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AIA4ALL

Development of new Open BIM use Cases for HVAC System Checks and Dynamic Simulations With IDA ICE

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Abstract. Digital planning today is based on Building Information Modelling (BIM); this method greatly profits from the approach of defining use cases that lead through the process. As such, a use case for functional tests of the Heating Ventilation and Air Conditioning (HVAC) systems is currently being developed that begins in design development phase of the planning process. Additionally, a use case concerning the linkage between open BIM and the dynamic simulation software IDA ICE is also under development. First results of these use case developments will be presented in this work, along with the challenges of working in open BIM environment using the open BIM standard Industry Foundation Classes (IFC).

Keywords: Open BIM, New Use Cases, HVAC System Checks, Dynamic Simulations

1. Introduction

The Exchange Information Requirements – EIR (German: Austausch Informations Anforderungen – AIA) – allows the client to define goals and use cases for a BIM-based construction project. The requirements for the BIM models and the information they contain can be derived from the AIA, the AIA thus describes who has to provide which information, when, and with what level of detail.

The BIM execution plan – BEP (German: BIM Ausführungsplan – BAP) builds on the AIA and defines the content and strategy of the collaboration of all parties involved in the project. If the AIA is the BIM requirements specifications, the BAP corresponds to the BIM implementation specifications of the contractors. The BAP is not a static document like the AIA, but is continuously updated throughout the life of the project. The interaction of AIA and BAP is essential for seamless digitization in the construction sector.

The aim of this project is to create a modular, machine-readable AIA that can be seamlessly integrated into the tool landscape of open BIM projects. This is done by developing an open platform for creating use cases for the AIA. The platform should offer the possibility of defining the necessary content, processes, structures, phases and roles and also generating the digital artifacts (config files, property definitions and rules) in order to be able to check the requirements as automatically as possible.

The use cases represented in this paper use the IFC standard (Industry Foundation Classes) [1] as a bridge to connect open BIM with the different industry applications. IFC is a standard for open BIM data exchange, it is usually used as means of referencing or archiving. The IFC is like the PDF of BIM, which means an IFC file is a frozen copy of the original content that can be viewed, measured, used for clash detection, simulation, etc. [1]. A typical IFC workflow is as follows: a BIM expert creates the design model and exports an IFC version of it. Other team members can later import the IFC file in their own software and use it for coordination. For this reason, the IFC standard has been selected for the data exchange of the use cases in this study.

Depending on the method how the IFC file was created, it can contain a great number of information classified under various property sets called “IfcPropertySet”. An IfcPropertySet is a container class that holds properties within a property tree. These properties are interpreted according to their name attribute [1]. In order to facilitate the information transfer between a BIM model and the different industry applications, this work defines where the information can be found within a BIM model and in which IfcPropertySet. This work also references IFC entities: An entity is a class of information defined by common attributes and constraints according to [ISO 10303-11] [1]. Multiple IfcPropertySet can be assigned to an entity.

This work describes two use cases that were elaborated in project AIA4ALL [2]. In addition to defining the IfcPropertySet for the simulation use-case, an additional testing step was conducted using IDA ICE [3]. Since IDA ICE can already read an IFC file, the team was able to test some models and study the inconsistencies in the transfer of information.

2. Results

2.1 Open BIM use case “Functional tests of HVAC systems”

Step 1: Operation mode analysis

At an early design stage, this step aims to provide an overview and an early evaluation of the building’s HVAC systems. The process includes performance analyses of the building’s heating and cooling systems carried out for 20-25 operating points in lieu of the usual two operating points (standard outdoor temperature winter/summer). This process helps to avoid perceivable issues such as oversizing of the heating and cooling systems, frequent part load operation, and the installation of unnecessary plant components.

Moreover, the operation mode analysis process can be used to create operating strategies for the heating and cooling systems and to conduct a cost analysis of the different variants at an early design stage. Similarly, the operation of the heating and cooling sources (e.g. geothermal probes) can be evaluated through this process to enable balanced operation and avoid system oversizing. The operation mode analysis process can also assist in defining the critical HVAC systems that should be monitored with sensors through technical monitoring (step 2 and step 3).

In order to successfully conduct an operation mode analysis, a great number of data points or properties must be defined. The required information include supply and return temperature of the energy plant, supply and return air temperature of the air handling unit, equipment cooling and heating efficiency, outdoor weather conditions, indoor setpoint temperature, airflow, etc. Until now, all this information has to be extracted manually from different design documents (HVAC plans, schematic diagrams, and sequence of operations), which can be time consuming and might lead to errors. Additionally, this manual process does not allow for collaboration and automatic transfer of information and updates.

