A Suggestion for Improvement of IFC Data in Energy Performance Index (EPI) based on Open BIM

Jungsik Choi[a] , Inhan Kim[b], Minchan Kim[c] and Jeongwon Ryu[d]

[a]College of Engineering, Kyung Hee University, Republic of Korea
[b]Department of Architecture, Kyung Hee University, Republic of Korea
[c]BIM Business Div., U·MID SYSTEM, Republic of Korea
[d]Department of Architecture, Sunmoon University, Republic of Korea
E-mail: jungsikchoi@gmail.com, ihkim@khu.ac.kr, mchan_07k@naver.com, jwryu@sunmoon.ac.kr

Abstract

As many countries are becoming more aware of environmental issues, both the governmental and private sectors are making more of an effort to achieve eco-friendly construction. However, the assessment of circumstances for building energy performance and green building standards of legislation are still based on two dimensions and manual work. This takes time, costs, and labor and makes assessment inaccurate and inefficient. Therefore, this study suggests methods to improve the eco-friendly building permission process and to automatize the open BIM-based assessment of the EPI among several eco-friendly building standards.

Keywords –

Building Information Modeling (BIM); Building Permission; Energy Performance Index (EPI); Industry Foundation Classes (IFC); Open BIM

1 Introduction

Global warming and environmental problems are some of the most critical issues in modern life, which raises the importance of energy conservation and greenhouse gas emissions reduction, and most countries are endeavoring to achieve “low-carbon, green growth” [1]. As construction is a major cause of greenhouse gas emissions, which lead to global warming, the field gives considerable attention and effort to developing energy-saving, eco-friendly, and sustainable construction technology [2]. Many countries evaluate the sustainability of buildings and implement systematic and institutional practices to reduce the negative influence of construction on the environment as they develop eco-friendly building certification systems, such as GBCC, LEED, CASBEE, BREEAM, and EarthCheck. The Korean government has established the Green Building Development Support Act [3], which promotes eco-friendly construction and encourages energy efficiency and performance improvement. This act obligates buildings over a certain size to follow the Energy-Saving Design Standard and submit an Energy-Saving Plan and Energy-Saving Plan Design Review. In spite of these efforts on both governmental and private levels, the current assessment circumstances for performance, laws, and standards of eco-friendly building still depend on two dimensions and manual work, which is time consuming and inefficient because of the repetitive work involved and impeded feedback. The demands to solve this problem and improve the efficiency of eco-friendly building permission examination emphasize the importance of BIM technology. BIM is a technology that creates digital information on a building. In addition, the information needed for the life-cycle can be obtained and managed by using digital information.

Therefore, the BIM application on eco-friendly building permission examination analyzes necessary details effectively and accurately with the BIM-based integrated information model. It also establishes integrated and objective assessment circumstances for eco-friendly construction in various and complicated relations between buildings and the environment. Thus, the objectives of this study are as follows:

- To improve the eco-friendly building permission process based on the Energy-Saving Design Standard
- To provide a base study for the development of the Automatic Assessment System for the EPI

This study proposes an assessment method by connecting assessment criteria and IFC data and suggests a solution and a process of assessment.

To automatize the assessment of the EPI,

- It is necessary to check if a building satisfies assessment criteria through IFC data exported from the BIM authoring tool

- Required information and IFC data should be connected
- Assessment criteria should be analyzed in advance

2 Cases Studies

2.1 Analysis of Related Studies

Roh et al. used GBT, a BIM-based template, to suggest a use for the BIM application in eco-friendly building certification. GBT organizes necessary information and a series of procedures for eco-friendly building certification examination, and this study provides background work for BIM-based certification examination using GBT [5].

Yi and Park proposed a method to automatize open BIM-based Examination for requirements in the Energy-Saving Design Standard and some parts of the EPI. The method extracts necessary information from IFC data about the “thermal transmittance of exterior wall” in the requirements of the architecture part and “shading device” and “boiler efficiency according to type” items in the EPI [6].

Lee et al. saved the BIM model in the gbXML format and sent it to Ecotect Analysis, an energy performance analysis program. The study analyzed the annual energy acquisition and consumption according to geological information, direction, and elevation plan and pointed out problems of the EPI. The study applied BIM for energy performance assessment and presented possibilities for quantitative assessment and a clear certification standard [7].

