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OBJECT-ORIENTATED HAZARD ANALYSIS IN BUILDING CONSTRUCTION PROJECTS

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Safety planning, as well as planning for hazards and risks in building construction projects, are mostly carried out on paper-based 2D plans. There are various methods, such as safety analysis and risk assessment, which can be applied to improve the health and safety of construction workers. Safety planning needs to be integrated into the design and planning phase. Building models are made in 3D; the challenge is to connect both to a single model. This paper solves this problem by carrying out a hazard analysis for collecting and formalizing basis data, and then integrating the calculated results into a 3Dbuilding model. Therefore, the advantage is that a knowledge base can be obtained for all project participants, who can quickly access the risks and hazards connected to their respective buildings.

Keywords: Building information modeling, Construction management, Safety planning.

1 INTRODUCTION

The theme of "object-orientated hazard analysis in building construction projects" reflects a model-based analysis of the hazards and risks at construction sites. In this case, components of the object-oriented reference are added and hazards and risks identified. This paper shows such an analysis, integrating the theoretical inputs into a 3D building model. The goal is to organize risks in a way that these can be associated with building elements.

First, this paper provides an overview of the literature on related technology and research. Afterward, the main issues connected to hazard analysis in Germany and the United States are presented. Next, the paper investigates the possibility of adapting knowledge-based construction-process planning to a hazard analysis. Subsequently, dangerous situations and workplaces are identified. The results of the hazard analysis are discussed and implemented in a case study of an actual park house for cars and trucks.

2 BACKGROUND

Construction remains one of the most risky professions in the industrial sector. The main reasons are the constantly-changing construction environments, the inconstant personnel situation, and the reciprocal influence of the companies involved in the process. Statistics show a clear decline in the accident rate since 1995. However, the decreasing number of accidents is not a reason to be complacent.

High occupational accident rates in the construction industry are a well-known problem worldwide. Through the analysis of hazards and through their assessment, as well as compliance with labor regulations, the number of accidents can be reduced further. To act preventively, an attempt will be made to integrate rules and regulations in a digital building model. Based on such early implementation, the overall framework of planning can be checked for compliance with safety standards, and can be accordingly changed and adjusted in the first phase of the project.

Building Information Modeling (BIM) represents a promising development in the architecture, engineering and construction industries. With this technology, accurate building models can be digitally displayed. It supports the design through all its phases until the project is completed, and allows better analysis and control than existing manual processes.

BIM not only entails the use of intelligent three-dimensional models, it also means significant changes in workflow and project requirements. BIM presents a new paradigm in the architecture, engineering and construction industries. The integration of all persons involved in the project, and the potential for creating greater efficiency and satisfaction, leads to a synergy between the various disciplines. Thus, the object-oriented approaches to the hazard analysis identify and optimize the prevention measures of the Department of Safety Engineering (Eastman et al. 2011). According to the object-orientated hazard analysis in building construction projects, there are some research approaches that can be divided into three categories (Melzner and Bargstädt 2013a):

- **Manual tools for improving safety planning**: The so-called “Design for Safety” (DFS) Aids consider security issues during the design phase to involve the cooperation of all stakeholders with regard to the safety assessment (Gambatese et al. 1997, Cooke et al. 2008).
- **Possibilities of visualization and their potential for improving safety**: The possibility that the safety equipment can be visualized has great benefits. 3D models, which include railings and similar objects, are easier to grasp and understand than traditional plans (Kiviniemi et al. 2011, Kim and Ahn 2011).
- **Automatic construction safety analysis**. An example is the “automated safety rule checking” algorithm by Zhang et al. (2013). The goal is to identify hazards through a rule-based inspection process, and thus increase safety on the site. It will not only identify risk points, but also display appropriate safety measures. Based on this method, a case study showed that this application is flexible and customizable, and is applicable to different international conditions and health and safety regulations (Melzner et al. 2013b).

