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6D BIM–Terminal: Missing Link for the design of CO₂-neutral buildings

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6D BIM–Terminal: Missing Link for the design of CO₂-neutral buildings

Figl H¹, Ilg M², Battisti K³

¹ IBO - Austrian Institute for Building and Ecology, Austria

² ib-data GmbH

³ A-NULL Development GmbH

hildegund.figl@ibo.at

Abstract. By 2050, the building sector has to become nearly CO₂-neutral in order to achieve the climate protection targets of the Paris agreement. This tremendous challenge can only be met by taking the carbon neutrality into consideration from the early stages of the planning processes. The overall aim of the project is to provide a life cycle analysis throughout the entire planning and construction process of a building with a special focus on CO₂-neutrality. To this end, Building Information Modeling (BIM) is an appropriate method. The project aims to close the gap between specialist consultants and BIM applications. For that, relevant data for cost estimation, scheduling construction planning and management or sustainable building aspects, shall be added automatically to BIM elements. This data exchange shall be carried out using open BIM and IFC interface according to ÖNORM A6241-2 via a central platform, the "6D BIM Terminal". For more complex calculations the respective specialist planning software shall be made ready to exchange data in IFC format. Thus, life cycle analyses and life cycle cost assessment, as well as specifications for tender, can be performed on the basis of the building model. The expected results of the project are as follows:

- The prototype of a "6D BIM Terminal"
- Interface for existing specialist planning software to the 6D BIM Terminal
- Guidelines for planners
- List with the required properties (PSet's)

1. Introduction

1.1. Motivation

By 2050 at the latest, the building sector will have to become "largely" carbon-neutral if the climate protection goals of the Paris Agreement shall be achieved. Since carbon neutrality of buildings (Zero Carbon Buildings) is a major challenge, it must be part of the building design from early stages of the planning process and must not be ignored at any stage. At the same time, the CO₂ reduction should be affordable and should not be at the expense of other environmental aspects. Therefore, costs, as well as other life cycle indicators, are also needed for the overall optimisation of CO₂-neutral buildings.

Building Information Modeling (BIM) as a process of optimizing the design of buildings using an intelligent digital building model that can be collaborated by the whole planning team offers the best prerequisites for the continuous consideration of ecological aspects during the whole planning process. However, while in other countries (Great Britain, Norway) the 3D-BIM mode of operation has been anchored in planning practice for some time now, German-speaking countries have only recently



begun to face up to this technology. In the further dimensions of time (4D), costs (5D) and sustainability (6D), there are hardly any applications throughout Europe. Hence, specialist planners and consultants who do not work on the basis of CAD programs operate predominantly outside the digital building model – also in supposedly BIM-based planning.

1.2. Objective

The overall objective of the project "6D BIM Terminal: Missing Link for the Planning of CO₂-neutral buildings" is the lifecycle analysis of buildings during the planning and construction phase with a special focus on the planning and construction of CO₂-neutral buildings. This shall be done by closing gaps between BIM-based design planning and engineering design. Data that goes beyond geometric and design information and is necessary for the consideration of costs, deadlines and sustainability aspects (4D, 5D and 6D) shall be supplemented as automated as possible with the help of predefined reference BIM elements. The data structure of these BIM elements shall be based on (inter) national standards (IFC, bsDD, ASI property server). The project focuses on the life cycle analysis of the building materials and technical building equipment used in the building, as there are still the essential barriers to the exchange of information between design software and specialist planner software.

In addition to planners and civil engineers, the process should also support procurers and calculators. Therefore, a further aim is to compile the BIM elements from items of the Austrian Performance Description for Building Construction ("Standardisierte Leistungsbeschreibung Hochbau", LB-HB) and thus to create tender specifications largely automated on the basis of the digital building model.

The process shall take place via a central platform, the "6D BIM terminal". Bills of quantities, LCA data, life cycle costs and the list of tender items shall be generated based on the digital building model.

The results are intended to support SMEs in particular. They should facilitate the entry into complex BIM planning, which is more than just a 3D planning. Since the results should be general and the SMEs shall not be forced to buy expensive software and training, the data exchange should be done using open BIM.

