# ⑳ Automated Jobsite Hazard Analysis (JHA) using Safety Ontologies in Building Information Models (BIM)

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**Abstract:** Job hazard analysis (JHA) is a process of identifying potential hazards for each job step of work activity and recommending safe work procedures to prevent safety incidents. This paper contributes in automating the process of current manual based JHA by proposing a framework of integrating ontology-based JHA in building information models. A prototype of a BIM plug-in has been developed to read JHA ontology in OWL and XML file format. It is then applied to a BIM and checks work tasks in the construction schedule. The JHA-BIM prototype generates visual understanding of simulated building model and estimated work spaces. The framework has been validated in a sample BIM and also through comparison with traditional manual safety planning and work space modeling efforts. The results indicate more time-efficient and accurate job hazard analysis using the proposed JHA-BIM framework.

*Keywords* : Job Hazard Analysis (JHA), Building Information Modeling (BIM), Ontology, Construction Safety, Safety Planning, Simulation

## 1. Introduction

About 90% of workplace injuries can be traced to unsafe work practices and behaviors (Teo et al. 2005). As good safety practices and records create a positive, hazard free, and productive work environment, planning for safety at the front-end of a project is not only the first but also a fundamental step for managing safety (Waly and Thabet 2003). A job hazard analysis (JHA) is a technique that focuses on job tasks as a way to identify hazards before they occur. It focuses on the relationship between the worker, the task, the tools, and the work environment (U.S. Department of Labor 2002). As a process of identifying potential hazards for each step of an activity and proposing safety rules to prevent potential incidents related to these hazards, in the United States, the Occupational Safety and Health Administration (OSHA) recommends performing JHA for construction activities to highlight and react to potential hazards. The basic procedure for conducting a JHA includes (1) identifying all job steps of a given activity; (2) identifying potential hazards related to these different job steps; and (3) proposing action procedure (e.g., safe procedures or precautions) to eliminate, reduce, or control each hazard (National Safety Council 1997).

## 2. Background

The complex and dynamic nature of the construction industry and its on-site work patterns are widely recognized. Safety planning in an unstructured construction environment is thus more challenging.

Traditional safety planning relies on frequent manual observation, which is labor-intensive, time-consuming, and thus highly inefficient. Safety planning together with project execution planning can convey what is to be built, what safety measures are necessary when, where, and why (Chantawit et al. 2005). 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 determine hazard prevention techniques. Since their approach is manual and based on experience, the observed results are often error-prone due to subjective judgments of the decision maker.

JHA is time-consuming, inaccurate and hard to keep up-to-date with changing construction schedules. Useful information about potential hazards and associated safety rules from job steps of previous JHAs may be missed if steps of the previous activity are identical to steps of the new activity but the previous activities fall into different categories than the new activities and thus are ignored.

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Because of the complexity and time-consuming nature of JHA, safety personnel must perform JHAs months before the activity actually is scheduled to be performed, before the activity actually is scheduled to be performed (Wang and Boukamp 2008).

Information and communication technologies (ICT) such as Building Information Modeling (BIM) (Eastman 2011) and Virtual Design and Construction technology (VDC) have become well-known tools in the Architecture, Engineering, and Construction (AEC) industry. Many researches aiming to improve the safety planning practice use ICT. Benjaoran and Bhokha (2010) developed an integrated system for construction and safety management based on 4D CAD model and rule-based algorithms (Hazard Explorer and Safety Measure Advisor). Zhang et al. (2011) introduced an automated safety rule checker for Building Information Models (BIM), which can also install fall related protective safety equipment according to the pre-defined regulations automatically.

Gruber (1993) defined ontology as "an explicit and formal specification of a conceptualization." Ontological modeling is a systematic approach for representing knowledge in ontologies (Wang et al. 2011). The main areas, in which ontological modeling is applied, include communication and knowledge sharing, logic inference and reasoning, and knowledge reuse (Feruzan 2007). However, related research efforts applying ontological modeling is sparse in the AEC/FM domain. The e-COGNOS project explored a domain specific ontology for knowledge management and context modeling and reasoning in the construction industry (Lima et al. 2005). Wang and Boukamp (2011) presented a framework aiming to improve access to a company's JHA knowledge by using ontologies for structuring knowledge about activities, job steps, and hazards in OWL and XML format. It also includes an automatic ontological reasoning mechanism for identifying safety rules applicable to given activities. A prototype system (JHA Advisor) was developed to perform the reasoning mechanisms.