3 RESEARCH METHODOLOGY

This research contributes to the improvement of safety at construction sites. Consequently, priorities will be identified during occupational accidents in the construction industry to obtain a general overview of dangerous situations and workplaces during the construction phase. After that, categories will be formed in which hazards and risks can be shown and analyzed. The hazards and risks considered form the basis for the analysis of risks in the project under consideration. Subsequently, the hazards of the construction methods will be implemented through an example in a

3D building model. Through this implementation of an example, based on an actual project, the effectiveness in practice can be investigated and the advantages and disadvantages demonstrated.

4 EXECUTION OF HAZARD ANALYSIS

The identification of hazards and risks associated with the construction of a building can be divided into three categories: 1) hazards caused by the building geometry, 2) hazards caused by the building and construction environment, and 3) risks caused by the construction method.

Hazards and risks of these categories are identified with individual methods. Hazards caused by the building geometry are geometrical structures (lines, areas, rooms) of the building and their construction components. Hazards caused by the building and construction environment are identified depending on the particular area in the work. Each construction method consists of different processes, which result in different risks and dangers. The result is a clear structure, which is necessary for understanding the hazards and risks so that they can be implemented in a database.

Hazards caused by the building geometry cannot be turned into risks yet, because no statistical enquiry has been conducted. Hazards caused by the building geometry are marked by the spatial structure of a building. Examples of these are geometric figures, such as rectangles or circles, and geometric shapes. The combination of such different elements creates the geometry of a building. These factors, of geometric figures, were used as the three main categories: line-related (e.g., distance from working area to the building edge), area-related (e.g., openings in the floor), and spatially-related hazards (Melzner and Bargstädt 2012).

In conclusion, the studies of the hazards related to lines found that these are mainly connected to people slipping or falling in an accident in connection with the elements. The area-related hazards are predominantly caused by tripping, slipping, crashing, and falling. In contrast, the space-related hazards are characterized by impairment of the human senses.

The identification of risks is based on the identified evaluations of occupational accidents (Schüler 2001). The statistical accident rate of the year 1992-1997 is derived from the frequency distribution of accidents and the corresponding probability. This is divided into five levels. Tables 1 and 2 show how the severity and probability of accidents in this study are weighted:

The assessment of risks is made from the calculated probability of occurrences and the severity of the accidents. The following functional model describes the course of the risk assessment (Figure 2):

After creating the basis for risk assessment, risk assessments can be identified for the various work processes in building construction.

5 IMPLEMENTATION

With the allocation of risks to different components, the theoretical part is complete and the insights gained are put into the building model. In this project, the implementation is carried out in the BIM-software ceapoint desiteMD 1.2.1. It is possible to merge different information sources, and visualize and analyze a building model; for instance, use geometrical data with spreadsheets, and schedule software interactively.

Table 1. Classification and assessment of the probability of occurrence

Percentage of probability	**Literal meaning**	**Weighting factor**
≤ 20%	Very low	1
> 20 ≤ 40%	Low	2
> 40 ≤ 60%	Medium	3
> 60 ≤ 80%	High	4
> 80 ≤ 100%	Very high	5

Table 2. Weighting of the severity of the accident (based on Rozenfeld et al. 2010)

Severity of the accident	**Weighting factor**
Minor injury (L)	1
Medium injury (M)	5
Severe injury (S)	25
Death (D)	100

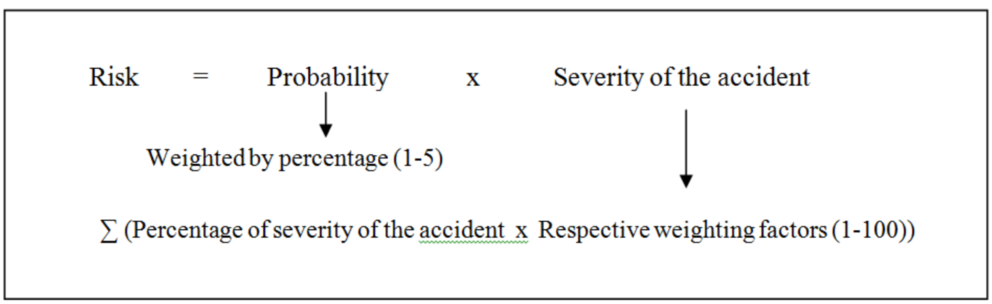

Figure 2. How the risk is assessed.

