

A STUDY ON THE CONSTRUCTION OF BIM DATA INTEROPERABILITY FOR ENERGY PERFORMANCE ASSESSMENT BASED ON BIM

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ABSTRACT: Early design phase energy modeling is used to provide the design team with first order of magnitude feedback about the impact of various building configurations. For better energy-conscious and sustainable building design and operation, the construction of BIM data interoperability for energy performance assessment in the early design phase is important. The purpose of this study is to suggest construction of BIM data interoperability for energy performance assessment based on BIM. To archive this purpose, the authors have investigated advantage of BIM-based energy performance assessment through comparison with traditional energy performance assessment and suggested requirement for construction of open BIM environment such as BIM data creation, BIM data software practical use, BIM data application and verification. In addition, the authors have suggested BIM data interoperability and BIM energy property mapping method focused on materials.

Keywords: Building Information Modeling (BIM); Energy Performance Assessment; Data Interoperability; Energy Property; Industry Foundation Classes (IFC)

1. INTRODUCTION

The increase of CO₂ emission causes global warming and accelerating the environmental pollution. The statistic which shows that construction sector takes the 23% of overall energy consumption emphasize the necessity of building energy performance analysis as part of the national policy. Buildings bring with social and economic profit while its life cycle, but it caused serious environmental destruction due to the use of energy, water and other natural resources. Such destruction must be minimized for green society [1]. So the importance of the concept of green building which can reduce energy consumption is on the rise at internal and external, and this is national issue.

Belonging to various fields of business subjects are actively working on the introduction of BIM (Building Information Modeling) to build green building, which can be utilized efficiently the information that occurs in the construction industry and variety energy performance analysis assessment of building is possible in the early design phase. BIM can changes the design of 2D-based to 3D-based design, generate and manage the overall information that is generated during the life cycle of building. And it can provide prior review, cost estimating, quantity take-off and energy analysis from building design phase. The energy performance analysis using BIM is greatly reduced time and cost, because BIM data model already contains more than 70% of the information for building energy analysis [2].

Especially, if the energy performance analysis could be possible at early phase of design changing, will be able to expect design efficiency compared to the design alternatives of energy aspects. Currently, the alternatives are consistently presented for BIM to be in such an environment.

However, the energy performance analysis in currently environment of Open-BIM still difficult to apply perfectly, due to uncertainty and lack of initial building input data and lack of interoperability between the BIM software and the Energy performance analysis programs [3-5].

For solving those, to produce the requirements for the energy performance analysis in an environment of Open-BIM and suggest the way that can solve it, then will become actively accurate and effective energy performance analysis in the BIM environment.

The purpose of this study to maximize the effectiveness of BIM applies in the field of eco-friendly with identify environmental conditions and requirements in the early phase of design for effectively applied to the evaluation of the energy performance analysis in Open BIM environment. This allows presented establishment of the Open-BIM environment for energy performance analysis.

- (1) Research the concept of the Open-BIM and overview of the energy performance analysis. And identity the status of applied Open-BIM through case studies at internal and external instance.
- (2) The requirements for energy performance analysis in the Open BIM environment theorem separated

by aspects of the written BIM data, utilizing BIM software and application and verification of BIM data. Then identify specific details about the necessity and apply measures each requirement.

- (3) The establishment Open BIM environment for energy performance analysis by priority of requirement and can be applied at the level of the initial research for energy performance analysis in the Open BIM environment. It contains propose to compatible system BIM data, established BIM property (focus on material mapping), developed converter for support data transformation.

2. ENERGY PERFORMANCE ANALYSIS IN THE OPEN BIM ENVIRONMENT

2.1 Concept of BIM

Construction industry is composed by various areas and calculated variety information which composed the information from pre-stage and required information for present stage through step-by-step for the progress of the project. BIM express the attributes of intelligent building element's (wall, slab, door, window, roof, stairs etc.) each properties (function, structure, use) by applying parametric techniques, then recognized their relationships to each other and reflect immediately the change elements of the building. BIM makes possible to analyze the data considering the structure and energy as well as to provide information on the quantity, cost, schedule and material list for assist rapid decision-making to the progress of the project's construction industry, because it can be obtained by calculation or simulation using all of the data attributes, relationship and information within the building object [6]. So, BIM representation information and property information for representation architectural information, the property information includes the name and materials which included in building objects additional as well as attribute information (e.g. building material's thermal transmittance information for energy performance analysis) can be applied in various fields. The characteristics of BIM enable more effective energy performance analysis in BIM environment, and it is necessary to construct the details of requirements that are based objections to activate. The Open BIM environment can data compatible between the software through a neutral format, such as the IFC (Industry Foundation Classes).