Farzad and Ahmad provided an integrated BIM-based methodology for eco-friendly building certification, energy performance assessment, and the automation of estimation. They built a database by analyzing related information and established a BIM Library and predefined codes, which enable related information to be entered into BIM data. They also suggested an effective use of BIM data with the application, which connects BIM authoring tools and energy performance analysis tools [8].

2.2 Energy-Saving Design Standard of Building

The Green Building Development Support Act consists of Green Building Certification, the Energy Efficiency Rating System, and the Energy-Saving Design Standard of Building and defines obligations to submit an Energy-Saving Plan and Energy-Saving Plan Design Review when a building owner requests a building permit or a usage change.

The Energy-Saving Plan Design Review presents a checklist that confirms requirements and their credits. The Energy-Saving Plan Design Review is divided into Mandatory, EPI, and building energy requirement assessment, while the Energy-Saving Plan is divided into Architecture, Machine Equipment, Electrical Adiabatic, and New Renewable. Since the Mandatory in the Energy-Saving Design Standard of Buildings contains the obligation to follow the Chapter 2 Energy-Saving Design Standard of Buildings and EPI, these should be examined before deciding on the Mandatory.

3 Analyzing Energy Performance Index and Extracting Necessary Information

Analyzing assessment criteria is essential for the Automatic Assessment System for the EPI. It extracts the required information for the assessment criteria, and this information defines the necessary information for the BIM data.

The Parts of Architecture in the EPI consists of 14 categories, and the required information and necessary information from the BIM data are extracted to satisfy the requirements from each item. Necessary information is the information that satisfies the relevant required information and should be considered in the BIM model view. Additionally, related standards and necessary calculation methods regulated by the law should be examined. For example, the “Mean Thermal Transmittance of Exterior Wall,” which is the first category in the EPI, needs not only the “Confirming Wall,” “Relation between Wall and Exterior,” and the “Thermal Transmittance of Wall,” but also the “Azimuth and Area of Wall,” ‘Confirming Window,” “Relation between Window and Exterior,” “Azimuth and Area of Window,” and “Thermal Transmittance of Window Information” because the Energy-Saving Design Standard of Buildings defines certain calculation methods, as shown in Table 1.

Table 1. Calculation Method of Mean Thermal Transmittance of Exterior Wall

Classification	Calculation Method
Mean Thermal Transmittance of Exterior Wall	Ue ＝ [Σ(Thermal Transmittance of External Wall each Cardinal Point × Area of External Wall each Cardinal Point) ＋ Σ(Thermal Transmittance of Window and Door each Cardinal Point × Area of Window and Door each Cardinal Point)] / (Σ Area of External Wall each Cardinal Point ＋ ΣArea of Window and Door each Cardinal Point)

Table 2. Portion of Extracted Necessary Information

Evaluation Items	Requirements Information	Necessary Information	Necessary Object	Necessary Attribute	Necessary Relation
Mean Heat Transmission Coefficient of External Wall Ue (W/㎡.K) (Including Window and Door)	Mean Heat Transmission Coefficient of External Wall	Confirming Wall	Wall		Space
		Relation between Wall and Exterior	Wall	Exterior	
		Azimuth of Wall	Wall	Azimuth	
		Area of Wall	Wall	Area	
		Heat Transmission Coefficient of Wall	Wall	Heat Transmission Coefficient	
		Confirming Window	Window		Wall
		Relation between Window and Exterior	Window	Exterior	
		Azimuth of Window	Window	Azimuth	
		Area of Window	Window	Area	

Necessary information for each piece of required information can be extracted and categorized for BIM-based automatic assessment. The necessary information for the assessment of the Parts of Architecture in the EPI is shown in Table 2.

4 Plan for Open BIM-based Assessment Criteria Examination

4.1 Analyzing Relations between Necessary Information and IFC Data Structure

To improve the interoperability between BIM software in various parts of the construction industry, buildingSMART International has developed the IFC format as an international standard, and IFC-based BIM is the internationally used for standard open BIM [9]. IFC is an EXPRESS language-based data structure that expresses architectural information as Entity, Attribute, and Relation. This structure represents an object of a building, its attribute, and relations [1, 10].

Analyzing relations with the IFC structure determines the possibility of extracting necessary information from related IFC-format BIM data and provides an understanding of the relations [11].

This chapter introduces a method to analyze relations between necessary information and the IFC structure to extract the necessary information mentioned in the previous chapter.

