Potential of digital tools for BIM-based risk management

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Abstract

In this paper, we first outline the basics of the risk management process and the status quo of the application of BIM-based risk management in the construction industry, using statistical data. In order to be able to digitally link risks to costs, deadlines and qualities with the help of digital tools, various technologies are examined. The presented digital tools are used in different areas and at different times in the construction process. These tools are then linked to the BIM method. Here, we list which BIM use case and which tools can digitally support the process. Finally, we show the potential for the integration of digital tools into the risk management process. The paper provides incentives for actors in the construction industry of various structures to improve their own risk management and to apply the BIM method holistically with the help of digital tools.

Keywords: risk management, BIM, BIM tools, BIM Use case

1 Introduction

The construction industry, as well as the risk management process, are undergoing a transformation due to ever-increasing digitization, that goes hand in hand with political pressure, competitiveness and the challenge of acquiring new talent. Nevertheless, the risk management process continues to be carried out in the same, accustomed manner without making use of the potential of digitization. Within the risk management process consisting of identification, assessment, control and monitoring of risks, possible negative and positive deviations from the project goals are recorded, analyzed and dealt with. Despite the digitization trend, analogue tools are still used frequently in the project and risk management process. Though digital tools offer great potential for project management and the achievement of classic project goals in terms of deadlines, costs and quality, they have so far received little attention in the risk management process.

The Building Information Modeling (BIM) method improves the linking of processes and the exchange and further processing of information. More precise information is generated when using digital tools and the information flow between stakeholders is enhanced. In addition, digital tools allow a faster generation, call up and processing of digital information. A relevant factor for successful risk management is up-to-date information on risks. Thus, with the support of digital tools and methods, risk management can become a more effective control tool for project management in the medium term. Risk management can be more efficient and the data obtained from projects can be evaluated and processed for subsequent projects.

This paper addresses the research objective of identifying the usability of digital tools for the risk management process. Tools like ConstructionIQ and Construction Data Connector already enable software-based risk management. In addition to software, the use of digital tools offers further advantages for risk management. Therefore, the analysis presented here goes beyond the application possibilities of such software.

2 Principles of risk management & methodical approach

The term risk describes deviations from project goals that arise due to influences on productivity. The project goal is to complete a project on time, on budget and on quality (Girmscheid 2010). The term risk includes both positive and negative deviations from projekt goals. (Hoffmann 2017). With properly applied risk management, these influencing deviations can be identified and controlled.

For the successful use of a risk management system, an acknowledgement of risk management must be created and integrated within the company, the organisation or project (Girmscheid 2010). DIN ISO 31000 provides a process structure for a risk management system (DIN ISO 31000). The risk management process consists of the steps identification, assessment, control and monitoring [Figure 1]. After a risk has been identified as such, its impact is assessed in terms of probability of occurrence and amount of damage. In the next step, measures are taken to reduce the probability of occurrence and/or the extent of damage. The monitoring step serves to review assessments regularly and update the measures taken (Girmscheid 2010).

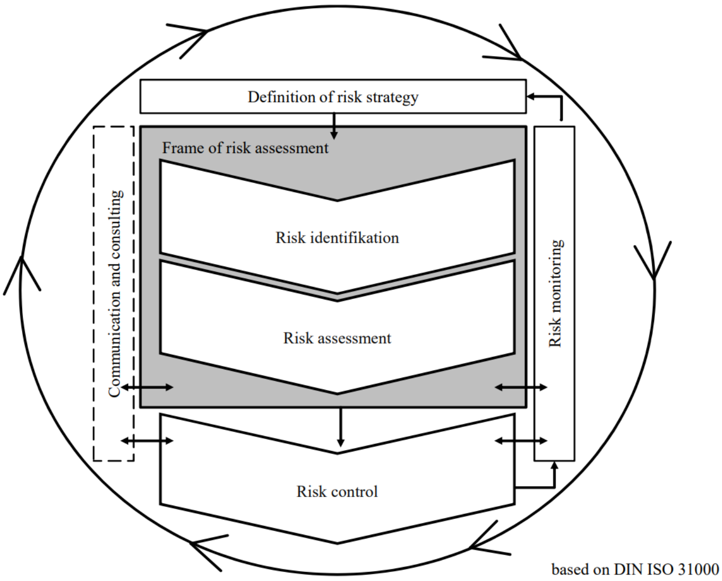

Figure 1. isk management process

The advantages of the application of risk management are clear, but risk management is still only systematically practised by few construction companies. In order to obtain a clear overview of the current situation regarding the application of the risk management process among construction companies, Eilers et al. investigated it in a survey of 249 construction companies (Eilers et al. 2020).

