BIM-generated data models for EnergyPlus: A comparison of gbXML and IFC Formats

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Abstract

Building Information Modelling (BIM) aims to promote collaboration between project partners by providing a single model with the required relevant information. BIM data is meant to be provided to multiple domain-specific applications in an effective manner. We consider two data formats used to facilitate this interoperability: (i) gbXML format, developed by Green Building Studio and (ii) IFC format, developed by buildingSMART. Both of these formats can be used to provide geometry information and other data to Building Performance Simulation (BPS) applications. However, gbXML and IFC have unique data structures, which has consequences for how the original geometrical and spatial data from the BIM model is translated. In this context, the present contribution aims to assess and compare the usage of IFC and gbXML data formats in separate workflows, thereby observing consistency of building data and efficiency of the process. First, the main differences and specifics of the two formats are investigated and several case models are developed. Using a BIM authoring tool both formats are then tested in a typical workflow including the use of a BPS tool. To explore the implications of the quality of the BIM model, a second workflow (with the same case models) was set up in a different BIM authoring tool. These workflows and their outcome with regard to BPS were analyzed and the capabilities and differences of the two formats were studied in detail. The results of this study show that both data formats are capable of extracting and transferring geometrical information from BIM models. However, the successful transfer of this information is strongly related to the quality of the BIM representation. Demonstrative simulation runs show that incorrect BIM-based building geometry data can produce misleading results. Moreover, the overall approach to using gbXML and IFC to perform BPS is currently rather cumbersome and difficult to validate.

1. Introduction

In recent years more attention has been paid to improving the quality of exchanged data and to managing information integrity between professions involved in building projects. Building Information Modelling (BIM) promotes collaboration between disciplines by providing a single 3D CAD model, containing relevant data about a building throughout its life cycle, which can be exported to various function-specific software (Eastman, 2008). BIM can help to increase the efficiency of BPS by facilitating the data input for simulation and therefore allowing more scenarios to be investigated. (Maile et al., 2007). A BIM model provides detailed information on a building, which can serve as input for BPS and therefore reduce the amount of time needed to set up a simulation model manually (Laine et al., 2007). The Architecture Engineering Construction (AEC) industry has developed two data formats to facilitate interoperability between software and to exchange building information between disciplines. One is gbXML format, developed by Green Building Studio (gbXML, 2014). The other one is IFC, which is an object-based, open file format, developed by buildingSMART (former AIA) and has been used to transfer data between various participants in a building project (buildingSMART, 2014).

For the purpose of Building Performance Simulations (BPS) both formats have the ability to extract building data necessary for energy simulation from the BIM model and transfer it to the respective software. In most cases, simulation

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processes require information on building geometry (Maile et al., 2013). Simulation engines typically require complex 3D geometry to be broken down to space boundary surfaces (Jones et al., 2013). There are numerous software tools, which convert rich geometry and prepare it for simulation (Bazjanac, 2008; Bazjanac et al., 2011; Hitchcock and Wong, 2011).

This paper aims to assess and compare the transfer of building geometry data via IFC and via gbXML format into BPS. For this purpose, two different workflows are developed and tested with regard to consistency of data, efficiency of the workflow and the validity of the results.

2. gbXML and IFC

The gbXML data format was initially developed in 1999 by Green Building Studio Inc. strictly for the purpose of energy analysis (gbXML, 2014). It retrieves geometry and non-geometrical information from the model and saves it in a text format under pre-defined notations. The information is divided into three different categories: *ShellGeometry*, *SpaceBoundary* and *Surface*. Software tools employing gbXML do not always use all three in order to retrieve geometry. Most of them implement *ShellGeometry* and *SpaceBoundary* since in combination they represent geometry more accurately. Some use solely the *Surface* element to obtain the geometrical information (gbXML, 2013).