4.1.1 General Decision Rules

To extract necessary information from IFC data, it is necessary to analyze the object, its attribute, and its relations and to judge the possibility, which leads to constructing decision rules. Based on the necessary information and categorized information defined in the previous chapter, the Entity, Attribute, and Relation of related IFC structure are mapped along with the process. For example, the “Thermal Transmittance of Wall,” as shown in Figure 1, should be taken to confirm “IfcWallStandardCase,” which means the wall in the IFC structure, and the thermal transmittance of the wall is extracted from the BIM data by finding the value of “Pset_WallCommon-ThermalTransmittance” through “IfcPropertySingleValue” in “PropertySet,” which is defined for an additional property in the IFC structure.

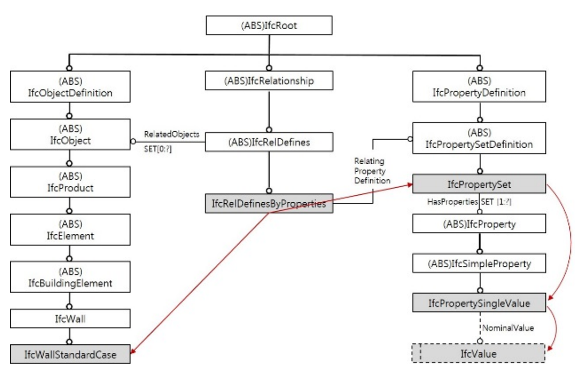

Figure 1. EXPRESS-G Diagram for Thermal Transmittance of Wall

4.1.2 Case for Extra Decision Rules

In spite of the presence of the IFC data structure related to necessary information, extra decision rules are required for precise information extraction. For example, the “Area of Wall and Slab” information can be extracted from the IFC structure because “IfcElementQuantity” defines the area of the object and “IfcRelDefinesByProperties” defines the relation between the object and the attribute in the IFC structure. However, this method is inappropriate for the calculation of spatial units because this information means the total area of an object. Likewise, slab is the same case. Part of the area related to a specific space is needed rather than the total area of the wall, as shown in Figure 2.

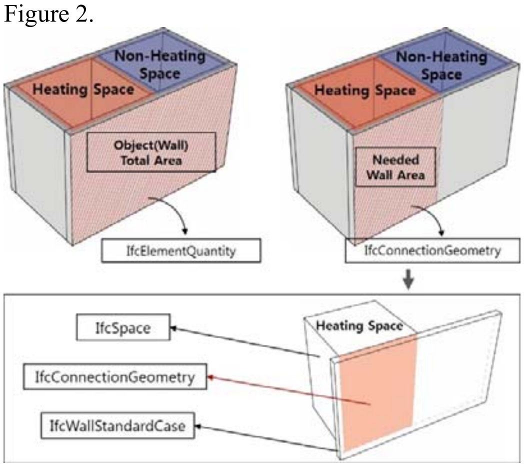

Figure 2. Extra Decision Rule for Area of Wall

Therefore, an extra decision rule is defined to extract that information from the IFC data. To extract the area of the wall in the IFC data, as shown in Figure 3, the wall related to a specific space can be found through “IfcRelSpaceBoundary,” which means objects related to space in the IFC structure, by finding “IfcSpace,” which means space in the IFC structure. After that, whether the wall is exterior is determined by confirming the value of “Pset_WallCommon-IsExternal” through “IfcPropertySingleValue” in “PropertySet.” Finally, the relevant area can be extracted through “IfcConnectionGeometry,” which means the connection surface between the space and wall and below the structure. This extra decision rule should be arranged separately to apply the development of the examination module.

4.2 Limitation of IFC Structure and Solutions

IFC is an international standard format used in various areas of the construction industry and is a neutral file format for the exchange of BIM data between different software and for interoperability. Thus, for effective information exchange, all the information in the lifecycle in various construction fields should be able to be stored in the IFC format. However, because the information related to the construction process is massive and complicated, there is a limitation of defining the data system, which can store all the information from each category. In addition, even though the IFC is constantly upgraded, it does not enable the data structure to store all the information. This causes data loss when data from different parts are exchanged. It also impedes data interoperability and interrupts effective uses of BIM data. Therefore, this chapter identifies necessary information that the IFC structure does not support and suggests a way to extract and store this information [12].

