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Suggestion of the Core Element Technology to Improve BIM Data Interoperability Based on the Energy Performance Analysis

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Abstract

To apply the BIM technology to the construction domain, it is necessary to prepare the environment before the development of the applied technology. This study focuses on the requirements for applying the BIM technology to the energy domain in various construction domains. The purpose of this study is to suggest the core element technology based on the BIM data interoperability among the requirements for the BIM-based energy performance analysis. To achieve this purpose, the authors have investigated the advantage of the BIM-based energy performance analysis through a comparison with the traditional energy performance analysis and suggested requirements for energy performance analysis in the open BIM environment. In addition, the authors have suggested a configuration plan of the core element technology to improve the BIM data interoperability. Architects can use the existing data to find the best design alternative that optimizes the building energy efficiency without extra modeling work for the energy analysis using the suggested BIM technology in this study.

Keywords: *Building Information Modeling (BIM), Energy Performance Analysis (EPA), Data Interoperability, Industry Foundation Classes (IFC)*

1. Introduction

Statistics show that the construction sector takes 23% of the overall energy consumption, which emphasizes the necessity of the building energy performance analysis as part of the national policy. Buildings introduce social and economic profits during their life cycle but cause serious environmental destruction because of the use of energy, water and other natural resources. Such destruction must be minimized for a green society [1]. Thus, the importance of the concept of green buildings, which can reduce energy consumption, is internally and externally on the rise and is a national issue.

Building Information Modeling (BIM) to build green buildings, which can efficiently use the information in the construction industry and variety energy performance analysis of buildings, is possible in the early design phase. BIM can change 2D-based designs to 3D-based designs and generate and manage the overall information, which is generated during the life cycle of the building. It can provide the prior review, cost estimate, quantity take-off and energy analysis from the building design phase [2]. The energy performance analysis using BIM significantly reduces the time and cost because the BIM data model contains more than 70% of the information for the building energy analysis [3]. In particular, if the energy performance analysis is possible in the early phase of design changing, the design efficiency can be expected to be comparable to the design

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alternatives of energy aspects. Currently, the alternatives are consistently presented for BIM to be in such an environment. However, the energy performance analysis in the current environment of open BIM remains difficult to perfectly apply because of the uncertainty, lack of initial building input data and lack of interoperability between the BIM software and the energy performance analysis programs [4-6]. To solve these problems, we deduct the requirements for the energy performance analysis in the open BIM environment and suggest the method to solve it; then, the energy performance analysis will become actively accurate and effective in the BIM environment.

The purpose of this study is to maximize the effectiveness of BIM in the field of green buildings and identify the environmental conditions and requirements in the design phase to effectively evaluate the energy performance analysis in the BIM environment using the core element technology, so that the BIM data interoperability improves.

2. Energy Performance Analysis in the openBIM Environment

2.1. Concept of BIM

The construction industry is composed of various areas and calculated variety information, which includes the information from the pre-stage and required information for the present stage through every step in the progress of the project. BIM express the attributes of each property (function, structure, use) of an intelligent building element (wall, slab, door, window, roof, stairs, *etc*.,) using parametric techniques; then, BIM recognizes their relationships to each other and immediately reflect the change elements of the building. BIM enables one to analyze the data considering the structure and energy and provide information on the quantity, cost, schedule and material list for rapid decision-making in the process of a construction project because it can be obtained by calculation or simulation using all data attributes, relationship and information in the building object [7]. Thus, the BIM representation information and property information to represent the architectural information and the property information, which includes the name and materials in the building objects and attribute information (*e.g.*, building material's thermal transmittance information for the energy performance analysis), can be applied in various fields. The characteristics of BIM enable more effective energy performance analyses in the BIM environment, and it is necessary to construct the details of requirements based on the objections to activate. The Open BIM environment can be data-interoperable between the softwares through a neutral format such as the Industry Foundation Classes (IFC) [8].

