DEVELOPMENT OF WEB-BASED SUN-HOURS AND ENERGY ANALYSIS SYSTEM USING IFC

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Abstract

The objective of this study was to develop a tool capable of analyzing various design schemes during the early stages of design by building a reasonable BIM data system for sustainability analysis and using the architectural BIM model to carry out sunshine and energy analysis in a web environment. We devised a module to extract the variables required for energy analysis from IFC files and developed a software program to gather meteorological data, material properties and management schedule so as to calculate the annual energy requirement and consumption of a building in order to predict its energy efficiency rating. A web prototype was also built to implement the tool for sunshine and energy analysis.

KeyWords : Web-based, Building Information Modeling, IFC, Solar-hour, Energy analysis

1. Background

Starting in 2012, it has become obligatory in South Korea to apply Building Information Modeling (BIM) in any prize contest or turnkey project worth 50 billion won or more as part of the Green Growth policy adopted by the government.

In South Korea, the application of BIM is being expanded in all sectors, i.e. architectural, structural, mechanical, and electrical engineering, following the announcement of the BIM Adoption Guidelines made by the Ministry of Land, Transport and Maritime Affairs (MLTM) and the Public Procurement Service in 2010.

At present, building environment analysis (mostly energy analysis and sun-hour analysis) is partly carried out as part of BIM-based design. As for sun-hour analysis, the analysis software was developed domestically, but is not suited to domestic sun-hour criteria. Sun-hour analysis is made by input of a Drawing Exchange Format(DXF)-based two-dimensional model into the analysis program, followed by additional materialization of a three-dimensional model. Such a process of analysis requires a long period of work time and makes it difficult to compare alternatives promptly in the schematic design stage.

As for energy analysis, domestic guidelines for BIM application require that dynamic energy simulation (EnergyPlus or DOE-2 Engine basis) should be carried out for major buildings in the stage of detail design and that energy efficiency should be reviewed on the basis of the shape, direction and window-to-outer wall ratio of the buildings.

2. Purpose of the study

BIM-based sun-hour and energy performance analysis methods are required to do separated modeling works for simulation. According to the report of LBNL, energy and environmental assessment analysis has been reported that is required about 80% of the time and effort for the simulation of 3D building modeling. The purpose of this study is that to reduce the modeling time for the simulation of the separate by IFC format. Therefore, architect can reduce the time and cost required to achieve optimal results through the rapid comparison of alternatives.

The purpose of this study is to develop a Web-based interface module that can make sun-hour and energy analyses in the schematic design stage, using International Foundation Classes(IFC), which is a format interchangeable with BIM. This study also aims to materialize energy-saving buildings through prompt comparison of alternatives by making it possible for architects to realize a system of making sun-hour and energy analyses on the Web, using a BIM model and IFC in the schematic design stage.

3. Web-based analysis tool

3.1 Sun-hour analysis

The statutory sun-hour requirement (based on endurance limit of sun-hours) in South Korea is two consecutive hours between 9:00 AM and 3:00 PM or four hours on and off between 8:00 AM and 4:00 PM based on the hours during which a building receives direct rays from the sun on the winter solstice (December 21), as summarized in the following Table 1.

Table 1. *Fulfillment of minimum sun-hour requirement*

Total sunlight-hours 8:00 AM ~ 4:00 PM	Consecutive sunlight-hours 9:00 AM ~ 3:00 PM	Fulfillment of endurance limit of sun-hours
Secured	Secured	Satisfied
Secured	-	Satisfied
-	Secured	Satisfied
-	-	Not satisfied

Sun-hour analysis is divided into Window sun-hour analysis and Waldram analysis. Window sun-hour analysis fixes sun-hours based on the ratio of the subject window exposure to the sun versus outer wall sun exposure. Waldram analysis fixes sun-hours based on the sun path at a representative point of the subject window and whether other buildings interrupt the sunlight or not. Table 2 summarizes the features of the two analysis methods.

Table 2. *Features of Window sun-hour analysis and Waldram analysis*

Type	Analysis method
Window sun-hour analysis	· Based on the ratio of subject window exposure to the sun versus sun exposure of the entire outer wall · Generally, sunlight-hours are calculated based on whether 50% or more sunlight is received.
Waldram analysis	· Based on the sun path at a representative point of the subject window and whether other buildings interrupt the sunlight or not. · Generally, this method requires shorter analysis time.

