and published a booklet that addresses most of the general safety concepts when performing trenching and excavations (OSHA 2015). All material used for the development of the training module is being validated with the Code of Federal Regulations Subpart P which covers safety procedures and standards for excavation activities (*Excavations, 29 C.F.R.* 1926).

Figure 3: Interactive training module interface

Lessons one through three are more of an introduction to the module. The content includes both text and audio in Spanish to aid the users in the understanding of the concepts shown. From lesson four though ten the users will start interacting with the model by dragging objects and placing them in correct locations. Also, walkthroughs with audio and texts to identify unsafe behaviors and features. In figure 3 an example of a simple true or false scenario is shown. The 3D model will allow the users to play animations to see a walkthrough before having to answer different questions about the configurations and safety procedures shown.

After completing each lesson the user will receive immediate feedback for the answer provided which includes OSHA regulations and standards. At the end of the module the user will be evaluated in all concepts presented throughout the lessons to assess module effectiveness.

Conclusions

After conducting phases 1 and 2 it was clear that the main causes of accidents or “fatal four” are the biggest concern of both the safety professionals and the construction workers. The results from both phases suggested that there is a lack of knowledge and training which can be addressed with the implementation of an interactive training module. Even though fall prone activities were the ones most mentioned by participants the authors decided to develop the module in excavation safety since there is a similar training module already created to address that type of hazards.

One of the most important results obtained from the survey is that many workers think the safety rules and procedures are difficult to understand. This issues is one that the authors are directly attending by developing an easy to follow and engage training module. Workers are also appeared to be unaware of the potential risks they constantly face while on construction sites. The low mean values on questions such as the ones when they had to answer if they could control the risks, the potentially fatal hazards and the will to take more risks raise the concerns on how safe they are acting on the field. All this feedback served the authors to tailor the training module in a way that these main concerns are being addressed.

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