IFC-based linking of the risk management process using a building data model

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Abstract. A vital element in working with BIM are standardised exchange formats that enable the exchange of information from digital building models between different software solutions and project participants. In this context, the Industry Foundation Classes (IFC) defined in DIN EN ISO 16739 represent a central standard for implementing the open exchange of information. Although approaches for integrating risk management are already available in IFC, they do not sufficiently reflect the needs of the construction industry. In order to increase project quality through risk management and the universal application of the Building Information Modelling (BIM) method, it is essential to map the generally valid information on the risk management process in IFC. The following article thus presents starting points for the further integration of risk management in IFC. The aim is to link all relevant risk information in a digital building model through an analysis and the development of an approach.

1. Initial situation: Risk management and BIM

In 2015, the German Federal Ministry of Transport and Digital Infrastructure (BMVI) included risk management - along with nine other aspects - in a 10-point plan for major building projects in Germany [1]. An analysis of the misalignment of numerous major projects revealed that risk management is a central control variable for leading construction projects to success [1]. While the application of risk management is a standard practice for other industries, the construction industry still does not seem to place enough attention on risk management. In 2019, a study conducted by the University of Wuppertal among 249 german construction companies and public contracting authorities revealed that around two-thirds of the companies surveyed - despite the commission's findings around the development of the 10-point plan - do not apply a risk strategy. Projects do not systematically track risks and do not incorporate lessons learned from projects into follow-up projects [2].

With regard to the frequently criticised delays and cost increases in construction projects, the industry misses the opportunity to recognise negative deviations from project goals at an early stage and to take countermeasures in time due to the negligent handling of risk management. In particular, inefficient documentation and company-internal isolated solutions for risk management are cited by a large number of companies in the study by the University of Wuppertal as a reason for the inadequate application of risk management in ongoing work processes [2]. Especially with regard to this aspect, the BIM method and the associated digital linking of information in a project offers potential for the implementation of risk management information [3]. By digitally linking risk information, isolated solutions can be avoided, the associated processes are made more efficient and the attractiveness of dealing with risks increases for all project members.

A key feature of working with BIM are standardised exchange formats that enable the exchange of digital information between different software solutions and project participants [4]. In this context, the Industry Foundation Classes (IFC) defined in DIN EN ISO 16739 represent a central standard for implementing the open exchange of information [4] [5]. With the help of IFC, information is standardised and defined for use with BIM to ensure the sufficiency and accuracy of information exchange between the various stakeholders [6]. Approaches for integrating risk management are already available in IFC. However, a more detailed analysis shows that the approaches standardised in IFC do actually not cover the needs of the construction industry sufficiently. In addition to that, the existing approaches focusses particularly on occupational safety [4]. In contrast to the current approach, the focus should be on the information needed within the steps of the ISO risk management process and not limit the information to a specific topic. Therefore, this paper addresses this issue and presents starting points for the further integration of risk management in IFC and digital building models. Here the focus is on the analysis and presentation of possibilities for integrating the relevant information on risk management in IFC.

2. Framework and methodology

This paper presents a three-step methodological procedure to develop an approach for integrating risk management in IFC. The three steps are divided into a literature analysis (step one), a gap analysis (step two) and the development of relevant processes and their validation (step three).

Step one (see chapter 3), the analysis of the current status, examines the processes of risk management on the basis of a literature analysis. This results in the to-be processes of the construction risk management. These processes are validated by survey results and semi-structured expert interviews with 19 practical users of risk management in german construction projects. Finally this results in the as-is status, which can be compared with the to-be processes.

Based on the process analysis, an analysis of the differences between to-be and as-is processes is carried out in step two (see chapter 4). With the help of an analysis based on the gap analysis, that is common in business administration. A gap analysis first determines goals, considers the as-is state, assesses strategic and operational gaps and identifies measures to close these gaps. Finally, milestones are defined to review these measures [7]. For this purpose, this paper compares the information required for the to-be process for risk management with the information that are already available for risk management with open exchange formats (here IFC). This is done through the exemplary application of the PSet_Risk to a building data model. The result is an overview of needs for integrating risk management information in IFC. A solution proposal is developed for this gap. Specialised tools such as software solutions for automated linking of model and data are not considered in depth in this paper. Instead, it is about the possible solutions of the IFC file format and how they harmonise with systematic risk management.

In step three (see chapter 5), this paper validates the results of the exemplary application and the development of the current status quo. Therefore workshops with risk managers and executives of the construction industry were carrried out by using the method of the "World-Cafe" [8]. The aforementioned methodological approach is summarised in Fig. 1:

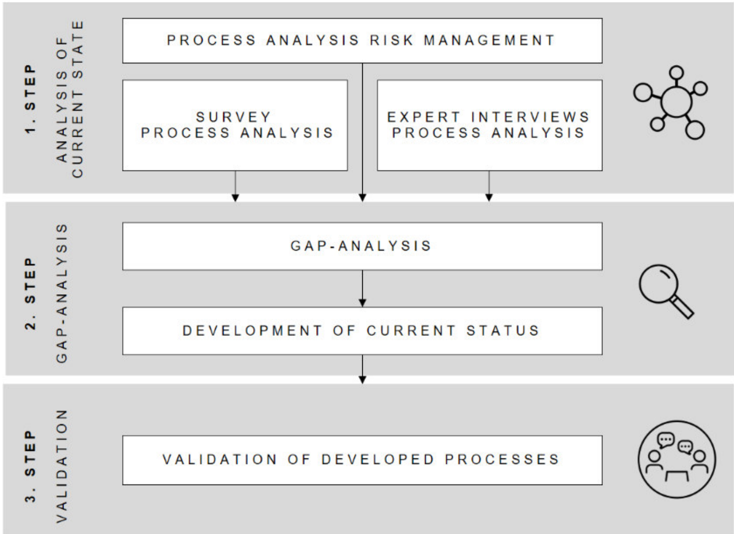

Figure 1. Flowchart of the methodical approach Source: own illustration

3. Analysis of the application of BIM in risk management

BIM describes a method that integrates and links all relevant data of an asset in a digital building model over the entire life cycle (from conception, planning and realisation to use and deconstruction) [9] [5].

Initial approaches to integrate BIM and risk management already exist in the literature [10] [11] [12]. In this paper risk management is understood as "coordinated activities to guide and control an organisation with regard to risks" [13]. In the aforementioned initial integration approaches, however, the focus is regularly on ensuring occupational safety and health, with the result that a comprehensive consideration is not carried out. As the definition of risk management shows, the process does not refer to a single special topic - such as occupational health and safety - but to all risks that prevent a company from implementing its corporate strategy [14]. Therefore, for an integration of risk management in IFC, there should be no thematic restrictions regarding the origin of the risks. With this in mind, this paper first presents an analysis of the status quo regarding the linking of BIM and risk management. Subsequently, a process analysis is carried out to show the possibilities for the successful exchange of information during the risk management process using the BIM method. Based on this, the results of the process analysis are validated.

3.1. Fundamentals for the integration of BIM and risk management

Three principles are important for the application of BIM in the context of the risk management process. The principles Integration, [3] [2], Dynamics [3] and Accuracy [6] ensure a smooth application process. The integration of digital data into the respective process steps during project processing is imperative. This allows an information basis to be built up over the entire life cycle of the property and the information can be accessed by the respective parties involved [15]. Furthermore, the exchange of information in the individual phases and between the different users is facilitated.

Risk management must be understood as an integrated process in order to form an effective project management and controlling instrument [13]. The various work processes and their contents of risk management are interdependent and influence each other [2]. Furthermore, due to the constant change in the information base, all processes must be able to adapt and develop dynamically.

By using the BIM method, the aforementioned processes can be made more transparent and effective with the transfer of information to the risk management process:

1. Precise information about the entire project are necessary prerequisites for the application of risk management [16]. BIM helps to structure the information growth over the entire life cycle of a construction project, enabling the knowledge to be used for process improvements in the company and knowledge gain for subsequent projects [17].

2. The exact project status is essential for successfully applied risk management [3]. Through BIM, the as-is status of a construction project is recorded and the information is available digitally and visually.

3. The BIM method makes changes in projects digitally readable and adaptable. Due to open standards, the relevant information can be exchanged between the parties involved.

3.2. Process analysis of risk management

In order to analyse the information needs of risk management for integration into the BIM method and for open exchange formats, a process analysis of risk management is necessary.

The basis for the implementation of risk management is the company's internal process definition. The risk management process is defined within the company and includes the predefined parameters of the risk management strategy. The management is responsible for the process.

The risk management process describes the individual steps of risk management in project processing. As in the risk management strategy, the responsibilities, risk tolerance limits, communication channels, risk management methods and documentation methods are defined for each process step [18]. The risk management process, which must always be kept up to date, is divided into four main steps. These consist of the steps risk identification, risk assessment, risk control and risk monitoring. Continuous controlling, careful documentation, regular communication and consultation complete the control loop of risk management [19]. In a construction company, the steps start in the realisation phase and run through all service phases of the Fee Structure for Architects and Engineers (HOAI). The HOAI is a legal regulation issued by the German Federal Government to regulate the fees for architectural and engineering services in Germany and describes nine service phases throughout the lifecycle of a building.

The risk management process is a constantly repeating process. DIN ISO 31000 provides the process structure for risk management shown in Fig. 2 [18]. DIN ISO 31000 for risk management does not define any parameters for application to an IFC file. Only the common basic terms and the elements of the risk management system are presented here.

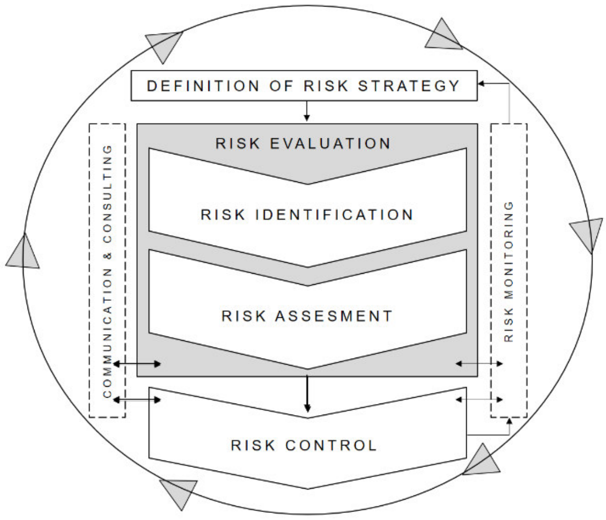

Figure 2. Risk Management Process Source: own illustration based on DIN ISO 31000

A prerequisite for linking information from the risk management process with a building data model using IFC is the specification of the relevant informations for risk management. An analysis of research on risk management, BIM and IFC showed that the theoretical risk management process of identification, assessment, control and monitoring is partly implemented in the construction industry, but at the same time there is no precise overview of which information is needed when, for what and by whom [20]. The research project 'BIM-based risk management' at the University of Wuppertal therefore breaks down the risk management process on an information basis and shows at which point in the risk management process which information flows in, who created it and for which steps it in turn serves as input [20]. The basis for this was provided by the semi-structured expert interviews conducted as part of the project and the survey (cf. section 3.3). Fig. 3 shows the relevant input and output information for the identification process step.

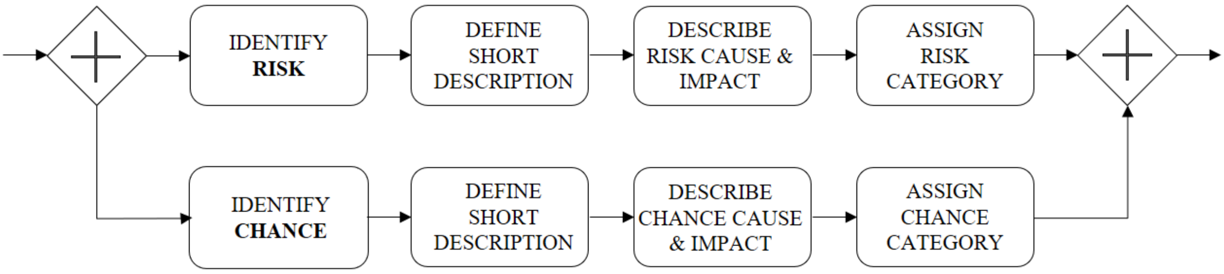

Figure 3. Process step of risk and chance identification Source: own illustration

As illustrated above, within the step of risk identification, risks and chances that could occur in the project are listed. Risks represent negative deviations from project goals, chances represent positive deviations. Regardless of whether an aspect is identified as risk or chance, following the identification, the risk or chance is defined by a short description that ensures easy recognition within the following steps. In the next step, the cause and impact of the risk or chance are demarcated. Risk categories such as technical, financial or legal support the identification by offering indications of the areas in which risks or chances could occur.

These evaluations represent the first step in linking risk management with BIM. The identified informations that are relevant for the risk management process should be mappable in the digital building model via IFC in order to integrate the risk management process into it. Only through a complete mapping of the risk informations, the model supports controlling the risks and redundancies by storing informations can be avoided.

3.3. Results of survey and expert interviews on process analysis

The identified BIM information from the process analysis was then validated using surveys and expert interviews. The results presented below are based on the survey on risk management in the construction industry implemented in 2019 among 249 construction companies and semi-structured expert interviews with 19 risk managers, which paint a clear picture of the current application of risk management in construction companies within Germany.

Regarding the flow of information and documentation as well as the level of detail in the implementation of risk management, different degrees of professionalisation can be observed in the construction companies. Risk assessment is largely intuitive and shaped by the experience of the individual employee. After project completion, the knowledge gained is usually only passed on to selected employees in discussions at the communication level. Hardly any company carries out a systematic evaluation of the previous risk list or a systematic continuation and feedback into its system. This means that the potential of risk management is not fully utilised.

The analysis reveals three main shortcomings in the current application of risk management:

1. empirical data on risks from completed projects is not evaluated, so that an overview of typical risks and their probabilities is lacking;

2. the exact functioning of the risk management process and its application in construction projects is often not clear; and

3. there is a lack of tools to document risk management across all processes of the risk management cycle and to evaluate it for follow-up projects.

In addition, the analysis of various software tools in the field of risk management and BIM did not find a solution for the application of risk management using BIM at the building component level. In this respect, the conclusion was that a conceptual development of a suitable interface and application possibility between risk management and BIM is necessary under consideration of standardised data formats [20].

One way to connect risk management and BIM is to integrate the relevant information into an open data model. Not all BIM-related software can support the generation and management of risk information [21].

4. Requirements for the further development of IFC with regard to risk management

The results of the process analysis on risk management as well as the survey of existing degrees of realisation of risk management in practice show that a deeper standardisation as well as the inclusion of further information are necessary for a more effective implementation. Thererfore, this chapter presents recommendations for the further development of IFC with regard to risk management in a construction project.

4.1. Analysis of the consideration of risk management in IFC

Manufacturer-independent, lifecycle-oriented and internationally recognised exchange formats, in addition to processes, represent an essential basis for the successful application of the BIM method. The Industry Foundation Classes (IFC) offer such an international, manufacturer-neutral, lifecycle-spanning and open exchange format, which enables an open exchange between the project participants and the software systems used by the project participants [5] [15]. IFC are defined and developed by buildingSMART and updates and extensions are published at regular intervals. These are specified in ISO 16739, the current version is IFC4.3.dev [22]. This standardisation makes IFC suitable as an open standard for the exchange of information for the loss-free transfer of building data models [23]. The basis is the description of an object-oriented data model with its geometric and alphanumeric parameters and attributes. The contents of an IFC file are, for example, the project structure, model elements, CAD layers, model element specifications, relations between structural and model elements, quantity specifications, manufacturer specifications and material names [2]. For this purpose, the IFC format is divided into layers; elements from upper layers can refer to lower layers [24]. Specifications for objects and their attributes are made in the respective layers. In addition, property sets (PSets) are defined in IFC, which serve to group attributes in clusters (e.g. PSet_PumpTypeCommon for the definition of attributes for pumps or PSet_Warranty for the description of attributes for warranties) [25]. The relationship between an object and a PSet is established via the entity IfcRealDefinesByProperties [26] defined in IFC, which is shown in Fig. 4.

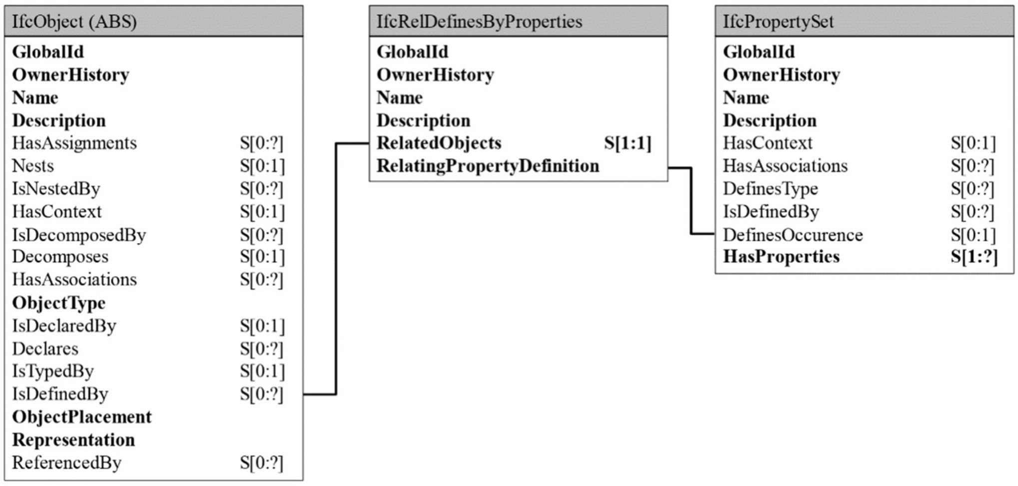

Figure 4. Relationship between an object and a PSet Source: own illustration in accordance with (buildingSMART 2019)

An analysis of the attributes in an IFC data structure with regard to the mapping of risk management shows that currently only the PSet_Risk contains attributes for risk management (see also section 4.2). The PSet_Risk is classified in the schema IfcSharedFacilitiesElements, which together with IfcProcessExtension and IfcSharedMgmtElements describes the basic concepts for facility management (FM) [27]. There is no further naming of entities or PSets with associated attributes for risk management, e.g. in the schema IfcConstructionMgmtDomain.

Initial research projects are investigating the integration of risk management, BIM and IFC (see for example [28] [29] [30]. However, these research projects also show that IFC does not yet fully enable the integration of risk management. For example, Zhou et al. describe that IFC does not have sufficient entities to fully represent the risks of the project, so that the IfcBuildingProxy entity is regularly used for integrating risk information in the objects [30]. However, this entity has strong restrictions as it does not describe a specific object [31] and information losses may occure.

4.2. Proposal for the further development of PSet_Risk

As described in Section 4.1, PSet_Risk offers initial approaches to implement this information linkage. In order to make full use of the advantages of the BIM method, it is important to map the risk information in its entirety using IFC. Only in this way can qualitative and quantitative assessments be carried out within the framework of the risk management process. The following is therefore an exemplary application of the PSet-Risk in a digital building model in order to compare the data of the PSet_Risk contained in IFC with the previously evaluated data relevant for the planning and construction process. The exemplary application was carried out in the digital building model of a new building of a public educational institution, which was commissioned in 2018. The digital building model, which is shown in Fig. 5, was modelled as part of an ongoing research project, continuously updated and is thus available to the authors for further research.

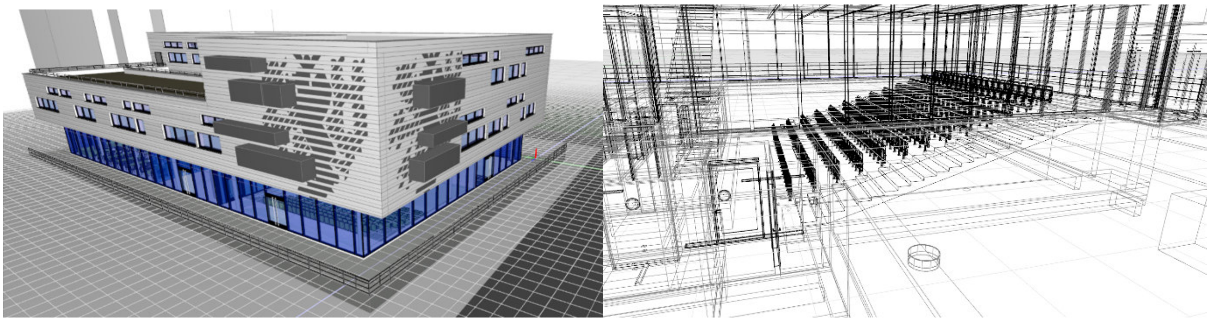

Figure 5. Screenshots of the digital building model Source: own illustration

Table 1 below summarises the results of this comparison. It indicates that seven attributes from the PSet_Risk are congruent with the attributes that were evaluated and described as relevant in the analyses and surveys presented in Chapter 3. For ten pieces of information that are relevant from a practical point of view, there are currently no attributes in the PSet_Risk, so that no open data transmission based on IFC is currently possible for this information. The attribute AuffectsSurroundings is defined in IFC, but has not yet been described as relevant in the analysis. A further evaluation can be carried out on this.

Table 1. Reconciliation of Pset_Risk with the risk management process informations

Step of the risk management process	Relevant information from the perspective of the surveyed practice partners	Attributs PSet_Risk
Identification	Numeration	RiskType
	Description of the risk	-
	Short name	-
	Risk cause	RiskCause, NatureOfRisk, SubNatureOfRisk1, SubNatureOfRisk2
	Risk impact	RiskConsequence
	Risk category	-
Assessment	Probability of occurrence	AssessmentOfRisk
	Impact costs	-
	Impact deadlines	-
	Impact quality	-
	Approx. Date of occurrence	-
	Risk priorisation	RiskRating
Control	Countermeasure Acceptance	-
	Countermeasure Transfer	-
	Countermeasure Avoidance	-
	Countermeasure Mitigation	PreventiveMeasures
	Risk owner	RiskOwner
Monitoring	Revision date	-
		AffectsSurroundings

Accordingly, it seems necessary to expand the attributes in PSet_Risk with additional attributes that can map the information necessary from a practical perspective. To ensure clarity, the existing PSet_Risk could be divided into four subsets, which are oriented towards the risk management process:

1. PSet_Risk_Identification for the identification of risks,
2. PSet_Risk_Evaluation for the evaluation of risks,
3. PSet_Risk_Steering for the control of countermeasures and
4. PSet_Risk_Monitoring for monitoring risk management.

When working with risk management, the four steps of the risk management process form a guideline and define the actions taken along process. Depending on the step that is being adressed within a project, different data will be used and connected to a model. To keep this logic of the risk management process we recommend using those four PSets. It will support the understanding of risk data within a model and provide the data in an easily adoptable way. The exchange and storage of risk management data can be supported and optimised by the further development of PSet_Risk. The IFC-based digital building model then offers the possibility for transparent and traceable, data-based processes in risk management. The additional amount of data due to the application of risk management to the models is manageable and is therefore to be treated neutrally.

5. Validation of further development

In order to validate the proposal mentioned in section 4.2, the results on the integration of risk management in BIM were continuously validated. For this purpose, workshop methods such as the 'World Café' method were used. The aim of this method is to bring workshop participants into an open discussion by assigning them to smaller and changing groups. This minimises the possible reticence of individuals to introduce topics in front of the whole group. Problems are discussed and reflected upon intensively within a given time frame. The final stage is the presentation of the individual groups to all participants. In addition, the participants were asked in expert interviews about their current status in the application of risk management in their company [8].

The aforementioned workshop took place in March 2021 as part of a practice partner meeting of the research project 'BIM-based risk management'. Each practice partner was led into a predefined zoom session with another practice partner. The small groups answered three predefined questions about the digital building model and its implementation. These were critically examined and answered in the allotted time of ten minutes. The questions were:

- How do you rate the practicality?
- What templates do you need for your chosen software or exchange format to support the application of your risk management process?
- How do you rate the current application possibilities of risk management in software solutions/exchange formats?

The answers were shared by each practice partner after the zoom sessions and discussed with the participants present. 14 practice partners took part in the workshop. Six practice partners have a managerial position in construction companies. Eight practice partners gave their input from the perspective of building owners and project managers. The workshop was conducted by a research team from the University of Wuppertal. On the question of the practical suitability of the model, all participants gave positive to very positive feedback on the added value of practical application. On the question of the information required, there was feedback that the available attributes cannot fully represent the risk management process of a construction project and that the focus here is only on technical risks. In conclusion, all participants of the workshop agreed that there is high potential in the application of risk management through the IFC exchange format, but that a detailing of the application specifications is necessary. The participants stated that the integration of risk information into the digital building model has a high added value for communication between the project participants and that the information can be used for the transfer of knowledge into the company and for the documentation of the construction project. According to the participants, there is a lack of mature standardisation and mapping in open data exchange formats.

6. Conclusion and perspectives

This paper demonstrates that BIM-based linking of risk management information with the digital building model is possible. The findings revealed a need for linking risk information with an IFC file. The presented approach is one solution. In addition, further research should be conducted in order to confirm, for example, optimisations in the planning, execution and operation of buildings. This is due in particular to a structured growth of information over the project cycle, the as-is state of a building that can be retrieved at any time, and the digital traceability of changes.

These optimisation potentials can be generated in particular when open exchange formats such as IFC are used within the framework of the BIM method. However, the analysis and surveys carried out show that the attributes currently contained in IFC are not sufficient to fully map the risk management process. In particular, essential attributes are missing in PSet_Risk, thus no qualitative and quantitative assessment of the risks as well as no differentiation in the extent of damage between costs, deadlines and quality are possible. Furthermore, the roles in the risk management process are not fully mapped.

This is where the proposal for the further development of PSet_Risk can be applied. Through the further development, attributes are integrated that enable a qualitative and quantitative assessment of the risks and can also map the risk management processes in IFC. This will allow the information relevant to risk management to be stored, exchanged and evaluated over the entire life cycle on the basis of open exchange formats. Continuing risk management in all life cycle stages is crucially important to fully use the potential of risk management. IFC simultaneously enables the integration of risk information from all stakeholders and the use of the information by these stakeholders. Since it is particularly important for the success of risk management to involve all stakeholders, this approach is of outstanding importance.

This article presents the first results of a research project at the University of Wuppertal. Based on the available analysis and results, further research will be conducted to further improve the integration between BIM, open exchange formats such as IFC and risk management.

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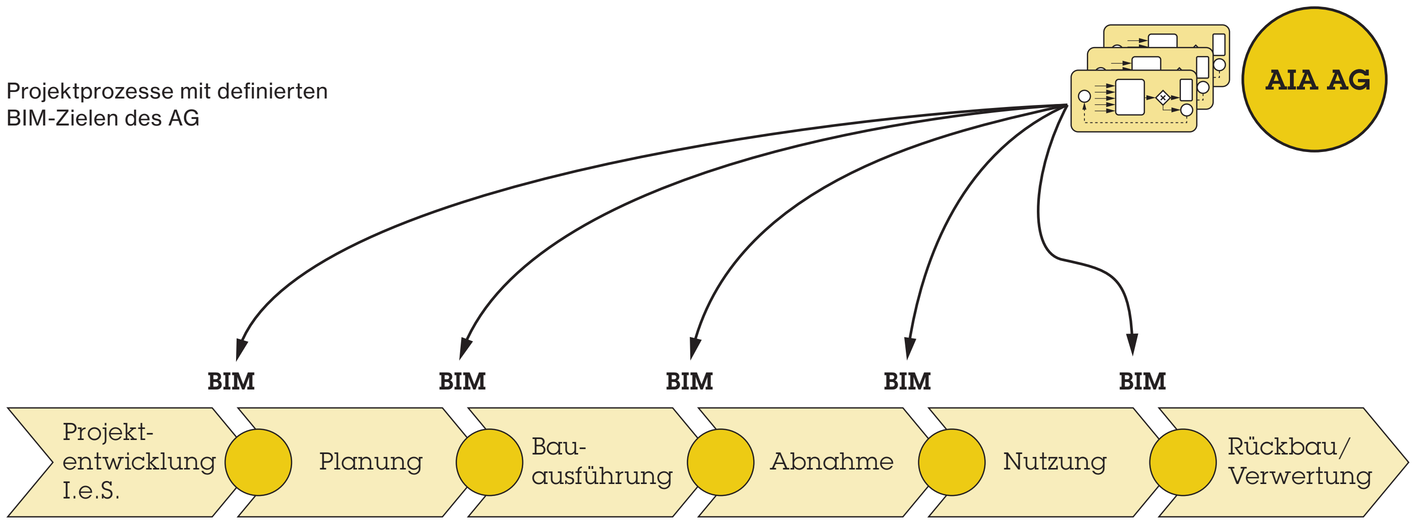

BIM-Basisprozesse

Potenziale für die Vereinheitlichung von BIM-Anwendungen

Das BIM-Institut der Bergischen Universität Wuppertal untersuchte öffentlich zugängliche BIM-Anwendungen in Deutschland, Österreich und der Schweiz. Die Analyse zeigt, das gleiche BIM-Prozesse bei den Anwendern unterschiedlich verstanden werden.