In this case open BIM can be of great use as the BIM model can include many of the abovementioned data points and is ideal for collaboration. Therefore, this work has focused on identifying the multiple properties required for an operation mode analysis that can be found in a BIM model.

The first step is locating where the different information or data points can be found in the BIM model. For this purpose, the software Revit has been used and most properties of interest were found under three levels (object, room, and piping system). Figure 1 shows some example properties and on which BIM level they are located.

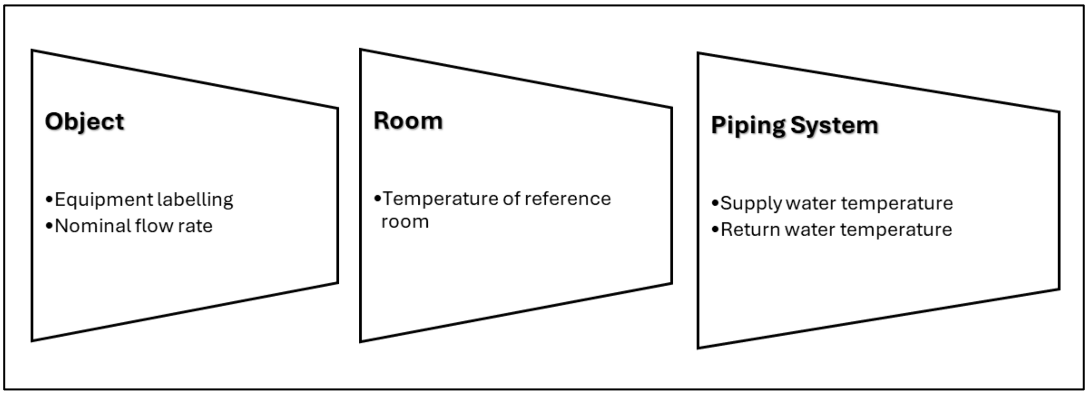


Figure 1: *Example properties listed under their corresponding BIM location (Object, Room, Piping System)*

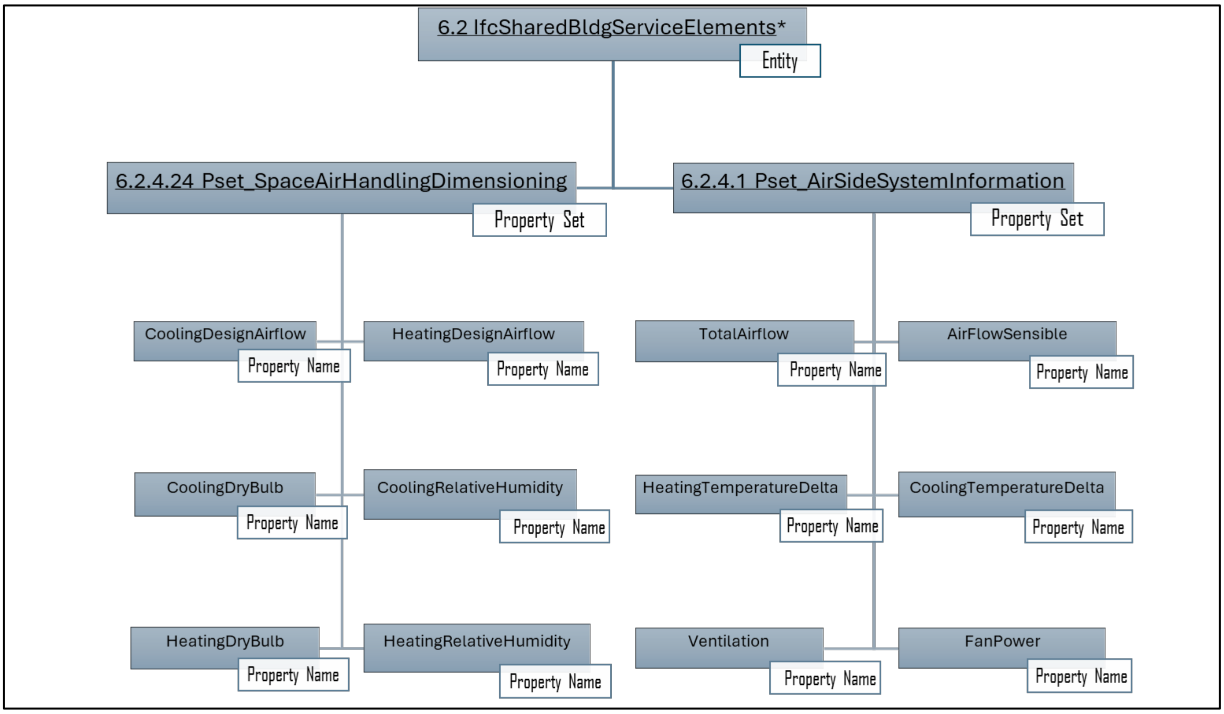
The next step involves studying how an IFC file can properly be created from a BIM model to include the properties of interest. This requires an understanding of the IFC structure in order to determine how the information is best stored in an IFC file to allow for collaboration. Using [1] the IFC structure was studies to find the most suitable IfcPropertyset (short: "Pset") to contain the required information. By identifying in which PSet a property is located in the IFC standard and to which Entity it is linked, this work helps streamlining the information retrieval and the data sharing in the BIM environment.