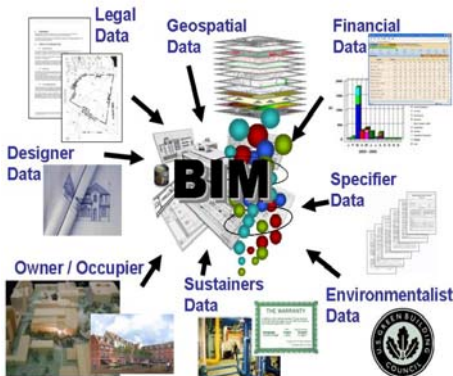


Fig. 1 Application of BIM [7]

2.2 Overview of the energy performance analysis

In the general energy performance analysis process it may causes erroneous interpretation while relevant information such as drawings, photos, and other project information entered manually for provide energy model, when change the design of the building need to change the energy model separately so additional work by architects and engineers to spend time [8]. On the other hand in BIM environment, building data can be including various parameters such as building's representation information, construction type, and thermal properties for energy performance analysis, so saving time and increase the accuracy compared by existing process and the result of the analysis can be quickly reflected [4].

The architects create a BIM data model after design using BIM software for energy performance analysis in BIM environment. The create model passed up to energy analysis software exported by IFC file type. At this time the BIM data included the parameters for energy performance analysis such as building' shape information, construction type, and thermal properties. Such information imported from energy analysis software directly or indirectly, and value of the results rating of the energy analysis performance is feedback to the architects who will be able to reflected in the design alternatives. So the absence of data interoperability of the energy performance analysis software is very important for reliability on the result of the energy performance rating.

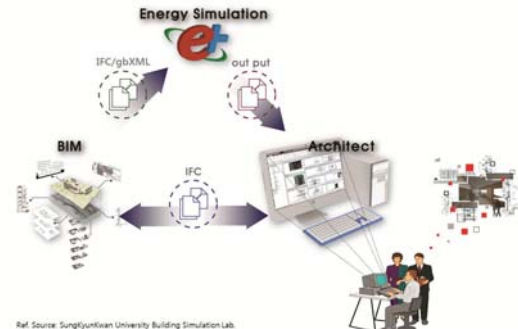


Fig. 2 Example of energy performance assessment in the BIM environment

2.3 Case Study

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

(1) Build London Live 2008

The collaborative design competition spanning 48 hours in June 2008 at London. BIM technology has been applied in the design process from the initial planning stages. Fig.3 is an example of the energy analysis results of the competition winner's. The example was performed 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 of wind, sun shadow pattern analysis, daylight factor analysis and natural light were evaluated in detail. In the

prize design step optimized for design purpose, the land and prize design has chosen the alternative through pre-analysis the amount of energy in the building throughout the design phase with BIM technology [9].

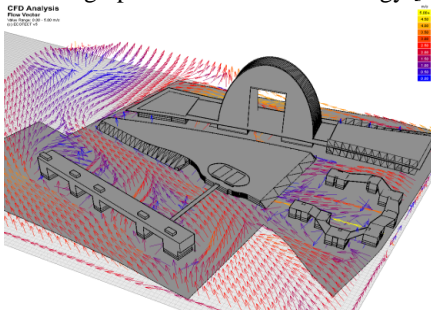


Fig. 3 Example of energy analysis (Seoul BIM Forum team)

(2) Norway – International competition of National Art Museum

It was run automatic model validation and quality control in the BIM model International competition examination step1, and automatically calculating the area of the building surrounded by the external wall and the slab, according to the reference value of the thermal resistance of the heat loss using by EDMmodelServerLite self-developed which carried out energy performance analysis of the BIM model [10].

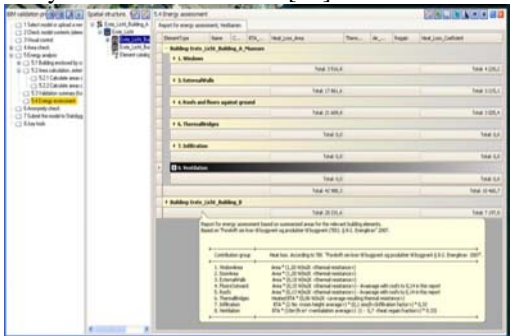


Fig. 4 Example of energy performance assessment Result

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

The first order Design Competition applying BIM in 2009, it was used to energy performance analysis about the perimeter of the building airflow analysis, sun shadow analysis of the final placement, sight analysis of each household, sun shadow analysis in complex, energy and CO2 emissions analysis, analysis of the energy efficiency rating of the building through introduction of BIM in the early design phase [11].

