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The use of a BIM-based framework to support safe facility management processes

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ABSTRACT

Maintenance personnel in the field of facility management (FM) are at constant risk of electrical shock, falls, crushing, cuts and bruises, and as a result, have a much higher rate of injury and illness than the national average. Case study analysis confirms that many recorded accidents could have been avoided had the victim followed appropriate hazard mitigation steps to safely execute a FM task. Currently, safety information is conveyed through training seminars, documents, and meetings. This information, although comprehensive, often remains fragmented among multiple resources. Research has shown that the more time and effort an individual must spend obtaining information, the less likely they are to retrieve the information and obey the stated warnings, directly relating to injuries and fatalities. This research attempts to mitigate these issues by describing current market trends, available technologies, and limitations. The paper presents a BIM-based framework to support safe maintenance and repair practices during the facility management phase, through safety attribute identification/classification, data processing and rule-based decision making, and a user interface. By developing a BIM-based framework for FM safety, an underutilized/under-researched usage of BIM is being explored.

1. Introduction

1.1. Background

Buildings in the United States and around the world are becoming increasingly complex, utilizing sophisticated technologies for communication and operational control. The role of facility management (FM) staff is critical to the planning, maintaining, and managing of these complex facilities [1]. As skilled professionals, FM staff use knowledge in multiple disciplines such as mechanical, electrical, plumbing, and fire protection (MEPFP) to ensure the functionality of the built environment [2]. Often, the complexity of the systems will dictate the requirements for FM staff and the expertise areas that are required for the management of the facility.

Due to the maintenance and repair requirements of these facilities and the time sensitivities associated with these tasks, workers in this field are at high risk of injury including, electrical shock, falls, crushing, cuts, and bruises. As a result, FM personnel in the United States have a much higher rate of injury and illness than the national average when compared to all other fields of employment (See Fig. 1) [3]. Within the private sector from 2008 through 2012, FM employers recorded 98,420 cases of occupational injuries and illness, with 26,190 cases requiring a minimum of 31 days away from work [4–8]. In the same time frame, 293 people lost their life in the field of facility management, also referred to as General Maintenance and Repair [9–13]. This number accounted for roughly 1.3% of all work related fatalities in the United States and has shown an increase of 64% from 2008 to 2012 (Fig. 2). Case study analysis of the Fatality Assessment and Control Evaluation Program (FACE), issued by The National Institute of Occupational Safety and Health (NIOSH), confirms that many of the recorded accidents could have been avoided had the victim followed appropriate hazard mitigation information to safely execute the FM task, defined in this research as *safety protocol*.

To mitigate some of the risks associated with FM tasks and to comply with many federal, state, and local laws, organizations provide job specific training and numerous safety specific documents to protect their FM employees [14]. These are proven and effective methods for the protection of staff, but require the information to be utilized comprehensively. In other words, no single training seminar or safety document supersedes the others. This requires the FM personnel to comprehend all the safety information collectively and enact the applicable safety protocol with each FM task. With majority of onus on the worker's interaction with the safety information, it is not surprising that human error is the cause of 70–80% of all operational accidents [15].

This research attempts to mitigate the issues presented in Section 1 by describing current market trends in relevant FM safety information development, delivery, and storage (Section 2), available technologies for safety storage, retrieval, presentation, and associated analysis of these technologies (Section 3), and presents a framework to support

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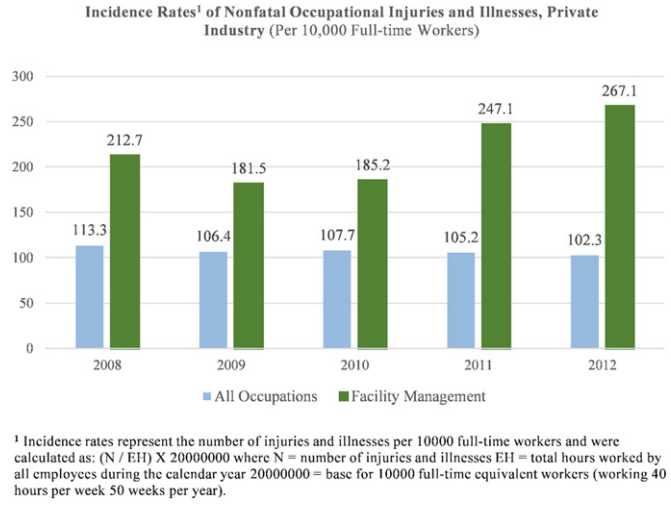

Fig. 1. Comparison of incidence rates.

safe maintenance and repair practices during the facility management phase (Section 4).

