Development of an IFC-based IDF Converter for Supporting Energy Performance Assessment in the Early Design Phase

Inhan Kim1, Jieun Kim2* and Jongcheol Seo3

1 Professor, Dept. of Architecture, Kyung Hee University, Korea
2 Master Course, Dept. of Architecture, Kyung Hee University, Korea
3 Research Professor, Dept. of Architecture, Kyung Hee University, Korea

Abstract

Currently, Building Information Modeling (BIM) has been recognized as one of the main processes and technologies that can enhance design and construction quality by simulating and optimizing business works for better performance, lower costs, and shorter lead times. Accordingly, BIM has emerged as one of the main issues of environmentally friendly and energy-efficient design in the field of architecture. In particular, several researches on BIM-based energy performance assessments have been carried out focusing on the early design phase. However, energy performance assessment tools have a fundamental problem concerning data interoperability among them owing to the lack of a standardized data format and access method.

To address such issues, an Industry Foundation Classes (IFC)-based Input Data File (IDF) converter was developed in this research to use as a middleware to minimize the loss of information and generate additional information during the performance analysis process. This paper introduces the IDF converter supporting energy performance assessments, integrated material library, etc. and demonstrates the efficiency of its use in a case study.

Keywords: Building Information Modeling (BIM); energy performance assessments; Industry Foundation Classes (IFC); Input Data File (IDF)

1. Introduction

In response to the increasing severity of environmental pollution, a call has been issued for environmentally friendly, energy-efficient designs that minimize carbon emissions. Accordingly, the adoption of Building Information Modeling (BIM) in the construction industry has been investigated for various energy performance assessments in the early design phase. BIM can now house all of the information created during the change from 2D to 3D design. It can also be used for pre-checking, cost estimation, quantity takeoff, energy analysis, and other types of assessments during the building design phase (Eastman et al., 2008). Specifically, an energy performance assessment is performed in the early design phase by 3D simulations based on a theoretical analysis of parameters such as CO₂ emissions, heat loss analysis, and so on.

However, despite its advantageous properties, the data interoperability of BIM with other software packages remains incomplete, which makes energy assessments somewhat subjective (Augenbroe et al., 2003; SmartMarket report, 2007; Dong et al., 2007). The subjectivity of these assessments in BIM is due to the absence of a standard format and differences in data structure among the various types of analysis software. In the absence of specific, elaborate guidelines, limitations in data synchronization due to differences in data formats and software interfaces often cause users to be distrustful of energy assessment results (Crawley et al., 2005).

This research focuses on the development of a standard system for BIM data for use in the early design phase to alleviate data interoperability problems in energy performance assessments. The purpose of this study is to develop a data converter that enhances data interoperability by supplementing information and preventing losses before IFC BIM data reaches the energy analysis tool.

This paper is organized as follows: Section 2 explains problems related to BIM-based energy performance assessments and proposes a method to achieve data interoperability. Section 3 explains the process for choosing a primary software and data format to support the development of a converter.
and defining parameters for energy performance assessments. The interface of the IDF converter is also described in Section 3. In Section 4, the IDF converter is illustrated in the context of a case study used to verify the converter's performance and the results are detailed. Finally, Section 5 suggests alternative future studies for the IDF converter.

2. BIM-based Energy Performance Assessment

2.1 Overview

In the early design phase, an energy performance assessment is performed to give the architect and the owner ideas concerning the energy efficiency of the planned structure using estimated energy consumption data. BIM can be used to assess the energy performance via 3D modeling energy simulations according to the purpose of users, and so on.

The energy performance assessment analyzes sunlight and shadow, building orientation, air-related variables, thermal comfort, and so on, at each level of the building design. The development of advanced technology in the construction industry and the reorganization of environmentally friendly construction are regarded as some of the most effective points of the BIM-based construction process (Moon et al., 2009).

2.2 Problem statement

Currently, many methods and tools are available to analyze building energy efficiency; however, the algorithms supporting them and the energy analysis tool environments have not been interconnected because of their proprietary specified characteristics (Kumar, 2008, Schlueter et al., 2009, Bazjanac, 2005). Data loss can occur during the interoperability process of conversion between different software and data formats. These problems decrease the objectivity and accuracy of energy analysis results to both the owner and the architect. Furthermore, the gap between the simulated energy performance assessments and the real energy assumptions of a building in the maintenance phase leads to inaccurate BIM-based energy analysis results (Maile et al., 2007).

The majority of the studies referenced suggest solutions that involve comparing the properties of the existing data formats and tools for energy performance assessments. Development of new software and new methodologies for energy analysis has also been proposed. Here, the authors suggest the development of a converter that exports building data from the BIM modeling tool into a format compatible with energy analysis tools. The materials of the building object are one of the most important factors for energy analysis. However, even though users define the building materials in the BIM modeling tools, the materials must be input again in the energy analysis tools. This converter can be an alternative solution to problems involving data interoperability.