2.2. Overview of the Energy Performance Analysis

The general energy performance analysis process may cause erroneous interpretation when relevant information such as drawings, photos, and other project information is manually entered for the energy model. The, when the design of the building is changed, the energy model must be separately changed, which creates additional work for the architects and engineers [9]. In the BIM environment, the building data can include various parameters such as the representation information, construction type, and thermal properties of the building for the energy performance analysis, which saves time and increases the accuracy compared to the existing process, and the analysis result can be quickly reflected [2].

The architects create a BIM data model after the design using the BIM software for the energy performance analysis in the BIM environment. The created model is transferred to the energy analysis software and exported as an IFC file type. At this time, the BIM data include the parameters for the energy performance analysis, such as the shape information, construction type, and thermal properties of the building. This information is directly or indirectly imported from the energy analysis software, and the rating of the energy

analysis performance is feedback to the architects to be reflected in the design alternatives. Thus, the absence of data interoperability of the energy performance analysis software is notably important for the reliability of the result of the energy performance assessment.

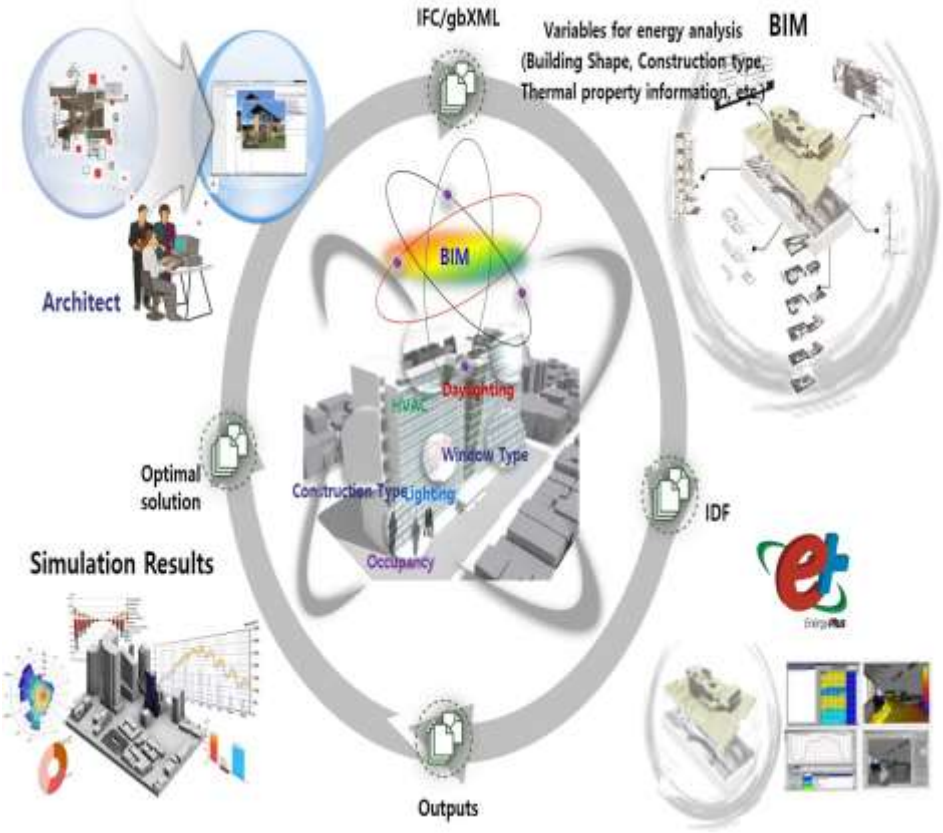

Figure 1. Example of Energy Performance Analysis in the BIM Environment

2.2. Case Study

The concept of eco-friendly construction is an internally and externally national issue, and BIM practices are a growing trend in the energy performance analysis depending on the activation of BIM.

(1) Build London Love 2008

The collaborative design competition spanned 48 hours in June 2008 at London. The BIM technology was applied in the design process from the initial planning stages. Figure 2 is an example of the energy analysis result of the competition winners. The example was the energy performance analysis by Ecotect. The monthly flow of prevailing wind through annual meteorological data, solar radiation analysis based on the annual insolation, analysis of the wind direction and wind speed, sun shadow pattern analysis, daylight factor analysis and natural light were evaluated in detail. In the prize design step, which was optimized for the design purpose, the land and prize design selected the alternative method of pre-analyzing the amount of energy in the building throughout the design phase with the BIM technology [10].