The implementation process, including the risk lists in the BIM-software, requires several steps and components that enable a successful implementation solely through their interaction. The risks are calculated on the basis of the probability and severity of an accident in a database. Then the processes have to be inserted manually once into the BIM-software. At this point, the structure model will be assigned to a complementary project structure, which is described with risk assessment. The calculated risk of sub-processes in the database is also implemented once. For this purpose, the newly created project structure is exported as a cpixml-file so that it can be edited manually. The source of this file is opened and assigned to the sub-processes, with the respective identification number of/for the associated risk. Thus, it is possible to link the hazard to the risk value in the later implementation, or make a query with the help of the color representing it.

By linking the individual components to the newly-added objects of risk, an assessment can be carried out. This will retrieve the maximum risk value that was assigned by selecting and linking the component during the entire construction phase. To generate the representation of the risk directly in the building model, a special function is created. This can be marked, depending on the definition of the components, in color in an automated way. In this research, the maximum achievable risk value of 655 was divided into five stages, classified according to color, with the existing risk represented in color. Figure 3 shows an example of the color design of the building in accordance with risk classification and the maximum risk value. Any component can be retrieved through its selection; its maximum risk value will be displayed, which is represented by its color design. It is possible to identify the components and processes with which the respective risks are associated.

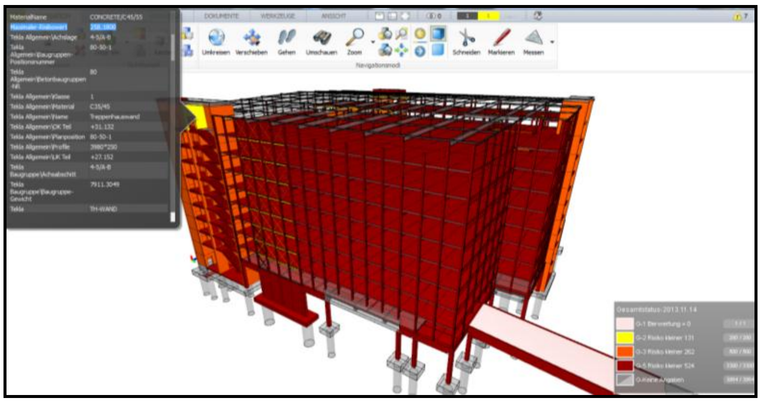

Figure 3. Issue of risk and automated color design of the building.

Object orientation is provided by the combination of the components with the added processes, including risk as a new project structure. The associated risks are behind each component, and stored in a quickly-accessible manner. The visualization is provided by the colored components, depending on the highest unallocated risk value. There is a direct link between them.

6 CONCLUSION

The aim of this paper, "object-orientated hazard analysis in building construction projects," is to allocate component risks and hazards and to implement these in a 3D building model of an actual construction project. The results of the implementation indicate a direct link between the risks and the components. They can be selected in the 3D view, and linked directly to one or more risks, and to one or more components. The output of the risks is through an automated color representation of the components. The output of the maximum risk value is on the relevant component. In addition, various selected sets can be formed. The entire research also includes a concept, based on an object-oriented checklist, which also includes the output of an analog risk list and can be applied to the construction site.

The topic of risk analysis, based on 3D building models and object-oriented implementation, allows a rapid and early detection of hazards and risks, whereby active measures for prevention can be adopted. With this work, a first step in object-oriented hazard analysis has been investigated. Many other points need to be considered, such as suggestions for automated prevention and 4D integration. A starting point for further research would also indicate measures for minimizing the risks. This could take the form of labor safety regulations or relevant health and safety measures for the particular processes.

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