Industry Foundation Classes, or IFC, is the official international standard for open BIM and is registered with the International Standardization Organization (ISO). EXPRESS data definition language is used to describe entities and relationships, including data verification rules in the data scheme. In addition, EXPRESS-G (graphical data notations) is used to display large information models (buildingSMART, 2014; Dong et al., 2007). The IFC adopts the "top-down" approach, which creates a complex, hierarchical schema in a large data file (Dong et al., 2007). Additionally buildingSMART developed a standard for the information flow in an integrated project called Information Delivery Manual (IDM). The main goal of the IDM is to ensure that all relevant data for a specific task is described in the 3D BIM model in such a way that it is accurately imported and processed by the respective software

3. Methodology

In order to analyse and compare the effects of building geometry data transfer for the purpose of BPS, two different workflows were defined (Fig.1).

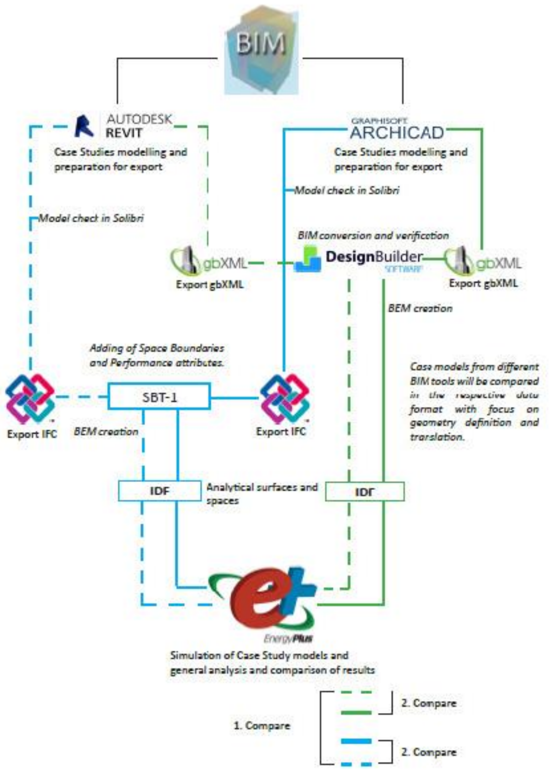

Fig. 1 – Two different workflows to transfer BIM data to BPS

Furthermore, several models were developed and created using two different BIM authoring tools (Fig. 2).

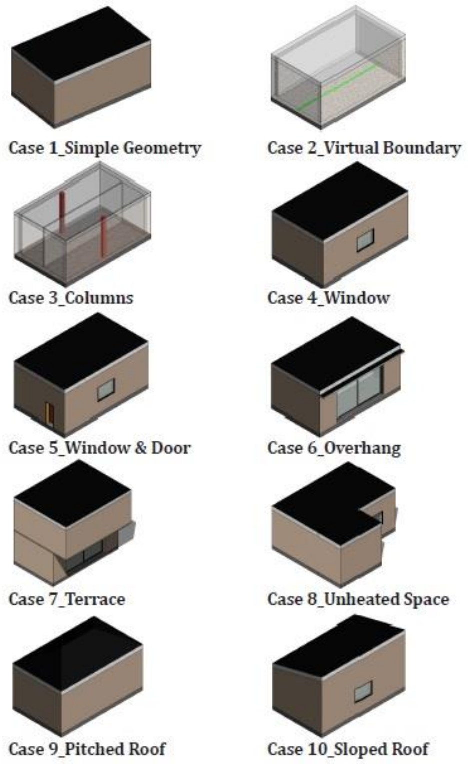

Fig. 2 – Case Study Models

3.1 Selection of Software

Autodesk Revit (Autodesk, 2014) and Graphisoft ArchiCAD (Graphisoft, 2014) are among the leading BIM software platforms (AEC, 2013). Therefore, they are chosen as the BIM authoring tool. An important precondition for the seamless export of both data formats is the creation of a "clean" 3D BIM model that has a comprehensive and consistent geometry structure.

DesignBuilder is the selected pre-processing tool for gbXML. It supports importing BIM through gbXML and allows for IDF export, which is the format needed to be imported into EnergyPlus (EnergyPlus, 2014). Lawrence Berkeley National Laboratory (LBNL, 2014) has developed a semi-automated tool, called Space Boundary Tool (SBT-1) that retrieves building and spatial geometry data from the IFC schema and breaks it down to heat transferring surfaces. SBT-1 has been made commercially available and is used for the present case. In its current and only version it imports IFC2x3 Coordination View 2.0, an earlier variant of the IFC schema, and exports v. 7.2 IDF format for EnergyPlus.