3. Development Process for Supporting Energy Performance Assessments

The aim of this study was to develop an IFC-based IDF converter for energy performance assessments in the early design phase. Software and data formats are chosen and parameters for energy performance assessments are defined in this section. The materials of a building are listed based on Ashrae_2005_Material, a material template for one of the selected software packages as a solution to data interoperability issues. Finally, the IFC-based IDF converter is developed.

3.1 Software and data format for energy performance assessments

3.1.1 Software

Recently, various energy analysis tools have been developed for energy performance assessments. As previously mentioned, each system and analysis environment yields different results from the same building information, thereby creating uncertainty for users regarding the accuracy of the results. This research analyzes the following three representative BIM-based energy analysis tools:

• IES/VE (IESVE, 2011): This tool is an integrated set of all applied programs required for building energy analysis, developed by a British company. This tool has a proprietary modeling format and various
building energy analysis functions, such as heat loss, heat gain, natural sunlight, HVAC systems, and solar access rights with importing Green Building XML (gbXML) files.

- Ecotect (Autodesk, 2011): This tool supports the IFC and gbXML data formats, and is usually used to analyze energy performance in the design visualization and development phase. This tool is compatible with CAD-based rendering programs and can perform building modeling and material mapping in a 3D interface.

- EnergyPlus (EnergyPlus, 2011): This tool has the advantage of the DOE-2 engine and BLAST, and can be used to calculate energy consumption using annual weather data via an interface; it can also be used to analyze HVAC systems, heat balance loads, heat airflow in multiple zones, natural sunlight, and solar access rights. It also supports the IDF data format.

The EnergyPlus system in the tools mentioned above is more detailed and diverse with respect to building energy performance assessments. It is highly accurate and is free to use. EnergyPlus can also be developed and expanded for a range of applications and purposes utilizing main engines.

The process of energy performance assessment can be divided into three steps as follows:

- Design phase – Create the BIM model using a BIM modeling tool.
- Middle-ware phase – Convert to an IDF file with the IDF converter after exporting the IFC file from the BIM modeling tool.
- Energy analysis phase – Analyze the energy performance after the IDF file is exported from EnergyPlus.

### 3.2 Parameters for energy performance assessments

The parameters for energy performance assessments are classified into three phases based on the inputting properties of EnergyPlus. These parameters are discussed in detail in Section 3.3 for the IFC-based IDF converter and its interface. Table 2 shows the high-level parameters for each phase.

### 3.1.2 Data format

The typical data formats used for general interoperability between BIM modeling tools and energy analysis tools are IFC and gbXML. Table 1. shows a comparison of data interoperability among diverse BIM-based software packages with building data created in ArchiCAD and Revit (Dong et al., 2007; GSA, 2007).

gbXML is a data format developed specifically for energy performance assessments. Because it is supported by the main BIM-based modeling tools, it has been developed into an industry-standard schema to improve integrated modules. IFC is an international standard data model advocated by the International Alliance for Interoperability (IAI) and is used to exchange and share building data in BIM-based tools. Although it contains a large amount of data, IFC is not specialized for a specific part like gbXML which is specialized in energy.

Research indicates that the IFC format is more interoperable with ArchiCAD and Revit than gbXML is. IFC can be used not only with energy analysis tools, but also with BIM-based tools, which is useful over the entire building life cycle. As IFC continues to be developed as a standard data format, data interoperability between many types of BIM-based tools becomes more feasible. Furthermore, IFC contains a free-form representation. Thus, the IFC data format is more effective than gbXML in terms of data interoperability for energy performance assessments over the entire building life cycle.

### 3.2 Parameters for energy performance assessments

- Design phase
  - Material
  - Material Infrared Transparent
  - Material Air Gap
  - Window Material: Glazing
  - Window Material: Gas
  - Construction
  - Zone
  - Building Surface: Detailed
  - Fenestration Surface: Detailed

- Middle-ware phase
  - Version
  - Simulation Control
  - Building
  - Timestep
  - Surface Convection Algorithm: Inside
  - Surface Convection Algorithm: Outside
  - Heat Balance Algorithm
  - Site: Location
  - Site: Ground Reflectance
  - Global Geometry
  - Site: Ground Temperature: Building Surface
  - Site: Building Surface

- Energy analysis phase
  - Heating & Cooling Loads
  - HVAC Template: Thermostat
  - HVAC Template: Zone: Ideal Load Air System
  - Thermal Comfort – PMV
  - People

There are nine categories in the design phase; some of the parameters entered in EnergyPlus are highlighted in a dark color in Fig.2, because input is impossible.
The reorganized Ashrae_2005_Material list with standard codes for energy analysis. Fig. 3. shows part of the building industry. A total of 270 materials are used in the energy analysis tool. Fig. 4. The IDF converter can save time for the user by avoiding the re-entry of material data during the design phase. However, most of these parameters were not confirmed as properties in the 3D modeling tools (Revit and ArchiCAD) differs significantly from the EnergyPlus Ashrae material list.