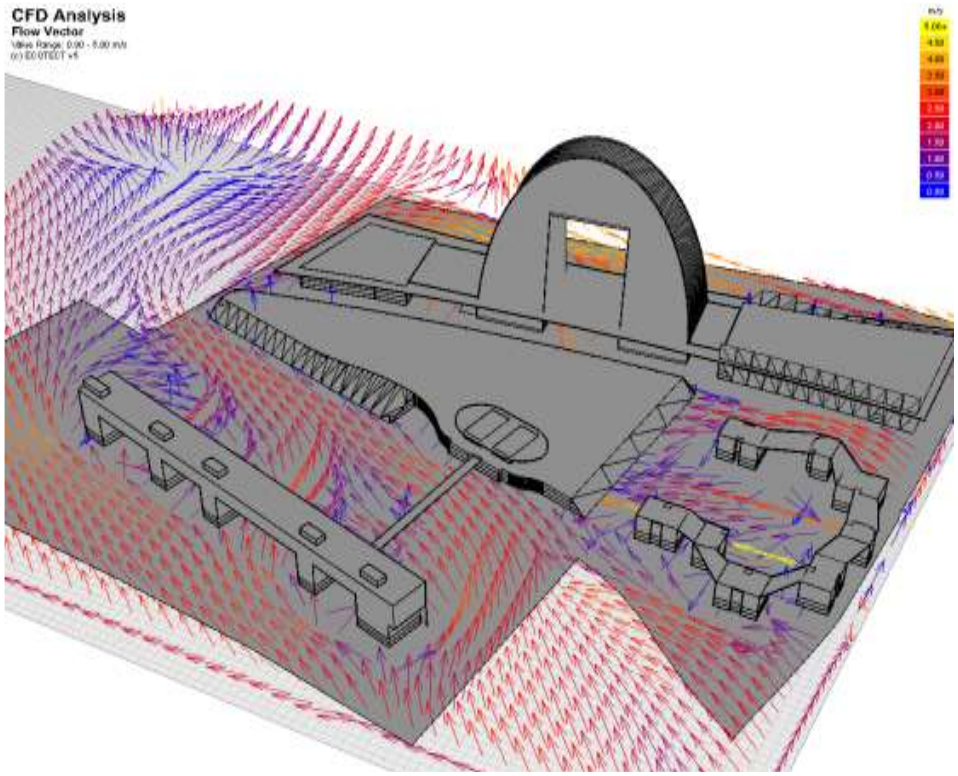

Figure 2. Example of Energy Analysis Result

(2) Norway – International Competition of National Art Museum

An automatic model validation and quality control was run in the BIM model International competition examination step 1. The area of the building surrounded by the external wall and slab was automatically calculated according to the reference value of the thermal resistance of the heat loss using by the self-developed EDMmodelServerLite, which performed the energy performance analysis of the BIM model [11].

(3) Korea LH Corporation – Design Competition in District 3, Unjeong, Paju

The first-order Design Competition applied BIM in 2009 to analyze the energy performance of the perimeter of the building airflow, sun shadow of the final placement, sight of each household, sun shadow in the complex, energy and CO_2 emissions, and energy efficiency rating of the building by introducing the BIM in the early design phase [12].

(4) Korea DGIST – Masterplan and Design

In this project, the BIM modeling standard for energy analysis was applied to an envelope model, which included the exterior wall, slab, roof, window and shade. The submission target is the IFC file that transformed the envelope model, material characteristics of each building component, and thermal zone information. Basic modeling was performed using the BIM software, and the energy analysis was performed using the DOE-2 loaded software to reflect the submitted material characteristics and thermal zone information [13].