For the comparison of data quality throughout the process the Solibri Model Viewer was used to visualize the information (Solibri, 2014).

3.2 Case Study Models

The main objective for the design of the Case Study models is to incorporate building elements, which have been frequently reported to have problems with geometry during export of either gbXML or IFC (Hitchcock and Wong, 2011; Moon et al., 2011). The basic design is kept as simple as possible. All Case Studies contain basic geometry information regarding walls, floor, and roof. Thermal specifications are defined and at least one zone is assigned. The models are shown in Fig.2.

3.3 Performance Study

The process of generating, extracting, transforming and simulating building geometry for the purpose of BPS is defined by an array of actions, necessary for a successful workflow. These operations are done in consecutive steps to outline a workflow, which facilitates data format comparison at different stages. Figure 3 gives a detailed outline of the steps taken.

First a case study model is created either in Revit or ArchiCAD. The definitions for the building elements and the spaces are identical. Next, the data is exported using the IFC or the gbXML format. The files are then imported into the respective pre-processing tool – DesignBuilder or SBT-1. Using these software, IDF-files are created and finally imported to EnergyPlus and simulated. Additionally all the cases were simulated in EnergyPlus via manual data input, in order to create reference models for the comparison of the results.

After each step, the data is analysed and compared with the original files to establish if and how the conversion process has affected the quality of the information.