The authors assigned unique codes to each material to generate an integrated library. Using this library, material data and properties (roughness, thickness, conductivity, density, and specific heat) can also be converted when building data is exported from the BIM modeling tool to the energy analysis tool. The integrated material library also provides a reference that helps users to identify relevant materials and input its corresponding code during the design phase. These material data can be re-identified and revised in the IDF converter. Thus, this process is effective for preventing the loss of material data that has been input into the BIM model and also eliminates the need to re-enter it in EnergyPlus.

### 3.3 IFC-based IDF converter

#### 3.3.1 Overview

The IDF converter is a middleware tool that converts BIM-based data designed for energy performance assessments to data that can be applied to a final energy analysis tool. The development language and tool used were Microsoft Foundation Class and Visual Studio 2008, respectively. IFCEngine.dll was used to import the IFC files, and OpenCascade was used for 3D building visualization.

Revit and ArchiCAD were chosen to enable export to the IDF converter. This process is effective for preventing the loss of material data that has been input into the BIM model and also eliminates the need to re-enter it in EnergyPlus.

![Fig.3. Integrated Material Library with Codes](image-url)

Their corresponding codes. It is evident from the figure that the default material list of the BIM modeling tools (Revit and ArchiCAD) differs significantly from the EnergyPlus Ashrae material list.

The authors assigned unique codes to each material to generate an integrated library. Using this library, material data and properties (roughness, thickness, conductivity, density, and specific heat) can also be converted when building data is exported from the BIM modeling tool to the energy analysis tool. The integrated material library also provides a reference that helps users to identify relevant materials and input its corresponding code during the design phase. These material data can be re-identified and revised in the IDF converter. Thus, this process is effective for preventing the loss of material data that has been input into the BIM model and also eliminates the need to re-enter it in EnergyPlus.
3.3.2 Main function of the IDF converter

The user interface of the IDF converter was initially composed of five tabs based on the three phases defined in Chapter 3.2.1. The tabs were labeled "design information," "middleware," "schedule," "analysis function," and "system," as shown in Table 3.

The material input box is shown in Fig.5. First, material information delivered from the software was mapped to the material list, which was already implemented in the IDF converter. Next, it was recognized in EnergyPlus after organizing composites by basic material and modifying the general material properties to those contained in this paper. The organization of the IFC 3D viewer promotes user understanding by identification of the building object visually.

4. Validation Test

The authors performed a sample validation test of the IDF converter to verify its performance in the context of an energy performance assessment. The sample building was designed by Revit Architecture in 2011 and the building materials used in the test were selected as Wood in the integrated material library.

4.1 Verification scenario

The validation test was performed for IFC data and was based on the library in the design tool organized according to the material coding system (Fig.6.). The sample building had five floors and was composed of an external wall, slab, roof, window, and door as minimum essential components for energy analysis. Each external wall was randomly assigned
one of the wood materials listed in the integrated material library mentioned above. Finally, the building model was imported into EnergyPlus in the IDF data format via the IFC-based IDF converter. The final external wall material was compared with the material indicated in the modeling phase.

4.2 Results

The building data transferred via the IDF converter was converted as a result of recognition of the external walls of five floors based on the assigned wood material codes.

Some general problems were encountered, such as difficulties during the energy performance assessment when a user investigated the material parameters and reentered them correctly. Some of these problems were resolved by the validation process (Fig.7.) with mapping codes of the materials. However, some new problems were encountered in the integrated material library application and IDF converter validation processes.

The first problem was that users were confused by the entry of the same essential parameters and the data presentation in the different software environments; this was due to the absence of standard guidelines for modeling. The second problem was related to the zoning of space, which is the most important issue in energy analysis. The IFC zone data exported according to the drawing software's space zoning method was read incorrectly and caused problems because the relationships between the spaces and the connected building objects were not translated correctly. Finally, the integrated material library had limited application to the Korean architectural practice because it was made by Ashrae Material, which is an international standard.

4.3 Discussion

Through the above validation, the authors discovered three main types of issues that should be addressed in the development of the IDF converter. Solutions for these problems will be identified in future work.

• Modeling Guidelines – The lack of BIM modeling guidelines (which could be standardized for energy performance assessments) confused users and resulted in inefficiencies. Future studies should be conducted to develop guidelines specific to the software properties. Such guidelines could be used to organize the entire process from 3D modeling to IDF converter use.