Table 1 shows three examples of operation mode analysis properties that were mapped onto IFC properties, PSets and entities. For the purposed of this study, IFC 4.3 has been used as it is the latest available version and is about to become the next ISO standard.

Table 1: *Example of matching properties to their corresponding IfcPropertySet*

Property	Entity [1]	IfcPropertySet [1]	Property Name [1]
Heating Load	6.2 IfcSharedBldgServiceElements	6.2.4.27 Pset_ThermalLoad	TotalHeatingLoad
Equipment Efficiency	7.7 IfcPortsAndWaterwaysDomain	7.7.4.4 Pset_EnergyRequirements	EnergyConversionEfficiency
Outdoor Temperature	7.2 IfcBuildingControlsDomain	7.2.8.12 PEnum_TemperatureSensorType	OutsideTemperature

Within the scope of this work more than a hundred properties that are usually needed to conduct an operation mode analysis have been mapped to IFC. For many of the common HVAC systems such as air handling units, chillers, boilers, and energy storage devices it was possible to identify according PSets and Properties. For example, Figure 2 shows the PSets of an air handling unit that are relevant for an operation mode analysis. Note that the IFC hierarchy for an air handling unit includes many more entities and IfcPropertySet but only the ones required for the purpose of this use-case have been included in the diagram.



*IfcSharedBldgServiceElements = IFC Shared Building Service Elements

Figure 2: *Entity and IfcPropertySet of an air handling unit*

This is considered the first step towards using a BIM model to efficiently and instantaneously obtain the information needed to conduct an operation mode analysis. This, however, requires the BIM model to be built correctly and comprehensively to include the required data points and to be updated regularly to take advantage of the open BIM benefits.

Step 2: Technical Monitoring

"Technical monitoring" describes a process, which ensures that the building's mechanical systems function correctly and perform according to plan. In order to successfully carry out technical monitoring during operation, target operating conditions must be defined early in the design process together with the systems' measuring points and their acceptable ranges. Additionally, it is important to determine the metering infrastructure in the schematic design (SD) and design development (DD) phases.

The next step in technical monitoring includes data collection and transmission followed by corrective actions. To achieve this objective, the project must guarantee the transmission of collected data to an external monitoring service provider, who evaluates whether the target values are achieved. The results are usually documented in a report that presents the deviations from the target values and indicates the possible causes or deficiencies. Support is later provided for the correction of deficiencies followed by another performance review.

As part of this work, the team had hoped to create guidelines to simplify the process of including the above key elements in the open BIM project and to define the digitizing process of data collection, deviation detection, and carrying out corrective actions. However, after learning more about the common practices in the industry, it was realized that the measured data is typically not modelled in open BIM or – if it is put into the BIM model – at a much later stage in the process. This unfortunately means that today the required information for technical monitoring is generally not available in a BIM model. As open BIM becomes more accessible and widespread, it is believed that measured data will soon be included in the model (or linked to the model). Future a use-case can then be developed to streamline the information exchange for the purpose of technical monitoring.

Although the latest version of IFC was used, some properties could not be matched to standard IFC (e.g. measurement equipment). In these cases, it is possible to extend the IFC standard with a set of proprietary definitions. These have to follow the semantics and syntax of IFC but can otherwise be freely defined. Within the scope of the project, it is attempted to complete these definitions and then propose them to Austrian Standards Committee 273 in order to become a national standard. This ensures that operation mode analyses get better market acceptance and broader tool support.

