Building performance simulation from a BIM

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Abstract
All building in the Netherlands have to comply with the building code and especially the Energy Performance Buildings normative calculation Energy performance standard for buildings (EPG). Presently in all major building projects the Building information Model is used to optimize the information and calculation flow within projects. However, current links between BIM and EPG only use the building’s geometry from the BIM. The applied installation concept is entered (once again) into the EPG-simulation tool or the information is linked to the space as an installation concept. In both situations the technical installation data in the BIM can deviate from the entered data used in the EPG calculation. The transfer of data from a BIM to an EPG-simulation was built. Herein IFC is used as a universal data transfer format. Completing the data transfer using the methodology described in this study can provide a solution for a number of applications. This study builds a bridge between the BIM and simulations, and as such offers a principle solution for the coupling between building services and Design and Decision Support Systems.

Keywords – BIM; EPG; simulation; IFC; data transfer

1. Introduction.

In today’s building industry the Building Information Model (BIM) cannot be missed. The idea of BIM originates from Chuck Eastman, who wrote in 1975: ‘Any change of arrangement would have to be made only once for all future drawings to be updated. All drawings derived from the same arrangement of elements would automatically be consistent’ [1].

In the beginning of the 21st century BIM is widely used in the building industry. The BIM replaces the 2D drawings with a 3D representation of the building that has to be (re)build. The virtual model is used as an information database with objects as the carriers of information. This gives way to several applications. It enables the calculation of the amount of materials needed to construct the building or it can detect clashes where geometries overlap. The
BIM is also used for generating 2D drawings which will be used for constructing the building. Reasons to use a BIM are to:

- Reduce the failing costs;
- Optimize a design;
- Reduce the lead time of the design process;
- Use a database with objects within the BIM for:
  Planning, Calculation of costs and Simulation.

The last-mentioned reason, the use of the BIM database for simulation, is the subject of this article. For the American market alone there are 417 different software programs available [2] to create building simulations. These programs offer a diversity of possibilities ranging from raw calculations of energy consumption based on ratios to complex detailed calculations in which the airflow per cubic centimeter is calculated using Computational Fluid Dynamics. Each of these simulations requires a different input. Herewith an optimum has to be found in the complexity and duration of the input and the level of detail and reliability of the output [3].

Working with BIM has become a standard working method on which projects are designed. Besides, EPG simulations are applied regularly, because of regulations on sustainability. The EPG (Energieprestatie norm voor gebouwen), which could be translated as the Dutch Energy Performance standard for buildings, is a calculation method for the so-called Energy Performance Coefficient (EPC). Standardized in the Dutch standard NEN 7120 [4]. This standard is legally required in the Netherlands at the application for a building permit, in order to show that the object to be build does not consume more energy than legally allowed.

Within the current way of working the EPG simulation is positioned outside the BIM (Figure 1, above). This is because the BIM does not include all the information needed for the EPG simulation. Only the building-geometry is transferred in the current connections between BIM and EPG (Figure 1, below). The architectural contours are then taken from the BIM, the information about the installations is added as templates and it is projected to the spaces in the geometry. This way of working has two variants:

- The information about the installations is added by the EPG-simulation tool and connected to the imported spaces.
- The information is textually added to the BIM model, as an installation concept. In combination with modelled installations, the BIM contains the information about the installations twice. In that way the BIM, being a tool for clear communication, loses its purpose.

When there are changes in the BIM or in the calculation this results in inconsistency between the BIM and the simulation, which means the reliability of the EPG-result is reduced. For example in situations where at the
last moment an austerity is being implemented and the EPG simulation is not revised, the EPG of the realized building will be inconsistent with the calculation. For transparency in the expected energy use of a building it is important to guarantee the quality of the EPG simulation. This creates the need for a good link between the BIM and the EPG simulation. Also it is of importance that the data exchange occurs free of errors and quicker, thus automatically.

Figure 1 shows that the link between the BIM and EPG simulations is currently limited to the geometry. Currently the transfer of the geometry is in a development stage. In the technical journal TVVL, BINK [5] and Vabi [6], two EPG-simulation software vendors, describes their developments on the transfer between BIM and EPG. In practice experiments are conducted with this link, but real application is hardly used. Table 1 shows all EPG-certified software vendors who offer a connection to the interoperable BIM data formats.

Table 1 EPG software with BIM connectivity.