• Space Boundary – Space boundary performs an important role in determining the spatial orientation of building objects. The space boundary had different levels of awareness according to the modeling methods and the software environment. For accurate energy performance assessments, a space boundary corresponding to its properties should be defined after analyzing the relevant studies (Lam et al., 2003; Bazjanac, 2010).

• Integrated Material Library (coding system) – Because the existing integrated material library was developed based on the Ashrae material guide, it cannot be used effectively in the Korean construction industry. The integrated material library should be updated to include the material classification systems that are widely used in Korea,
and the names of all materials should be translated into the Korean language for well-suited use.

5. Conclusion

In the construction industry, energy analysis simulations (which occur in the early design phase using BIM technology) have been the focus of much research because of the increasing importance of environmental concerns. However, in most energy performance assessments, data interoperability is difficult to achieve between different software packages owing to the lack of a standardized data format and access method.

To address the problems mentioned above, the authors developed an IDF converter, which is a BIM-based tool that can convert data between the IFC and IDF formats. Thus far, they have developed parameters for each phase of the energy analysis and developed a material library that includes the material lists of multiple software packages. After this, the IDF converter was developed, and the converter was then validated by applying some of the material code. As a result, space boundary definitions that reflect both current research and BIM modeling guidelines can be used in the developed IDF converter, and this provides a possibility for supporting energy performance analysis and assessments in BIM use.

Further research efforts will be made to resolve and improve issues discussed in Section 4.3. In detail, an additional material coding system needs to be developed in the future, and the mapping of materials between software must be made more efficient. Furthermore, the functions and performances of the IDF converter should be improved in order to be most efficient based on its use.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2011-0029852).

References

1) Eastman C., Teicholz P., Sacks R. and Liston K. (2008) BIM Handbook, 1st ed. USA, Wiley & Sons.
2) Augenbroe G., de Wilde P., Moon H.J. and Malkawi A. (2003) The design analysis integration (DAI) initiative, Proceedings of the 8th IBPSA Conference, Netherlands, pp.79-86.
3) SmartMarket Report (2007) Interoperability in the Construction Industry, McGraw Hill Construction.
4) Dong B., Lam K.P., Huang Y. C., and Dobbs G.M. (2007) A comparative study of the IFC and gbXML informational infrastructures for data exchange in computational design support environments, Building Simulation, pp.1530-1537.
5) Crawley D.B., Hand J.W., Kummert M. and Griffith B.T (2005) Contrasting the capability of building energy performance simulation programs, United States Department of Energy and University of Strathclyde and University of Wisconsin.
6) Choi J.S., Kim J.E. and Kim I.H. (2010) Development of open BIM-based construction for energy performance assessment in the design phase, Proceeding 2010 BIM academic Conference on buildingSMART Association, Gangwon, Korea.
7) Moon C.Y., Choi M.S. and Park S.H. (2009) A case study on BIM based building energy performance evaluation, 29(1), pp.697-700 (in Korea).
8) Kumar S (2008) Interoperability between building information models (BIM) and energy analysis programs, Master Thesis, USA: Faculty of the School of Architecture, University of Southern California.
9) Schluerter A. and Thesseling F. (2009) Building information model based energy/exergy performance assessment in early design stages, Automation in Construction, 18, pp.153-163.
10) Bazjanac V. (2005) Model based cost and energy performance estimation during schematic design, Conference on Information Technology in Construction, Dresden (Germany).
11) Maile T., Fischer M. and Bazjanac V. (2007) Building Energy Performance Simulation Tools - a Life-Cycle and Interoperable Perspective, CIFE Working Paper 107, Stanford University.
12) IesVe Inc. (2011) <http://www.iesve.com/software/ve-pro>.
13) Autodesk Inc. (2011) Autodesk Ecotect Products <http://usa.autodesk.com/adsk/servlet/index?id=12602821&siteID=123112>.

14) Energy Efficiency and Renewable Energy (2011) EERE EnergyPlusProducts <http://apps1.eere.energy.gov/buildings/energyplus/energyplus_about.cfm>.

15) GSA (2007) National 3D-4D BIM Program, Warroad Border Station Pilot Study <http://www.gsa.gov/bim>.

16) Lam K.P., Wong N.H., Shen L.J., Mahdavi A., Leong E., Solihin W., Au K.S. and Kang Z.J. (2003), 8th International IBPSA Conference, Netherlands, Building Simulation, pp.697-704.

17) Bazjanac V. (2010) Space boundary requirements for modeling of building geometry for energy and other performance simulation, 27th International Conference, Cairo (Egypt), CIB W78.