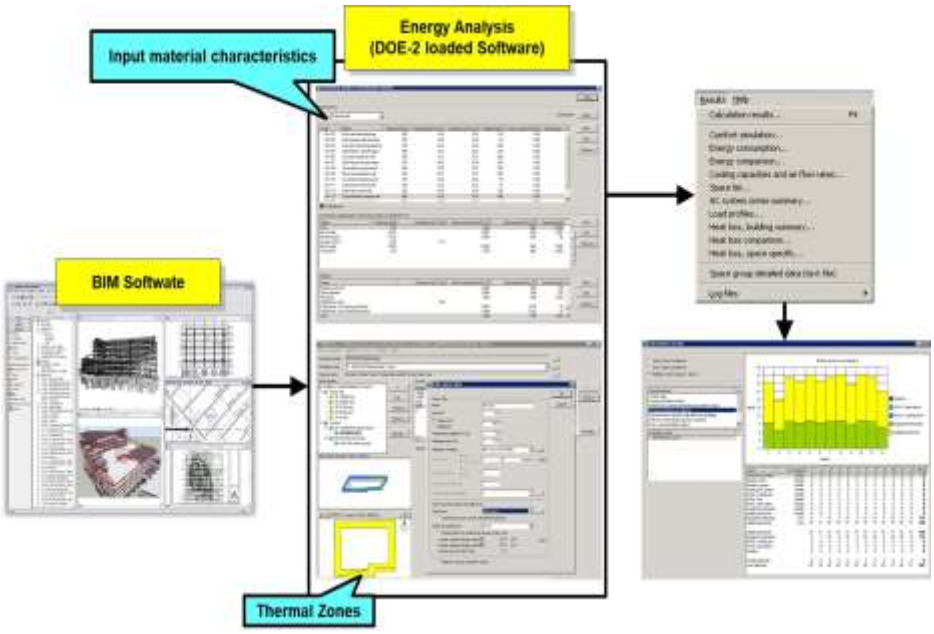

Figure 3. Energy Efficiency Process

(5) Korea Power Exchange (KPX) – Design Competition for head office relocation

A design review report was submitted on eco-friendly construction, and a BIM model was written in the original format and IFC2x3 format. The visual check, functional quality check, and energy efficiency analysis proceeded [14].

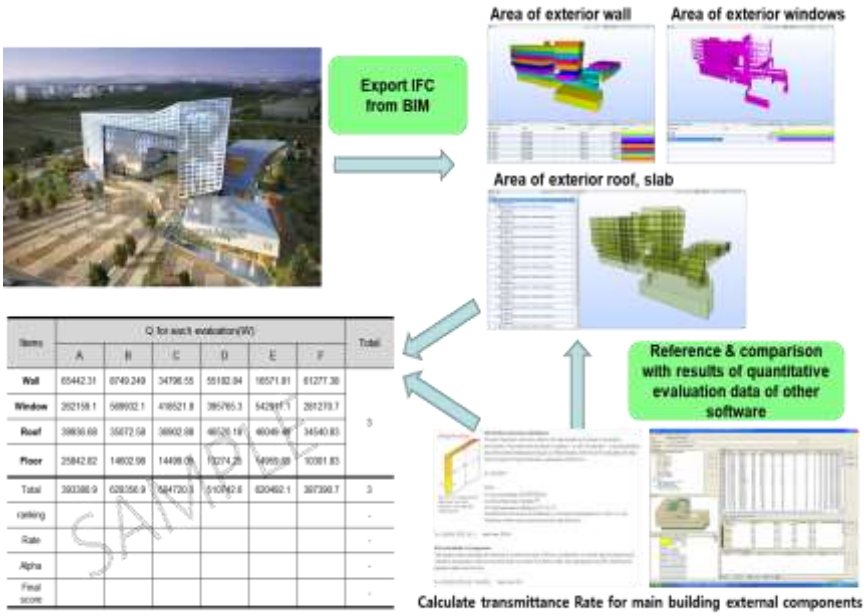

Figure 4. Energy Assessment Method of Envelope Model

(6) Public Procurement Service (PPS) – BIM guidelines

The PPS was announced "BIM guidelines" in 2010 to provide BIM work on the standards in Korea. This guide is under revision and has been defined using BIM to review the design stage of the energy efficiency. The PPS guide is notably important

because it is mandated to apply the BIM to official business construction design in total service [15].