2. Methods

The work packages defined for the implementation of the "6D BIM Terminal" are:

- Development of process patterns – based on use cases (survey of software producers and users, analysis of processes, responsibilities, data interfaces, software components)
- Properties for building elements and HVAC: Definition of the property set (PSets), identification of missing or incorrect properties in the IFC standard and ASI property server, formulation of missing items in the Performance Description for Building Construction
- Conception and development of the "6D BIM Terminal"

Applied methods and standards for the calculation of LCA and cost data are:

- LCA according to ISO 14040/48, EN 15804 and baubook acceptance criteria
- Life cycle costs according to ÖNORM B 1801

Note: In ÖNORM A6241-2, there is a concrete indication that the ÖNORM B1801-1 object construction is to be applied for time (4D) and the costs (5D); in the field of sustainability (6D), no information is given on the methods to be used.

3. Results

The expected results of the project up to November 2019 at a glance:

- Preparatory standardisation work: Identification of the properties required for the life cycle analysis (PSet's) incl. guide for planners and specifications for software houses
- Reference elements: Catalogue with 6D BIM components that can be used as a reference and adapted to specific projects
- The prototype of the "6D BIM Terminal" with a functional user interface, API interfaces and reference catalogue as a tool for cross-organizational collaboration that enables the exchange

of 3D planning programs with complex BIM systems for the specialist planning by generating complex 6D BIM elements from "simple" 3D elements.

3.1. Preparatory work: properties of building materials and building elements

3.1.1. Standards, References

For a planning team whose members usually use software programs from different distributors a neutral transfer format is required for the different data in order to work on a common building model. An internationally standardized database, model and file format are the Industry Foundation Classes (IFC). These have been an official ISO standard (ISO 16739) since the IFC4 was released [1]. The IFC standard is based on building objects, such as walls, columns, etc. for architectural planning; pipes, air outlets, heaters, valves, etc. for technical building equipment. The IFC does not only define the building objects, but also the properties for these objects.

The international reference database for IFC-based properties is the buildingSmart Data Dictionary (bsDD). The bsDD serves as an extension and namespace for the IFC data model. It allows the linking of terms and expressions, their dependencies and definitions (data type, units, value ranges, ...) across different languages.

For the national application of BIM technologies in Austria, OENORM A 6241-2 [2] was created by the Austrian Standard Institute (ASI). This standard regulates the technical implementation of a uniform, structured multi-dimensional, BIM-based data model. An important part of the ÖNORM A 6241-2 is the so-called ASI property server, which is unique in Europe. The online database (<http://db.freebim.at>) defines a multi-dimensional data model and exchange format for interdisciplinary cooperation on the basis of the "IFC4 Add 1" standard. ÖNORM and property server are intended to create the basis for the "exchange of graphical data and related factual data" on an IFC and bsDD basis. All characteristics, materials and values defined in the data structure of the property server are identified by a unique identification number (GUID) assigned by bsDD and thus fixed once and unchangeable for Austria.

3.1.2. Matching the properties

Data required for 6D planning are costs, deadlines, LCC and LCA indicator values. The technical description of materials is based on building physics / structural properties and the positions of the Performance Description for Building Construction (LB-HB).

The building physics and building ecology properties and values for the reference elements in the "6D BIM terminal" come from www.baubook.info [3], an online database for ecological construction products. Cost data, dates and positions of Performance Description for Building Construction (LB-HB) are stored in the construction software ABK. At the beginning of the project, these characteristics were compared with the BIM standards and references (IFC, bsDD, ASI property server).

As a result, IFC, bsDD and the ASI property server turned out to provide a useful working basis, but needed a variety of revisions or additions:

- The existing building physics and building ecology properties lack clear definitions.
- The properties regarding the life cycle analysis of materials and elements are incomplete, obsolete or wrongly defined.
- The BIM properties are still largely missing for elements in the HVAC area.
- The BIM properties are practically not used in practice.

Hence, a key outcome of the project is the Property Set, which will be forwarded to the ASI standard groups and to the local group of bsDD (bsAT – building smart Austria).