2.2 Open BIM use case “Dynamic simulation in early planning phase with IDA ICE”

A successful import of a BIM model into IDA ICE is rare. Most BIM models are either not readable by IDA ICE or miss key elements and are partially corrupted. Within the scope of this work, the data exchange between open BIM and IDA ICE was studied, identifying missing links and deficiencies. Furthermore, a guidance document that specifies how an IFC file should be created to enable a smooth import into IDA ICE has been started.

For the use case dynamic simulation multiple steps are needed. Similar to the previous use-case, the first step was identifying the Psets that contain the information needed for dynamic simulation. Generally, the most relevant information that is needed for simulation is the object’s geometry (including windows and doors), the thermal properties of the object, setpoints and internal loads. Table 2 shows a few examples of simulation properties that were mapped to IFC.

Table 2: *Example of mapping simulation properties to IFC*

Property	**IfcPropertySet [1]**	**Property Name [1]**
Slab U-Value	6.1.4.19 Pset_SlabCommon	ThermalTransmittance
Window Transmittance	6.1.4.11 Pset_DoorWindowGlazingType	SolarTransmittance
Zone Occupancy	6.2.4.25 Pset_SpaceThermalLoad	People
Zone Heating Setpoint	5.4.4.24 Pset_SpaceHVACDesign	TemperatureMin

The current version of IDA ICE is capable of reading the geometry, the thermal properties, and the object’s orientation from an IFC file. However, at this point the zone setpoints and internal loads (lighting, equipment, and occupancy) cannot be automatically imported into IDA ICE. Therefore, by defining the corresponding PSets and Properties, this work lays the grounds to a seamless connection between open BIM models and IDA ICE.

The next step within this use case is to import different IFC files to IDA ICE, focusing mainly on testing the geometry. The imported objects had different façade elements, different roof styles, and a combination of above and below ground floors. The goal here is to detect deficiencies and test the geometry limits of IDA ICE.

Figure 3 shows an example of a successful IFC import into IDA ICE, where the geometry was correctly interpreted, including the roof, basement walls, windows and doors. On the left side is the IFC file viewed in Revit and on the right is the IFC file as read by IDA ICE. Note that IDA ICE combines the windows of a zone when they are on the same wall, keeping the same total area. This helps reduce the simulation time while maintaining the zone’s thermal gain/loss with the outdoors. Additionally, IDA ICE displays underground walls with a darker color to indicate that they are surrounded by the ground.

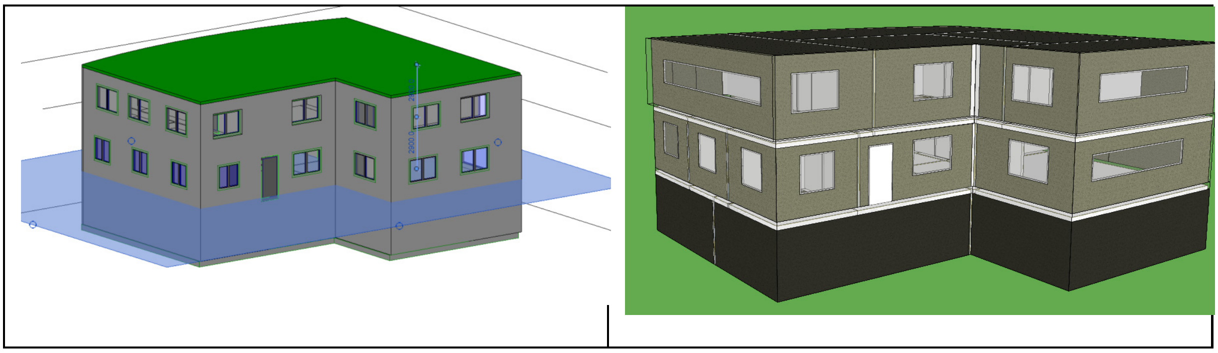


Figure 3: *Left IFC file viewed in Revit, right the same IFC file imported and read by IDA ICE*

Figure 4 on the other hand represents an import that was not as successful. On the left side is the IFC file viewed in Revit: the object appears to include a pitched roof and a glass façade. However, those items are not correctly interpreted by IDA ICE. The glass façade is translated as an opaque façade while the pitched roof could not be imported as a roof element; instead it is simply a background image in IDA ICE.