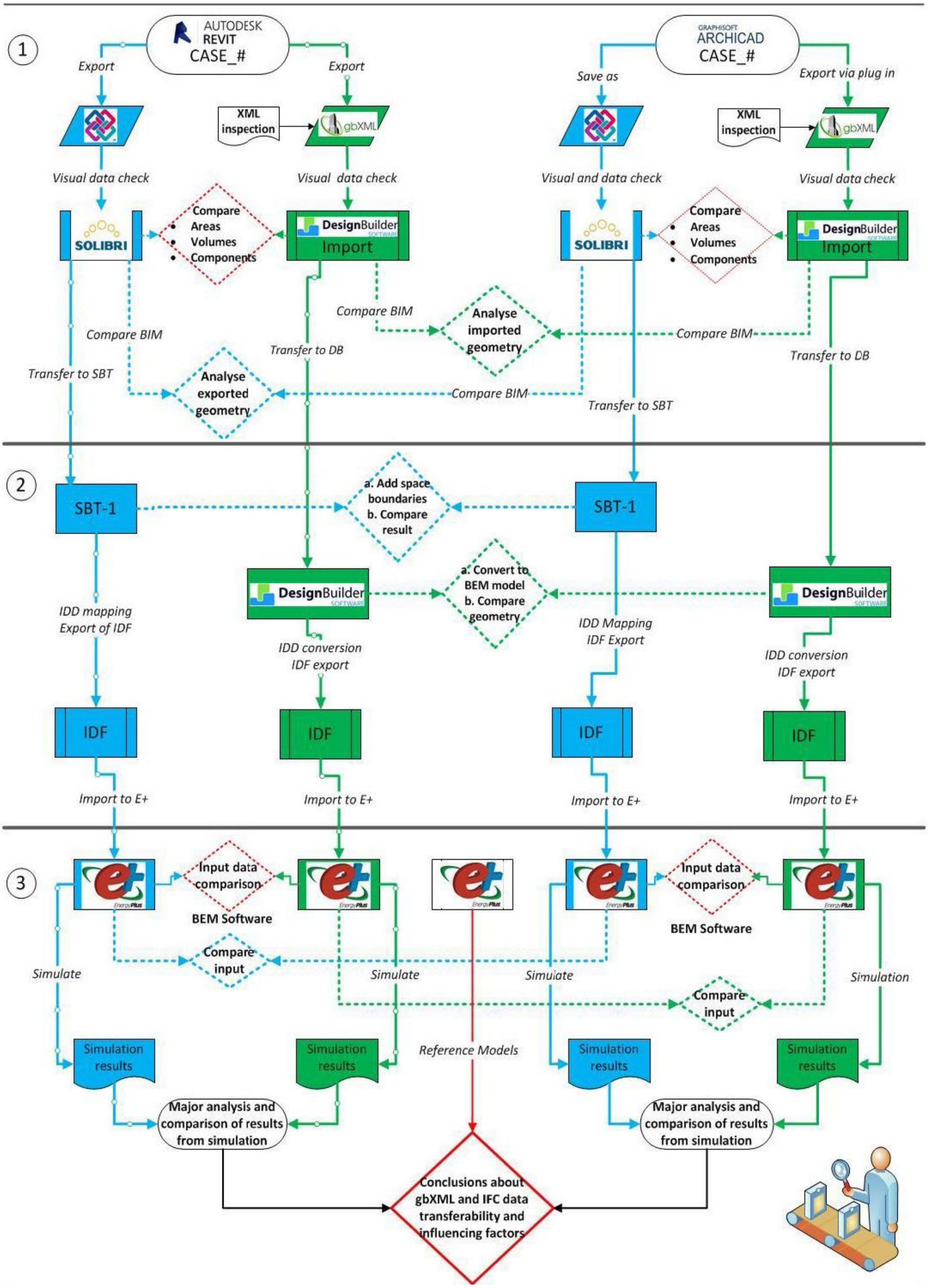

Fig. 3 – Detailed diagram of the workflow

4. Results and Discussion

Both gbXML and IFC have shown reasonable performance in extracting and storing building geometry data and its non-geometric specifications. Four in all twenty exported gbXML formats appeared to be incorrect and only one of the IFCs (see Table 1). The parameters analysed for this comparison are the volume, the area, and the geometry. The measured accuracy is the percentage of the correct data obtained.

The gbXML recognizes and defines the required information for energy analysis from the BIM model and locates information under predefined elements in its schema. This stresses the fact that the created model and its geometry have to be sufficiently accurate at the time of export.

IFC has a fairly complicated data structure and strict hierarchy, which defines relationships between building elements and space in a contingent manner. This is why it is important that the information in the BIM model is structured in accordance to IDM. This provides a more coherent data structure for further processing.

Table 2 shows the results after the original data was processed and transformed to IDF. Some of the errors were caused by the definition of the native model in the BIM authoring tool and some are due to the technical performance of the intermediate tools. By comparing tables 1 and 2 it can be seen that the original BIM data has been altered during the conversion to IDF via SBT-1, leading to several errors. There are also some inconsistencies in the gbXML workflow.

Fig. 4 and Fig. 5 show the absolute difference in Total Site Energy [$kWhm^{-2}$] for all the cases

Table 1 – Comparison of extracted IFC and gbXML data (extraction failures are denoted via cross marks)

Extracted building data	gbXML		IFC	
	Revit	ArchiCAD	Revit	ArchiCAD
Case1_Simple Geometry	✓	✓	✓	✓
Case2_Virtual Boundary	✓	✓	✓	✓
Case3_Column	✓	✓	✓	✓
Case4_Window	✓	✓	✓	✓
Case5_Window and Door	✓	✗	✓	✓
Case6_Overhang	✗	✓	✓	✓
Case7_Terrace	✓	✓	✓	✓
Case8_Unheated Space	✓	✗	✓	✓
Case9_Pitched Roof	✓	✓	✓	✗
Case10_Sloped Roof	✓	✗	✓	✓
Measured accuracy	90%	70%	100%	90%

Table 2 – Comparison of processed IFC and gbXML data (transfer failures are denoted via cross marks)

BEM generated building data	gbXML-DB		IFC- SBT-1	
	Revit	ArchiCAD	Revit	ArchiCAD
Case1_Simple Geometry	✓	✓	✓	✓
Case2_Virtual Boundary	✗	✗	✓	✓
Case3_Column	✓	✓	✗	✓
Case4_Window	✓	✓	✓	✗
Case5_Window and Door	✓	✗	✓	✗
Case6_Overhang	✗	✓	✓	✗
Case7_Terrace	✓	✓	✓	✗
Case8_Unheated Space	✓	✗	✓	✗
Case9_Pitched Roof	✗	✗	✓	✗
Case10_Sloped Roof	✗	✗	✓	✗
Measured accuracy	60%	50%	90%	30%

