Interdependence between Structural Engineering and Construction Management
Edited by Ozevin, D., Ataei, H., Modares, M., Gurgun, A., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-6-2

IMPROVING OCCUPATIONAL HEALTH AND SAFETY BY USING ADVANCED TECHNOLOGIES AND BIM

AGNES KELM, ANICA MEINS-BECKER, and MANFRED HELMUS

Construction Management and Economics, University of Wuppertal, Wuppertal, Germany

Despite a slight decrease in the number of accidents at work on German construction sites, a large number of accidents on construction sites occurred as a result of the collision of different trades. An important potential is in the optimization of the safety and health by making available predefined information about work safety for all involved trades. The aim of the project is the application of the BIM-method and the use of RFID-technology and Augmented Reality to improve work safety in the real estate and construction industry. It has to identify, define, and standardize information relevant to work safety so that they can be used for prevention-measures with Building Information Modeling (BIM). To do so, a process map was developed to map all relevant occupational health and safety processes during the lifecycle phases of a building. Therefore, all work safety-relevant processes have to be identified and defined. Furthermore, a demonstrator was developed in order to show possibilities like the usage of Augmented Reality (AR) and a commercially available tablet with a web app, in combination with Bluetooth beacons and RFID technology, based on a common data base. This will lead to the possibility of cross-company planning regarding work safety-relevant processes with BIM as well as the optimization of work safety in additional use of AutoID-Technologies.

Keywords: Digitalization, Modern technologies, RFID, Auto-ID, Personal protective equipment (PPE), Augmented Reality (AR), Safety at work.

1 INTRODUCTION

The digitization of the economy has been progressing steadily for several years, also in Germany. With regard to the construction sector, the focus is on the method of building data modeling. Compared to other countries, the method has not yet been applied uniformly in Germany. Against the background of optimizing the effectiveness and efficiency and strengthening the competitiveness of the associated construction and real estate industry of Germany - even in international comparison - the implementation of the BIM method is also essential for health and safety during construction work and maintenance.

The research project "Application of the BIM-method and the use of RFID-technology to improve work safety in the real estate and construction industry" is part of a longer-term overall concept to be set up. The aim is to promote the standardization efforts of building data models with regard to processes and the associated flow of information between the project participants in all lifecycle phases (Bodtländer *et al.* 2017). At the same time, this will help to create transparency with regard to the BIM method for those involved in construction.

The BIM method provides detailed information about all aspects of the construction and adds value for everyone involved in the construction process. This includes, for example, the availability of a 3D representation, the description of the whole construction workflow and data about changes during the whole life cycle of a building. The goal is to show that using this compiled data when applying the BIM method, current, and future software solutions can be implemented to increase workplace safety fast and efficiently.

Emerging technologies such as Augmented Reality and the Internet of Things allow new ways to access, visualize and annotate the stream of information surrounding us. Using these tools, we are able to implement new safety and accident prevention measurements based on different data sources. The BIM method is an important keystone in this because it provides all the required data for the implement. Key benefits to improve safety are the capability to directly getting informed about dangers as well as showing important safety information when needed. Based on our process map, a demonstrator was developed that shows how a process can be implemented.

2 RESEARCH APPROACH

The goal of the research project is, to connect the preventive design of work with the BIM-method within the construction industry. For this connection, a prevention strategy BIM with new tools for bigger support of occupational health and safety will be created with prevention partners from the construction industry. The pilot-application shows exemplary application possibilities and describes new forms of the cooperation between prevention partners and constructing partners in an alliance of prevention. As a result, basics and examples for further systematic usage and working on digitization of preventive occupational health and safety during the stages of construction, usage, maintenance, and reconstruction of real estate are developed (Bodtländer *et al.* 2018).

3 RESEARCH METHOD

For BIM to be successfully used in the area of occupational health and safety, the processes must first be looked at in detail. According to the definition of the University of Wuppertal (BUW), the lifecycle of a real estate consists of five phases: development, planning, realization, operation & maintenance, and demolition. Within these phases, new information is generated from various roles from various information sources. The extensive consideration of all these phases is not feasible in a single research project. For this reason, the BUW has decided to subdivide the lifecycle of a real estate in a structured manner and to develop the respective sub-areas in independent research projects, which are always interlinked. Through the close networking, synergies can be used as best as possible and a broad knowledge foundation can be established. This enables the chair of Construction Management & Economics at the BUW to publish the gained findings in a targeted way in the general public, thereby continuing promoting the digitization of the real estate value chain.

Existing safety-specific software products accompanied were worked out by interviews and a survey among German software developers for safety-specific applications to evaluate the current impact of BIM for health and safety in Germany.

To show that the defined processes can be implemented using existing state-of-the-art hard- and software a prototype for the Microsoft Mixed Reality Headset HoloLens as well as an of-the-shelf tablet pc was developed. For the development, modern development tools were used that allowed automatic data distribution among all devices. Custom software libraries to import IFC files were developed so they can be used in the demonstrator. Because we not only had the 3D

model but also the logical, representation we could use it for annotation and to connect devices inside the building with specific tasks.