The main purpose of this research is to propose a framework aiming to automate the project-based JHA process of construction and provide more accurate results. The proposed framework integrates JHA ontology in BIM leveraging the ontology-based JHA representation framework proposed by Wang and Boukamp (2011). The scope of this research focuses on JHA of concrete structure related construction activities. The research on preparing the JHA ontology from traditional JHA documents is presented by Wang and Boukamp (2011), which is not the

focus of this research.

## 3. Framework and Methodology

The purpose of this research is to integrate ontology-based JHA knowledge in BIM. The first step is to prepare computer-readable, ontology-based JHA knowledge from traditional JHA documents or databases, including an OWL-based representation of JHA concepts and XML-based representations of recommended procedures for addressing hazards. The OWL-based JHA concept representation is created in Protégé (2012), including four classes: Task, Activity, Job-Step and Potential-Hazard. Procedures are stored in an XML file.

After the developed system has identified the potential hazards, recommended procedures, highlighted the related building model elements and also visualized the estimated work space, a JHA report is generated in an automated manner. The JHA report includes the traditional textual information and also a screenshot of the simulation of the building model showing the current status of the project along with the estimated work space. The safety manager can use this report at both the construction planning stage and also in the construction phase: 1) the 3D model can give him/her a good understanding of the jobsite and assist the decision making process; and 2) the graphical report can be used as a guide for the safety inspection and also as a checklist to ensure the adherence to each of the recommended procedures.

## 4. Implementation and Results

A prototype was developed using Microsoft Visual C# to implement the proposed framework (Figure 1). The developed GT JHA Advisor is designed to be able to leverage different sets of JHA knowledge and also BIM model.

As an artificial test case, a simple structure has been modeled in a BIM software including slabs, walls, staircases, and columns. All building elements were linked to a corresponding schedule. The original OWL and XML were obtained from the work published in Wang and Boukamp (2011) and have been edited according to the framework of this research. For each Task in the schedule, the corresponding Activity, Job_Step, Potential_Hazard and Recommended_Procedures were shown (see Figure 1). An informative report (see Figure 2) was automatically generated by the system an excel sheet. 210 JHA reports similar to Figure 2 were automatically generated after the

execution of job hazard analysis in the prototype. After that, the researcher manually checked and compared the content of the report with the JHA document. The generated reports were found to be 100% correct in terms of the JHA concept, the recommendation of relevant procedures and also the picture showing the status of the construction and the linked building elements.

## 5. Discussions and Conclusions

This paper presented a framework for automated, ontology-based job hazard analysis (JHA) in building information models (BIM). The proposed framework introduces significant automation in existing manual/experience-based JHA processes allowing the user to apply different sets of JHA on the building information models. Simulation of safety and visualization of models with estimated work space becomes possible. The developed knowledge or best practice can be transferred and applied by staff that might have different levels of experience. The prototype's initial validation indicates the system to be more efficient compared to the manual efforts in terms of accuracy. It allows the safety manager to plan for safety at the front end of a project automatically.
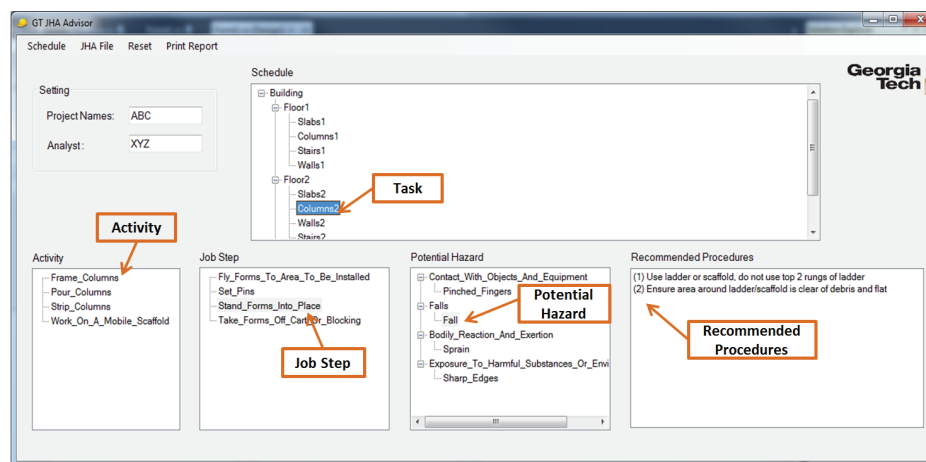


**Figure 1.** GT JHA Advisor Interface



**Figure 2.** Sample JHA report generated by GT JHA Advisor automatically

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