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Role of visualization technologies in safety planning and management at construction jobsites

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Abstract

Workplace safety is significant to the construction industry throughout the world. Despite rigorous efforts of safety professionals and strong governmental enforcement of safety laws and regulations, there has not been a significant decline in fatalities, injuries and illnesses in the construction industry. Extensive research on this topic has indicated that the dynamic nature of the construction industry is one of the main reasons. Each construction project is unique and identifying all possible hazards and safety risks is always challenging. In recent years there has been a significant increase in the use of visualization technologies in different phases of the construction project life cycle. Visualization technologies such as Building Information Modeling (BIM), 4D simulations, and 3D Immersive Virtual Reality Environments can result in improved occupational safety by allowing architects, engineers, and contractors to visually assess jobsite conditions and recognize possible hazards before the construction proceeds. This paper presents three case studies that investigated the effectiveness of above-mentioned visualization technologies in developing, communicating and implementing construction site safety plans. The case studies results indicated that 3D/4D dynamic tools are more effective in safety planning and management as compared to the 2D static drawings because they closely simulate the actual jobsite conditions. In addition, the visualization technologies are found to be very effective in construction safety education and training in both formal and informal settings.

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Keywords: Construction safety; visulization technoliogies; Building Information Modeling; 4D simulations; Virtual reality head gears

1. Introduction and background

Safety performance is of vital importance throughout the construction industry [1]. The accident rate in construction is among the highest in comparison to other industries all over the world [2]. Although dramatic improvements have

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taken place in construction technologies and processes in recent decades, the safety record in the construction industry continues to be one of the poorest [3]. Inappropriate work planning and supervision; insufficient communication between workers and supervisors; and lack of safety training and practices are identified as key contributing factors behind most fatalities and injuries [4].

Safety planning is an essential part of the construction planning process but is typically carried out to a certain extent separately from other project planning and control tasks [5]. Traditional safety planning relies on manual observations, gut-feelings and experience of the safety planner. A typical safety plan depicts what safety measures are necessary, when, where, and why. The link between planning for safety and work task execution is often weak: for example, many contractors use two-dimensional drawings (2D) or field observations to identify hazards. Since their approach is manual and based on experience and gut-feelings, the observed results can be error-prone due to subjective judgments of the decision maker [5].

Recently, there has been considerable interest in improving worksite safety through safer design and work method statements using Building Information Modeling (BIM) [6, 7]. A building information model allows constructors to visually assess jobsite conditions and recognize hazards [8]. The utilization of BIM technologies can result in improved occupational safety by connecting the safety issues more closely to construction planning, providing more illustrative site layout and safety plans, providing methods for managing and visualizing up-to-date plans and site status information, as well as by supporting safety communication in various situations, such as informing site staff about making safety arrangements in response to a particular risk or warning about various risks [9]. The use of BIM also encourages other project partners to involve in both risk assessment and planning [5].

Rajendran and Clarke [10] outlined the following areas where Safety and Health (S&H) professionals can use BIM technologies: (1) Design for safety; (2) Safety planning (job hazard analysis and pre-task planning); (3) Worker safety training; (4) Accident investigation; and (5) Facility and maintenance phase safety. For these tasks, S&H professionals can use 3D renderings generated from the BIM models and walk-throughs animations. In addition, 4D phasing simulations focused on the safety procedures can be generated to show how temporary safety elements and areas of concerns transition throughout the duration of a project. A byproduct of integrating safety with BIM is safety related training videos for construction workers. Using a BIM model for safety training creates a visual tool that allows on-site labor to understand the actual project conditions. It can also help cross the common language barriers associated with foreign workers because training is done through visualization [9]. Franconeri and Simmons indicated that animated stimulus with moving and looming stimuli captures the human attention-span for a significantly longer amount of time when contrasted with static imagery [11].

Eastman et al. reported two examples of the use of BIM in safety planning and management [12]. In the first project, a theme park, the project team modeled envelopes for testing rides to ensure that no activities were taking place during the testing period within the test envelope. Using 4D simulations, they identified a conflict and resolved it ahead of time. On a second project, a steel frame building in Yas Island of Abu Dhabi, massing cylinders were used to model the spaces occupied by the activities of the welding crews. Clash detection between cylinders was then used to identify possible exposure of workers to dangers posed by other teams from time to time.

1.1. Building information modeling for construction safety: scope and applications

The existing research studies on the utilization of BIM technologies for safety planning and management can be divided into the following categories: (1) Design for safety; (2) Design inspection and monitoring; (3) Safety planning; (4) Safety training; and (5) Facility management and emergency responses [7]. A brief summary of some of the important studies is presented below.

Ku and Mills evaluated potential of BIM as a design-for-safety (DfS) tool [13]. They indicated that BIM can facilitate early collaboration between architects/engineers and constuctors, via automated checklists of rule-based safety information such as codes and regulatory information. Via a theoretical framework, they evaluated usefulness of BIM as a DfS tool and provided research suggestions for designing future BIM tools for safety. Based on this concept, Qi et al. designed a prototype Construction Safety Checking system. This tool automatically checks for fall hazards in a BIM model and provides design alternatives to the users [14].

Kim and Ahn used BIM technologies for temporary facilities planning of a building project [15]. They mentioned that the temporary facilities planning process is tedious and requires a lot of attention due to the following reasons: