BIM Based Information Delivery Controlling System

B. Klusmann[a], Z. Meng[a], N. Kremer[b], A. Meins-Becker[a] and M. Helmus[a]

[a]Chair of Construction Management & Economics, University of Wuppertal, Germany
[b] Chair of Design Computation, RWTH Aachen University, Germany
E-mail: klusmann@uni-wuppertal.de, meng@uni-wuppertal.de, kremer@dc.rwth-aachen.de, a.meins-becker@uni-wuppertal.de

Abstract –

The definition of how agreed information deliveries in building projects are achieved and implemented for different objectives and use cases is always a major topic in project management. This procedure is normally specified in accordance with international standards. However, the absence of checklists, guidelines and recommendations for action leads to vaguely defined content and blurred structure of required documents at each building phase. Based on the aspects above, this paper aims to establish standard employer's information requirements (EIR) and BIM execution planning (BEP) during the life cycle of a project and build an online platform for the execution of semi-automatic checking. For this purpose, the existing EIRs and BEPs would be firstly analyzed and compared with each other as well as with other standards. Practical experience is gathered through expert interviews and workshops and complements the comparative analysis. Subsequently, the resulting requirements for EIR and BEP are presented in checklists and guidelines, which form the basis for the development of a controlling instrument. To develop an online tool, the information requirements and test criteria of this instrument are then derived from a database of process modelling from University of Wuppertal (BUW database). Furthermore, a workshop among experts was organized to collect the necessary functions of the software. Eventually, the online platform should consist of two main functions: generation of EIR files in the form of mvd XML according to various BIM objectives and use cases from the client, and the validation of the EIR by comparing IFC files from a contractor with the MVD files. The results of the checking could be BCF files or a final report as possible symbols for a successful information delivery.

Keywords –

Database of Process Modeling; Exchange Requirements; Information Delivery Manual; Model View Definition; Semi-automatic Checking

1 Introduction

In the construction and real estate industry there is an agreement that the highly efficient and accurate exchange of information along the life cycle of a project should be achieved. To carry out a construction project based on building information modeling (BIM), the client should firstly define the employer's information requirements (EIR). The contractors then describe how the BIM objectives and agreed information delivery are achieved and this is implemented in the BIM execution plan (BEP). This procedure is gradually becoming mandatory in different countries depending on their own specifications. For example, in Britain all projects assigned by government should approach the goal of using complete exchangeable BIM models upon common data environment (CDE) for collaboration from April 2016 [1][2]. However, the specific checklists, guidelines and recommendations for action are still missing, so that the content and structure of the necessary documents are currently not clearly defined.

In this research project, detailed information requirements and data delivery processes in BIM-based construction projects will be structured based on use cases from the database of process modelling from University of Wuppertal (BUW database). For each use case, one or more MVD files will be created based on formulated exchange requirement tables. Furthermore, a controlling instrument based on model view definition (MVD) accomplishing the automatic checking will be developed. Finally, an online platform which provides use cases and MVD templates as well as checking functions will be built and published as open resources.

2 State of the Art

To classify the topic, the preliminary work of the University of Wuppertal in the field of process databases and the current standards for information exchange are important. These areas are explained below.

2.1 University of Wuppertal database of Process Modeling

In recent years, the University of Wuppertal has built up a database for processes in the construction and real estate industry. This database is supported by a visualization based on the Business Process Management Notation. Since 2016, this database has been continuously enriched with information on the technical processes through various research projects. The focus was initially on the continuous flow of information in construction projects, answering the following questions: When (time) who (process owner) processes what (information input), after which (other applicable information), why (process goal), to what (information output)? In the course of the Building Information Modeling method, the question of "how" becomes more and more important, since it is an essential aspect of the intended automated information exchange.

The structure of the database and the flow of information with all other linked information currently consists of five levels that represent different levels of detail of the information. The essential levels for the project "BIM based information delivery controlling" are level three, which contains concrete exchange documents or files and the processes for them, and level five, which shows the concrete information requirements (EIR) for the generation of a document or the execution of a process. The structure is shown in a reduced form in Figure 1.
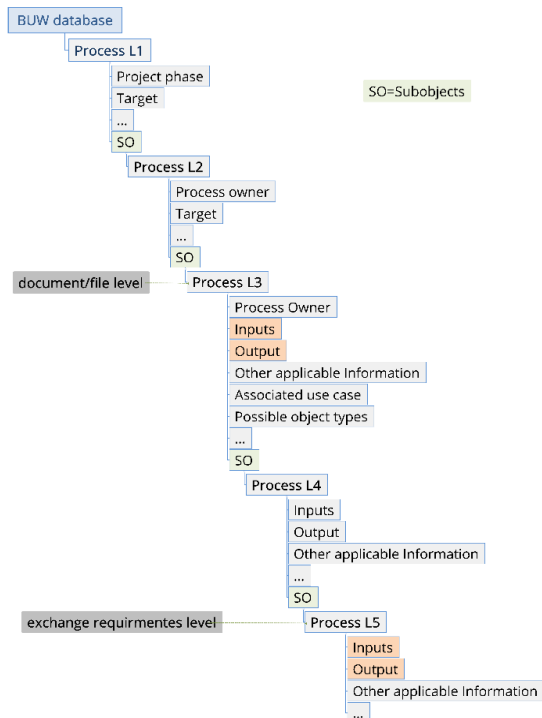
database

The aim of the process database, which is continuously being developed, is to create the basis for an electronic transmission of information in the construction industry without media format differences. The information the database contains is based on standard processes in the German construction industry and taking into account the various project participants and areas of responsibility, thus serves as a basis for the structured exchange and verification of information.

2.2 Guidelines of BIM use cases

In the course of structuring data for processing within the BIM method, so-called BIM use cases were developed. These use cases always define a certain framework within the existing business process, which is now implemented differently through data exchange within the BIM method. In this way, all relevant exchange processes are to be successively identified, coordinated and adapted. The use cases will be part of the employer's information requirements (EIR) and thus define the contractual relationship between the client and contractor.

Currently, there is no established structure for the implementation of use cases. Within the framework of the project implementation, DIN EN ISO 29481-1 is used as a guideline, which contains information delivery manual (IDM) for building information models [3]. The basic framework for the connection of the data is shown in Figure 2.

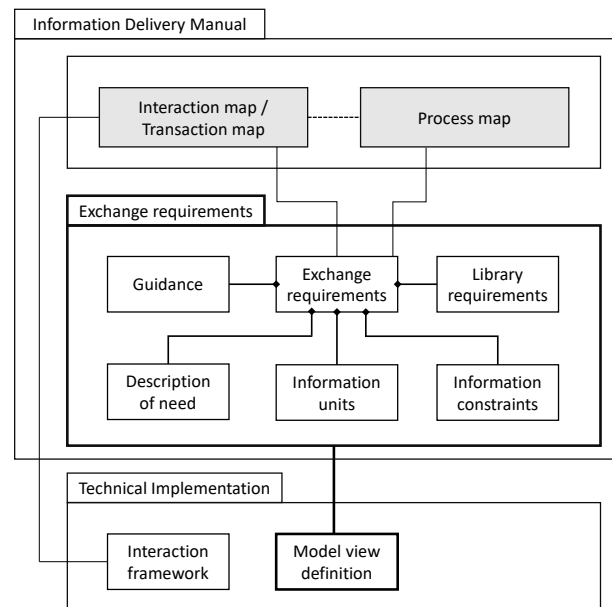Figure 1. Structure of the University of Wuppertal

Figure 2. Part of IDM basic framework [3]

This approach is also pursued by the Use Case

Management of Building SMART International [4]. There, building SMART attempts to collect and structure use cases and make them available to the construction and real estate industry. The approach currently differs from that in this research project with the generation of a test file (MVD) being semi-automatic and not having to be carried out manually.

The research team is in close exchange with the use case management of buildingSMART International and the further ISO 29481 development, ensuring that current developments for standardizing the structure of use cases are considered in the project.

2.3 Common Data Environment

The exchange of information within projects is increasingly taking place in common data environments (CDE). CDEs thus serve as a single source of information for the collection, management, exchange and documentation of information, be it graphical information from a model or non-graphical data in various data formats. This shared data environment helps project teams to always have access to all information. To support project workflows, CDE providers offer various modules and functionalities for processing documents and data. In the course of standardization efforts, DIN SPEC 91391 "Common Data Environments (CDE) for BIM projects - Functions and open data exchange between platforms of different vendors" was developed as a first approach. It consists of the two parts "Modules and functions of a common data environment; with digital appendix" [5] and "Open data exchange with common data environments" [6].

The content of DIN SPEC 91391 is the first description of the requirements for manufacturer-independent processing of data within BIM projects. This is important for an implementation of a functioning BIM information delivery controlling in practice, because in this way it can be guaranteed that an open data exchange between different CDE's can be generally valid. A BIM use case is transferred to a CDE use case in a CDE. CDE workflows that support the semi-automatic processing and checking of data are assigned to this CDE use case.
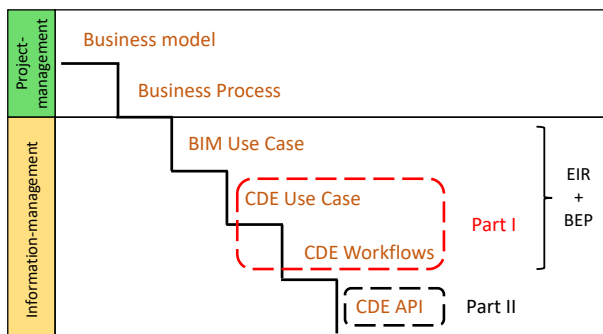

Figure 3. Process detailing from business plan to CDE workflow [5]

According to Figure 3, the areas BIM Use Case, CDE Use Case and CDE Workflow are dealt with in DIN SPEC 91391:1. while the description of the CDE API for the concrete exchange of data is given in DIN SPEC 91391:2. In accordance with DIN SPEC 91391:1, CDE's are divided into three different BIM levels, which represent the different development stages of CDE's. While the common CDE providers currently offer a BIM Level 2 CDE, which in particular provides documents, information containers or nested information containers with metadata, a BIM Level 3 CDE will in future allow direct access to model elements and attributes. The development of a BIM-based information delivery controlling can thus be part of a BIM Level 3 CDE, as it ensures that the information processing requirements of information requests are fulfilled. Accordingly, DIN SPEC 91391 will be considered within the project.

2.4 Information Delivery Manual

In order to describe the concrete information about who delivers what to whom at which point during the life cycle of a project, buildingSMART introduced the information delivery manual (IDM) standard [7]. The IDM plays therefore an important role in specifying the information requirements in tenders, contractors and for guidance in projects [8]. According to ISO 29481-1, the primary IDM components include use case, process map (PM), exchange requirement (ER) and model view definition (MVD). In this case, the user, such as the client, can generate an IDM by defining strategic goals, get machine readable file as MVD, and link IDM to different types of requirements (see Figure 4).
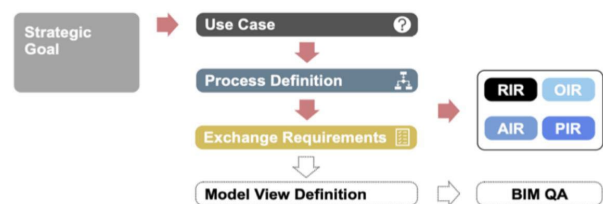

Figure 4. Process of generating IDM and its assignment to various requirements [8]

However, due to the complexity of development process, vague definition for information on exchange as well as lack of physical shared servers and administrator, it is still difficult to implement or share the IDMs under current specifications [1]. To solve these issues, the schema of idmXML is still under development and supposed to be published in ISO 29481-3.

2.5 Model View Definition

When the exchanged information in collaborative work is based on an IFC model, the corresponding partial model in accordance with exchange requirements is able to be expressed as model view definition (MVD) [7]. To allow the quickly mapping of a specific IFC element, the MVD is usually formalized as mvdXML.

The MVD file not only allows the storage of exchange information in a machine-readable format but also enables the checking of IFC files delivered by the contractor. For instance, a MVD checker based on open standard formats for structuring validation rules and BIM collaboration format (BCF) for issue reports was proposed and developed by Zhang, Beetz and Weise [9]. As most of the users are not used to XML format, software suppliers should make more effort in expressing the MVD in a user-friendly way, such as by describing the objective of data exchange [10].

2.6 Linked Data and buildingSMART Data Dictionary

By building a semantic web of data, a machine is able to trace the links between data. Thus, to promote the interoperability of various vocabularies, classification systems, ontologies, etc., the linked data, which origins from semantic web, is introduced in the field of architecture and construction [11].

For international collaboration, the buildingSMART data dictionary (bSDD) was implemented based on the structure from international framework for dictionaries (IFD) and collects tremendous terms and descriptions in multiple languages. It currently contains more than 60,000 concepts and since version 2 X 4 of IFC model serves as a central repository for standard PropertySets (PSet) extensions [12].

The bSDD database is accessible and editable with API. In this project, for example, the GET function by bSDD API is used for extracting all standardized PSets and properties and importing them into University of Wuppertal database, so that the same items would not be created twice. If some attributes or PSets corresponding to specific process in BUW database are created, it is also meaningful to POST the new items into bSDD ensuring that they could be referenced to by other users dealing with similar use case.

3 Concept and methodology

The basic concept of BIM-based information delivery controlling (see Figure 5) consists of three essential steps. Step one consists of a client using an online platform to select BIM use cases to be carried out in the project. The basis for the use cases is the existing BUW database (see section 2.1). The selected BIM Use Cases are provided for the project both as a printed version in the IDM structure and as a digital test file (MVD). In the second step, the contractor will create an IFC model that meets the requirements of the test file. This can be done in any software with IFC export. In the third and last step, the IFC model is checked on the basis of the MVD. During the check, the system checks whether information has been stored within the required fields and whether this information can plausibly describe the required attribute. The check result is returned via a BCF report and a check report.
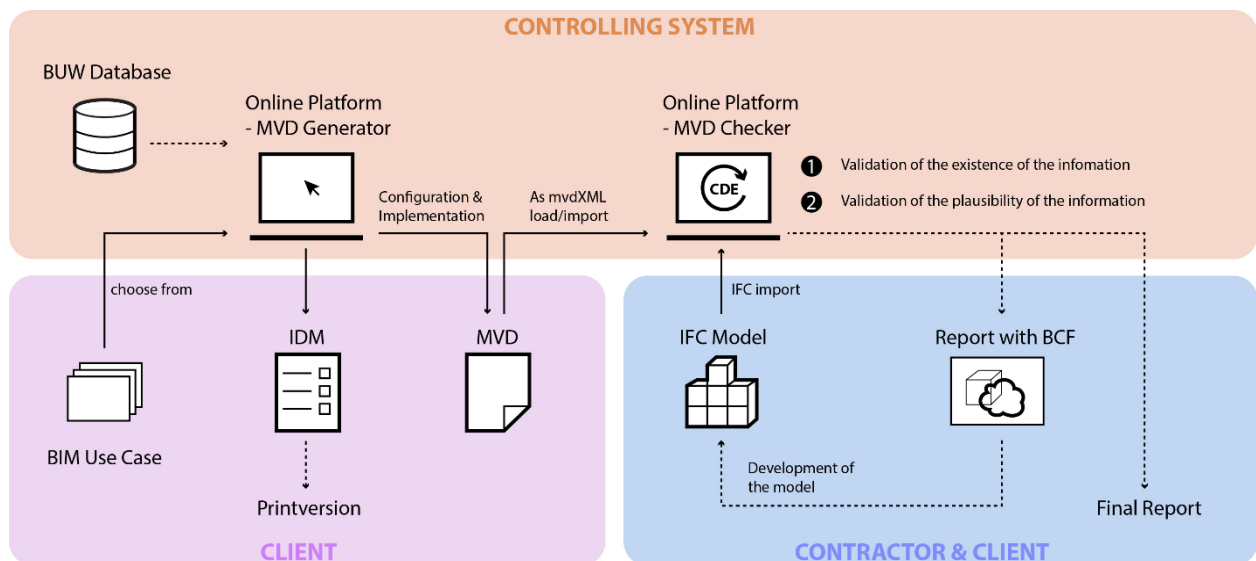

Figure 5. Concept of the BIM Based Information Delivery Controlling System

The Controlling System area is planned as a demonstrator within the project, but will fulfill the requirements for a CDE implementation (see section 2.3).

3.1 Collection of Information

Various methods are used to collect the information required to build BIM use cases. This includes a literature research, a review of existing databases (CAFM Connect, buildingSMART Data Dictionary, Use Case Management bSI) as well as the use cases of clients from BIM pilot projects in practice. In addition, the researched and newly developed use cases were coordinated with partners from industry and local authorities. The development and validation of the information is a continuous process.

3.2 Challenge IFC-connection

Besides the acquisition of information, the biggest challenge is to translate the structured information requirements into the object-based structure according to IFC or to assign the information requirements to the correct objects, generating a functioning inspection file

(MVD). This relationship is shown schematically in Figure 6.

The BUW database contains the technical processes that are necessary to fulfill a construction project. The functional processes are mapped to possible objects according to DIN 276 (costs in construction), which in turn are mapped to IFC classes. The complex filtering of possible objects for a process towards a concrete object for a use case is done by building BIM use cases with level 3 processes.

The same structure can be seen in the BIM profiles of CAFM Connect, from which information is taken into account when referencing objects. In addition, the IFC Property Sets (Psets) are imported from the buildingSMART Data Dictionary (bSDD) so that they can also be used when generating the MVD. This ensures that already existing information is processed.

The information requests to be checked are built up by the bSDD both via the processes built up in process levels and via the Psets. The basis for this is a prepared template (see section 4.2). The combination of template and selected processes on process level 3 for the BIM use case leads to the concrete structure of a mvdXML.
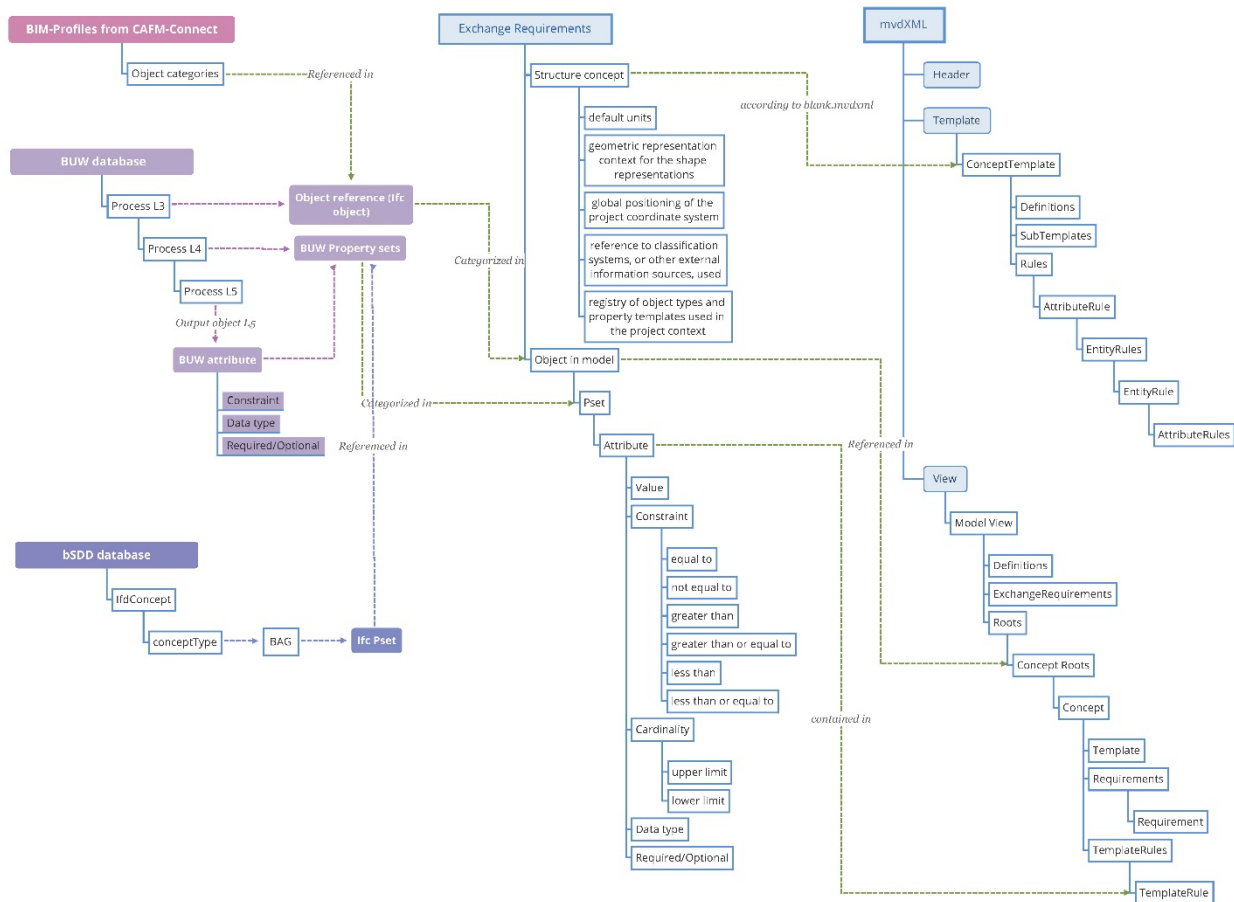

Figure 6. Structure of the data connection for generating mvdXML

4   Implementation

The development of a BIM based information controlling system is carried out in five steps: 1. Establishment of exchange requirements based on specific processes in each use case from BUW database; 2. Generation of MVD files according to exchange requirements; 3. Preparation of IFC model as to be checked file; 4. Examination of IFC file using MVD checker; 5. Building an online platform embedded with all functions. Since the controlling tool is still under test, sample files are taken to explain these implementation procedures in detail.

4.1   Definition and export of exchange requirements

As mentioned in section 2.1, the BUW database contains a tremendous amount of process data, and each use case contains process activity from level 1 to 5, person in charge, relevant object, necessary attributes, etc. Therefore, it is first of all essential to define which items should be contained in exchange requirement table. Because the request of information delivery or file exchange is merely driven by one specific activity at process level 3, only the items at level 3 or its sublevel should be included. To be more specific, process name, person in charge, relevant object, related attributes and property sets are important components in the exchange requirement table. Furthermore, to validate the plausibility of value to the attribute, general conditions should be provided, such as unity, data type, range, cardinality. The exchange requirements are consequently defined by a table or csv file, which forms the basis for generation of MVD (see Figure 6).

4.2   Generation of MVD file

The generation of a computer readable MVDs is based on utilizing predefined mvdXML template files which define the document structure. The template files are filled using exchange requirement information data provided by the BUW database as csv file (Figure 7). This results in standard conformant mvdXML files that can directly be used to validate IFC models.

To be more specific, the process of generating mvdXML itself is carried out in 4 steps: 1. Reading the provided data defined as csv file and extracting all necessary information, such as process name, person in charge, relevant object, IFC object name, property set, attributes and value. 2. Translating the extracted information into structured inputs for the mvdXML template files. 3. Filling the predefined placeholders in the provided template file with translated data. For example, list entries for object references and IFC object names are written into the concept root node. While the

entries for property set, property name and all value definition define the constraints in concept nodes. 4. Generating the output files as mvdXML. Multiple mvdXML files are generated for every process name and its associated process owner.
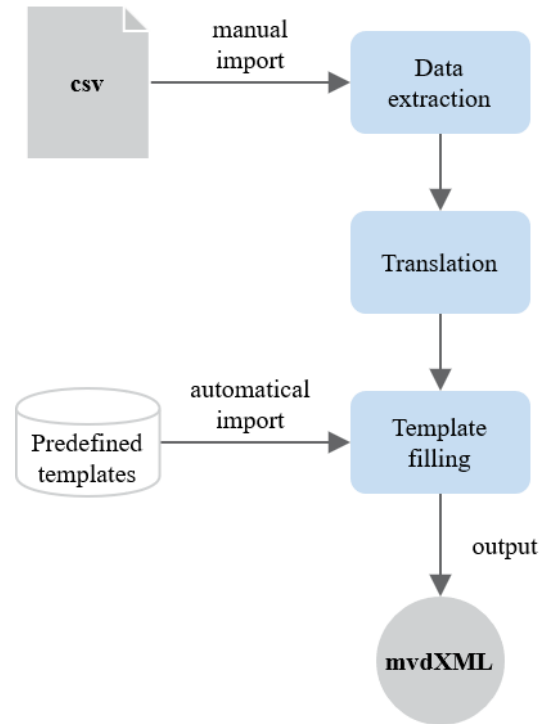