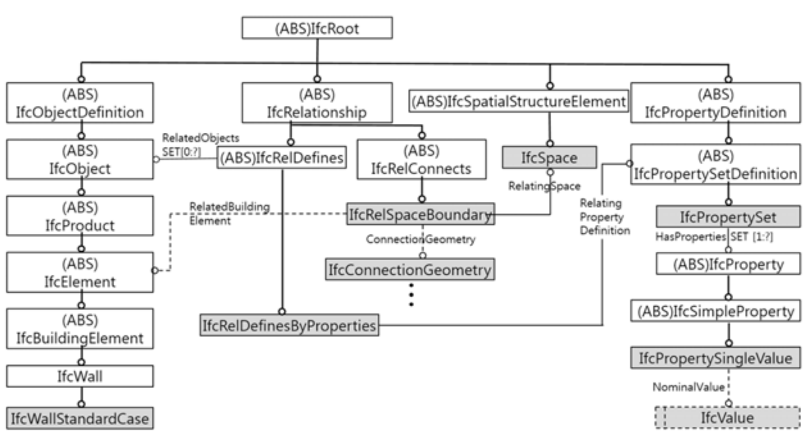

Figure 3. EXPRESS-G Diagram for Area of Exterior Wall

In the previous chapter, it was pointed out that some necessary information cannot be defined by the IFC structure after analyzing and mapping relations between necessary information and the related IFC data structure. This information can be omitted in the exchange of BIM data and cannot be evaluated because the examination system cannot identify it. Therefore, it is necessary to find an alternative to save this information as IFC-format BIM data.

4.2.1 Entering Additional Attribute

The additional attribute should be defined and entered in the object because the value of the thermal transmittance of the object is not included in the IFC structure. Although this attribute can be defined as “Thermal Transmittance” in “Pset_Common,” it only regards the curtain wall, window, door, slab, and wall, but not the roof, which needs to be defined and entered additionally. When the model is made in the BIM authoring tool, the attribute of the thermal transmittance of the roof can be entered additionally by “IfcPropertySingleValue” in “PropertySet” and can be checked in “IfcPropertySingleValue” to extract necessary information.

4.2.2 Predefining Decision Rules

It does not need to be defined additionally, but should be predefined and can be inferred and judged according to the attributes saved in the IFC file. The living room can be judged by the name of the space, which is defined in the IFC structure. This space name should be categorized and organized previously, and the correct name for the space object should be entered in the BIM modeling process.

4.2.3 Using Proxy Object as Alternatives

Since the adiabatic shutter, adiabatic outer door, and shading are not defined in IFC, the related necessary information can be saved or extracted by “IfcBuildingElementProxy” from the IFC Entity. “IfcBuildingElementProxy” is an entity for saving the objects that are not defined in IFC. The adiabatic shutter object should be saved to “IfcBuildingElementProxy” after inputting the necessary information and name by using a general object when creating the adiabatic shutter in the BIM authoring tool. Afterward, information on the adiabatic shutter can be extracted from “IfcBuildingElementProxy” in the IFC data.

Figure 4. IFC Data for Adiabatic Shutter

Using these three solutions enables the conversion of the necessary information, which is not available in the IFC structure, into IFC data. It prevents data loss in the exchange of data and ensures accurate evaluation. These methods and standards should be managed in separate documents.

4.3 Problems and Solutions of IFC Conversion Function in BIM Authoring Tool

The BIM authoring tool helps a designer to build an architecture model and input architectural information with a 3D parametric object. In other words, it is a tool to connect the designer and the architecture model built in digital space. The model made by the BIM authoring tool is the digital information with the designer’s plan, and the information of the architecture model should be converted to IFC without any loss. When the information is suitably converted to the IFC structure, the IFC data is reliable as an architectural information model and interoperability for a variety of software is ensured. In particular, the reliability of the IFC data is important because IFC data contains information for evaluations, and the reliability of IFC data affects the reliability of the evaluation. However, the IFC conversion function supported by the BIM authoring tool causes data loss and an information gap, which hinders the reliability of IFC data, effective use of BIM, and accuracy of evaluations. Therefore, this chapter analyzes the problems that occur in the conversion of necessary information to IFC data in the BIM authoring tool (Revit) and suggests solutions.