3.2. 6D BIM Terminal

3.2.1. Principle idea

Currently, only 3D information is output by the CAD programs; the other features for the material and element description of the IFC4 format have not been supported by any CAD software yet. The CAD software tools are capable of exporting IFC4 compatible data, but in fact they are conversions of older IFC formats. Therefore, the 6D BIM-Terminal should enable specialist planners from the various disciplines to import 3D data via the IFC interface, to automatically supplement the data required for the 4D, 5D and 6D planning in the respective project phase and subsequently to export them in the appropriate format again. The 4D, 5D and 6D properties should be semi-automated assigned via matches with a reference element catalogue.

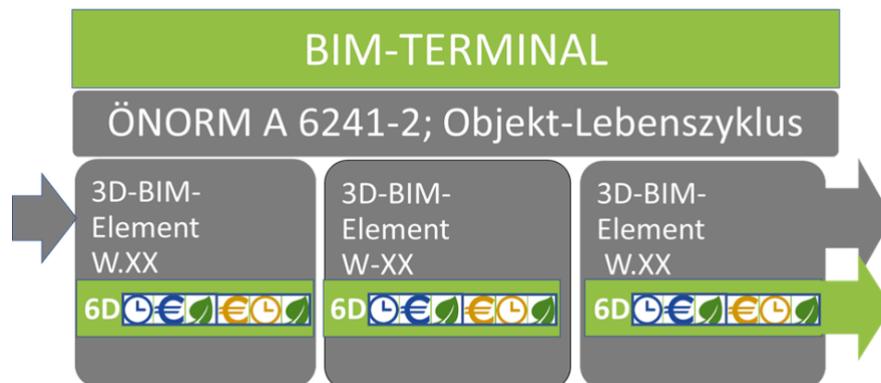


Figure 1: In the “6D BIM terminal”, the 3D information from the CAD programs is read in and supplemented with missing 6D information (4D: time, 5D: installation costs, 6D: LCA data, in each case for the construction and follow-up costs). Specialist consultants can read out the data they need, filtered from the BIM terminal.

3.2.2. Reference elements

One focus of the project is the creation of a reference element catalogue with prefabricated elements according to BIM standards. The composition of the reference elements comes from the “IBO Passive House element catalogue” [4]. These elements are available online in the www.baubook.info database [3] with building physics and life cycle assessment data. The data is either used directly in baubook for LCA calculations or passed on to other software programs as energy performance calculation tools free of charge via an XML interface.

The existing XML interface has been used to transfer the baubook elements to the construction management software ABK. These elements include the material structure and formulas for the calculation of the life cycle assessment data as well as essential building physics properties such as the U-value. With the likewise imported baubook LCA data for building materials, the LCA indicators of the element can be calculated directly in ABK. More important, in ABK the cost data and the tender items from the Performance Description for Building Construction (LB-HB) were assigned to the elements. For the assignments, the corresponding properties (e.g., materiality, thickness, and height of an element) had to be aligned with the 26,000 tendering items of the LB-HB. If several matching positions were found, the entire item group was assigned to the element and the most ecologically and economically relevant items pre-selected as the default value. This tendering item is automatically activated as soon as an IFC object is matched with the reference element in the “6D BIM terminal”.

The reference elements shall be the main part of the functionality of the “6D BIM terminal”. Suitable models for regular updates and additions to the element catalogue are currently being developed.

3.2.3. Process flow (Figure 2)

In the current process description for the “6D BIM terminal”, the following roles are modelled:

- Designer (responsible for digital building model)

- Procurer (responsible for tender)

Both of them can start the process (has to be defined in the BAP (BIM Processing Plan)).

A central document for a project is the project element list (PEL). The basis of the PEL is a project element catalogue (PEC). The PEC can be derived from a general element catalogue.

Within the project element catalogue the designer has to provide the data the procurer needs in order to be able to determine (deduce) the corresponding tender items and masses. These data shall allow for the automated creation of the call for tenders, the life cycle costs and the life cycle assessment later in the process. In the further process, the catalogue will be exchanged between the designer and the procurer, since the procurer may add further elements or specify individual elements. Hence, it is important that the responsibility for the creation and maintenance of the project element catalogue is time-related in the hands of one role. The project element catalogue can also serve as a base document for requirement formulations to the BIM model as part of a BAP (BIM Processing Plan).