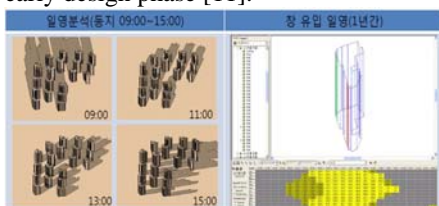


Fig. 5 Analysis of sun shadow

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

It has submitted a design review report on eco-friendly construction and submitted BIM model written to the original format and IFC2x3 format. Visually check, functional quality check, and energy efficiency analysis proceeded [12].

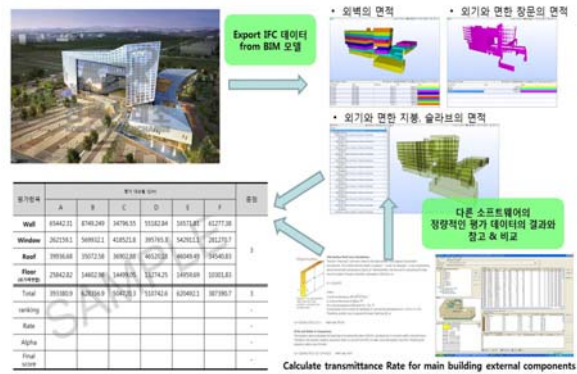


Fig. 6 Energy assessment method of envelope model

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

It was announced “BIM guidelines” in 2010 for the purpose of providing BIM work on standards. This guidance has been defined utilizing BIM for reviewing the design stage of energy efficiency. It is very important in future application, cause since 2012, it is mandated plan to apply BIM to official business construction design in total service to more than 50 billion won [13].

Table 1. BIM application criteria for energy efficiency check in guideline

Design phase	Schematic Design (Design Competition/ Design-Build)	Design Development
BIM application criteria	Outline Energy efficiency check	Energy efficiency check
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 ASSESSMENT

The requirements for energy performance analysis in Open BIM environment theorem separated by aspects of the creating of BIM data, utilizing of BIM software and application and verification of BIM data. Then identified specific details about the necessity and apply measures each requirement.

3.1 Aspects of the creating of BIM data

(1) Development of BIM usage scenarios

A common standard have to provide through development of scenarios applied the each steps and scopes for efficient energy performance analysis for buildings. To achieve this, the work considered in energy performance analysis phase are defined and then draws a way of detailed use through comparison and analysis between the existing work process and BIM work process. For example, the Energy Plus suggested software for examination of energy efficiency in the PPS guideline can define design variables as per energy performance analysis target. Therefore the rules of law, software representation and common business rules have to properly reflect to related BIM properties for heat loss case.

(2) Development of BIM model standard

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

Nowadays, Common BIM model guideline is consistently developed but a little of focused on energy performance analysis in domestic and foreign. BIM model guideline included input variables of specific definition have to develop because energy performance analysis requires specific information and function [14].

Fig. 7 is explanation of BIM modeling creation example by BIM model standard (OGC-BPEA).

(3) Construction of BIM property system

Many of 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 common energy performance analysis. Nevertheless, the required input variables have different property information system from standard for BIM assessment that makes imprecise energy analysis. Therefore constructing specific property mapping system between energy performance analyses

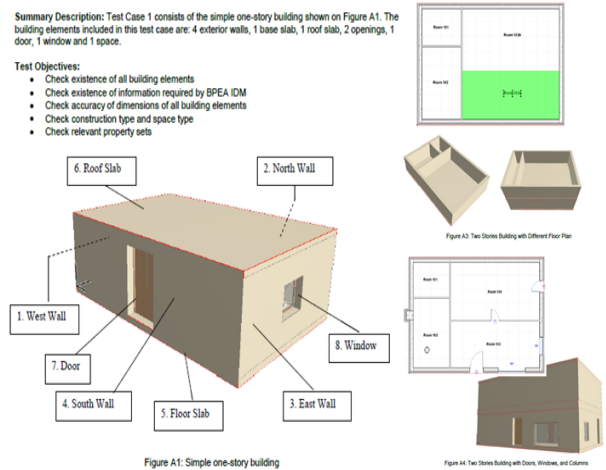


Fig. 7 Example of BIM modeling creation (OGC-BPEA Test case) [15]

requires and BIM object properties can make accuracy energy performance analysis assessment in BIM process. Especially it needs to connect between building object properties and BIM software representation through the way of mapping in energy performance analysis assessment.