This study developed an interface module with which to come up with elements (i.e. wall, roof, window) needed for sunlight-hour analysis from an IFC file by using VC++2005 and TNO_IFC Engine DLL. The development was made through the use of Waldram analysis, which required shorter analysis time than the other method to obtain a result more promptly in the schematic design stage.

A user engaged in three-dimensional modeling should delete IDs automatically given to the object and re-designate ID only for the subject window. Thus, the sun-hour analysis interface module was designed in a way that would confine the analysis to the ID-designated window.

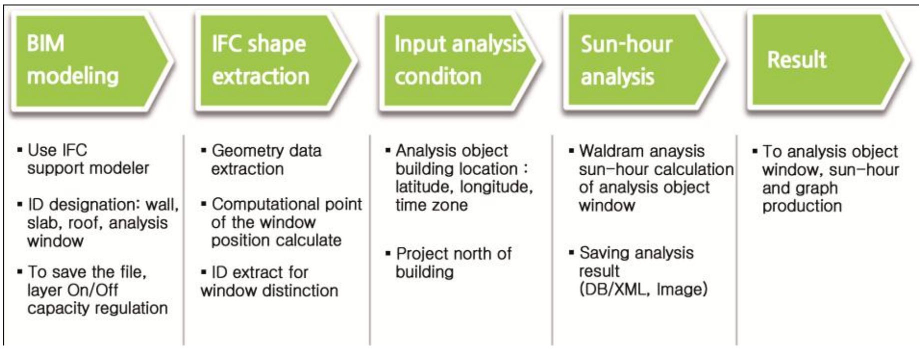


Figure 1. *IFC-based sun-hour analysis process*

Fig. 2 displays a Web screen of the sun-hour analysis. A user performs the sun-hour analysis on the Web through project creation, IFC file upload, and establishment of the latitude, longitude, and azimuth angle of the subject. Fig. 3 shows the result report on the sun-hour analysis. With it, you can check sun-hours for households and whether statutory the endurance limit of sun-hours has been satisfied.

Figure 2. *Main and project creation screens in sun-hour analysis*

Figure 3. *Result report on sun-hour analysis*

3.2 Energy analysis

The Web-based energy analysis made to predict the building's energy performance used the EnergyPlus engine and developed an IDF file-creating module by combining the configuration information-extracting module (out of attribute information in the IFC file) with configuration information and database (concerning meteorological data, physical property of construction materials used, building operation schedule, etc) (Fig. 5). Fig. 4

shows an energy analysis system configuration diagram.

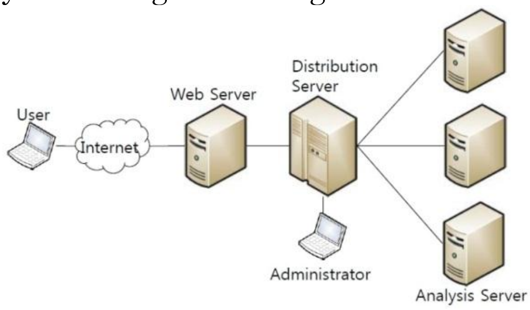


Figure 4. *Energy analysis system configuration diagram*

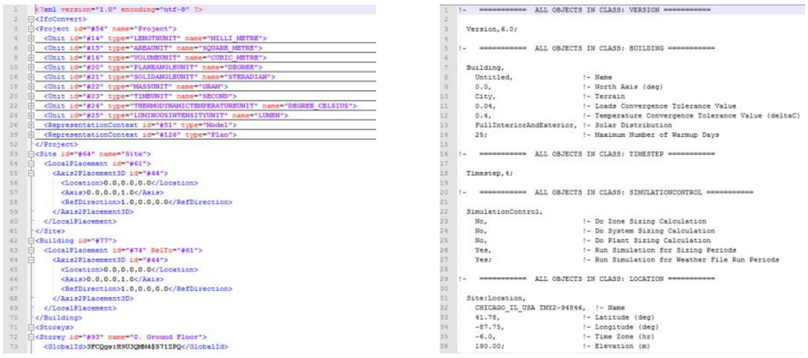


Figure 5. *IFC information-extracting file and created IDF file*

This study established a database with which users can enter meteorological data, physical property values of construction materials used, or building operation schedules themselves. Meteorological data used in the study was based on meteorological data (DOE-2 format) in 11 areas from the Korean Solar Energy Society converted into EPW file, which is a weather data input format for EnergyPlus. The database for building operation schedules was established using ASHRAE 90.1 Energy Standard and a domestic building energy efficiency rating prediction program (ECO2).