Table 1. BIM Application Criteria for Energy Efficiency Check in the PPS Guideline

Design phase	Schematic design / Design development	Detailed design
BIM application criteria	Summary energy efficiency check (optional)	Energy efficiency check (optional)
Scope	Heat load analysis through heat gain and heat loss of building envelope	Load analysis through dynamic energy simulation
Method	- Use of Energy plus or DOE-2 based software - Do not reflect performance of individual material and equipment system	- Use of Energy plus or DOE-2 based software - Input of location, envelope, thermal zone, use profile, ventilation/ infiltration

3. Requirements of BIM Environment for Energy Performance Analysis

The requirements for the energy performance analysis in the open BIM environment theorem separated by creating of BIM data, using BIM software and application and verification of BIM data. Then, specific details are identified about the necessity, and measures are applied for each requirement.

3.1. BIM Data Creation

(1) BIM usage scenarios

A common standard must be provided through the development of scenarios in each step and scope for an efficient energy performance analysis of the buildings. To achieve this purpose, the work considered in the energy performance analysis phase is defined, and detailed use is devised through comparison and analysis between the existing work process and the BIM work process. Various work process analyses based on BIM can be confirmed through IDM for the Architectural Design to Building Energy Analysis (BEA) provided by buildingSMART International. In Korea, the Energy Plus suggested software to examine the energy efficiency in the PPS guideline can define the design variables for each energy performance analysis target. Therefore, the rules of law, software representation and common business rules must properly reflect the related BIM properties for the heat loss case.

(2) BIM model requirements

The necessary guideline for standardized modeling in the BIM data creation phase must suggest for Open BIM invigoration, effective application and evaluation. The modeling standard is compartmentalized into common standard and detailed standard for a specific purpose. The common standard consists of basic contents for the BIM model creation, and the detailed standard consists of related contents per specific purpose. At this point, specific contents can have discrepancies for the energy performance analysis target and purpose or properties of detail and level of detail (LOD).

Nowadays, the Common BIM model guideline is consistently developed but slightly focuses on the domestic and foreign energy performance analysis. A BIM model guideline with input variables of specific definitions must be developed because the

energy performance analysis requires specific information and function [16]. Figure 5 explains the energy analysis results by BIM model standard (Common BIM Requirements 2012).