In autumn 2019, the companies were surveyed via an online survey and additional expert interviews. The result of the study was a highly diversified picture. On the one hand, 60% of the companies pursue risk management according to a standardised strategy, on the other hand, a third of the companies assess risks purely on the basis of the experience of the employees without drawing on data. In almost all companies, risk assessment ends after the planning phase, so there is no transfer of risk information from a completed project to the next. Risk management processes have not yet been linked to the BIM method; rather, risk management is currently regarded as a separate task (Eilers et al. 2020).

Based on the results of the survey, this study will first conduct two literature analyses on digital tools and BIM use cases for the contruction industry. These literature analyses serve to reflect the current options of digital linkage for risk management. Finally, the applicability of the individual tools for the steps of the risk management process is analysed and presented by reference to workshops and expert interviews.

3 Potential of digital tools by using the method BIM

The support of the risk management process by digital tools holds high potential to better assess risks. Especially the possibility of using digital tools by the operational project levels (Buchholz 2017), provides faster information and more accurate assessments and contexts to take measures and minimise risks.

3.1 Digital Tools

In order to present the possibilities of linking digital tools with the risk management process, digital tools for supporting the planning and construction process in the construction industry are analysed and presented on the basis of a literature analysis. The digital tools are used in different areas and at different times in the construction process. For the selection of digital tools, an analysis of research projects and construction projects was carried out with regard to the tools used in these projects. In the following section, a differentiated selection of digital tools is briefly presented and analysed.

Comparing the results of the different digital tools, they can be divided into two data delivery categories. Tools that provide real-time information and tools that provide visual results. The following table lists the tools analysed, their intended use and the data delivery category.

Table 1. Literature analysis of digital tools

Digital tool	Use	Data delivery category	Source
Laserscan	Raster scanning of surfaces, terrain survey; review of building components; CAD reconstruction, 3D measurement of buildings	visual data	(Kraus 2004)
Unmanned arial vehicle (UAV)	Scan of roofs, high facades or terrain conditions; mobile control; creation of point clouds	visual data	(Kraus 2004)
Radio-frequency identification (RFID)	Transponders that store data and transmit it over a frequency range to a reader; active and passive transponders; Identification of data	real time data	(Arnold 2008)
Quick response (QR-Code)	2D code for storing information such as product data, videos, web addresses; readable via cameras or mobile; shown of current plans or room information in a construction project	real time data	(Uitz & Harnisch 2012)
Barcode	Optoelectronically readable writing; data transfer and marking of products; reading with optical readers	real time data	(Arnold 2008)
Mobile Data	Data acquisition independent of workplace; display and acquisition of data by mobile terminals; push and pull methods; data transmission via WLAN or GSM	real time data	(Sauter 2008)
Virtual Reality (VR)	Representation of a computer-generated reality; walk-through via VR glasses; realistic	visual data	(VDI 2020)

	impression of a planned building; location-independent presentation of construction projects		
Augmented Reality (AR)	Integration of models or additional information into the physical reality; reality and model become one in the integration and enable a realistic impression of the environment.	visual data	(VDI 2020)

3.2 BIM use cases

The digital tools presented in the previous section can be used in context of different BIM use cases. BIM use cases are defined processes with a specified goal. The use cases can be defined by the client or selected internally by the company (VDI BG 2020). The basis for a BIM use case is a BIM model. The BIM model represents the modeling of information for the construction industry, whereby 3D geometric information as well as physical characteristics are handled (VDI BG 2020).

In order to gain an overview of the current understanding of BIM use cases from the perspective of science and practice, the authors reviewed BIM use cases published in the german-speaking area. 309 BIM use cases from a total of 17 publishers were reviewed (Eilers et al. 2021). In addition to scientific institutions, the review included consulting service providers, BIM managers, economically active companies, public institutions and associations.