<table>
<thead>
<tr>
<th>Software company</th>
<th>EPG software</th>
<th>Data exchange format</th>
</tr>
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<tbody>
<tr>
<td>BINK software</td>
<td>BINK, EPG</td>
<td>gbXML</td>
</tr>
<tr>
<td>De twee snoeken</td>
<td>Toetsingsmodule 2: EPG</td>
<td>IFC</td>
</tr>
<tr>
<td>Vabi</td>
<td>Vabi Elements EPG</td>
<td>IFC</td>
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As a starting point for this research, the exchange of the building-geometry is considered to be fully functional. The result of this research is added to this exchange. The purpose of this research is to enable universal exchange of data between design and simulation software. This ensures that the building data needs to be entered once into the BIM, resulting in consistent information. This is shown in figure 2.
To realize this exchange of data, the Information Delivery Manual (IDM) is used helping to define the exchange requirements required for the EPG software. The BIM must be provided with the information described in the exchange requirements to be able to be used as input for the EPG simulation. With this data transfer the following advantages are accomplished:
- Time saving: faster calculations and a shortened iteration time;
- Unambiguous data: data link between BIM and EPG software;
- Reusable data (one time only data changes); data is saved in a template.

The data transfer from BIM to Vabi can only be applied when installation components in the model are modeled. This happens when the model reaches the Final design phase. In earlier design stages the model is not sufficient developed to be useful for the EPG simulation. Besides modelling the installation components, these components should include the information as required in the EPG simulation. Entering the data in the BIM leads to that this data must be transformed into object parameters.

For an integration of an EPG-simulation into BIM, the data required for the EPG-simulation should be implemented in the BIM. The question which data is needed, is answered by extraction of required input data of the EPG-simulation tool. In the design software it is examined which data is already included and which data should be added.

Because the data from the EPG simulation software is entered in the BIM only once, the development of the data transfer starts in the EPG simulation software (Figure 3, right side). The EPG simulation software forms the basis for the exchange requirements that have to be implemented into BIM in order to perform a simulation. When the exchange requirements have been implemented the BIM is exported to IFC. During the export to IFC a transformation of the data takes place. In IFC the model is validated for the exchange requirements, before it is imported into the EPG simulation software. The building-geometry can be directly read by the EPG simulation software. The transfer of installations is complex. In the design software, the installations consist of objects and relations between these objects, while the EPG simulation software works with templates including system principles.
To exchange information the objects should be interpreted as a system, otherwise the EPG simulation software is unable to interpret which installations are meant. Concerning the installations a challenge of mapping (object based to rule-based) has to be overcome.

The case study, as a practical example of this process, is obtained by putting together the models of the architect, construction engineer and installation consultant.

The study specifically focuses on the data mapping, which is required for the coupling of the design software and the simulation software. The IFC-based data Information Delivery Manual (IDM) of BuildingSMART is used for this transformation. When IFC is used, the methodology described, can be applied to other software combinations as well e.g. the MVD Model View Definition. The project is shown in figure 3 where the red box visualizes the connection between Revit and Vabi, the connection between Revit and Vabi is also the scope of the research.

Fig. 3 The demarcation puts the gears fixed on a certain position.

The idea of linking BIM to the EPG simulations has been worked out by several software vendors. Research by Korhonen and Liane [7] shows that steps in this direction were taken in 2008. The link between different design and simulation software applications is studied in this research. It can be concluded that RIUSKA (the product of the commissioner of the study) is the predecessor of data transfer via IFC.

Several software developers are working on solutions that connect to this study. BINK [8], de Twee Snoeken [9] and Vabi [10] have realized links with the construction geometry. BINK indicates it is able to read IFC files if they comply with the demands of the Vereniging Initiatief Groep Open Standaarden (VIOS) [11]. Vabi has provided a manual with requirements for the construction model in order to be imported. The German company Linear [12] operates with the link of object data. Systems can be simulated in this way. However, this is a closed environment which complicates universal data transfer. Cormier et al. [13] provide a clear description of how the data-
transfer from BIM to a simulation can be carried out. In this study a BIM based on the IF format is used for simulations with EnergyPlus and TRNSYS. However, in this study also just the building geometry from BIM is used in the above software developments and research no universal bridge was built between the installation model (BIM) and the simulation tool. The study of Wimmer et al. [14] approaches this study the most.

Wimmer et al. [14] use the HVAC model as data carrier for a simulation. The program that is used for simulations is Modelica, a simulation tool in which objects are provided with data and interconnected (intelligent principle diagrams). However, this transfer does not use IFC, because IFC cannot capture the level of detail pursued for HVAC objects. The data transfer thus takes place by a custom defined XML.

The starting point of this research is that the building geometry of the BIM can be replicated in the Vabi software, see figure 4. However, the developments at BINK and Vabi still need further working out. Besides replicating the building geometry the following principles have been used for the data link between Revit and Vabi:
- The modeled installations are used as input for the simulation;
- The transfer of data is based on the IFC format.
- The receiving software is Vabi for execution of the EPG simulation (for demarcation).

In comparison to the studies mentioned above this is an unique combination of starting points.