The energy analysis process is composed of: converting the BIM model into an IFC file and uploading it to the Web; creating an IDF file out of the XML file made by extracting configuration information from the IFC file and the user's input data; and executing energy analysis, using the IDF file and EnergyPlus.

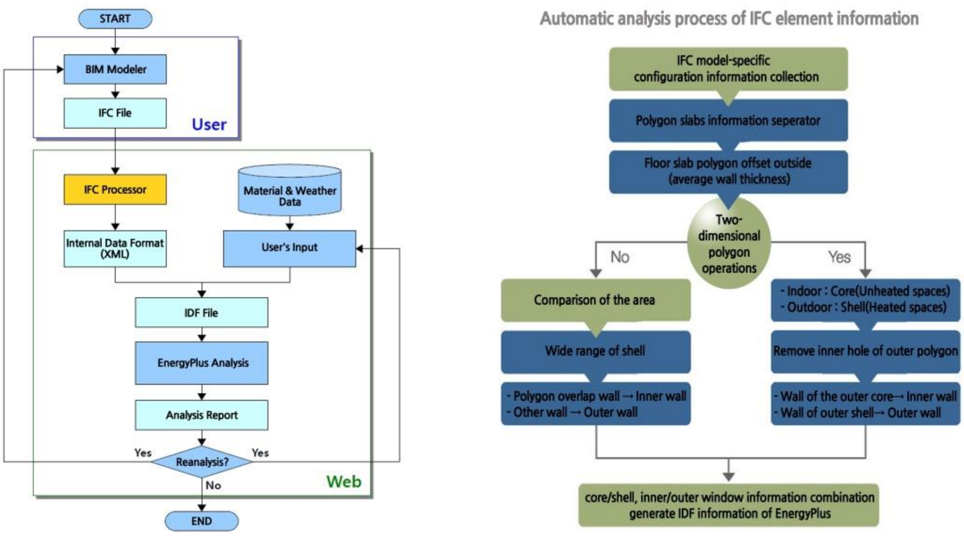
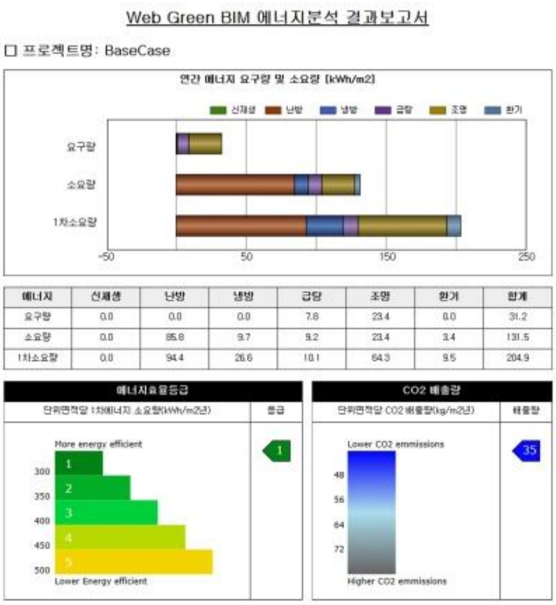


Figure 5. *Program development process and automatic analysis of information on IFC element*

Concerning the algorithm for automatic analysis of information on IFC element, this study designated wider areas as shells and smaller areas as cores through the comparison of different areas. Polygonally overlapping walls were recognized as inner walls and other walls as outer walls. It was arranged so that users can manually apply mechanical and HVAC system (CAV, VAV, FCU, Hot Water Plant, Chilled Water Plant, etc) on the Web by floor and enter types of lighting and lighting load per unit space. Figures concerning human bodies, devices and hot water load are based on basic values presented by domestic energy efficiency ratings (Fig. 6, 7). Concerning a project for which analysis has been completed, an energy analysis result report is drawn up and one can check annual energy requirement and consumption (kWh/㎡), energy efficiency rating and carbon dioxide emission (Fig. 8).