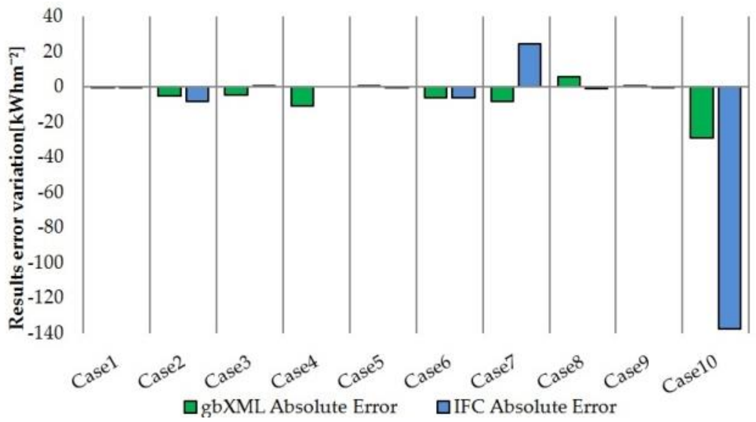

Fig. 4 – Error variation in results- Revit

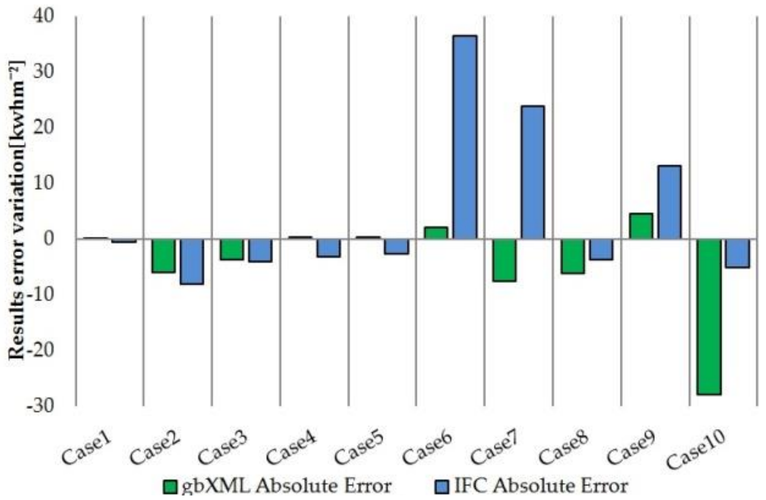

Fig. 5 – Error variation in results- ArchiCAD

5. Conclusion

In the course of evaluating and comparing the use of IFC and gbXML for the purpose of BPS, it becomes clear that both data formats are capable of extracting and transferring spatial and geometrical information from BIM models. Successful data export is strongly related to the quality of the building model, generated in a BIM-authoring tool. In order to preserve the quality of the data, one is highly dependent on the receiving software, which converts and prepares the information for input to EnergyPlus.

In its default schema, populated with building semantics, gbXML stores building geometry in a pre-defined structure, which does not preserve the integrity of the geometric model. Its primary function is to facilitate work between BIM and building performance analysis. It has been the preferred format for that purpose. Future improvements should be focused on making it a more reliable and robust data format.

IFC has been developed in view of the needs of the AEC industry to assist integrated BIM work and exchange of building data between disciplines. In its role as an open data format, it provides a contingent and hierarchical informational structure, which captures the needed building geometry for conducting building performance analysis. More efforts could be invested by energy software vendors to use this format, given its promising way of storing and translating data.

For the particular workflow studies, both gbXML and IFC require pre-processing BEM tools. DesignBuilder, used for gbXML data conversion and IDF export, provides an integrated platform for energy analysis with BIM and EnergyPlus. But using the software to appropriately prepare the data for simulation in EnergyPlus requires expertise. On the other hand, SBT-1 for IFC is a basic tool for simplification of geometry, but its potential to convert complex geometry into Space Boundaries has not been further developed. Currently the development is disrupted. Both workflows have been proven to be tedious and rather time consuming. Furthermore, a certain level of knowledge is required regarding the whole process, tools applied, and technical specifications. In addition, the process does not result in a direct feedback to the original model, reducing its potential toward effective iterative design improvement.

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