3.2 Aspects of BIM data application

(1) Analysis of BIM data interoperability system

Software supported energy performance analysis are dissemblance for a way of BIM data supporting, It makes problem of standardized data interoperability or partial data lost. Therefore, The BIM data interoperability system has to analyze to solve problems of objectivity and accuracy decline. To achieve this, the data interoperability system has to analyze case by case because of representing for aim and composition as per software. The almost of energy performance analysis was based on the gbXML but there need interoperability discussion about software that is support the IFC of BIM data representation [4].

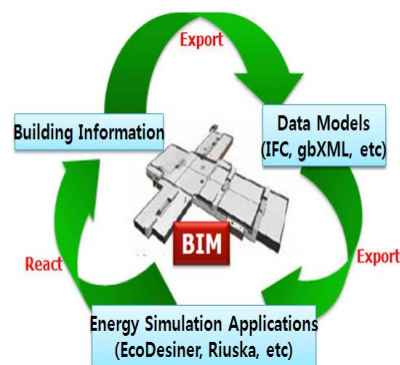


Fig. 8 Flow of BIM data for energy performance assessment

(2) Development of Open-BIM supporting Viewer

To check the energy performance analysis object and result, there need to development of energy performance analysis assessment visualization system. The system has

to support the BIM data information and the visualization function of property information for energy performance analysis assessment. Furthermore, there need to development of a converter for difficult part that is hard to solve problems through existing method in BIM data interoperability system.

3.3 Aspects of BIM data application and verification

(1) Verification through the development of the energy performance analysis assessment module

It has verification process for application target, scope and method etc. of energy performance analysis in BIM process. If problems are searched in verification, the process for solving those problems has to be done by feedback. Furthermore, development of the analysis module that can support requiring conditions and the Open BIM supporting Viewer have to do verification process for the more specified and automated energy performance analysis assessment.

(2) Assessment and verification in business practice

In the longer term, it needs to be verified what result of energy performance analysis methods and development system on BIM applied actuality building in BIM process. Related fields have to be induced through the verification of various BIM based energy performance analysis assessment and the increase of BIM standard and energy simulation usability.

4. CONSTRUCTION PLAN OF BIM DATA INTEROPERABILITY FOR ENERGY PERFORMANCE ASSESSMENT

In this study, as mentioned above, contents are chosen to preferentially progress for the Open BIM based environment in earlier research phase applicability. Detailed contents are following.

4.1 Suggestion of BIM data interoperability system

There are two kind of the energy performance assessment process. One is design phase to BIM data creation using BIM software. The other is energy analysis phase to application of the design phase and energy analysis software.

In the design phase, many of software are using in domestic like ArchiCAD, Revit and Digital Project etc. In the energy analysis phase, Energy plus, Ecotect, IES/VE, Riuska etc. are using for various aim. Normally the IFC and the gbXML is considered for interoperability but the IFC international standard data format on Open BIM environment is focused in this study. Furthermore, the energy performance analysis data format is decided to use IDF format of Energy plus that is software PPS suggest.

The IFC file includes building representation information, material information and others for energy performance analysis in the design phase. However, partial IFC information is transferred to the Energy plus. In the transferring process, importing of different

property systems as per energy performance analysis software makes confusion because of nonstandard data interoperability system. Therefore, in this study, proposal to a middle process between the design phase and the energy performance analysis phase for supplementation of data information loss and creation of additional information.

4.2 Construction of BIM property system (focused on the material information mapping)

The material property of energy performance analysis properties in the design phase is compatible with partial representation information and material property information because of different definition of software. Therefore, suggest way of the material information addition that has representation and material property in integrated material library. For this, support the integrated material library that is based on the Ashrae material information and arrange the mapping way of material properties [16].

Through this process, it hopes save time in existing inefficient work way and process. The existing work have to rework when modeling data is imported to Energy plus software because resave of data to default values.

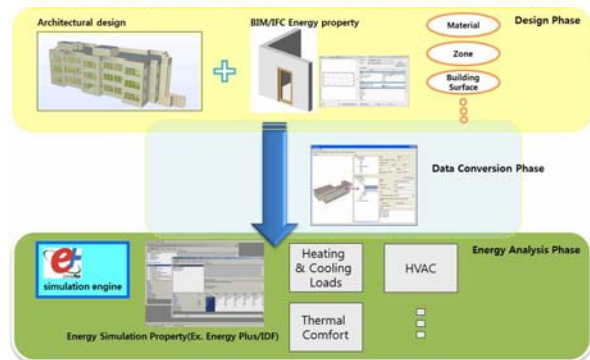


Fig. 9 Process of energy performance assessment in the BIM environment

4.2.1 Construction process of integrated material library

The process of the integrated library construction process in this study is as in the following. Preferentially, the Ashrae material library list that is the best standardized in abroad and used in the Energy plus software as basic information format are arranged. The linking between the BIM software ArchiCAD and Revit library list is visualized as color in the Excel data. A domestic library classification system that is referenced in the Architectural Information Center system is arranged as 1st integrated material library. In addition, it tries to get interoperability by codes used in BIM software object. It is focused at the integrated material library and the Ashrae material standard.