2. Relevant FM safety information

Comprehensive safety information is typically available within an organization; however, this information is often uncategorized and fragmented among multiple resources that would need to be referenced prior to a FM work activity [16,17]. Research has shown that the more time and effort an individual must spend obtaining information, the less likely they are to retrieve the information and obey the stated warnings [18–20]. Conversely, minimizing the amount of time and effort to the lowest possible level of information retrieval, has shown a much stronger likelihood of safety protocol implementation [20]. This is especially important in a field where tasks are often time sensitive. Working under the stress of too many work orders and short deadlines results in rushing, which has been shown to be directly correlated to occupational injuries and fatalities. According to The Lawrence Berkeley National Laboratory [21], "Injuries due to time pressure are most often the result of a conscious or semi-conscious decision on the worker's part to circumvent a known preventative measure to a known safety hazard in the interest of getting the task done on time or rushing to keep ahead of a process following close behind." The inconvenience of having to retrieve uncategorized safety related information from a number of fragmented sources, retards the FM task, requiring time sensitive activities to be rushed, and often distracting attention from hazards that would normally be recognized.

Exploring which contract entities input safety data, when the data are presented, where it is stored, and how it is extracted, provides insight into the fragmentation of current market safety protocol. This research explores a potential solution to mitigate the uncategorized and fragmented nature of current market safety information by providing job specific safety protocols at the lowest possible level of information retrieval through the use of a singular BIM-based framework. The framework acts as an intermediary between the stored job specific safety protocols and the FM personnel assigned to the task.

2.1. Safety information sources

Information that is applicable to the safe maintenance of a facility comes from a number of sources. This information is often presented by the contract entities, through a number of contract required documents throughout the buildings lifecycle, as presented in Fig. 3. Design drawings, specifications, and 3D models provide information such as powers sources, disconnect locations, elevations, etc., and are often developed during the design phase. When architects and/or engineers (A&E) begin to design a building, the routing of power, proximity of disconnects, the number of isolation valves, the elevation of equipment components, and many other considerations, all affect the maintenance requirements during the FM phase. A conscious understanding of this cause and effect and the subsequent design in support of downstream lifecycle phases is known as Prevention through Design (PtD) or Design for Safety (DfS) [22–24]. The use of PtD/DfS is a powerful tool to improve accident mitigation; however, has historically been focused on the construction phase and less on FM.

Along with the considerations made by the design team, the capturing of supplier/contractor procurement decisions within a project could also play a significant role in the development of FM safety protocols. Contractor selection of a manufacturer for procurement of materials and/or equipment results is a substantial amount of applicable safety information that is presented through submittals and O&M manuals. Information such as maintenance cycles, maintenance protocol, required tools, and contact information, all play a role in the downstream development of a safety protocol. Recently, with a focus on BIM-FM, FM personnel have become involved in projects during the design and construction phase in order to aid in this type of decision making. This is often achieved through specific equipment specifications or collaborations with suppliers/contractors.

In addition to project specific information, safety information applicable to the FM staff will come from organizational policies and procedures. Through safety meetings, checklists, handbooks, manuals, and legal precedence, the internal requirements for the maintenance of a

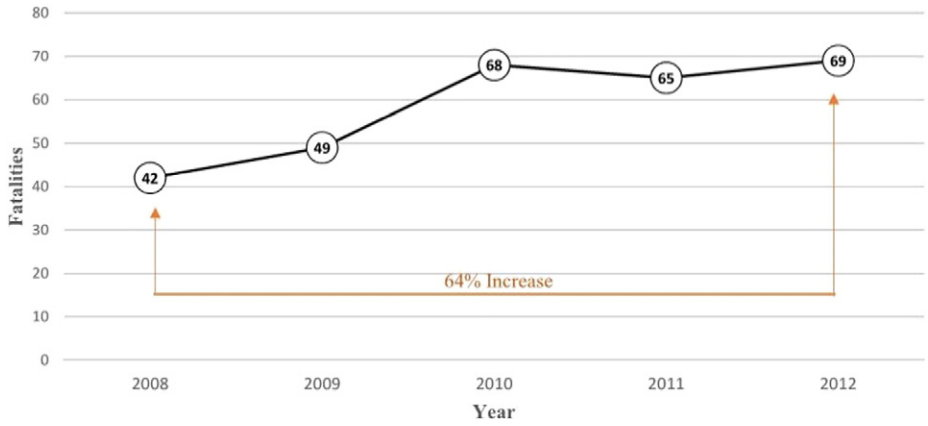

Fig. 2. FM fatalities from 2008 through 2012.