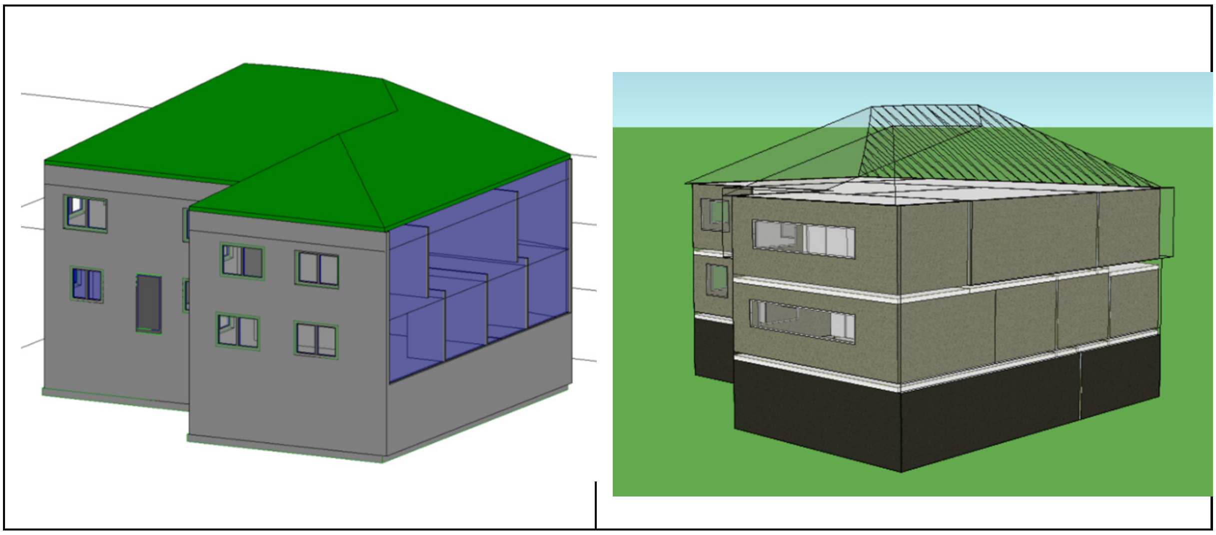


Figure 4: *Left: IFC file viewed in Revit; right: the same IFC file as read by IDA ICE*

After a few tests, it was realized that while some of these issues can be rectified by adjusting the IFC file before importing it, others are not that simple. For example, when creating the IFC file, the glass façade should be defined as IfcWindow, not as IfcCurtainWall for correct interpretation by IDA ICE.

Little available information was found from the software developer on how to correctly assign the geometry elements in an IFC file so that it can be flawlessly read by IDA ICE. This led the team to take the initiative to draft a well-defined guideline on how the IFC model is best created to support dynamic simulation with IDA ICE. The guideline document is currently being developed further by continuously testing different open BIM models.

3. Conclusions

The open BIM processes have been used for years to share project information in a way that supports collaboration for all project participants [1]. This paper has introduced two use-cases (functional tests of HVAC systems, and dynamic simulation) than can benefit from the open BIM process. The functional tests of HVAC systems processes require a lot of information and data points, some of this information is commonly available in a BIM model, while others (e.g. measuring data) is not. This paper has focused on the properties that are generally available in a BIM model and studied how to map them to the IFC standard.

While the use case for functional testing of HVAC systems is a new approach, the simulation use-case has been tested by many scholars by transferring information from BIM to dynamic simulation tools such as IDA ICE. However, this paper has focused on finding IfcPropertySets that are suitable to carry the information that cannot be transferred to IDA ICE at the moment (e.g. internal loads and infiltration). Additionally, as part of this work, many IFC files were imported into IDA ICE and tested for inconsistencies in the properties that can be interpreted by IDA ICE (e.g. geometry).

4. Abbreviations

AIA	German: Austausch Informations Anforderungen; English: Exchange Information Requirements (EIR)
BAP	German: BIM Ausführungsplan; English: BIM Execution Plan (BEP)
BIM	Building Information Modeling
HVAC	Heating Ventilation and Air-Conditioning
IFC	Industry Foundation Classes
Pset	Property Set

Data availability statement

The data supporting the paper can be found under https://www.ait.ac.at/bim-bibliothek

Author contributions

Anita Preisler was responsible for the conceptualization of the two open BIM use cases presented in this paper. She also undertook the supervision of the research activities including planning, coordination, and mentorship.

Sama Schoisengeier carried out the formal analysis and investigations required to build, test, and validate the open BIM use cases presented in this paper. As the writer of the original draft, she was responsible for documenting and visualizing the results.

This paper, which defines and presents two open BIM use cases, is part of a larger research project that includes more open BIM use cases. The mother project is managed by Gerhard Zucker on the national level and by Alina Stipsits on the company level.

Competing interests

The authors declare that they have no competing interests.

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