Autoren: Maike Eilers, Daiki John Feller, Anica Meins-Becker

Im Zuge einer fortlaufenden Recherche seit Juni 2019 hat das BIM-Institut der Bergischen Universität Wuppertal für die Öffentlichkeit bereitgestellte BIM-Anwendungen unterschiedlicher Herausgeber aus der DACH-Region in einer Übersicht zusammengeführt und analysiert. Im Ergebnis konnte kein herausgeberübergreifendes, heterogenes Verständnis für die Strukturierung, die Beschreibung und den Inhalt von BIM-Anwendungen festgestellt werden.

Die Bereitstellung gleichartig strukturierter BIM-Anwendungen für Baubeteiligte kann für die Verschiedenartigkeit Abhilfe schaffen und Transparenz fördern. Eine Vereinheitlichung sieht dabei nicht nur vor, vorhandene Inhalte in einen gleichen Aufbau zu überführen, sondern darüber hinaus auch das Ziel, jede BIM-Anwendung gleichartig auszurichten und inhaltliche Elemente gleichartig, gegebenenfalls standardisiert, auszudrücken.

Motivation der Untersuchung

Gemäß VDI wird eine BIM-Anwendung als „Durchführung eines spezifischen Prozesses oder eines Arbeitsschrittes unter Anwendung der Methode BIM" definiert. [1] Entsprechend kann eine BIM-Anwendung die Beschreibung einer Leistung im Kontext des Building Information Modeling darstellen und unterscheidet sich rein methodisch, von ihrem Äquivalent ohne Anwendung der Methode BIM. BIM-Anwendungen können folglich als Auftrags- oder bereits als Kommunikationsgrundlage dienen und so die Transparenz innerhalb eines Projektes fördern. Die Durchführung von BIM-Anwendungen dienen dazu, die BIM-Ziele des Auftraggebers zu erfüllen, siehe Titelabbildung.

Artikel online lesen:
www.build-ing.de/S189

Bild: BIM-Institut der Bergischen Universität Wuppertal/HUSS-MEDIEN GmbH ■ Autorenbild: privat

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Status Quo von BIM-Anwendungen

Um sich einen Überblick über das aktuelle Verständnis von BIM-Anwendungen aus Sicht der Wissenschaft und Praxis zu verschaffen, sind die Autoren im Juni 2019 dazu übergegangen, in der DACH-Region veröffentlichte BIM-Anwendungen zu recherchieren, zentral zu sammeln und auswertbar zu machen. Hierbei wurden bis heute mehr als 220 BIM-Anwendungen von insgesamt 17 Herausgebern erfasst. Bei den Herausgebern handelt es sich neben wissenschaftlichen Institutionen um beratende Dienstleister, BIM-Manager, wirtschaftlich tätige Unternehmen, öffentliche Einrichtungen sowie Verbände.

Um bei der Menge der recherchierten BIM-Anwendungen Übersichtlichkeit zu schaffen, wurden die BIM-Anwendungen von Seiten der Autoren inhaltsspezifisch gemäß Anwendungszweck geclustert und anschließend kategorisiert. Sofern einzelne BIM-Anwendungen inhaltlich mehreren Kategorien zugeordnet werden konnten, wurden diese in den jeweiligen Kategorien berücksichtigt. Hieraus resultierend konnten 16 BIM-Anwendungskategorien identifiziert werden.

Folgende Anwendungskategorien wurden erfasst:

- **Anreichern eines Bauwerksinformationsmodells gemäß BIM-Anwendung**
- **As-built-Erfassung**
- **Datenableitung aus dem Modell**
- **Erstellung von 2D-Plänen**
- **Georeferenzierung des Liegenschaftsmodells**
- **Ist-Daten-Erfassung**
- **Kalkulation**
- **Kollaboration**
- **Kommunikation**
- **Liegenschaftserfassung**
- **Liegenschaftsmodellierung**
- **Monitoring**
- **Regelprüfung**
- **Simulation**
- **Terminplanung**
- **Visualisierung**

Im Zuge einer anschließenden Analyse je Anwendungskategorie konnte festgestellt werden, dass die jeweils zugeordneten BIM-Anwendungen – bei gleichem inhaltlich verfolgtem Anwendungszweck – herausgeberübergreifend keine einheitliche Systematik erkennen ließen. Diese Heterogenität äußerte sich dabei unter anderem in Bezug auf den Inhalt der Beschreibung, die Struktur der Durchführungsbeschreibung der BIM-Anwendung sowie die Struktur der Detaillierung der Beschreibung. [2]

Zur Verdeutlichung der oben geschilderten Situation wird anhand des Beispiels der Anwendungskategorie Terminplanung die Vorgehensweise der Autoren erläutert.

Im Rahmen der Recherche wurden unter anderem das Karlsruher Institut für Technik ▸

(KIT), der Hauptverband der Deutschen Bauindustrie e. V., die DEGES, die DB Netz AG sowie BIM4INFRA als Herausgeber von BIM-Anwendungen für die BIM-Anwendungskategorie Terminplanung identifiziert.

Das KIT bezeichnet die BIM-Anwendung als modellbasierte 4D-Planung, welche die Verknüpfung des Terminplans mit Elementen im Modell zur 4D-Planung, das Erstellen und Fortschreiben von Terminplänen sowie das dynamische Ableiten von Daten zur Darstellung des Bauablaufs beschreibt. [3]

Der Hauptverband der Deutschen Bauindustrie e. V. beschreibt seine BIM-Anwendung Terminplan wie folgt: „BIM-Modelle können mit einem Terminplan verknüpft werden, um daraus Simulationen des Bauablaufs zu erstellen. Dabei werden den Vorgängen des Terminplans jeweils bestimmte Elemente des Modells zugeordnet. Die Verknüpfung kann auf verschiedenen Detailstufen erfolgen, z. B. auf Ebene der Bauteilgruppen oder einzelner Bauteile. Durch die Verknüpfung zwischen dem BIM-Modell und einem Terminplan können Animationen des Bauablaufs erstellt werden. Hierdurch kann vorab die Herstellbarkeit des Bauwerks transparent überprüft werden. Zusätzlich ist eine visualisierte Optimierung des Bauablaufs, die Durchführung von Variantenvergleichen sowie eine Plausibilisierung der Leistungsansätze möglich. Eingangsdaten der Terminplanung sind auf die Terminplanstruktur und auf den Bauablauf abgestimmte BIM-Modelle.“ [4]

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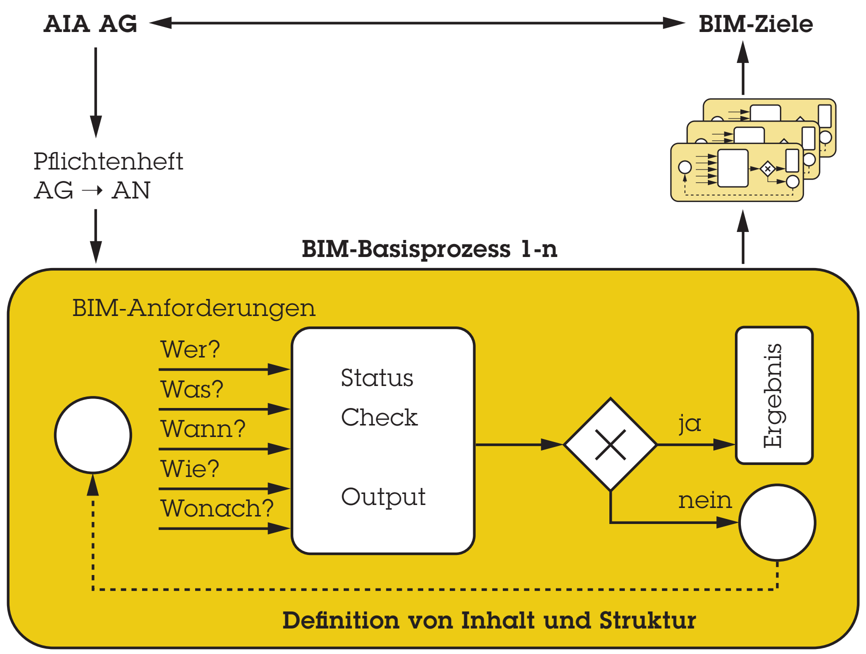
www.biminstitut.uni-wuppertal.de

DEGES verfolgt mit der BIM-Anwendung 4D-Bauablauf und Baufortschrittskontrolle folgende Ziele: Hohe Terminsicherheit, Verknüpfung von Modellen und Terminplanung. [5] Die DB Netz AG verfolgt mit der BIM-Anwendung 4D-Planung das Ziel der Verknüpfung der geometrischen Modelle mit Terminplaninformationen zu 4D-Modellen. [6] BIM4INFRA2020 hat das Ziel der Nutzung eines durch Verknüpfung von Vorgängen der Terminplanung mit den zugehörigen Modellelementen erstellten 4D-Modells zur Darstellung und Überprüfung des geplanten Bauablaufs in seiner veröffentlichten BIM-Anwendung Terminplanung der Ausführung. [7] Wie an diesen Beispielen zu erkennen ist, erfolgt eine Durchmischung zwischen Zielen und Prozessschritten der Herausgeber, außerdem eine unterschiedliche Detailtiefe der Anwendungsbeschreibungen sowie Anwendungszeitpunkte in der Praxis und Abgrenzungen zu weiteren Prozessschritten in der Ausführung.

Zusammenfassend wurde festgestellt, dass – sowohl in Wissenschaft als auch in der Praxis – in Bezug auf Inhalt und Struktur einer BIM-Anwendung teilweise ein unterschiedliches Verständnis besteht. Als Grund hierfür ist eine fehlende, übergeordnete Standardisierung des schnelllebigen Aufgabenfeldes zu nennen. Zum aktuellen Zeitpunkt beschäftigen sich Arbeitskreise, beispielsweise im Rahmen der VDI-Richtlinie 2552 oder beim buildingSMART, vermehrt mit dem Inhalt und der Struktur von BIM-Anwendungen. [8]



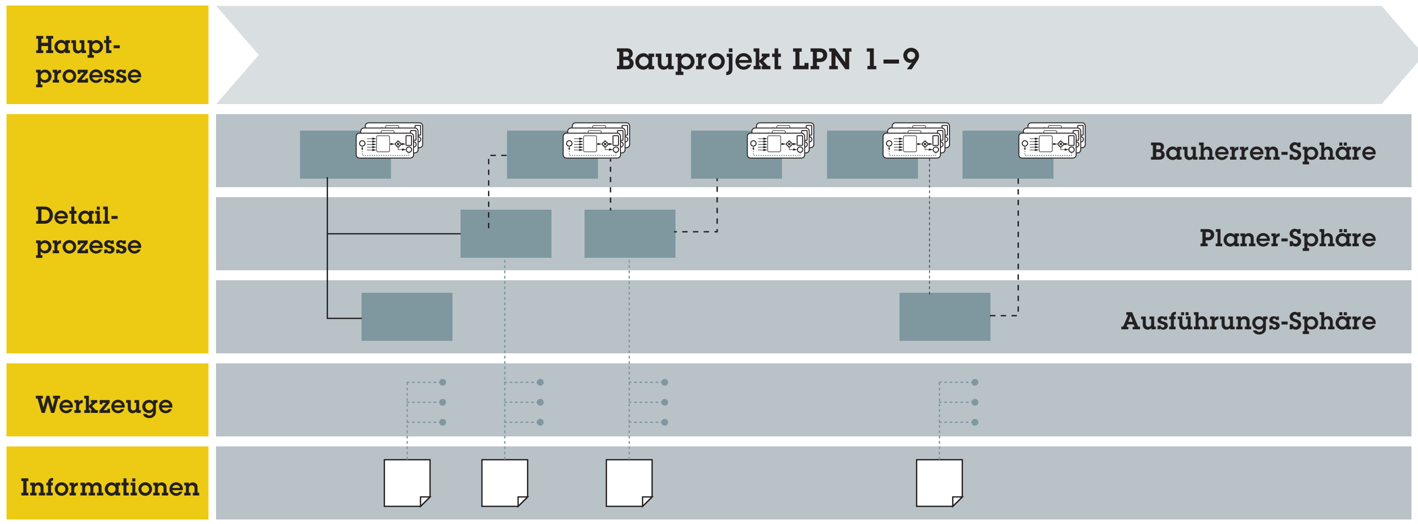
Übersicht BIM-Basisprozess

Ableitung von BIM-Basisprozessen durch die Recherche

BIM-Basisprozesse verfolgen den Ansatz, allgemeingültig die anzuwendende Methode unter Berücksichtigung der Informationsanforderungen (im Sinne der VDI 2552 Blatt 2 „BIM-Anforderungen“) zu beschreiben und dargestellt wie in Abbildung „Übersicht BIM-Basisprozess“. Die BIM-Anforderungen je BIM-Basisprozess bedingen dabei die Beschreibung der durchführenden Verantwortlichkeit, des notwendigen Inputs für die Durchführung, des Zeitpunkts der Durchführung (im Projekt), der allgemeingültigen technischen Umsetzung, der zu berücksichtigenden Regularien und Vorschriften sowie des generierten Outputs.

Infolge der geschilderten detaillierten Beschreibung können Anwender transparent und umfassend die Start-, Durchführungs- und Endbedingungen je Arbeitsschritt und im Gesamtkontext der jeweiligen BIM-Anwendung einsehen. Über eine Beschreibung des jeweiligen BIM-Basisprozesses erhält der Anwender darüber hinaus einen schnellen Einblick über den durchzuführenden Arbeitsschritt. Standardmäßig sind, sowohl für die Beschreibung als auch für die BIM-Anforderungen, generische Textbausteine eingearbeitet, die im Kontext der BIM-Anwendung zu spezifizieren sind.

Bilder: BIM-Institut der Bergischen Universität Wuppertal/HUSS-MEDIEN GmbH ■ Autorenbild: privat



Integration von BIM-Basisprozessen in den Bauablauf

Tabelle 1 zeigt einen Überblick der identifizierten BIM-Basis-Prozesse. Insgesamt wurden 15 BIM-Basisprozesse definiert [9], die im Kontext der Methode BIM als wesentlich zu erachten sind, welche sich in die Cluster: Daten schreiben, Daten erfassen, Daten ableiten, Daten verarbeiten (extern), Kommunikation sowie Andere einteilen.

Tabelle 2 stellt die BIM-Anforderungen beispielhaft für den BIM-Basisprozess „Erstellung eines Bauwerkinformationsmodells“ dar.

Die Auswahl der jeweiligen Arbeitsschritte als BIM-Basisprozesse erfolgte dabei unter Berücksichtigung möglichst einfach verständlicher, allgemeingültiger und umfassender Eigenschaften. Eine zu umfangreiche oder abstrahierte Systematik verschlechtert die Verständlichkeit sowie die Anwendbarkeit und damit einhergehend die Akzeptanz durch die Anwender.

Für ein besseres Verständnis der BIM-Basisprozesse, ihrer Anwendung und ihres Mehrwerts wird das angeführte Beispiel Terminplanung ▸

(spezifiziert aus Sicht bauausführender Unternehmen) aufgegriffen und veranschaulicht.

Im Allgemeinen wird die BIM-Anwendung durchgeführt, um einen Terminplan auf Grundlage eines Bauwerkinformationsmodells zu erstellen. Als Mehrwert resultiert dabei eine frühzeitige Erkennung von logischen und/oder bauablauforientierten Problemen sowie eine erhöhte Terminsicherheit.

Aus fachlicher Sicht ergibt sich folgende Prozesskette für die Erstellung der Terminplanung unter Anwendung der Methode BIM:

- **Ableitung und Definition geeigneter Bauabschnitte für die Terminplanung aus dem Modell (entspricht BIM-Basisprozess Datenableitung aus dem Modell)**
- **Ableitung von Terminen und Dauern sowie das in Beziehung setzen der Vorgänge auf Grundlage der zuvor definierten Bauabschnitte (entspricht BIM-Basisprozess Terminplanung)**
- **Zurückspielen der generierten Informationen (Termine und Dauern) in das Modell (entspricht BIM-Basisprozess Anreicherung eines Bauwerkinformationsmodells gemäß BIM-Anwendung)**

Durch die Aufschlüsselung und Beschreibung des Prozesses „Terminplanung erstellen" mithilfe der BIM-Basisprozesse und der Anpassung der generisch mitgelieferten Beschreibungen erhalten Anwender eine Beschreibung der notwendigen Anforderungen an Soft- oder gegebenenfalls Hardwarelösungen, notwendigen Informationen, zu berücksichtigenden Regelwerken und Vorschriften. Eine unternehmensspezifische Anpassung sowie Überführung in die Umsetzung wird durch eine solche neutrale, aber fachlich und methodisch genaue Beschreibung vereinfacht.

Fazit und Ausblick

Die Recherche zeigt auf, dass das Verständnis – gemessen an der hohen Anzahl herausgeberspezifischer Definitionen und Begrifflichkeiten – in Bezug auf BIM-Anwendungen unterschiedlich gehandhabt wird. Hieraus resultieren die immer größer werdenden Kommunikationsschwierigkeiten bei Baubeteiligten. Positiv zu werten ist dabei, dass Unternehmen durch die Bereitstellung ihrer aktuellen Best Practices BIM-Anwendungen Lösungsansätze aufzeigen, an denen sich weitere Anwender orientieren können.

Quellen

[1] VDI 2552 Blatt 2, Building Information Modeling – Begriffe. Juni 2018, Düsseldorf. Beuth Verlag GmbH

[2] Die aufgeführten Beispiele beschreiben nur einen Auszug der erkannten Uneinheitlichkeit der recherchierten BIM-Anwendungen und dienen zur Unterstützung für das Verständnis notwendiger Standardisierungen sowie Vereinheitlichungen von BIM-Anwendungen.

[3] Vgl. https://www.tmb.kit.edu/download/Katalog_d er_BIM-Anwendungsfaelle.pdf

[4] Vgl. BIM im Hochbau, Technisches Positionspapier der Arbeitsgruppe Hochbau im Arbeitskreis Digitalisiertes Bauen im Hauptverband der Deutschen Bauindustrie e. V., Dezember 2018

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[7] Vgl. https://bim4infra.de/wpcontent/uploads/2019/07/BIM4INFRA2020_ AP4_Teil6.pdf

[8] Die Autoren haben einen Entwurf für eine solche Struktur erarbeitet und mit Vertretern und Experten von Verbänden sowie der Praxis diskutiert, angepasst und weiterentwickelt. Abrufbar über https://biminstitut.uni-wuppertal.de/de/forschung/download-bereich.html > „Leitfaden zur Strukturierung von BIM-Anwendungen"

[9] Stand Oktober 2020

[10] Angepasste Darstellung

[11] Aufrufbar über https://biminstitut.uni-wuppertal.de/de/forschung/download-bereich.html > „Recherche BIM-Anwendungen DACH-Region"

Tabelle 1: Identifizierte BIM-Basisprozesse

BIM-Basisprozess-Cluster	BIM-Basisprozess
Daten schreiben	Erstellung eines Bauwerkinformationsmodells
	Ergänzung des Bauwerkinformationsmodells als Voraussetzung zur Umsetzung der BIM-Anwendung
	Ergänzung des Bauwerkinformationsmodells um erzeugte Informationen der durchgeführten BIM-Anwendung
Daten erfassen	As built-Erfassung (Geometrie)
	Liegenschaftserfassung
	Ist-Daten-Erfassung
Daten ableiten	Datenableitung aus dem Modell
Daten verarbeiten (extern)	Kalkulation
	Kollaboration
	Regelprüfung
	Simulation
	Terminplanung
	Visualisierung
Kommunikation	Kommunikation
Andere	Erstellung von 2D-Plänen

Autorenbild: privat

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Tabelle 2: BIM-Basisprozess „Erstellung eines Bauwerksinformationsmodells" (Beispiel) [10]

Übergeordnetes Cluster	Daten schreiben
BIM-Basisprozess	Erstellung eines Bauwerkinformationsmodells
Beschreibung	Ein Bauwerksinformationsmodell wird nach den Anforderungen einer Modellierungsrichtlinie erstellt. Das Bauwerksinformationsmodell kann aus Geometrie und/oder (attribuierten) Merkmalen bestehen.
Wer? (Verantwortlicher)	Verantwortlichkeit ist zu definieren.
Was? (erforderliche Arbeitsgrundlage, Input)	Projektinformationen, digitale Prüfregeln
Wann? (Zeitpunkt)	Informationslieferzeitpunkt ist zu definieren.
Wie? (Methode)	Modellierungswerkzeug ist zu definieren.
Wonach? (Vorgaben)	Modellierungsvorgaben, sonstige Anforderungen. Datenaustauschformate sind zu definieren.
Was? (Output)	Bauwerkinformationsmodell

Eine Standardisierung von BIM-Anwendungen wird momentan von verschiedenen Initiativen vorangetrieben. Durch die Beschreibung einer BIM-Anwendung aus einem oder mehreren Arbeitsschritten kann für jede BIM-Anwendung ein Idealprozess definiert werden. Aufbauend auf diesem Ansatz entwickelten und entwickeln die Autoren standardisierte Teilprozessschritte inklusive einer generischen Beschreibung und Definition von BIM-Anforderungen für BIM-Anwendungen.

Diese standardisierten Teilprozessschritte (BIM-Basisprozesse) sind aus der durchgeführten Analyse der BIM-Anwendungen-Recherche hervorgegangen. Hierbei dienen BIM-Basisprozesse sowohl als Bausteinsystem für die Neudefinition von BIM-Anwendungen als auch als Klassifizierungssystem für bereits definierte BIM-Anwendungen. Durch eine konsistente Beschreibung notwendiger Informationen je Arbeitsschritt sowie im Gesamtbild der BIM-Anwendung wird die notwendige Transparenz, beispielsweise für Zwischenprüfungen infolge Datentransfer, geschaffen.

Die Recherche ist über die Internetseite des BIM-Instituts einsehbar und verfügbar. [11] ▪

Don't risk your real estate

Actions to realize efficient project risk management using the BIM method

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Abstract –

At the beginning of a construction project, cost, time and quality are defined, which must be adhered to throughout the entire construction process. Compared to other industries, risk management in the construction industry is often treated negligently. Risk management is rather an additional documentation task than an effective project management and controlling instrument. However, systematically applied risk management and successfully implemented counter-measures offer the opportunity to significantly increase the result of the construction project. Information gained from an efficient risk management system can automatically be used as empirical values for subsequent projects, thus increasing the achievement of quality, cost and time targets in the long term. The application of the BIM method opens up new possibilities in terms of the automatic linking of risk management information to other processes, which have not been exploited to date.

The research project "BIM-based risk management" examines the application of risk management in construction projects on the basis of literature research, numerous interviews with experts and an online survey. The content of the analysis is the strategy of companies in implementing the classic phases of the project risk management process consisting of risk identification, risk assessment, risk control and risk monitoring. The result shows, that there is no consistent systematic approach to the use of risk management systems in the construction industry. Individual approaches, such as the use of Excel templates to identify risks, are being implemented, but there is no linking of information across projects or departments, which means that the great potential of project risk management is not sufficiently exploited.

On this basis, the research project develops an ideal-typical process for the application of risk management in construction projects. The resulting BIM use case risk management shows how this information can be automatically generated and made available via the BIM process.

Keywords –

risk management; Building Information Modeling; project risk management; risk management process; information delivery; Data linkage; Information controlling; Risk

1 Procedure and principles

Within the framework of the research project "Measures for the implementation of an efficient project risk management by using the BIM method" of the chair of Construction Management of the University of Wuppertal, solutions are being developed how the information linkage associated with the application of the BIM method can be used to improve risk management. The classical risk management process (see Fig. 1) based on DIN ISO 31000 is a sub-area of project management which is implemented over all life cycle phases of a project, involving all project participants and involving different business units. Together, the project participants identify potential opportunities and risks for the project at an early stage and take proactive countermeasures by means of the process steps of identification, assessment, control and monitoring. The risk management cycle is a continuous process. This means that the cycle is constantly repeated in the course of project processing [1]. Only project risk management is considered in the project. The aim of project risk management is to increase the transparency of risks in a construction project and to derive and evaluate measures to reduce unknown parameters and determine realistic target figures. This leads to a higher achievability of the project goals in terms of costs, deadlines and quality. Project risk management is distinct from corporate risk management, whose overriding goal is to maintain the company.

In the research project, which has been running since January 2019, the current application of risk management in construction projects was first examined. In view of the ever-increasing demands for a partnership approach to projects between client and contractor, the project deliberately considers both sides and in particular their interfaces in terms of risk management.

Through numerous expert interviews and an online survey, the strategy of companies in implementing the project risk management process was analysed. When looking at the existing risk management processes in terms of the flow of information, level of detail and responsibilities, differences in the approaches to risk management and the priority given to the issue became apparent.

2 Risk management

The term risk refers to the deviation from project goals caused by influences on productivity. The project objective is to complete a project on time, within budget and in line with quality standards [2]. The term risk includes both positive and negative deviations from targets. The positive deviation from goals is called opportunity, the negative deviation is called danger [3]. Since mainly the negative deviations can cause construction delays and cost increases, the term risk is used in this paper to refer to the negative deviation in particular. For the correct application of a risk management system it is necessary to create an awareness of risk management in the company, the organization or the department. A risk management system must be integrated within the company or the organization or project at various organizational levels. On the one hand, it must be integrated at the normative level, where the goals of the company or project are defined. An implementation on a strategic level, determines the risk strategy to achieve the defined goals. The risk management system, the focus of this paper, is implemented at the operational level [4].

The risk strategy defines the objectives to be achieved by risk management. The risk strategy must contain the following specifications [5]:

- The type of risks to be taken
- The level of risk tolerance
- The limit of the risk-bearing capacity
- The time limit in which the risks are dealt with
- Specifications on the risk management process

DIN ISO 31000 specifies a process structure for risk management, see Figure 1 [6].

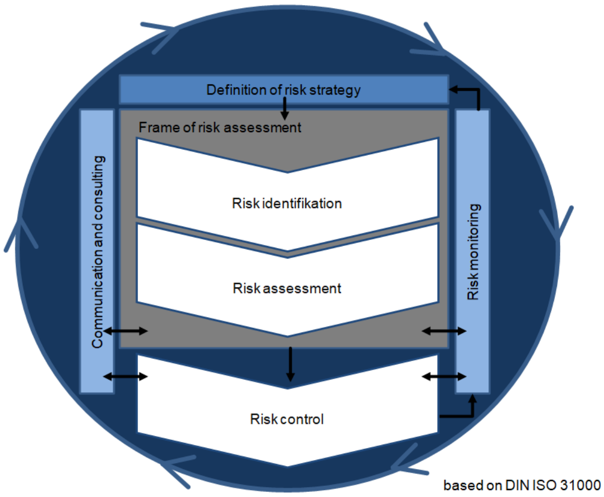

Figure 1. risk management process

The core of this process structure is transparency and openness. The process can only be successfully implemented if risks are not covered up, but are addressed openly. However, risk assessment and treatment cannot be carried out without defining an area of application, the context and setting risk criteria, see Figure 1. Throughout the cycle, continuous communication, documentation and review is required [7]. The risk management cycle is a continuous process. This means that the cycle is repeated in the course of project processing. The reason for this is that risks can change or new ones arise as the project progresses [8].

In the course of the risk management process, communication and consultation means that expertise from a wide range of fields is taken into account in the risk management process and that, as a result, different perspectives are considered in the identification, assessment, control and monitoring process. This also serves to obtain the necessary information required for risk management. Communication and consultation should take place between all those involved in the project or company [9].

Continuous monitoring and review of the existing risk management system is necessary to ensure the quality and effectiveness of risk management. In order to communicate the results of risk management, it is necessary to document risk management on an ongoing basis. This can provide information that is necessary, for example, for decision-making [10].

In order to apply a risk management process, the scope, context and criteria must be defined. This means that a risk strategy is defined as described above [11]. The definition of the scope includes a specification of the risk management processes and tools used and the necessary means and responsibilities. A definition of the cycle of involvement and an analysis of interfaces with other projects and stakeholders are also part of the definition of the scope [12].

In addition, the environment in which the defined objectives are to be achieved must be analysed. The environment has a significant influence on the design of risk management. The external and internal relationships are defined. External interrelationships include, for example, political, legal and social aspects, whereas internal interrelationships include responsibilities and roles in the company or project [13].

Risk criteria are necessary for risk assessment. Therefore, they must also be considered. Risks can be assessed from a variety of perspectives within the company or organization, such as individual sub-projects of a major project or different levels within an organization. Since the approach and procedures differ depending on the viewpoint, criteria must be defined for risk assessment. For example, the type, extent and measurement of effects and the decision-making criteria for risks are defined [14].

3 Steps of the risk management process

The environment of all risk management processes is the risk strategy. This is used to formulate objectives and framework conditions. The next steps are the sub-processes identification, assessment, control and monitoring. Continuous controlling, careful documentation and regular communication and advice complete the risk management control loop [15].

3.1 Identification

The aim of risk identification is to identify all existing risks that could jeopardise the achievement of objectives. In risk identification, a distinction is made between cause, event and effect. A cause results in an event that has an impact on the project objectives. This distinction is important because countermeasures for dealing with risks can only be developed if the cause of the effect is known [16].

With regard to the method of risk identification, a distinction is made between the type of recording, the time of recording and the integration of the identification into the structure of the company or project [17].

It is important to complete the risk identification before starting the analysis [18].

3.2 Assessment

In the course of the risk assessment, the probability of occurrence and the extent of damage of a risk are estimated. This can be qualitative (e.g. low, medium, high) as well as quantitative (e.g. 50%, €50,000 loss). Based on the risk assessment, it can then be decided whether or not the identified and assessed risks are handled in the following ways[19]:

- No further action is taken
- Options for risk treatment exist
- Whether further analysis is needed for understanding
- The existing control system must be maintained
- project objectives may need to be adjusted if necessary.

For this purpose, the risks that are to be treated with the highest priority must first be determined.

The assessment of risks can be divided into gross and net assessment. In the net risk assessment, only the residual risk is assessed with a countermeasure. The gross risk is therefore the purely assessed risk. The gross risk thus represents the entire extent of the risk, whereas the net risk only shows the residual risk after countermeasures. It is assumed, however, that the countermeasures to reduce the scope of the risk occur to the extent assessed [20].

3.3 Control

In the risk management process step, countermeasures are developed to deal with the risks. The effectiveness of the selected countermeasures is then assessed. If the remaining residual risk remains too high, a further or, if necessary, new countermeasure is defined. This results in an iterative process [21].

How a risk is treated depends on the risk behaviour of the company or project and the risk strategy that has been defined [22]. A basic distinction is made between cause-related and effect-related measures [23]. Cause-related measures reduce the probability of a risk occurring, whereas effect-related measures reduce the extent of damage [24].

A distinction is also made between active and passive measures. Active measures contribute to reducing the probability of occurrence and/or the amount of damage, thereby changing the risk structure. Passive measures, on the other hand, aim to minimize the extent of damage. An attempt is made to compensate for the occurrence of a risk [25]. The combination of several coping measures is also possible and common in order to keep the residual risk low [26].

A distinction is made between five different risk management strategies [27]:

- Avoidance
- Reduction
- Transmission
- Insurance
- Acceptance

With regard to the order of priority of the application of coping measures, there is no fixed order. This must be determined individually. All measures depend on the cost-benefit ratio, but also on the time schedule, the qualitative dependencies and the applicability.

3.4 Monitoring

As already explained, communication and consultation, recording and reporting, as well as monitoring and reviewing are also part of the risk management cycle according to DIN 31000, and these components of the cycle should take place at all stages of the process [28].

The risk management process of a company or project must always be reviewed. This part of the risk management process is therefore also called risk controlling [29]. On the one hand, risk controlling serves to determine whether the desired effectiveness of the management measure has been achieved. On the other hand, it serves the right insight if a risk has to be re-evaluated or a countermeasure is not effective. It must also be checked whether a risk no longer exists, for example, due to a change in planning, and whether the change in planning gives rise to new individual risks [30].

4 Study on the application of risk management in the construction industry

In order to gain an insight into the application of risk management in construction practice from the perspective of the client and the construction company, expert interviews and an online survey were launched by the University of Wuppertal. The structure of the web-based survey corresponds to that of the expert interview.

The online survey was completed at the end of September 2019. 249 participants took part in the survey. Among the participants are 50 construction companies, 47 private builders, 34 planning/architectural offices, 31 participants from the field of consulting, 25 public builders, 6 experts, 3 from the craft sector and 54 from other fields. The findings of the survey are summarized below.

4.1 Positive approaches visible in practice

Around 60% of the companies surveyed implement risk management in accordance with a uniform company-wide risk strategy. Risks are identified for the first time at the acquisition stage or at the start of a project and are continued through the subsequent project phases. Risks are usually recorded in Excel applications or the company's own software applications. Communication channels for risk management are generally short and, thanks to open discussion cultures, there are few fears of communicating risks.

The interviewed experts recognize advantages for the project business through risk management: Risks that are recognized early have a positive influence on the further course of the project. Costs are saved, customers are retained and experience and improvement potential for follow-up projects is generated. There is improved control of costs and cost transparency throughout the entire construction phase, and through the integration of the risk management system, all those involved are able to improve the reliability of deadlines and costs.

4.2 Identified problem areas

Instead of uniform guidelines for dealing with risks and a systematic approach, a good third of companies rely purely on the experience of their employees.

Risks are considered in greater depth in the bidding phase, but are neglected in the execution phase. When assessing risks, the effects of deadlines are usually not taken into account in the offer. Risk assessment is largely intuitive and is shaped by the experience of the individual employee. The risk assessment usually ends with the acceptance and is not continued until the end of the warranty. Companies often have clear divisions between the departments of acquisition and project execution or planning and implementation on the client side. After project completion, the knowledge gained is only transferred to a few colleagues in discussions at communication level. None of the companies carries out a systematic evaluation of the risks after project completion and a systematic transfer of this information to subsequent projects.

4.3 Conclusion of the study

Overall, it became clear that risk management is by no means accorded importance in every company. For about half of the companies surveyed, risk management hardly plays a role in their projects. The cost and schedule of a project is usually determined by higher authorities and the project participants lack the necessary room for maneuver. There is potential for a stabilisation of risk management processes: Regular identification of risks, adjustment of assessments and linking to other processes have so far hardly been used to make risk management more effective. There is often no consistent systematic approach to the use of risk management systems. It is more a combination of individual approaches, which are not sufficiently linked and therefore information is lost or not fully used. In view of the imbalance of many current major projects, the potential of an industry-wide application of risk management processes is evident here.

5 Outlook using BIM

The mentioned research project has the aim to show the development possibilities of risk management into the method BIM. Therefore, the participants of the study were asked for which use cases and to what extent they currently use the BIM method to generate integration potentials for risk management. The survey showed that BIM is already being used in companies. The most frequently used use case is the use case of 3D modelling and collision check. The 3D modelling is set up in the planning phase and attributes are defined to support the prefabrication process. In addition, the models are used to generate carcass and fit-out dimensions, which serve as a basis for the bill of quantities and costing. Schedules and costs are usually not yet linked in the respondents' BIM models. In some companies, there are also company specifications to digitalize the complete planning and construction processes. Tablets are also often used for construction site operations. These enable access to the documents, checklists and work aids in the cloud. In addition, barcodes are sometimes stuck into every room on the construction site and the site manager has the option of calling up the attributes and information important for the room via tablet. The complete defect management is generated daily via the tablet of the site manager and the information stored in the cloud. The areas of construction site logistics, modularization, systematization of construction products and components are currently the focus of integration into the execution. In addition, some of the construction companies also want to use their project model for later operation and extract an as-built model from the data and attributes. The aim is to use BIM to create a complete digitalization of the processes from the construction site or project. As a use case, construction companies have their own focus such as quantity take-off, calculation and quality assurance on the construction site. Developers usually use BIM to focus on 3D coordination. Documentation is an important use case for all parties involved. A market analysis of risk management software carried out in parallel to the surveys also revealed, that there is currently no BIM-capable offering, for example with an ifc interface.

5.1 Process modelled risk management

As the study shows, risk management is currently regarded and implemented as a separate process in most companies. There is currently no link to other project processes such as scheduling or cost planning. To be able to use the advantages of the BIM method for risk management, the process must first be linked to the other project processes.

The first step in linking with the BIM method in the research project is therefore to model the risk management processes and link them to the other project processes. For this purpose, the risk management process described in chapter 2 and 3 was created/modelled with the help of the Business Process Modelling Notation 2.0 (BPMN 2.0). Figure 2 shows an extract of the process and gives an overview of the type of modeling.

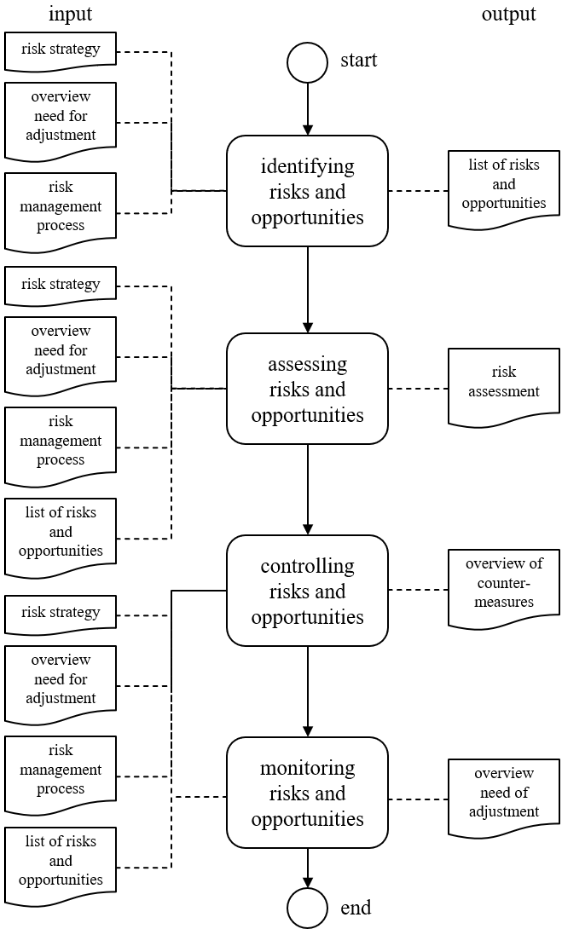

Figure 2. risk management process in BPMN 2.0

Each step of the risk management process shown in Figure 2 is broken down in more detail in further levels of the process model. The process "Identifying risks and opportunities" is divided, for example, into the process steps "Describing risks/opportunities", "Defining a short description", "Determining the cause and effect of the risks" and "Assigning a risk/opportunity category". In this way, all process steps are linked to one another and clearly presented.

In a second step, the modelled risk management processes are then linked to the other processes of the shown project, for example, cost control. In this way, it becomes clear at which point in the project, risks must be identified, assessed and controlled on the one hand, and which processes provide information in order to better assess risks on the other. Figure 3 shows an example of this information linkage.

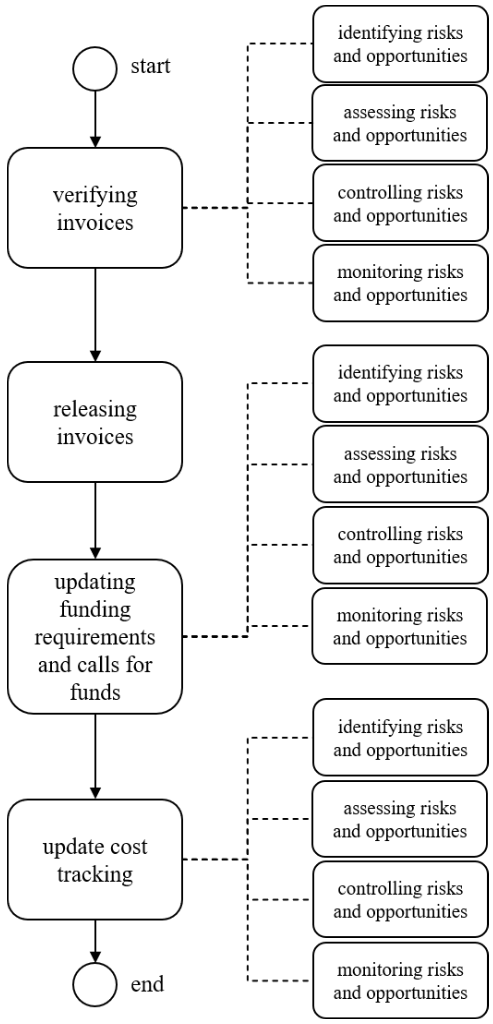

Figure 3. risk management processes linked to the process of cost management

The risk management process is represented on the process level, in which the methods and digital tools of a construction project are applied. The documents required for the risk management process in this section are formulated at a deeper, more detailed level.

The created risk management process now serves as a support process for the process steps in a construction project over the complete life cycle phase. In the further course of the research project, critical paths/processes in a construction project are analysed and the support process is integrated into them. This resulted in an overview of the critical processes for the different phases and from the point of view of the client and the construction company. Helpful tools and documents are formulated for each of these processes. The overview serves to link and identify potentials for the application of BIM.

6 Outlook research project BIM-based risk management

Processes have to be concretized, digitalized in the companies and responsibilities defined. Forms in the company and in the individual project phases must be digitalised and linked to software options. Checklists and required documents should be maintained regularly through experience and market adjustments and should be centrally stored for each employee.

In the further course of the research project, which will run until the beginning of 2021, optimization possibilities will be worked out based on the results of the survey so far and further potentials will be identified by using digital tools. A short self-check was developed for companies interested in a check of their own risk management processes. By ticking off the points, both approaches already successfully applied are made clear and ideas for further potential are offered.