In the case of an operable window, as shown in Figure 5, although it can be defined by “IfcWindowPanelOperationalEnum” of “IfcWindowPanelProperties” in the IFC data structure, the information of the operable window in the BIM authoring tool is not exported as a correct IFC structure, and it is omitted. Thus, an alternative is needed to convert and save the information of the operable window to IFC data.

By entering the information of the operational window into Type Comments, one of the attributes for the window object, the operation of the window can be represented in IFC data. After exporting to IFC, the operation of the window can be identified by confirming the information previously entered in "IfcPropertySingleValue," named Type Comments, which is a sub-structure of "IfcPropertySet," which is related to "IfcWindowStyle" (Figure 5).

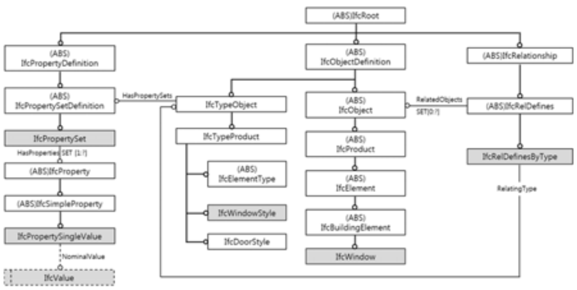

Figure 5. EXPRESS-G Diagram for Alternative

5 Suggestion and Application Scenario of Open BIM-based Automation Process for EPI

This chapter suggests a process to improve the permission process by using an open BIM-based automatic assessment system for the EPI and explains the procedure. In accordance with this method, the two-dimensional, manual work-based permission process can be improved for the BIM-based automatic assessment process, which extracts accurate and efficient results.

5.1 Creation of BIM Model and IFC Conversion

The designer builds a BIM model by considering related standards and requirements in the Energy-Saving Design Standard of Buildings with the BIM authoring tool. The designer should follow the BIM guidelines, which have standards and requirements, and these guidelines should contain the solutions mentioned in the previous chapter. The guidelines facilitate an accurate and smooth assessment process without any loss of required information in the conversion process.

Among the requirements for open BIM-based automatic assessment for EPI, this chapter focuses on the solutions mentioned in the previous chapter.

According to the solution, an additional attribute is entered for the thermal transmittance of the roof and entrance door, predefined attribute information for the living room, windbreak room, parking lot. For the adiabatic shutter, shading and proxy objects are used, and the attribute information is added. For the revolving door and operation of the window, the alternatives to compensate for the limitations of the BIM authoring tool are applied (Figure 6). Afterward, the IFC file is exported from the BIM authoring tool.

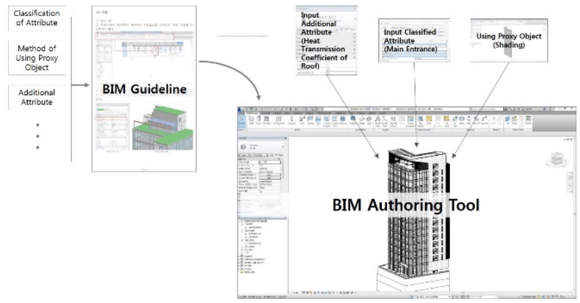

Figure 6. Creating BIM Model through Proposed Alternative

5.2 Assessment Module for IFC data

The assessment program examines if a building satisfies the EPI with IFC data converted by the BIM authoring tool. We developed an assessment module from the program function, which checks assessment criteria based on the rules applied when necessary information is extracted from IFC data (Figure 7). Moreover, the building assessment interface makes a user and an examiner to proceed with the EPI assessment with entering IFC data. Because some necessary information is not available in the IFC structure, the judgment rule should be predefined. External information can be used by entering information into the interface.

The visualization module is developed to make a user and an examiner to check if the building satisfies the assessment criteria and to give feedback for revising the design (Figure 7). The examination results and the total score are automatically input and calculated according to the results format in the Energy-Saving Design Standard, and this automatized process supports the permission process without changing the existing permission system. Because the results are automatically input into the document, the reliability and accuracy of the document and the evaluation can be ensured.