Figure 7. Technical process of generating a mvdXML file

An important aspect of this process is the reduction of effort in generating mvdXML templates by limiting their scope of application on property set definitions. It is possible to get by with a single concept template. However, it is also possible to nest templates in order to allow more complex subdivisions of nodes, as is the case for model view definitions.

Since the generation tool is still in active development, the process has only been applied on the use case 'facility management' so far. Further use cases will reveal other possibilities for improvement.

4.3   Preparation of IFC file

The controlling system is developed on the one hand for the client to regulate exchange requirements and to check the IFC file delivered by contractor. On the other hand it also helps the corresponding contractors improve their IFC file before they hand it in to the client. Moreover, to verify the atomization level of this tool, the procedure of importing key attributes in an IFC model should be tested. Hence, it is regarded as an essential part to document the process of preparing the IFC file.
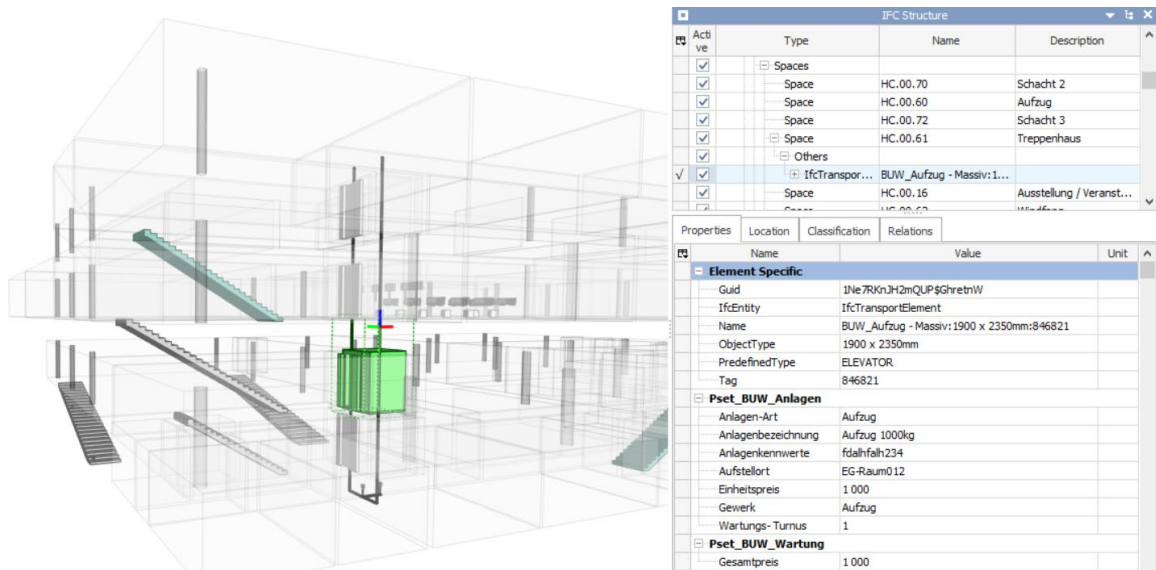
Figure 8. Preview of element "IfcTransportElement-ELEVATOR" with attributes defined by exchange requirements in BIM Vision [13]
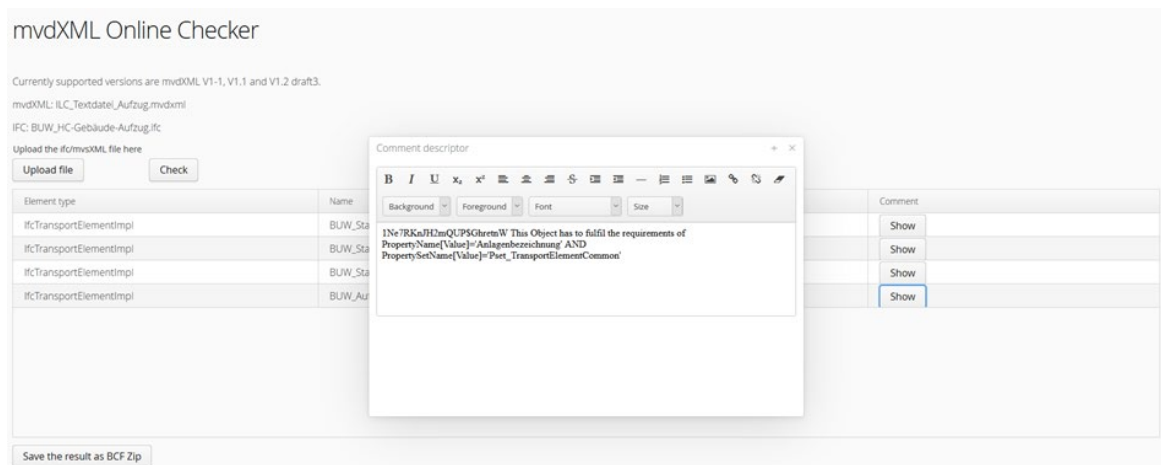