In the coming months, a possible integration of the Building Information Modeling (BIM) method will be examined. To this end, the first step will be to link the risk management processes with the other processes of a construction project. The resulting process model will then show which information from the project activities should be used for risk management and, vice versa, which information is generated by risk management for the further course of the project. The BIM method is intended to enable a structured collection of risk management data. With increasing planning accuracy, the linking of information can be continued down to the component level. The linking of identified risks with components of the digital building model in the realization phase, promotes the integration and thus the acceptance of risk management and visualizes its advantages for the project result. The principle of the BIM method "first plan - then build" allows an early consideration of risks already from the planning phase to increase the reliability of deadlines, costs and quality.

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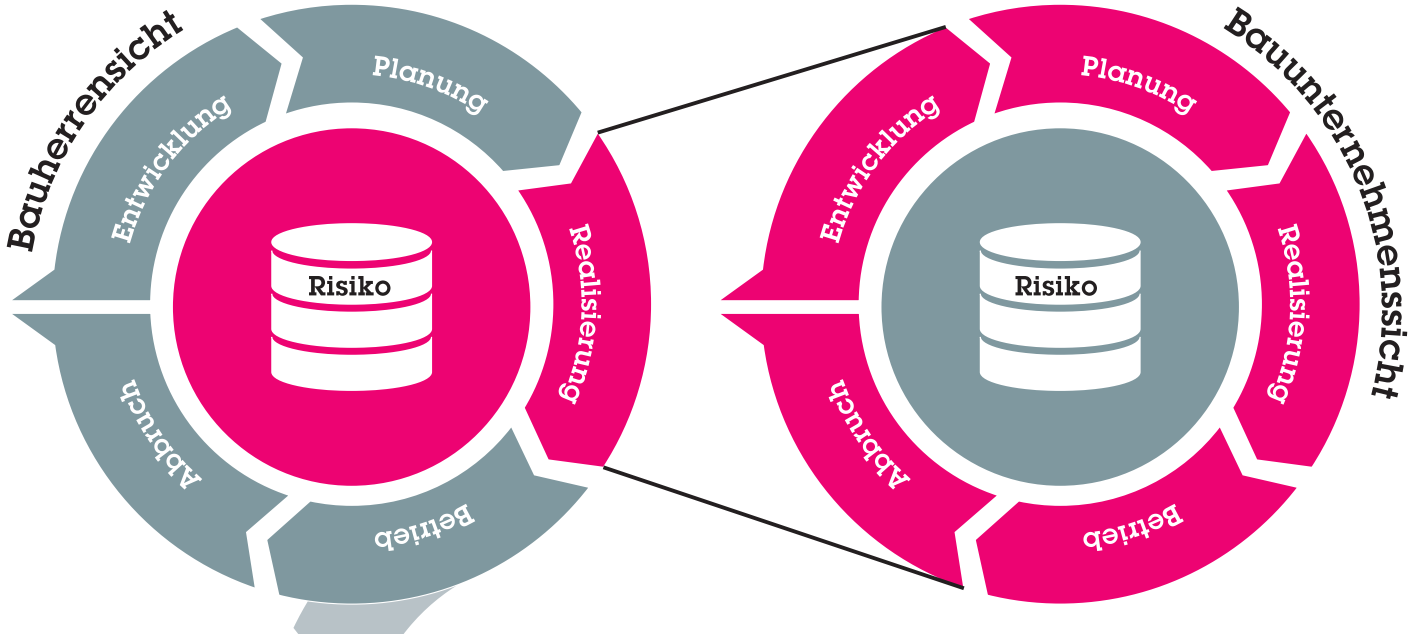

Abbildung 1: Übersicht der Projektskizze

Projektrisikomanagement

Wenn fehlendes Risikomanagement zum Risiko wird

Manche Großprojekte werden wegen ihrer spektakulären Architektur zur Legende. Andere graben sich dauerhaft ins Gedächtnis der grimmigen Bürger, weil nichts funktioniert – außer steigenden Kosten und verschobenen Terminen. Mit einem effizienten Projektrisikomanagement lassen sich solche Probleme nicht völlig ausschließen, aber drastisch reduzieren – vor allem durch den Einsatz der BIM-Methodik.

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Zu Beginn eines Bauvorhabens werden Kosten-, Termin- und Qualitätsziele festgelegt, deren Erreichen den gesamten Bauprozess prägt. Im Vergleich zu anderen Branchen wird Risikomanagement in der Bauwirtschaft oft nachlässig behandelt. Es wird als eine zusätzliche Dokumentationsaufgabe angesehen – und nicht als ein effektives Projektsteuerungs- und Controlling-Instrument. Hier bietet sich die Chance, mit systematisch angewandtem Risikomanagement und erfolgreich umgesetzten Gegensteuerungsmaßnahmen das Ergebnis des Bauprojekts maßgeblich zu steigern.

Gewonnene Informationen aus einem effizienten Risikomanagementsystem können automatisch als Erfahrungswerte für nachfolgende Projekte genutzt werden. Sie steigern langfristig das Erreichen von Qualitäts-, Kosten- und Terminzielen. Die Anwendung der BIM-Methodik öffnet im Hinblick auf die automatische Verknüpfung von Risikomanagementinformationen neue Möglichkeiten, die bislang nicht ausgeschöpft werden.

Im Lehr- und Forschungsgebiet Baubetrieb und Bauwirtschaft der Bergischen Universität Wuppertal läuft zurzeit das Forschungsprojekt „Maßnahmen zur Umsetzung eines effizienten Projektrisikomanagements durch Einsatz der Methode BIM". Im Rahmen dieses Projekts werden Lösungen erarbeitet, um mithilfe der BIM-Methodik das Risikomanagement zu verbessern. Im Blickwinkel stehen dabei Bauherren und Bauunternehmen (siehe Abbildung 1).

Der klassische Risikomanagementprozess gemäß DIN ISO 31000 (siehe Abbildung 2) ist ein Teilbereich des Projektmanagements. Er bezieht alle Projektbeteiligten über alle Lebenszyklusphasen eines Projekts ein und greift in unterschiedliche Unternehmensbereiche. Gemeinsam werden über die Prozessschritte Identifikation, Bewertung, Steuerung und Überwachung mögliche Chancen und Gefahren für das Projekt frühzeitig erkannt, um proaktiv gegenzusteuern. Der Risikokreislauf ist hierbei ein kontinuierlicher Prozess. Das bedeutet, dass sich der Kreislauf im Zuge der Projektbearbeitung stetig wiederholt [1].

In dem Projekt erfolgt ausschließlich die Betrachtung des Projektrisikomanagements. Die Ziele des Projektrisikomanagements bestehen in der Transparenz von Risiken in einem Bauprojekt, in der Ableitung und Bewertung von Maßnahmen zur Verringerung von unbekannten Parametern und in der Ermittlung realistischer Zielgrößen. Das Projektrisikomanagement grenzt sich daher vom Unternehmensrisikomanagement ab, dessen übergeordnetes Ziel der Erhalt des Unternehmens ist.

In dem seit Januar 2019 laufenden Projekt wurde zunächst die momentane Anwendung von Risikomanagement bei Bauprojekten betrachtet. Im Hinblick auf immer lauter werdende Forderungen nach einem partnerschaftlichen Herangehen an Projekte zwischen Bauherr und Auftragnehmer werden im Projekt bewusst beide Seiten und ihre Schnittstellen in Bezug auf das Risikomanagement betrachtet.

Durch zahlreiche Experteninterviews und eine Onlineumfrage wurde die Strategie der Unternehmen bei der Umsetzung des Projektrisikomanagementprozesses analysiert. Bei der Betrachtung der bestehenden Risikomanagementprozesse im Hinblick auf Informationsfluss, Detaillierungsgrade und Verantwortlichkeiten kristallisierten sich Unterschiede bei den Ansätzen zum Risikomanagement und zur Priorität, die dem Thema beigemessen wird, heraus.

> **„Angesichts der Schieflage** vieler aktueller Großprojekte zeigt sich das Potenzial einer branchenweiten Anwendung von Risikomanagementprozessen.

Positive Ansätze erkennbar

Rund 60 Prozent der befragten Unternehmen setzen Risikomanagement gemäß einer unternehmensweit einheitlichen Risikostrategie um. Diese definiert u. a. Ziele, die mit der Risikobetrachtung erreicht werden sollen, und basiert auf der Unternehmensstrategie. Die erstmalige Identifikation von Risiken erfolgt bereits in der Akquise bzw. mit Projektstart und wird über die weiteren Projektphasen fortgesetzt. Festgehalten werden Risiken meist in Excel-Anwendungen oder unternehmenseigenen Softwareanwendungen. Kommunikationswege zum Risikomanagement sind in der Regel kurz. Durch offene Gesprächskulturen bestehen wenig Ängste, Risiken auch zu kommunizieren.

Die befragten Experten erkennen durch Risikomanagement Vorteile für das Projektgeschäft. Früh erkannte Risiken beeinflussen den weiteren Projektverlauf positiv. Kosten werden eingespart, Kunden gebunden und Erfahrungen sowie Verbesserungspotenziale für Folgeprojekte generiert. Es erfolgt eine verbesserte Steuerung von Kosten und Kostentransparenz über die gesamte Bauphase. Durch Integration des Risikomanagementsystems werden von allen Beteiligten die Verbesserung der Termin- und Kostensicherheit benannt.

Identifizierte Problemfelder

Anstelle von einheitlichen Vorgaben zum Umgang mit Risiken und einem systematischen Ansatz setzt gut ein Drittel der Unternehmen rein auf die Erfahrung der Mitarbeiter.

Die Betrachtung von Risiken erfolgt in der Angebotsphase noch vertieft, wird in der Ausführungsphase jedoch vernachlässigt. Bei der Bewertung von Risiken werden die terminlichen Auswirkungen im Angebot meist nicht berücksichtigt. Die Risikobewertung erfolgt größtenteils intuitiv und ist geprägt durch die Erfahrungen des einzelnen Mitarbeiters. Die Risikobetrachtung endet meist bei der Abnahme und wird nicht bis zum Ende der Gewährleistung fortgeführt.

Oft liegt in den Unternehmen eine klare Trennung zwischen den Abteilungen der Akquise und der Projektausführung bzw. Planung und ▸

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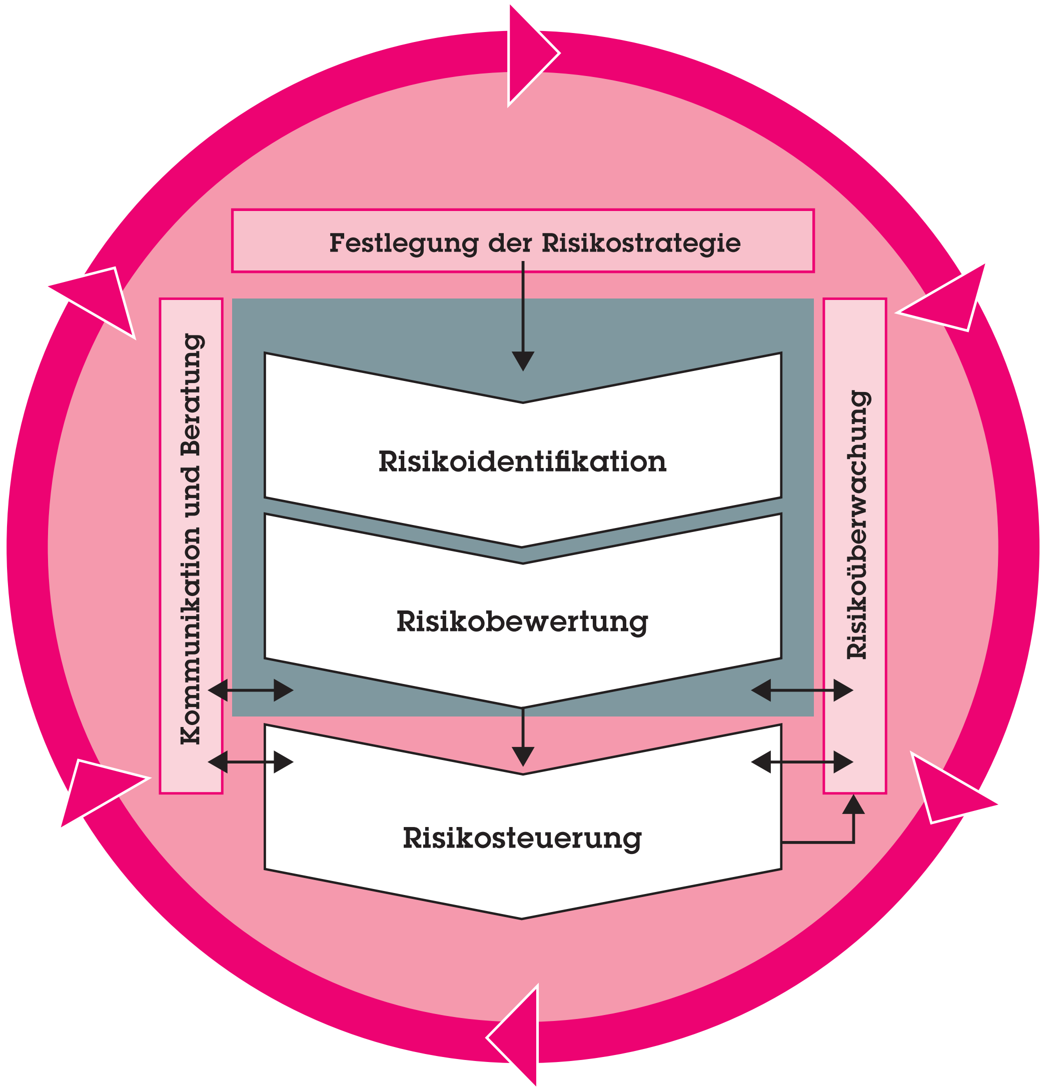

Abbildung 2: Übersicht des Risikomanagementprozesses (in Anlehnung an DIN ISO 31000)

Realisierung auf Bauherrenseite vor. Nach Projektabschluss werden die gewonnen Erkenntnisse nur im Gespräch auf Kommunikationsebene an einige Kollegen übertragen. Keines der befragten Unternehmen führt eine systematische Auswertung der Risiken nach Projektabschluss oder eine systematische Weitergabe dieser Informationen an Folgeprojekte durch. Eine parallel zu den Befragungen durchgeführte Marktanalyse zu Risikomanagementsoftware ergab zudem, dass es derzeit kein BIM-fähiges Angebot beispielsweise mit einer IFC-Schnittstelle gibt.