The reviewed BIM use cases were clustered according to their purpose and categorised. If individual BIM use cases could be assigned to several categories in terms of content, these were assigned in the respective categories. As a result, 16 BIM use case categories were identified. A list of all reviewed use cases can be accessed via the following link: *www.biminstitut.uni-wuppertal.de/de/forschung/download-bereich.html*. The use cases relevant to risk management were selected in the course of expert interviews and are briefly presented below:

The BIM use case "*Collaboration/ Coordination/ Communication*" describes the realisation of model-based meetings and reporting within a construction project (BIM Institute 2020). This provides a transparent presentation of information and responsibilities by promoting interdisciplinary collaboration. Planning decisions and the creation of forecasts for early problem solving are supported by images from laser scanners and UAVs. Building scenarios can be experienced through VR and AR and variants are created and examined without problems. This supports the transparent presentation of information and responsibilities for solving problems.

On the basis of publicly available cadastral, survey and inventory data, supplemented by a digital recording of the topographical and structural conditions, partially automated inventory models are generated for a specific building project and embedded in the environment. In the BIM use case "*inventory modeling*", laser scanning or a UAV is used for an actual condition survey of a property or existing building. (BIM Institute 2020). The point cloud created is the basis of the building information model of the specific building project. The developed as-built model can also be visualised and made accessible by revising it with a VR application.

A needs-based "*Visualisation*" of the building information model supports the planning processes and project management in terms of transparent and fast decision-making (BIM Institute 2020). The created visualisations support coordination with authorities and public relations. Through the application of VR and AR, the visualisations are experienceable. In addition, they serve as an instrument for marketing purposes and clear model-based communication with all project participants.

A fundamental process of various BIM use cases is the derivation of quantities and component lists "*Quantity and mass determination*" from the building information model (BIM Institute 2020). For this purpose, the geometric and semantic characteristics of the elements are evaluated. Further quantitative or qualitative characteristics (attributes) must be assigned to the components in the modeling software. A measurement by laser scanner or drone flight serves as a basis for determining quantities in the model.

In the BIM use case "*Construction progress control*", regular, model-based schedule monitoring takes place. Continuous monitoring and control of the construction progress (real time infomrations) based on the 3D model enables the monitoring of appointments (BIM Institute 2020). Services provided can be visualised in the model, transparently tracked and reported. With the help of RFID, QR code or barcodes, the deliveries of materials and the installation of products can be tracked and monitored. The application of drone images and laser scanning can be used to create actual comparisons of the construction progress.

The BIM use case of "*Logistics management*" simulates and creates model-based logistics concepts (BIM Institute 2020). In this way, logistics and the construction process are supported. RFID, QR code and barcodes are used to track information along the entire logistics chain.

Table 2 summarises the results of the analysis of BIM use case in relation to digital tools:

Table 2. Literature analysis of relevant BIM use cases in relation to digital tools (BIM-Institut 2020)

Use Case	Description	Digital Tools
Collaboration/ Coordination/ Communication (CCC)	Model-based and interdisciplinary cooperation	Laserscan, UAV, VR, AR
Inventory modeling	Digital recording of topographical and structural conditions	Laserscan, UAV, VR
Visualisation	3D/visual representation of planning	VR, AR
Quantity and mass determination	Automated quantity and mass determination on geometric and semantic characteristics	Laserscan, UAV
Construction progress control	Model-based schedule control, digital construction process simulation	RFID, QR-Code, Barcode, Laserscan, UAV, mobile Data
Logistics Management	Simulate and create model-based logistics concepts	RFID, QR-Code, Barcode, mobile Data

4 Connection of risk management processes with digital tools under consideration of BIM

Building on the analyses of digital tools for the construction process as well as BIM use cases in which these tools are used, we set these in relation to the risk management process in the following. For each phase of the risk management process, we list digital tools and BIM use cases that are suitable for use in the respective lifecycle phase of the project. In this way, we outline the potential of BIM for risk management.

4.1 Risk Identification

The aim of risk identification is to identify the cause of the event and its impact on the project goals (DIN ISO 31000 2018). In risk identification, various digital tools help to identify risks. For example, laser scanning or a UAV record information on the actual condition of an existing building or the terrain. Modeling a BIM model reveals collisions and interface problems. Missing data and missing links become known, allowing control measures to be taken. Communication and coordination improve by increasing the accessible information. Visualisations highlight problems or inconsistencies to the building owner or user. Room lists and other specific lists can be exported and the information can be used for risk management processes. Quantities and masses from the model reveal any discrepancies with the tendered quantities in the tender documents. On the basis of the modeling, simulations such as construction process simulations or modell-based rule checks are carried out. By using digital tools that provide real-time information, such as RFID, QR codes and barcodes, real time data is generated. This can be used for subsequent comparison with time scheduling. Visualisation with VR and AR is used to decide on planning variants with the client or other project participants and to carry out pattern.