Finally, the designer creates the BIM model in a BIM-capable software using the requirements for objects and properties as described in the agreed project element catalogue. He converts the created model from the own modeling software into the IFC format and sends the IFC model to the procurer for further processing. The procurer checks with suitable software whether the model contains the required classifications and properties. The successfully checked IFC elements are imported into the “6D BIM terminal”. Within the “6D BIM terminal” the IFC elements have to be assigned to reference elements from the project element catalogue. These reference elements contain a rule set which activates the allocation of the appropriate tendering items to the corresponding IFC elements. In the “6D BIM terminal” prototype, initially only the predefined reference elements will be available. Subsequently, a wide variety of stakeholders (manufacturers, software companies, specialist planners) are to import further reference elements in the specified format. Format and workflow are currently being defined.

The generated project element list is the data basis for an AVA software to use this list (database) to generate a tender in the desired form (ONLV Format according to ON A2063 [5] in Austria).

Note: At this point, the BIM based pathway could be abandoned and offers could be obtained in a traditional, classic way.

For bidders, a data package is prepared that allows to identify in the BIM model for each bid position those elements that trigger a position or deliver the masses for a position. The data package contains the project element list (PEL), the associated IFC data and an ONLV file. As a result, the bidder will be able to identify the structural conditions for positions more clearly and to be able to calculate prices more precisely. The bidder returns a priced offer in the classic ONLV data format. After examining all offers, a classic awarding documentation will be created in the ONLV data format. This is in turn transmitted to the bidder by means of a data container consisting of the project element list (PEL), the associated IFC data and the awarding documentation.

LCA and LCC data can be produced as a by-product of the tendering process when the project elements are mapped with the reference elements. In early planning stages the LCA&LCC data can be generated using the same logic as described in the process flow for the tendering process above. In this case the role of the “procurer” is taken by the LCA and/or LCC consultants.

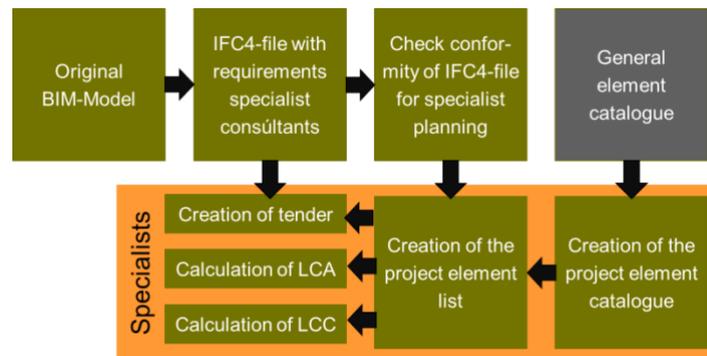


Figure 2: The designer creates the BIM model in a BIM-capable software using the agreed requirements for objects and properties and converts it to the IFC4-format. The conformity of the IFC file is checked and then imported into the “6D BIM terminal”. Within the “6D BIM terminal” the IFC elements are linked with reference elements from the project element catalogue. These reference elements contain a rule set which activates the allocation of the appropriate tendering items, LCA and LCC data to the corresponding IFC elements.

4. Conclusions

The “6D BIM terminal” will provide a tool for cross-organizational collaboration. The "Cooperation Tool" enables the exchange of existing 3D planning programs with complex BIM systems. The prerequisite is that the data is transferred via IFC4 to the BIM terminal. The tools will be operated by the project partners as a platform and provided to other software houses and stakeholders after the end of the project. Thus, the “6D BIM terminal” should also support for specialist software solutions outside the project team.

The main hurdles of the project An essential aspect of the project is the data exchange via open BIM. The biggest hurdles in the project therefore lay in the underlying standards, since relevant properties are incomplete, obsolete or wrongly defined, are largely missing as for the HVAC and are practically not used in practice. Hence, a key outcome of the project is the Property Set, which will be forwarded to the ASI standard groups and to the local group of bsDD (bsAT – building smart Austria).

The project results will be finished in November 2019.

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