Fazit der Befragung

Insgesamt wurde deutlich, dass dem Risikomanagement längst nicht in jedem Unternehmen Bedeutung zugemessen wird. Für etwa die Hälfte der befragten Unternehmen spielt Risikomanagement in ihren Projekten kaum eine Rolle. Die Kosten- und Terminschiene eines Projekts wird meist durch höhere Instanzen festgelegt. Den Projektbeteiligten fehlen dadurch die benötigten Handlungsspielräume.

Potenzial besteht bei einer Verstetigung der Risikomanagementprozesse: Regelmäßige Identifikation von Risiken, Anpassung von Bewertungen und die Verknüpfung mit anderen Prozessen werden bislang kaum genutzt, um das Risikomanagement effektiver zu gestalten. Oft besteht kein durchgehender systematischer Ansatz zur Nutzung von Risikomanagementsystemen. Es ist mehr ein Zusammensetzen einzelner Ansätze, die aber nicht ausreichend verknüpft sind. Deshalb gehen Informationen verloren oder werden nicht in vollem Umfang genutzt. Angesichts der Schieflage vieler aktueller Großprojekte zeigt sich hier das Potenzial einer branchenweiten Anwendung von Risikomanagementprozessen.

Bild: Bergische Universität Wuppertal/HUSS-MEDIEN GmbH ■ Autorenbilder: privat

Für Unternehmen, die sich für einen Check der eigenen Risikomanagementprozesse interessieren, wurde ein kurzer Selbstcheck entwickelt. Durch Abhaken der Punkte werden sowohl bereits erfolgreich angewendete Ansätze deutlich als auch Ideen für weitere Potenziale angeboten.

Ausblick Forschungsvorhaben

Prozesse müssen konkretisiert und in den Unternehmen digitalisiert werden. Die Verantwortlichkeiten sind klar zu definieren. Formulare im Unternehmen und in den einzelnen Projektphasen müssen ebenfalls digitalisiert sowie mit Softwaremöglichkeiten verknüpft werden. Checklisten und benötigte Dokumente sollten regelmäßig durch Erfahrungen und Marktanpassungen gepflegt werden und für jeden Mitarbeiter zentral abgelegt sein.

Im weiteren Verlauf des Forschungsprojekts mit Laufzeit bis Anfang 2021 werden – basierend auf den bisherigen Ergebnissen der Umfrage – Optimierungsmöglichkeiten erarbeitet und durch den Einsatz digitaler Werkzeuge weitere Potenziale herausgearbeitet.

In den kommenden Monaten wird eine mögliche Einbindung der BIM-Methodik geprüft. Hierzu werden in einem ersten Schritt die Risikomanagementprozesse mit den übrigen Prozessen eines Bauprojekts verknüpft. Das entstehende BUW-Prozessmodell zeigt anschließend, welche Informationen aus dem Projektgeschehen wann für das Risikomanagement genutzt werden sollten. Umgekehrt wird dargestellt, welche Informationen durch das Risikomanagement für den weiteren Projektverlauf generiert werden.

Durch die BIM-Methodik soll so eine strukturierte Erfassung der Risikomanagementdaten ermöglicht werden. Mit fortschreitender Planungsgenauigkeit lässt sich die Informationsverknüpfung bis auf Bauteilebene fortführen. Die Verknüpfung der erkannten Risiken mit Bauteilen des digitalen Gebäudemodells in der Realisierungsphase fördert die Integration und dadurch die Akzeptanz des Risikomanagements. Sie visualisiert außerdem dessen Vorteile für das Projektergebnis.

Bei der BIM-Methodik wird ab Projektstart definiert, wer welche Informationen zu welchem Zeitpunkt an wen und in welcher Form zu liefern hat. Diese Informationen werden vertraglich eingefordert und kontrolliert. Das ermöglicht eine frühzeitige Betrachtung von Risiken ab der Planungsphase. Im Ergebnis erhält man eine Steigerung der Termin-, Kosten- und Qualitätssicherheit.

Die Mitarbeiter des Forschungsprojekts freuen sich über Rückmeldungen zum Thema und Unternehmen, die an einer Zusammenarbeit interessiert sind. Unternehmen, die an Einblicken in das BUW-Prozessmodell oder an Anregungen zum Risikomanagement interessiert sind, können sich gern melden: puetz@uni-wuppertal.de ■

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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).

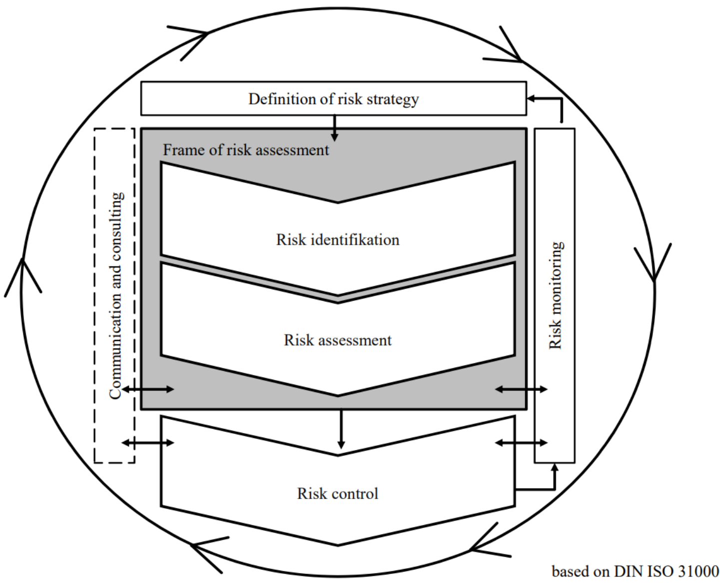

Figure 1. isk management process

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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BIM-based risk management in construction companies: a conceptual framework

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Abstract

With regard to the flow of information and documentation as well as the level of detail in the implementation of risk management in construction projects, we see different degrees of professionalization. Risk assessment of identified construction project risks is largely intuitive and affected by the experience of the individual employee. Hardly any company carries out a systematic evaluation of the preceding risk list or systematic continuation into its system.

Following a design-science research approach, we developed a conceptual framework for consistent risk management in construction companies that provides the basis for the application of BIM to risk management. The framework is based on a survey among 249 construction companies and expert interviews. The result of the analysis is: Empirical data on risks from completed projects are not evaluated; The exact functioning of the risk management process in construction projects is often not clear; There is a lack of tools that allow documentation of risk management processes. The designed framework combines these three issues and consists of three modules helping the implementation of structured risk management. Module one is a risk catalogue based on the risk catalogue, published by the Institute for the Construction Industry. [1] Module two is the representation of the target process of risk management in construction projects, which was modelled, based on literature review and expert-workshops. Module three is an excel-based tool for the application of the risk management cycle. The framework was iteratively designed, improved and evaluated in workshops. The paper provides incentives for actors in the construction industry to improve their risk management and it presents a basis to apply the BIM methodology to risk management in a next step.

Keywords: risk management, BIM, risk management process

1 Introduction

In 2015, an analysis of the failure of major projects in the construction industry showed that the topic of risk management and its influence on the construction process are decisive factors in the development of a construction project [1]. Alongside other aspects such as costs, deadlines and quality, risk management is crucial to the success of a construction project [2]. The risk management cycle, consisting of the identification, assessment, control and monitoring of risks, helps to identify deviations from planned targets at an early stage and to take countermeasures [3]. Proactive action can be taken, i.e. risks such as delays and cost increases can be avoided before they occur. Studies such as those by BBSR (2020) [4] and Stempkowski (2004) [5] show that systematic risk management can lead to positive effects such as lower cost fluctuations and quality deficiencies [5]. Unlike in other sectors, risk management has not yet been part of the core business in the construction industry. Little attention is paid to the identification and management of risks. As a study by Eilers et al. (2020) [6] shows, construction companies mostly apply company-wide strategies in risk management using Excel tools or in-house software solutions. However, the risk management of a project is usually not carried through to the execution phase. When assessing risks, the financial and scheduling implications are not considered in the tender submission. Risk assessment is largely intuitive and shaped by the experience of the individual employee. After project completion, the knowledge gained is only transferred to selected employees in a conversation at communication level. Hardly any company carries out a systematic evaluation of the previous risk list or a systematic continuation and feedback into its system.

There is potential here in making risk management processes more consistent: regular identification of risks, adjustment of assessments and linking with other processes can make the risk management of construction stakeholders more effective. Digital information is the most important aspect in the process. The acquired data from projects can be analysed and used for products, processes and subsequent projects. In this paper, we show how the status quo at construction companies can be improved and give an outlook on how the BIM method can be integrated into the process.

2 Research Method

A survey of 249 construction companies by means of a questionnaire on risk management in their company serves as the basis for the analysis and as the data basis for the creation of the framework. This evaluation is supplemented by expert interviews with risk managers in the construction industry. Both surveys were conducted in 2019 - by means of online questionnaires and semi-structured interviews respectively. From these two surveys, the status quo regarding the application of risk management and the need for development regarding risk management is derived [7]. In addition, a literature analysis of risk management tools was conducted. In the first step, software tools for risk management available on the market were researched. In the second step, these were examined with regard to their functions and the degree of digitalisation [6]. The conceptual framework, which was developed in a design science research approach, is based on the analysis described.

The development of the framework proceeded in a design cycle in three development cycles. In each development cycle, a workshop was held with 10-12 representatives of the construction industry. During the workshops, the contents developed so far were presented and discussed. Following the respective workshop, the experts' input was incorporated into the framework. The following figure graphically depicts the procedure in the design process.

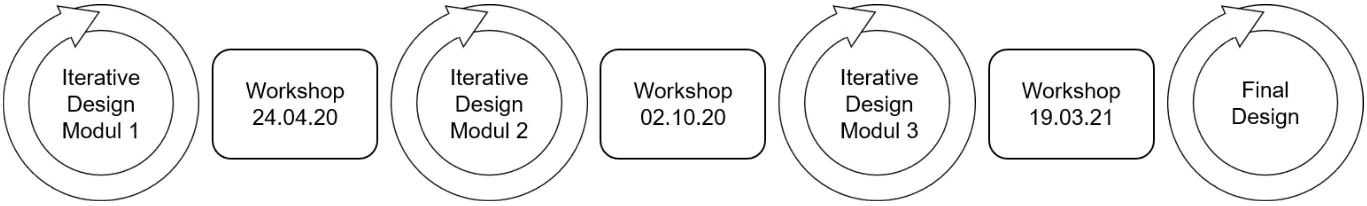

Figure 1: Design-cycle of the conceptual framework [own visualisation]

3 Conceptual framework

The results of the survey and the expert interviews serve as the basis for the creation of the framework. They provide the data basis for the development of modules 1 to 3 of the framework.

1.1 Results of the analysis

In summary, the interviews and the survey revealed that risks identified at an early stage, have a positive influence on the course of the construction project. Through risk management, customers are retained, costs are saved and potential for improvement can be generated for subsequent projects. In addition, greater transparency is created through information such as costs, deadlines and qualities and other risks, that are important for the entire construction phase. By scanning relevant construction processes and implementing risk management, systematic work is created and this results in higher employee motivation. Disadvantages of using risk management are, for example, too much effort for the risk management process with a small project size. A very risk-affine behaviour can make the bidder's competitive offer too unattractive if every risk is considered in terms of money and time. A balance should be found here. Risk management demands openness and a tolerance for mistakes from the staff. However, the feedback from the experts and from the survey was that there are no disadvantages by using risk management [6]. Furthermore, when analysing different software tools, we did not find a solution for the application of risk management using BIM at component level. Therefore, we conclude that a development of a suitable interface for the application in a software is necessary. We are developing the solution as part of the ongoing research project "BIM-based risk management" as a risk management tool for application in the context of BIM [7].

Overall, the analysis showed that three aspects lead to improvements in the project business when applying risk management in the construction industry: Risk catalogues as a basis for risk identification, a handbook for the implementation of risk management processes and a digital application for risk management (hereinafter referred to as risk management tool), which closes the gap in the software possibilities. The conceptual framework takes up these three aspects and offers a suggestion for implementation.

The first step in linking risk management with the BIM method is to model the risk management processes and link them with the other project processes of a construction project. Three modules are necessary for the linkage. Module 1 is the risk catalogue, which is necessary as a basis for the development of the subsequent steps. Based on the risk catalogue, module 2 models the target process of risk management, which is necessary for the application of different actors and sub-processes of a construction project. In module three, the findings from the previous modules are summarised and a user-friendly solution for application in construction projects is developed.

2.1 Modul 1: Risk catalogue for project risk management in a construction project

Module one is a risk catalogue based on the risk catalogue published by the Institute for the Construction Industry [8] and created by the working group Risk Management for Companies in the Construction Industry. Within the framework of a workshop, the developed basis of the risk catalogue was discussed with experts from the construction industry, which serves as the basis for the tool. Subsequently, the catalogue, developed in 2009, was expanded by the individual practice partners with explanations of their digital tools, aids and associated documents for each risk. Due to the fast development of digital tools, the original catalogue was expanded to up to date standards. About one third of the risks included were expanded or adjusted in this way. The risk catalogue was developed through a design thinking process. In this way, benefit, feasibility and marketability were equally taken into account. The workshop served to understand and observe the problem. A prototype of the catalogue was then developed, refined with the experts and finally brought into its final form. The results and requirements are divided into the client's view and the construction company's view and have been incorporated into the risk management tool. The risk catalogue is subdivided into the individual superordinate project phases, such as the bidding phase and the execution phase, and is subdivided into the categories of technical, scheduling, commercial, legal and other risks for each phase. Each risk type is assigned a number for each phase. The number is used for later documentation and risk tracking for analysis and collection of empirical values for subsequent projects. The following figure shows the structure of the risk catalogue using the example of technical risks for construction companies in the bidding phase. In total, the risk catalogue for construction companies contains 158 risks. The complete catalogue can be downloaded here:
https://biminstitut.uni-wuppertal.de/fileadmin/biminstitut/Download-Bereich/BIM-basiertes_Risikomanagement/Risikokatalog_Bauunternehmen.pdf

Status BUW: 2020

OP			OFFER PHASE		
OP	T	01	Technical	Project location	Ground conditions and investigation
OP	T	02	Technical	Project location	Building environment
OP	T	03	Technical	Project location	Weather conditions
OP	T	04	Technical	Project location	Country risk
OP	T	05	Technical	Project location	Environmental pollution
OP	T	06	Technical	Project size	
OP	T	07	Technical	Project scope of services	
OP	T	08	Technical	Competition assessment	
OP	T	09	Technical	Technical construction task	Changes: State of the art
OP	T	10	Technical	Technical construction task	Special proposals
OP	T	11	Technical	Technical construction task	Interface problems
OP	T	12	Technical	Quality of the tender documents	Incompleteness/contradiction in quality requirements

Figure 2: Presentation of the risk catalogue [own visualisation]

This risk catalogue provides a construction company with a basis for identifying risks. It can be used as a kind of checklist to identify risks in all phases of a project as well as in all substantive areas. It can be adapted to the individual circumstances of a company and constantly expanded.