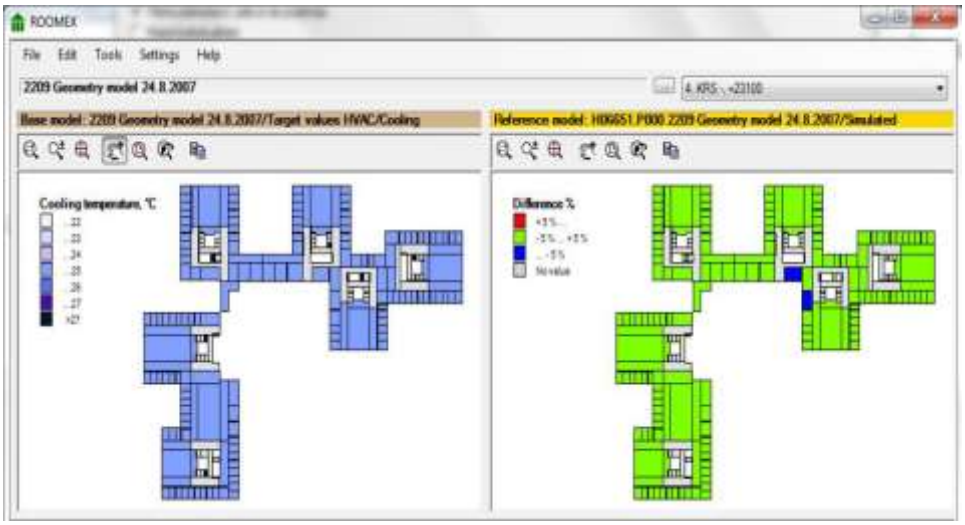

Figure 5. Utilization of an Energy Analysis Results in BIM-based Guide

(3) BIM Property System

Many input variables such as material properties (Wall, Windows, Slabs *etc.*), building types (Light, Medium, and Heavy), building geometry information, location, weather data, building operation scenarios and others are required for the common energy performance analysis. Nevertheless, the required input variables have different property information systems from the standard for BIM assessment, which makes the energy analysis imprecise. Therefore, a specific property mapping system among energy performance analyses must be constructed, and the BIM object properties can make the energy performance analysis in the BIM process accurate. In particular, it must connect the building object properties and BIM software representation via mapping in the energy performance analysis assessment.

3.2. BIM Data Software Application

(1) BIM data interoperability system

The software-supported energy performance analysis is dissembled to support BIM data, which causes the problem of standardized data interoperability or partial data lost. Therefore, the BIM data interoperability system must be analyzed to solve the problems of decreasing objectivity and accuracy. To achieve this goal, the data interoperability system must analyze individual cases because of the representation of the purpose and composition of each software. The energy performance analysis is based on gbXML, but an interoperability discussion about softwares that support the IFC of BIM data representations is necessary [5].

(2) openBIM supporting visualization system

To check the energy performance analysis object and result, an energy performance analysis assessment visualization system must be developed. The system must support the BIM data information and visualization function of property information for the energy performance analysis assessment. Furthermore, a converter must be developed to solve problems using the existing method in a BIM data interoperability system.

3.3. BIM Data Verification

(1) Verification through the energy performance analysis module

There is a verification process for the application target, scope, method, etc. of the energy performance analysis in the BIM process. If problems are found in the verification, the process to solve those problems must be included in the feedback. Furthermore, an analysis module that can support the required conditions and the openBIM supporting viewer must be verified for the more specified and automated energy performance analysis assessment.

(2) Verification in business practice

The initial stage is to verify the functional implementation of the system through various sample BIM models. In the longer term, the result of the energy performance analysis methods and development system on BIM must be verified by applying to actual buildings in the BIM process. Related fields must be induced by verifying various BIM-based energy performance analysis assessments and the increase in BIM standard and energy simulation usability.

4. Core Element Technology for BIM Data Interoperability Improving

The Open BIM environment must be established and can be applied at the level of initial research for the energy performance analysis. The procedure contains proposing to interoperable system BIM data, establishing the BIM property, and developing a converter to support the data transformation. The details are as follows.

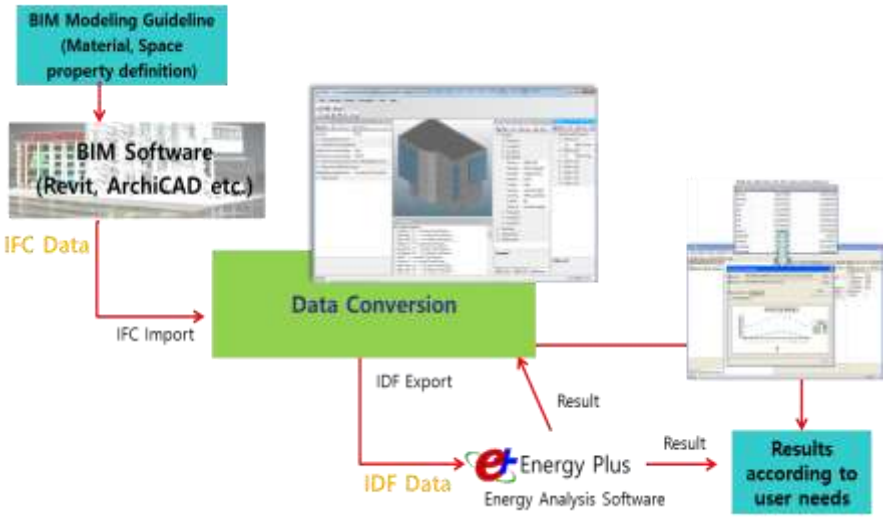

Figure 6. Process of Energy Performance Analysis in the BIM Environment

4.1. BIM Data Interoperability System

There are two types of energy performance assessment processes: the design phase to create BIM data using the BIM software and the energy analysis phase to apply the design phase and energy analysis software. In the design phase, many softwares are domestically used, such as ArchiCAD, Revit and Digital Project. In the energy analysis phase, Energy plus, Ecotect, IES/VE, Riuska, etc. are used for various goals. Normally, IFC and gbXML are considered for the interoperability, but the IFC international standard data format in the Open BIM environment is focused in this study. Furthermore, the selected energy