Figure 9. Screenshot of result from checking

In this case, the IFC model of a building from the University of Wuppertal is chosen as testing file as a result of its completeness and preciseness. In the very first trial, exclusively one element type (see Figure 8) is used for proof of exchange requirements for facility management. The specific attributes defined in exchange requirements are semi-automatic assigned in Autodesk Revit [14] by importing a shared parameter list.

4.4   Using MVD checker to verify IFC models

The MVD model checker tool is based on the open source software framework bimserver.org [15] . It is a generic tool for verifying IFC model contents for defined exchange requirements using mvdXML [16]. After successful verification, a report is returned as a BCF file, which contains all recognized issues.

Consequentially, the MVD model checker has two inputs, the IFC file and mvdXML file and one output, the BCF file.

The controlling tool is still under development, therefore the described validation measures are all based on sample files. These sample files are limited to basic data contents, for example an elevator IFC file and a mvdXML file containing constraints on an IFC transport element. The MVD Model Checker exposes a public REST API which takes the IFC file and mvdXML file as input and returns results as JSON or BCF ZIP formats [17]. After each validation the results are manually examined (see Figure 8). If an unexpected result has been identified, the user can then check the IFC file or mvdXML file and correct errors as appropriate.

To verify the correct behavior of the MVD Model Checker, multiple input files are tested for which the

results can be easily checked manually. That way, for example, a known issue in bimserver.org about IFC inverses has been triggered and was resolved. Boolean string values and complex expressions also have been improved using this method. For the upcoming steps, the difficulty is increased by using more complex IFC and mvdXML files.

4.5   Development of an online platform

Prior to the implementation of this controlling system, a workshop among construction management practitioners was held for coming up necessary functions of the platform and giving those functions priority. Hence, besides the core mechanism of controlling systems which is related to the MVD generator and the MVD model checker, there have been other required functions which were collected in the workshop to be implemented in the platform. The requirements that are rated highest are: automatic choosing of exchange requirement template based on selected use case; test tools are based on open standards and open interface; the application should be possible to reproduce the data records in a way that is understandable to the users, etc.

To realize these functions as well as to combine the MVD generator and checker in one application, a web-based platform is considered to be a suitable tool. The establishment of an online platform will be realized through the following steps: 1. Creating mockups for detailed discussions on user interface design; 2. Using HTML, CSS and JavaScript to build a frontend; 3. Building a backend in Python to drive the MVD model checker and MVD generator. The online platform is still under development and will be published as free resource in the future.

5   Conclusion

The feedback from practice as well as the current topics of the organizations for standardization (ISO, DIN, VDI, buildingSMART) confirm the relevance of the subject in the area of information exchange of the BIM method. In the research project a functioning concept was developed, which is currently in the final phase of implementation, in order to meet the technical and content-related requirements of a semi-automatic BIM-based information supply controlling. The final result of the demonstrator will be provided by the authors via the respective universities and the code will be published.

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