4.2 Risk Assesment

The risk assessment process step aims to decide how strongly a risk will affect the project goals (DIN ISO 31000 2018). The assessment is carried out by estimating the probability of occurrence, the extent of impact in terms of costs, deadlines and quality, as well as the expected date of occurrence.

Laser scanning and the use of a UAV provide information on the actual condition of an existing building or the site. Quantity and mass determinations are conducted on the construction site in order to specify a possible amount of damage in terms of costs and deadlines. Demolition measures are calculated on the basis of the known quantities, or partial invoices are supported. Through project processing with the support of a building information model, the identified risks are linked with dates and costs based on the quantity determination and the data extracts, and thus allow a statement about the amount of damage of a risk.

4.3 Risk Control

In the process step of risk control, control measures to deal with the identified and assessed risks are examined and selected. How a risk is handled depends on the risk awareness of the company or the project and the risk strategy defined (Girmscheid & Busch 2014).

The use of a laser scan or a UAV provides information on unknown conditions of a construction site. By obtaining and making information transparent with the help of digital tools, control measures can be better controlled. The precise information base supports the decision on an appropriate risk management strategy. The BIM use cases, such as quantity take-off, logistics management, construction progress control generate added value for the decision. The use of digital tools that provide real-time information generates real time data. Through the use of QR codes and barcodes, information is collected that provide assistance in controlling by tracking material and construction progress, improving or facilitating the logistics concept. Visualisations with VR and AR are used to decide on planning variants with the client or other project participants.

4.4 Risk Monitoring

The effectiveness of the selected control measures is assessed during risk monitoring (DIN ISO 31000 2018). In the course of this, it is also checked whether a risk no longer exists due to a change in planning, for example, and whether the change in planning gives rise to new risks (Girmscheid & Busch 2014). This results in an iterative process.

The use of a laser scanner or a UAV helps to determine the effect of a measure via the actual state or a real time comparison. In addition, the changes to the measures can be documented via the tools. When using BIM models and plan servers, the actual state recording can provide information on the planning process, and the plan progress control as well as the construction progress control provide information on the success of the measures by analysing the determined data from RFID, QR codes and barcodes, overviews as well as deviations and potentials can be evaluated when using the tool for the construction site.

Table 2. Connection of risk management processes with digital tools in relation to BIM use cases

Digital Tools	Risk Identification	Risk Assessment	Risk Control	Risk Monitoring
Laser-scan	Inventory modeling, CCC	Quantity and mass determinati on	Quantity and mass determination, Construction progress control	Inventory modeling, Construction progress control, As-build-Documentation
UAV	Inventory modeling, CCC	Quantity and mass determinati on	Quantity and mass determination, Construction progress control	Inventory modeling, Construction progress control, As-build-Documentation

RFID	Information readout, Automatic real time data, Construction progress control	Automatic real time data, Construction progress control, Logistics management, Tracking of informations, work safety	Logistics management, automatic real time data, digital Documentation,
QR-Code	Information readout	Construction progress control, Logistics management	Logistics management
Bar-code	Information readout, automatic real time data, Construction progress control	Construction progress control, Logistics management, Tracking of informations	Logistics management, automatic real time data, digital Documentation,
Mobile Data	Planning amendments	Logistics management, Planning amendments	Logistics management
VR	Visualisation, Inventory modeling, CCC, Pattern	Visualisation, CCC,	
AR	Visualisation, Inventory modeling, CCC, Pattern, Work safety	Visualisation, CCC, Work safety	

5 Conclusion

Based on statistical data on the use of risk management in the construction industry, we show the potential of digital tools apllied in BIM use cases for project risk management. Firstly, we analyse digital tools relevant for risk management and their possible applications outlining the digital possibilities in the risk management process. Based on this, the analysis of BIM use cases shows how digital tools can support them. Finally, the link to the phases of the risk management process provides an overview of the potentials of linking the BIM method with the risk management processes.

Risks are mainly due to the associated uncertainty. Uncertainty arises from low levels of information. The use of digital tools and BIM use cases in the context of risk management offers more transparent, accurate and up-to-date information compared to conventional project management. This paper shows how more accurate information can improve the risk management of construction projects. The tools examined are not exhaustive, but represent a selection of the most common tools currently used in the construction industry. Further tools and developments should be considered and anaylsed as needed.

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