performance analysis data format is the IDF format of Energy plus, which is suggested by the software PPS.

The IFC file includes the building representation information, material information and others to analyze the energy performance in the design phase. However, partial IFC information is transferred to Energy plus. In the transferring process, the import of different property systems for each energy performance analysis software introduces confusion because there is no standard data interoperability system. Therefore, in this study, a middle process between the design phase and the energy performance analysis phase is suggested to supplement the information loss and create additional information.

4.2. BIM Property System

The material property of the energy performance analysis in the design phase is compatible with the partial representation information and material property information because of different definitions of the software. Therefore, we suggest a method to add the material information that has representation and material property in the integrated material library [17]. For this purpose, we support the integrated material library based on the Ashrae material information and arrange the mapping path of material properties. Through this process, we hope to save time compared to the existing inefficient process. The existing method must rework when modeling data are imported to the Energy plus software because data are resaved to the default values.

(1) Integrated material library

The integrated library construction process in this study is as follows. Preferentially, the Ashrae material library list, which is the most standardized list abroad, and the Energy plus software are arranged as the basic information format. The link between the BIM software ArchiCAD and the Revit library list is visualized with colors in the Excel datasheet. A domestic library classification system, which is referenced in the Architectural Information Center system, is arranged as the 1st integrated material library. In addition, this process attempts to obtain the interoperability using the codes in the BIM software object. The focus is at the integrated material library and Ashrae material standard.

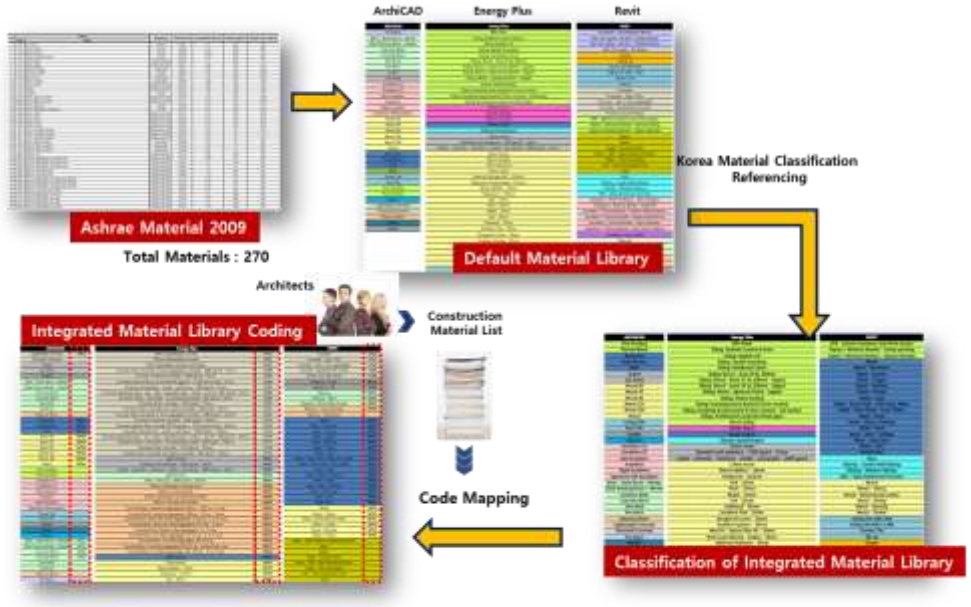

Figure 7. Construction Process of Integrated Material Library

(2) Material coding and software material listing

The Energy plus software includes the "Ashrae Material.Idf" file, which was established by the American Society of Heating, Refrigerating and Air-Conditioning Engineers to represent the structure and materials in this program. For 270 types of material in the Ashrae_2009_Material, representative codes and material properties are included in Energy plus v.7.0 [18]. The building material information is primarily set in the BIM software. Then, the building representation information and material information properties are also subtracted in the IFC exporting process. Complex objects of additional composition elements and material properties modify are the secondary set in the data-transporting phase. Thus, the data interoperability for the energy performance assessment is mapped to the material name to solve the interoperability problem.