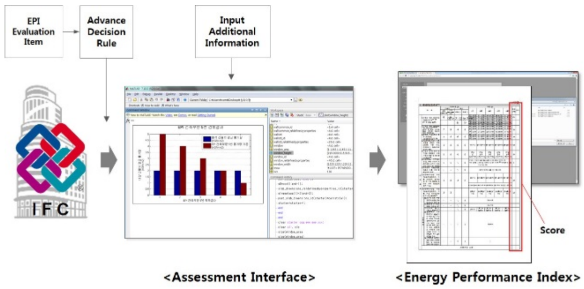

Figure 7. Development of Assessment Interface and Reporting Module

6 Conclusion

Changing two-dimensional manual work into a BIM-based three-dimensional information system in the green building permission process improves productivity, efficiency, and accuracy. In addition, the concept of open BIM in the BIM process ensures interoperability among a variety of software and the effective use of BIM data. Therefore, the objective of this study is to improve the eco-friendly building permission process based on open BIM. It is a base study for the development of the Automatic Assessment System for the EPI, proposes an assessment plan by connecting assessment criteria and IFC data, and suggests a solution and a process of assessment. This study

- extracts necessary information and required information for assessment criteria
- categorizes them into BIM information units by analyzing necessary information and connecting it with IFC data
- analyzes IFC structure and its relation to necessary data
- suggests solutions to the conversion problem and the limitations of the BIM authoring tool
- develops an automatic assessment system for the EPI that proceeds automatically from building the BIM model to visualizing the results by applying the solutions and methods suggested in this study

It is expected that time, costs, and labor will be reduced by the simplification and automation of the process, and not only the productivity and efficiency, but also the accuracy and reliability of the permission and design revision process can be improved.

This study focuses on the Parts of Architecture in EPI in the Energy-Saving Design Standard. A future study is expected to widen its range to the Energy-Saving Plan and Energy-Saving Plan Design Review and to find a method to automatize the open BIM-based evaluation in them.

Acknowledgements

This research was supported by a grant (15AUDP-C067809-03) from Architecture & Urban Development Research Program funded by Ministry of Land, Infrastructure and Transport of Korean government.

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2014-01370001).

References

[1] Kim M., Choi J., and Kim I. Analysis of problems regarding BIM model interoperability and suggestion of improvement direction for openBIM based energy performance analysis. In *Proceedings of the Society of CAD/CAM Conference*, pages 313-315, Korea, 2015.

[2] Kim I., Choi J., and Kim H. Proposition and Application of Mapping System for Input Data between Open BIM Data and Building Energy Simulation Software-Focused on Building Material Library and Energy Plus-. *Journal of the architectural institute of Korea: Planning & design*, 29(4):3-12, 2013.

[3] Ministry of Land, Infrastructure and Transport. Green Building Development Support Act. On-line: http://www.law.go.kr, Accessed: 15/04/2015.

[4] Kim M., Kim I., and Choi J. A Study on the Composition of BIM Model Guideline for Architectural Design Quality Assessment based on OpenBIM. In *Proceeding of architectural institute of Korea*, pages 57-58, Korea, 2015.

[5] Roh M., Kim I., Kim M., and Jun H. A Study on Developing Evaluation Environment of Green Building Certification Criteria Using GBT (Green BIM Template). *Journal of the architectural institute of Korea: Planning & design*, 29(6): 117-126, 2013.

[6] Yi D. and Park C. Code Check for EPI Using Open-BIM. In *Proceeding of the Korea Institute of Ecological Architecture and Environment*, Pages 76-77, Korea, 2014.

[7] Lee K., Kim I., and Choo S. A Study on Improvement of Energy Performance Index in Green Building Certification System using BIM. *Journal of the architectural institute of Korea: Planning & design*, 27(9):13-21, 2011.

[8] Farzad J. and Ahmad J. Integrating BIM with Green Building Certification System, Energy Analysis and Cost Estimating Tools to

Conceptually Design Sustainable Buildings. In *Construction Research Congress 2014*, pages 140-149, 2014.

[9] Kim I., Yoo H., and Choi J. A Study on the Interoperability Improvement IFC Property Information for Energy Performance Assessment in the Early Design Phase. *Transactions of the Society of CAD/CAM Engineers*, 17(6):456-465, 2012.

[10] buildingSMART international. *IFC2XEdition 3 Technical Corrigendum1*. 2006.

[11] Kim I., Kim Y., and Choi J. Building Code Typology and Application for Open BIM based Code Checking. *Transactions of the Society of CAD/CAM Engineers*, 19(3):224-235, 2014.

[12] Lee S., Park C., and Kim I. Issues and Prospects of BIM-to-BEM (Building Energy Model). *Journal of the architectural institute of Korea: Planning & design*, 30(4):199-206, 2014.