4 RESULTS

Within the framework of the research project, a process map was developed to map all relevant occupational health and safety processes including the associated tasks and responsibilities during the lifecycle phases of the planning, realization, and operation of a building. The required information (information input), as well as the generated information (information output) per process, were determined, assigned and combined into a continuous information process. Through close collaboration with experts from the field, the developed process map could be verified in the sense of the information protection of relevant information provision. Evaluations can then be generated from the developed information process, for example, required information for each responsibility and process in the corresponding lifecycle phase. Further evaluation variants are possible. These evaluations are ultimately intended as an aid to provide project-specific requirements (BIM requirements) to digital applications (BIM application), e.g. a web app for individual trades. In order to provide detailed information in a targeted and digital manner, a project-specific information management is necessary, which is the responsibility of the client. This should be defined at the beginning of the project in order to make use of preventive possibilities. In this case, the project sharing roles (for example, BIM author or BIM users), amount of information (e.g. a 3D model or concrete attributes), delivery times (e.g. after confirmation of the order) and digital tools (e.g. Tablet or AR- Application) are defined. The previous points form the basis for efficient building information modeling in terms of occupational health and safety. Only after an extensive adjustment of the digital requirements, a contractor can meet a client's qualifications, equipment, and requirements. An individual view of the organizational possibilities of the contractors is crucial since BIM has not yet reached the protection of the construction and real estate sector.

The demonstrator shows that BIM-based data can easily be integrated into current state-of-the-art software. With the help of modern frameworks and technologies, the data provided by the BIM procedure can be combined with information from external sources such as the user position and additional information such as the escape and rescue plan. Changes in the data are forwarded to all users immediately. An important part of the demonstrator is the direct communication channel between the different users of the system. This not only increases the safety it also shortens the response time for questions and helps resolve problems faster.

Microsoft Augmented Reality Glasses HoloLens is perfectly suited to show the user information directly at his workplace. Because this device is still under development and not ready for the mass market, we also use a current of-the-shelf tablet to show what can be used today. Because both solutions are connected with each other, they allow their users to create a dialog with each other. Because text input on is not very accessible, especially on the HoloLens it takes some time to type even a word, we provide a boilerplate of common sentences for the input.

First data from Autodesk Revit were exported to an IFC file to display the 3D model of the building on mobile devices. The data was then imported using a custom script-based IFC open-shell that also swapped some of the objects within the model with a version with a lower number of polygons so that mobile devices could draw them. Another problem that had to be solved was the file size of the IFC file for use on the web and mobile devices. Instead of loading the entire building, the Web application only displays a single floor. To show the user information without loading much in advance, everything that was not part of the visual representation was exported

to the JSON format, which was only a fraction of the original IFC. This file can be quickly loaded and processed on mobile devices to decide which floor or room to display and keep the file size low without affecting the functionality users need.

Figure 1. A detailed table with safety information as well as the required PPA for a task inside the building in the web and Android application.

Figure 2. The same table and required PPA from figure 1 in AR on Microsoft HoloLens directly besides the work item (shown as a hologram in the top-right).

5 CONCLUSIONS

The application of reference occupational health and safety process is discussed in many ways, especially in the context of individual construction projects. Against this background, it becomes even more evident how necessary the implementation and application of processes and consistent process models in the real estate life cycle are in order to obtain a large number of examples processes and develop further reference processes.

The feedback for the developed demonstrator has been very positive, especially the Augmented Reality application shows that it can provide additional value for safety without interrupting the workflow because of the hands-free nature of the hardware. It needs to be seen how fast this technology will be established and how the final release version of HoloLens will establish itself in the construction industry. The user only benefits from these devices with a strong user base and the availability of these devices.

The implementations for Microsoft HoloLens and the Android Tablet show that it is possible to implement safety and health protection measurements that can be embedded into existing workflows quite easily. Important for the future is that those experiments will be adapted for existing solutions to really improve work safety for the single worker.

Acknowledgments

This research project is funded by the German Social Accident Insurance (DGUV). In order to ensure a direct reference to the applicability in practice, the following practice partners support the research project: BfGA - Beratungsgesellschaft für Arbeits- und Gesundheitsschutz mbH, ISSA construction, Ingenieurbüro Dudek, Office-4 Baubetreuung GmbH, BG BAU – Berufsgenossenschaft der Bauwirtschaft and Chichon & Stolberg Elektroanlagenbau GmbH.

References

Bodtländer, C., H., M., Kelm, A., Meins-Becker, A., *BIM - Processes - Health & Safety*, ISEC-9, Valencia, Spain. doi: 10.14455/ISEC.res.2017.27, 2017.

Bodtländer, C., Helmus, M., Kelm, A., Meins-Becker, A., Arbeitsschutz – Building Information Modeling - Forschungsbericht zum Projekt Anwendung der Methode Building Information Modeling und Einsatz der RFID-Technik zur Verbesserung des Arbeitsschutzes in der Bau- und Immobilienwirtschaf, 2018.