(3) Development of data converter

In this study, a converter interface was formed to support the data converting phase for the data interoperability based on the arranged material library before the middle phase between the design phase and the energy performance phase. The converter includes the basic IFC object viewer that can visualize the IFC file. The converter converts the IFC file format to the IDF file format using the representation information and property information of the building object. Moreover, it can be an efficient counterplan to assess the building energy performance using the IFC because it is recognized as the identical material in various softwares when the integrated material library is used. The converter performs an energy consumption simulation and enables us to determine the optimized design with various building information of the geometry, material, heat, and system in each design stage. Users can more easily use Energy Plus, which is one of the most reliable software for building energy analyses in the world. The converter more easily provides the optimized engineering solution by inputting various detailed material information to the building modeling data.

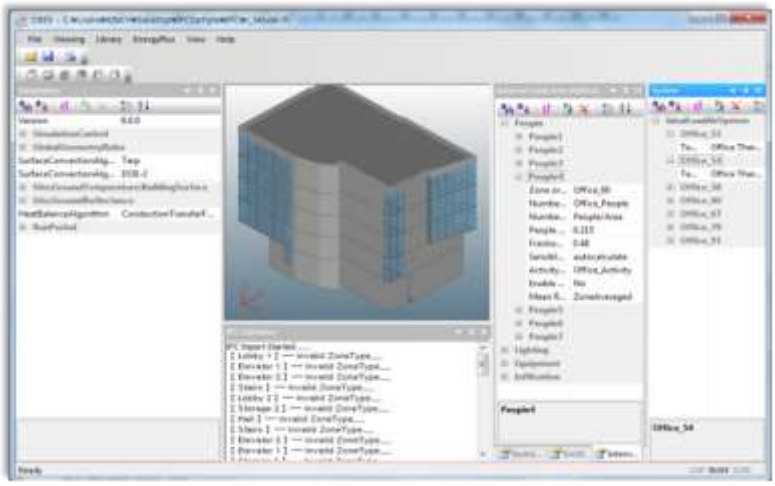

Figure 8. Example of Converter User Interface

5. Conclusions

The energy performance assessment of buildings using BIM is becoming more popular in the design phase because of the increasingly low-carbon and eco-friendly designs to combat environmental problems. However, the current environment of open BIM lacks the initial value of building information and interoperability between the BIM software and the energy performance analysis program. Therefore, in this study, the authors have

suggested a core element technology for BIM data interoperability, which improves based on the energy performance analysis.

In sequence, the method of constructing the openBIM-based environment is associated with the BIM data interoperability system suggestion and material information mapping. In details, the data conversion process is suggested after one recognizes the data interoperability problem and solves its problems for the BIM data interoperability system. In this step, the converter development content is included to complement and compensate for the loss of information that occurs because of the data interoperability of IFC and IDF. This method constructs a BIM property system to apply the integrated material library since the design phase with the material information mapping center. Thus, the energy performance assessment in the openBIM can facilitate the continuous spread of the related fields.

Through this study, architects can use the existing data to find the best design alternative that optimizes the building energy efficiency. They can also more easily input the building material data, which is one of the most difficult jobs for energy modeling. They can attempt various design alternatives using the energy simulation and find the effect of the LOD and material information about the building energy consumption. Building owners can obtain the building energy rating in the initial design stage, secure the optimal energy efficiency of the design, and reduce the cost for facility maintenance. They can also make the design satisfy all codes and standards related to building energy consumption. The suggested BIM environment technologies in this study can improve the data interoperability and reliability of the energy analysis results.

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