Early Stage Energy Refurbishment Assessment Tool for Buildings Using High-End BIM Data: Benefits and Challenges †

Jari Shemeikka, Teemu Vesanen *, Ala Hasan and Teemu Mätäsniemi

VTT Technical Research Centre of Finland Ltd., Tekniikantie 21, FI-02150 Espoo, Finland;
Jari.shemeikka@vtt.fi (J.S.); ala.hasan@vtt.fi (A.H.); teemu.matasniemi@vtt.fi (T.M.)

* Correspondence: teemu.vesanen@vtt.fi

† Presented at the Sustainable Places 2020, Online, 28–30 October 2020.

Abstract: It is important to assess the effectiveness of different energy refurbishment scenarios in the early design stages of apartment buildings. This paper demonstrates the main features of a new tool BIMeaser (BIM Early Stage Energy Scenario - a product of the European Union Horizon 2020 project BIM4EEB), which supports the decision-making process in the early stage of design. The tool uses the BIM and linked data from the BIM Management System (BIMMS) for faster initialisation of the actual state, resulting in more accurate building models. The tool finds solutions in accordance with the client's requirements while also aiming to minimize energy use and maximize the occupant's indoor climate comfort.

Keywords: apartment; renovation; energy performance; indoor climate; building information model; linked data; performance based design

1. Introduction

The concept of performance-based building design implies that the design options available at each design stage are validated against the refurbished building Owner's Project Requirements (OPRs) as well as requirements of the building regulations and local laws. Examples of OPRs are the project design goals, measurable performance criteria, cost targets, etc. This is very important in the early design stages, where the most effective decisions are made relating to the refurbished building's costs and performance. On the other hand, tools are lacking which are capable of easily transferring detailed available data as the input data required by sophisticated energy simulation software. An early stage tool is therefore needed, which should be able to deal with fast handing of the available digital data in order to evaluate both the energy requirements and the indoor climate of the building.

In this paper, we present the structure and features of a new tool BIMeaser (BIM Early Stage Energy Scenario tool). The target of BIMeaser is to speed up the decision making process in an apartment building's refurbishment project by enhancing effective informative discussion of technical design details between experts with different backgrounds in the design team. The aim is to make better decisions regarding the building's refurbishment design that should meet the building owner's project requirements (OPRs). In addition, the tool should be able to enhance the building's energy performance, cost effectiveness and the indoor climate conditions for the residents.

2. Method

Available commercial simulation tools are used to calculate the energy and indoor environment of buildings. However, such simulation tools are normally quite sophisticated. The accuracy of the

input data to such tools is very important in determining the quality of the results produced by these tools. On the other hand, a great deal of digital data could be available, which can be used to supply more accurate data to the simulation model if a connection exists.

In this paper we present a new tool BIMeaser. The main aim of the BIMeaser tool is to compute the effects of different renovation scenarios on the OPRs and thus support the design team in making best decisions. Figure 1 shows the main data flow in this tool [1]. The Building Energy Simulation (BES) data model can provide data to the energy simulator. Ideally the model would enable a common approach for other tools to provide input to energy performance simulation tools. In the BIM4EEB project this is demonstrated via communication between BIMMS (Building Information Model Management System) and the BIMeaser tool. All information in the BIMMS could be received from the BES (Building Energy Simulation) data model while the updated information produced by BIMeaser could be saved back to the BIMMS. Predefined renovation scenarios, e.g., recommended combinations of measures and related cost information, can be fed by the national renovation measure database. The BIMeaser tool is a front-end of the IDA Indoor Climate and Energy (IDA ICE) software (https://www.equa.se/en/ida-ice), which is a commercial dynamic high-resolution building simulation program. The selected renovation measures are applied to the As-Is building model, which is the latest content in the information model. The IDA ICE simulation software computes the indicators for building performance for different selected renovation scenarios, which are validated against the OPRs. Table 1 presents the OPR measures that the BIMeaser tool can calculate. It includes indicators for energy demands (delivered, primary, and renewable shares for heating, cooling and electricity), thermal comfort (accumulated deviations from indoor set-temperatures) and cost (investment, operating and pay-back time), evaluated for each scenario.

The BIMeaser tool was designed as a web application [2]. It was developed and tested in a local web application container (Tomcat). A basic authentication is configured for users in a testing phase. The BIMeaser tool stores its own data into a triple store (Jena database with Fuseki SPARQL endpoint). For each BIMeaser project or building to be analysed, a dataset is created into the triple store. This enables the possibility of defining fine grained access rights to project data. Renovation scenarios are loaded for simulation into IDA-ICE and finally OPRs calculated with BIMeaser are uploaded into BIMMS.

The tool is implemented by Eclipse IDE for RCP and RAP Developers, Apache Maven and Java programming language.
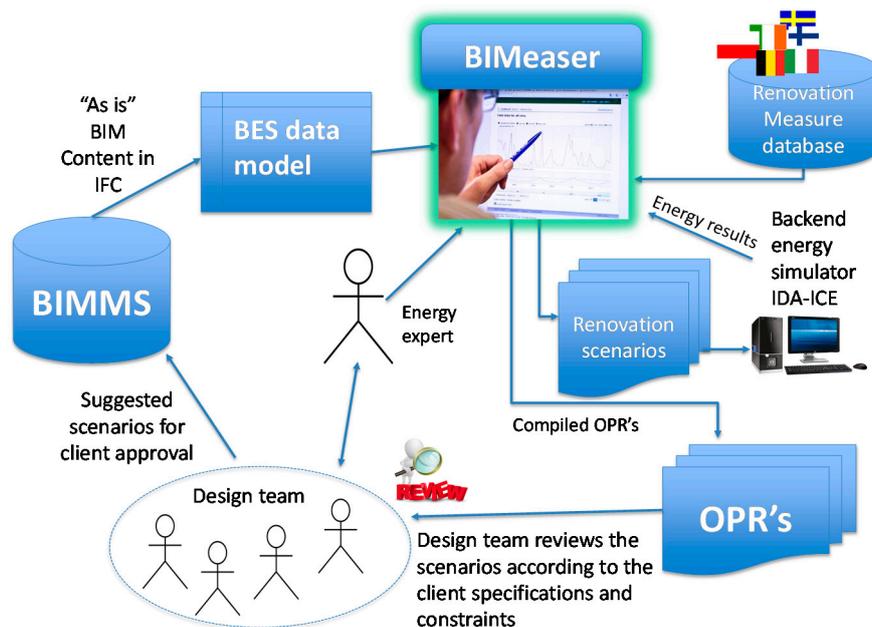