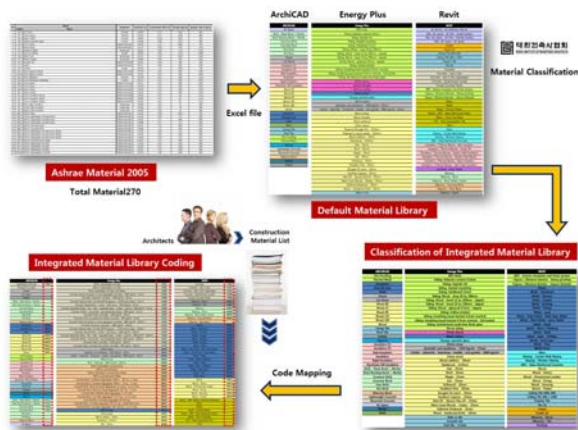


Fig. 10 Construction process of integrated material library

4.2.2 Material coding and listing

The Energy plus software include 'Ashrae Material.Idf' file that was established by American Society of Heating, Refrigerating and Air-Conditioning Engineers is used to representing structure and materials in this program. The 'Ashrae_2005_Material's 270 kind of material are including representative codes and material properties in the Energy plus v.4.0.

It is primarily set that building material information in BIM software. Then the building representation information and material information properties are additionally subtracted in IFC exporting process. Complex object of additional composition elements and material properties modify are secondary set in the data transporting phase. Through this way, data interoperability for energy performance assessment is mapped to material's name to solve interoperability problem.

4.3 Development of data converter

In this study, converter interface was form for supporting the data converting phase for 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 IFC file. The converter converts the IFC file format to IDF file format by using building object's representation information and property information. Moreover, it can be efficient counterplan to building energy performance assessment using IFC. Because it is recognized as same material even path through various software when use the integrated material library.

5. CONCLUSIONS

The energy performance assessment of the building is getting more popular in early design phase using BIM because of raising low-carbon and eco-friendly design in issue of environmental problem. However, in the current environment of the Open BIM have problem what lack of the initial value of building information and lack of interoperability between BIM software and energy performance analysis program. Therefore, in this study, to

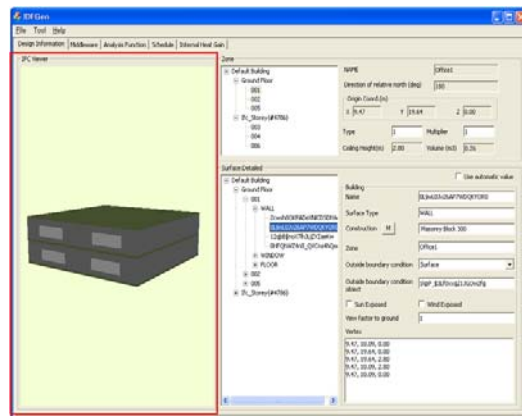


Fig. 11 Example of converter user interface

deduce the requirement for energy performance assessment in the Open BIM environment, and present the ways to solve it more accurate and effective assessment of the energy performance assessment of the Open BIM environment was to induce activation. For this, the study is to suggest a BIM data requirement in the early design phase to evaluate the energy performance assessment of the Open BIM environment.

In sequence, the way of constructing the Open BIM based environment associated with the BIM data interoperability system suggestion and material information mapping. In details, it is suggested the data conversion process after recognizing data interoperability problem and solving its problems for the BIM data interoperability system. In this step, the converter development contents was included to complement and addition information creation the loss of information that occurs when data interoperability of IFC and IDF. It is way for the constructing BIM property system that applications of the integrated material library since the design phase with material information mapping center. Thereby, facilitate the energy performance assessment in the Open BIM will be able to facilitate the continued spread of the related fields.

This study, however, as the early stages of the current study is limited to some of the requirements for a variety of energy performance assessment in the Open BIM environment was carried out. Therefore, future research should be conducted through suggest the way of problem solving in the overall requirements. In the construction of BIM property system case, it needs to detailed develop continuously through additional research and analysis. It has to construct interoperable energy performance object library that is free of current different library environment. The converter, moreover, need continuous improvement and supplementation to user interface.

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