**Fig. 4** Schematic relations between Vabi and a BIM project.
Relation between BIM and EPG relative to the phase of the process

This study is based on an EPG calculation performed in the final phase of the design process. It is common use to carry out this calculation in the pre-design phase, because in that phase it is easiest to optimize the EPC. Performing the calculation in a later phase could possibly be a repetition and could mean extra work. However, in the pre-design phase the model is not yet fully developed, so it is unusable for the simulation. Connection with the pre-design could be realized by working with generic elements in this phase that do record the required data. Another possibility is to use the current method and after that transfer the entered data into the BIM. The second option does not comply with the goal of this study, which is providing one-time only data input at one location.

Regardless of the connection to the pre-design phase the added value of this study is that the BIM becomes the starting point for the actual construction and the actual simulation calculation. This produces consistency: what will be build, is also calculated (including changes). When the results of this study are automated the quality guarantee will offset the amount of extra work it takes to adjust the BIM for optimization. In the recommendations a reference is made to the connection with the pre-design phase EPG calculation.

In this study extra information is linked to the EPG simulation related objects in the form of attributes and properties. Filling in the values within these properties it is important that the data in the BIM have been entered correctly. This requires extra attention and knowledge from the BIM modeler.

Typicals were used: spaces that occur multiple times in a building. One space is equipped with installations, with the remark that identical spaces have identical installations. When a model is used which is constructed in this manner a calculation cannot yet be made. This requires that all spaces are worked out.

The building consultant is dependent on the architect, because the building geometry from the architectural model is required to define the spaces in the building services model. These space are required for the link with the EPG simulation. That means risks and dependence. An automatic check whether all spaces have been modelled properly is not yet available as MVD. Thus strict modelling is required following a certain protocol. This restricts the modelling freedom of the architect, because generic objects with creative shapes are till now not applicable within these protocols.

With aggregate models (each party creates his own model and those are linked to each other) no adjustments can be made in the models of third parties. In order to obviate the exchange of models that do not comply with
the ERs, validation can be applied to the models. Then it is checked whether all the ERs are met.

From the data format (IFC) is determined which options are available for transmitting data. BuildingSMART (developer IFC) has a transmission manual, called IDM. This manual describes a process to extract the data required in the target program (Vabi) and convert this to verifiable data. Therefore, a use case description and process map are used to discover the required information. Exchange requirements are derived from the process map. The ERs are an overview of data that must be present in the BIM (Revit) to create an EPG calculation. To see if the BIM is suitable for the EPG-simulation, the data in BIM is mirrored with the exchange requirements. The information that is not present in the BIM is manually implemented. This makes the BIM contain all the information required for the simulation.

The standardization of the implementation is done by consistently adding the required parameters, defined in the ERs for the EPG simulation, to the objects in the central library. These parameters are first created in Revit. Then added to the families which are used in new projects. Through a script, the parameter location can be defined within the IFC (object to object). Thus, after the export the information of the ERs is traceable. By implementing ERs in the object library (central position) sequel projects are provided directly with the parameters. The values just need to be adjusted to the project specific situation. By creating a central file for the shared parameters and a library with objects which comply with the ERs, an unambiguous workflow is created.

A complete BIM which complies with the ERs is realized by applying the IDM and creating a content library containing objects with all required information. Because this is based on consistent information, a program can be written which can read the information from IFC. A program written upon IfcOpenShell reads the relation between objects and the position of objects to interpret the system which is applied in e.g. a space. Vabi is able to read these systems and to use them in an EPG simulation. This means that the information can be integrated in a BIM and be used within Vabi. By answering the main question it can be concluded that at the detail level of the EPG-simulation, the link between BIM and simulation software can be realized. The link is developed such that each building, in which the ERs have been implemented and validated, can be used. By applying the method to all the objects which are related to the EPG. The EPG-simulation based on a BIM can be executed. Through application of this link on the other elements of the EPG it is possible to generate the EPC. Because of the universal character of IDM and the application of IFC other software
programs like ArchiCAD and Bentley can also make use of this link. Using the BIM as the basis for the actual construction and the actual calculation secures consistency: what is being built is also what is calculated in the simulation, even when changes in the BIM occur.

BIM should become a central data model where all information can be accessed by a variety of tools dealing with the entire building definition and which should remove the need for a new building model to be developed for each tool [15]. However, there is still a long way to go. This research is trying to be software independent, In the application only one bridge between software is created, the bridge between Revit and Vabi. This demarcation was made in this study for practical reasons. The focus of the study is on the data transfer. The IDM is providing an independent platform. This means that instead of Vabi, the NEN 7120 can also be used as base for the IDM to create ERs for. Implementing of those ERs will provide a BIM which contains information for Vabi, BINK and De twee Snoeken. The interpretation should be made for each of the software vendors to reach their way of data processing.

**Resources**