3.1 Modul 2: Target process risk management

Module two was modelled on the basis of literature research and expert workshops. The basis for linking risk management processes with the BIM method is a consistent use of the risk management process that already exists. This means that the relevant process steps are known, clearly described and practised. The survey of the practice partners and other construction companies and clients showed that the risk management process has not yet been applied as standard, but rather that only individual sub-steps are implemented or that no structured procedure takes place. For this reason, the risk management process was first considered and modelled separately from the BIM method, a so-called support process.

The second step towards linking with the BIM method is the modelling of the risk management processes and their linking with the other project processes. For this purpose, the described risk management process was represented with the help of process modelling based on the structure of Business Process Modelling Notation 2.0 (BPMN 2.0) [9]. Each step of the created risk management process is broken down in more detail in further levels of the process model. The process "Identifying risks and opportunities", for example, is divided into the process steps "Describing risks/opportunities", "Defining a brief description", "Determining cause and effect of risks" and "Assigning a risk/opportunity category". In this way, all process steps are interlinked and clearly presented. In a second step, the modelled risk management processes are then linked to the other processes of the presented project, e.g. cost control. In this way it becomes clear, on the one hand, at which point in the project risks have to be identified, assessed and controlled and, on the other hand, which processes provide information in order to be able to better assess risks. Input and output documents describe where the information that is valuable for risk management comes from. The risk strategy specifies for the process step of risk identification, for example, in which categories risks are identified, from which sum these should be considered and whether only project or also company risks should be observed. The risk identification process produces a list of identified risks, which in turn serves as the basis for the risk assessment step. Here the aspects that need to be assessed can be determined.

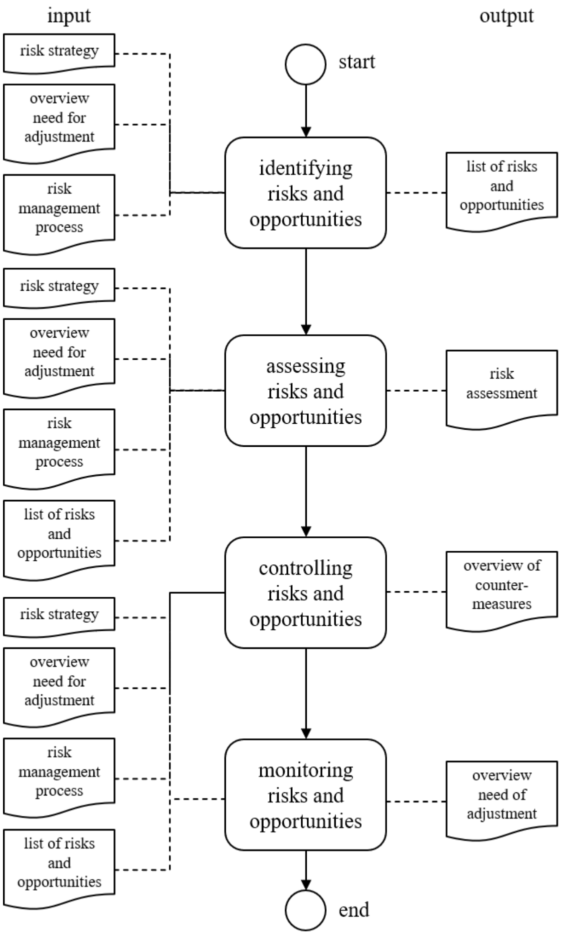

Figure 3: Support process risk management, excerpt: Overview [own visualisation]

In order to be able to present the risk management process clearly and easily understandable, the support process is displayed as a process model. This makes it possible to present the complex processes and information clearly and to map them using catchy symbols.

4.1 Modul 3: Riskmanagement-Tool

Module three is an Excel-based tool for applying the risk management cycle. The framework was iteratively designed, improved and evaluated in workshops. In the investigations of the status quo, it became clear that hardly any company is currently working with risk management software and the application of BIM is not advanced enough to link risk management directly to the method. The Excel tool therefore offers a possibility that, despite the need for development in the field of BIM, can be used directly by construction companies and clients and at the same time enables the digital recording and evaluation of information. The Excel tool includes a variety of macros and automations to simplify the processing and compliance of the systematisation of the information by the respective employee. The Excel format was chosen for ease of use in individual companies. The tool can be easily adapted to the individual needs of the company in order to increase the motivation of the use by the employees and to enable the integration into the respective work processes in the different companies. The following figure shows an excerpt from the tool.

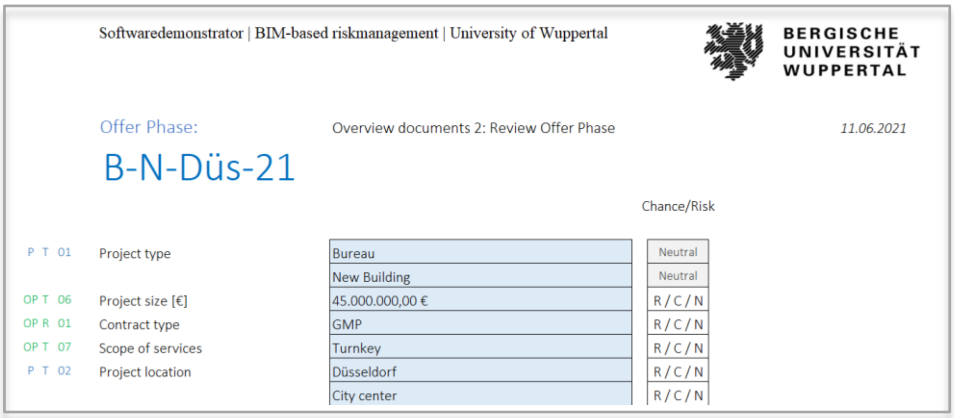

Figure 4: Screenshot of the risk management-tool [own visualisation]

The tool shows typical risks of construction companies and facilitates, the identification as well as the complete risk management process for the own construction project, based on the developed risk catalogue. The project information from the tool is evaluated after project completion and the transparent flow of information, regarding risk management in the construction project, is improved and made accessible to those involved in the construction. Through systematic data collection, the information gained can be used as empirical values for subsequent projects and thus increase the achievement of quality, cost and deadline targets in the long term. In addition, the experiences can be fed back to the respective departments in order to optimise the internal process of project handling. In this way, the tool offers a solution to the problems identified in the context of the stocktaking in the current implementation of risk management, both in construction companies and with clients. The tool serves as a template for further developments and should be understood as an active working tool. The entry is made for each individual risk, and each individual risk is evaluated according to neutral, risk or opportunity. Neutral individual risks are not transferred to the overview. Risks with danger or chance are transferred to the overview in which the risks are evaluated, controlled and monitored. In the assessment, the probability of occurrence and the extent of damage are determined in terms of costs and schedule deviations, in the control the measures such as transfer, avoid or mitigate and in the monitoring the success of the selected measures.

The tool for construction companies begins with a request for project information. Then, in individual worksheets, the phases of project selection, bid processing, execution phase and warranty phase are worked out according to risk categories in the risk catalogue that is being compiled. All activated risks are summarised in the "Overview" worksheet. The overview sheet of the documentation serves to illustrate the identified risks, the respective measures and gives an overview of the contractual target of the construction project with the actual deviations in costs, deadlines and quality. From this, knowledge can be gathered for subsequent projects and experience can be fed back to the respective departments. In addition, the findings can be used to optimise work processes and align the corporate strategy. The information can show optimisation possibilities in every area of a company. [3]

4 Discussion

A lack of risk management has already been described in the literature as a reason for the failure of construction projects. The basics of risk management in the construction industry are given by Girmscheid [2], for example. As the analysis of the status quo shows, there is currently no guidance for companies on how these aspects can be implemented in practice. This is where the conceptual framework comes in. The paper gives the actors in the construction industry incentives to improve their risk management, and it provides a basis for applying the BIM methodology to risk management in a next step. We have also developed a recommendation for action based on the previous results, which is available for download for interested users on the BIM Institute page. [10] The recommendation for action is subdivided into the individual process steps of risk management. Each process step provides ideas and possible actions for implementation. The implementation can be realised according to the individual possibilities of each company. At the same time, the recommendation for action serves as an opportunity to evaluate the previous implementation of risk management.

The developed framework serves as a basis for the application with BIM. The information for risk management and BIM can be combined in two ways. The first way is to integrate all the required information into an open data model, and the second way is to establish a link between the generated information captured by the BIM method and the risk management processes. Not all BIM-related software can support the generation and management of risk information and IFC has not yet defined a framework for risk information. [11] BIM can act as a central database. The relevant required information can be exported via the BIM coordination platform. By entering information, it can be filtered from the risk management tool so that risk management and BIM can be combined. The advantage of linking the IFC model with risk information is that the risk information is component-related and can, for example, be analysed process-dependently/status-dependently during construction progress control. By combining BIM and risk management, the user obtains a more accurate and detailed database through the collection of digital information.

Three principles are important for the application of BIM in connection with the risk management process. The principles of integration, dynamics and accuracy ensure a smooth process in the application:

The integration of digital data and information into the respective process steps must be possible for a smooth flow in project processing. Through this, a database can be built up over the complete life cycle of the property and the information can be accessed by the respective participants. [12] In addition, the exchange of information in the individual phases and between the different users is facilitated. The data should be stored in a predefined structure and provided with appropriate access rights. Each participant submits their information and transfers this information to the BIM collaboration platform using their own application software via a specific interface. The integration of information runs through the entire risk management/project workflow process. The entire process forms an integrated, interactive whole. The different modules are interdependent and influence each other. [13]

Due to the constant change from the information base, all processes must be able to adapt and develop dynamically. The BIM method makes the changes digitally readable and adaptable. For example, the BIM-based rule check verifies the actual state of the construction project and makes the conditions available digitally and visually. The exact project status is imperative for successfully applied risk management. [12]

Accurate information and data are most necessary conditions in the application of risk management. The applications of digital tools by different project participants often cannot directly exchange information due to different formats and standards. Using IFC standards, information is standardised and defined on the BIM collaboration platform to ensure completeness and accuracy of information exchange by different participants. [14] Information generated from the BIM model includes, for example, component-related quantities, qualities and all attributes that are necessary for determining the risk assessment or risk control.

The exchange of digital information between project participants is mandatory. Furthermore, the client can include the conditions made in the risk management tool as a basis in the AIA. A distinction should be made here between the project phases of project development, planning, realisation, operation and dismantling. Each phase is divided into the risk categories technical, scheduling, commercial, legal and other. The client defines measures, responsibilities and bases for each individual risk. This information can be requested from the contractor by the AIA in order to implement dynamic risk management. Here, of course, the exchange of data internally and to the project participants must be taken into account. Risk information may contain internal information such as costing approaches. Here, the management should specify which information may be passed on to the stakeholders and which information is only used internally.

For the application of BIM for the risk management process, processes must be concretised, digitalised in the companies and responsibilities defined. Forms in the company and in the individual project phases must be digitised and linked to software options. Checklists and required documents should be regularly maintained through experience and market adjustments and centrally stored for each employee.

5 Conclusion

This paper presents a conceptual framework for the application of risk management in construction projects. The development is based on surveys of the status quo of the application of risk management. By using the risk management tool, the critical processes in a construction project are analysed and the support process is integrated into them. This results in an overview of the critical processes for the different phases from the respective perspective of construction companies or owners. Helpful tools and documents are formulated for each of these processes. The overview serves to link and highlight potentials for the use of BIM. Advantages of using BIM applications and digital tools in the risk management process are better risk assessment, digital information management, information can be accessed promptly and regardless of location, and the evaluation and further processing of the digital data. [15]

When using the risk management tool in the various project handling processes, there is a high degree of potential for using BIM in the risk management process. When using the tool in the risk assessment form, the extent of damage must be determined for the area of costs and deadlines. Through the BIM applications quantity takeoff, cost planning and cost determination as well as scheduling, the assumption becomes more concrete and transparent for the project staff. The 3D modelling of the construction project is built up in the planning phase and attributes are defined to support the prefabrication process. In addition, shell and finishing dimensions are generated from the models, which serve as the basis for the bill of quantities and costing. Deadlines and costs can thus be determined in a simplified way and have a sound basis.

The integration of the BIM method also has a positive supportive effect on the risk control and risk monitoring of the individual risks in the risk management tool. Tablets are often used in construction site operations. These allow access to the documents, checklists and work aids in the cloud. In addition, barcodes are sometimes stuck into each room on the construction site and the site manager has the option of retrieving the attributes and information important for the room via tablet. The complete defect management is created daily via the site manager's tablet and the information is stored in the cloud. The areas of construction site logistics, modularisation, systematisation of building products and components are currently the focus of integration into execution. The various digital tools as well as the multitude of BIM applications offer higher certainty about the actual state and conditions on site here. [16]

In the next step, the results presented here will be transferred by the authors into software in order to develop a self-defined BIM use case "Risk management in construction from the perspective of a construction company". The BIM use case is created using the "Guideline for structuring and building BIM applications". [17] For the use case, the first step is to import a schedule and connect it to the 3D model of an IFC file. The use case then begins, for which programmed forms are used for the application of the risk management process in the construction process. The developed forms are all linked to each other as well as to the schedule and the 3D model. In each form, further properties and risk information can be added as a result to the 3D model or the respective selected construction element, or the user can have properties such as volume and area displayed in the form, e.g. for risk assessment. The process starts with the construction progress control and the user can enter data to get to the first form of the risk management process. The advantages of the implementation are that one has a transparent and seamless exchange of data and information between the scheduling and the digital construction data model. This links the risk management processes with real-time data and provides a well-founded data basis for documentation, for example, that can then also be used for construction diaries or communication with the client. [7]

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