Figure 1. BIMeaser tool main data flow and actors.

Table 1. The Owners' Project Requirements (OPRs) in the BIMeaser tool.

Impact Criterion	Indicator	Unit
energy savings	Delivered energy (purchased) for heating, cooling and electricity	kWh/m^2,a
energy savings	Primary energy	kWh-pr/m^2,a
energy savings	Renewable energy share of solar PV, solar thermal and biofuels	%
comfort	Overheated hours (e.g., hours when operative temperature is over 27 °C or just cooling load)	(-) Number of hours according to criteria for the average zone in building
cost	Total investment cost	(€) Renovation cost of a one scenario, VAT excluded
cost	Operational energy cost	(€/a) Sum of all delivered energy cost items, VAT excluded
cost	Payback time of the energy investment	(Years) Payback time of the energy investment for an individual scenario

3. Implementation

4. Conclusions

This paper presents the features of the BIMeaser tool (BIM Early Stage Energy Scenario tool) developed for the early phase evaluation of residential building refurbishment designs. The tool is able to download IFC models from the BIM Management system (BIMMS) to build the As-Is building model. Predefined renovation measures and cost information can be extracted from the national renovation measure database. The selected renovation measures are applied to the As-Is building model. The tool integrates the detailed dynamic high-resolution IDA ICE software (IDA Indoor Climate and Energy building simulation program) for the calculation of energy demands and indoor air comfort. BIMeaser retrieves the digital data of the building as input to the IDA ICE simulation and the results for selected renovation measures are computed. These results are indicators of the building's energy performance (delivered energy, primary energy, and renewable energy shares for heating, cooling and electricity), thermal comfort (sum of deviations from indoor air set-temperatures) and cost (investment cost, operating cost and pay-back time). These indicators are then compared with reference requirements, the Owner's Project Requirements (OPRs). This can be repeated until an improved design scenario is reached and agreed by the design team members. Therefore, BIMeaser provides an effective collaboration platform for experts with different backgrounds in the design team and can speed up decision making in building refurbishment projects.

The integration of the commercial simulation IDA ICE software with the BIM4EEB set of tools has been successful, although some issues appeared during the implementation. Firstly, there are still non-finalized quality requirements concerning the smooth workflow of data from the baseline As-Is model to the IDA ICE simulator because manual interventions are still required to accurately prepare the model, e.g., in specifying zones in IDA ICE. Secondly, simulation testing with a large demo building model of the project revealed that a detailed building energy model can be time-consuming so that running one simulation may require one to a few hours to accomplish. This implies that testing different renovation scenarios will need several hours and, therefore, it is not a one-meeting task to get sufficient data for decision making by the design team. Thirdly, the current implementation of BIMeaser requires a local IDA ICE license that is accessible to the tool. Therefore the use of the tool is limited to existing IDA ICE customers. However, the IDA ICE company Equa has already shown a demonstration of the Equa cloud that will be available in the future. If it includes similar programming interfaces as the local version, it would open the possibility of using BIMeaser with a wider group of people. All these issues will be thoroughly studied in the next tasks of the project when the BIMeaser tool will be subjected to further tests and analyses of exploitation potential.

Therefore, the benefits and challenges of the BIMeaser tool can be described briefly as follows: Benefits

1. The tool allows accurate build-up of the As-Is model of the building's energy and indoor climate using the BIM and linked data in the early design stage, when the building's most important design decisions are made.
2. It allows easy application of different renovation scenarios to the As-Is building, which is backed up by predefined renovation measures available in the connected national database.
3. The tool enhances collaborative work inside the design team using advanced energy and indoor climate modelling software. This is important for a buildings' design, which is a multi-domain task that should always be a collective work among the design team members.

Challenges

1. The accuracy of the BIMeaser tool relies on the availability of good quality BIM data on the renovated apartment building. However, this typically lacks digital documentation; in addition, available blueprints of the design are normally outdated, which will require a time-consuming manual build-up of the BIM (3D-CAD redraw).
2. The required time for running detailed simulation of large multi-zone apartment buildings models can be significant, which may hinder the intended fast collaborative teamwork.

References

1. Vesanen, T.; Shemeikka, J.; Hasan, A.; Shaun, S. List of Designers' Needs and Requirements for BIM-Based Renovation Processes, BIM4EEB Deliverable D2.2 (Public Report). Available online: https://www.bim4eeb-project.eu/reports.html (accessed on 7 January 2021).
2. Mätäsniemi, T.; Shemeikka, J.; Vesanen, T. Decision Support Tool, BIM4EEB Deliverable D6.6 (Confidential Software), 30.6.2020. Please Contact BIM4EEB Coordinator if Interested. Available online: https://www.bim4eeb-project.eu/contact.html (accessed on 7 January 2021).