Figure 6. *Main screen and project creation*

Figure 7. *HVAC and material quality setting*



에너지	신재생	난방	냉방	급탕	조명	환기	합계
요구량	0.0	0.0	0.0	7.8	23.4	0.0	31.2
소요량	0.0	85.8	9.7	9.2	23.4	3.4	131.5
1차소요량	0.0	94.4	26.6	10.1	64.3	9.5	204.9

Figure 8. *Energy analysis result report*

4. Simulation comparative analysis

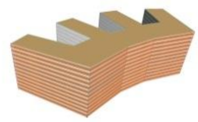
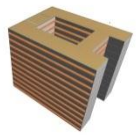
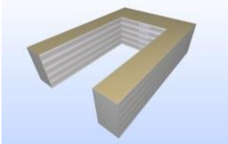
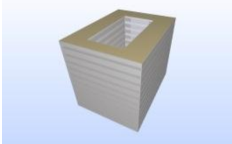
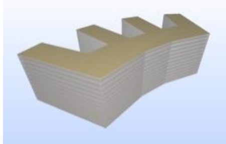
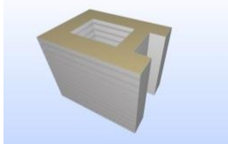
4.1 Building Energy Efficiency Rating Tool (ECO2)

ECO2 is a tool to rate the energy efficiency of domestic office buildings and was developed based on ISO 13790 and DIN V 18599. It uses the Monthly Calculation method for its basic rating logic to carry out quasi-steady state analysis. It extracts five items (heating, cooling, hot water, lighting and ventilation system) from the weather data in 14 locations throughout the country to evaluate source energy consumption per unit area. Users can input building shape and HVAC or new renewable energy types (geothermal, photovoltaic, solar heat or CHP). Also, users can then view the new renewable energy generation per unit area by outputting_energy consumption.

4.2 Analysis model overview and conditions

In order to anaylze the models, we selected an architectural model for schematic design (mass study) and carried out simulations on each option by using WebGBS and ECO2. Table 3 shows the BIM modeling image by option.

Table. 3 *BIM modeling image*

Division	ALT 1	ALT 2	ALT 3	ALT 4
BIM model (ArchiCAD 13)				
Solibri model viewer				

The design requirements follow the standards of Air Conditioning, Cooling, Sanitary Engineering. The thermal insulation performance and other main mechanical systems for the buildings are as shown in Table 4.

Table. 4 *The Thermal insulation Performance and main mechanical systems*

Division	Heat transmission Coefficient($W/m^2 \cdot K$)	Division		Design conditions
Roof	0.42	Heat Source	Cooling	Turbo-refrigerating machine(COP: 3.5) Cold water inlet, outlet temperature: 12℃/7℃
Floor	0.556		Heating	Hot water boiler(Efficiency: 85%) Hot water inlet, outlet temperature: 70℃/80℃
Wall(ex)	0.459		Hot-water	Hot water boiler(Efficiency: 85%) Hot water inlet, outlet temperature: 5℃/55℃
Wall(in)	2.58			
Window	4	Air conditoning		Variable air volume system

4.3 Results Analysis

The above four options and input elements were used in the simulation programs. Comparisons were made on the site energy demand, site energy consumption and source energy consumption with the following results:

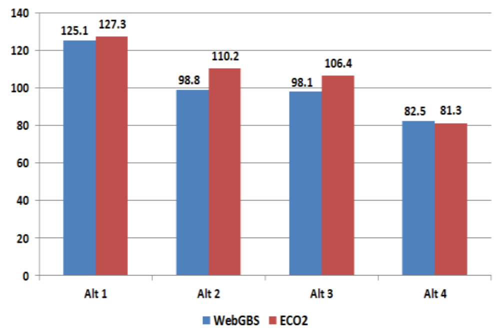


Figure 9*. Site energy demand*

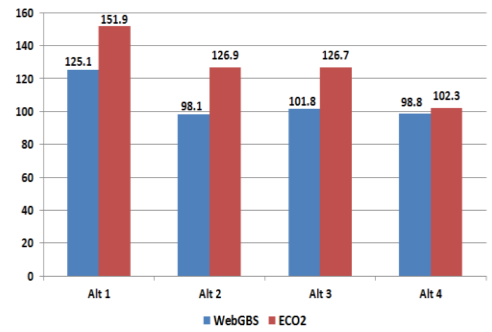


Figure 10*. Site energy consumption*

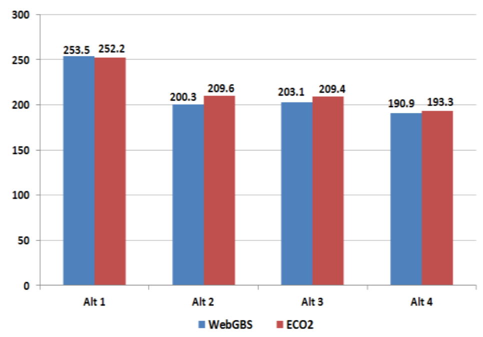


Figure 11*. Source energy consumption*

Division		ALT 1	ALT 2	ALT 3	ALT 4
Site energy demand	WebGB	125.1	98.1	101.8	98.8
	ECO2	151.9	126.9	126.7	102.3
	(%)	-17.64	-22.7	-19.65	-3.42
Site energy consumption	WebGB	125.1	98.1	101.8	98.8
	ECO2	151.9	126.9	126.7	102.3
	(%)	-17.64	-22.7	-19.65	-3.42
Source energy consumption	WebGB	253.5	200.3	209.4	193.3
	ECO2	252.2	209.6	209.4	193.3
	(%)	0.52	-4.44	-3.01	98.8

Table 5*. Comparison of result*

According to the simulation, in terms of site energy demand (figure9), WebGBS results are lower by 1.73% (ALT 1), 10.34% (ALT 2), 7.8% (ALT 3) and 1.48% (ALT 4) than ECO2. In average energy demand, WebGBS results are 4.87% lower than ECO2.

In site energy consumption(figure10), WebGBS results are lower by 17.64% (ALT 1), 22.70% (ALT 2), 19.65% (ALT 3) and 3.42% (ALT 4) than ECO2. In terms of average energy consumption, WebGBS results are 16.54% lower than ECO2.

In source energy consumption(figure11), which is an indicator of Building Energy Efficiency Rating, WebGBS results are lower by 0.52% (ALT 1), 4.44% (ALT 2), 3.01% (ALT 3) and 1.24% (ALT 4) than ECO2. In average source energy consumption, WebGBS results are 1.93% lower than ECO2.

5. Conclusion

In this study comparing WebGBS, a tool that uses IFC format to analyze energy performance on the web, with ECO2, which is a rating tool for Building Energy Efficiency Rating, four models were analyzed based on site energy demand, site energy consumption and source energy consumption. The results are as follows:

(1) Site energy demand showed 1.5%-10% differences in which WebGBS was lower on average by 4.9%.

(2) Site energy consumption showed 3.4%-23% differences. WebGBS was lower on average by 16.5%.

(3) Source energy consumption showed 0.5%-4.4% differences in which WebGBS was lower on average by 1.9%.

In conclusion, analysis results of the two programs showed similar values but the results for site energy demand analysis showed relatively high differences. It is believed that this was due to WEBGBS's selection of default values when selecting a heat source system, versus ECO2 variable system specifications.

Simulation tools currently used for BIM model-based environmental analysis are those optimized for each modeling program and can only be used by experts.

This study established a system that will help people make a sun-hour analysis and predict energy efficiency ratings easily on the Web, using IFC, which is an international standard and neutral format designed for interchange between BIM models. ECO2 and Green Building Studio offered by AutoDesk are used for web-based energy performance assessment tools at domestic and foreign. Both of two programs are similar to webGBS as it is possible for them to be analyzed on the web, however the difference lies in where it uses IFC, the standard BIM format.

Concerning the sun-hour analysis, this method produced identical sun-hour calculation results as verified through comparison with other programs. This method requires less time and expense, as it is done through Web-based analysis with BIM models converted into IFC, compared to existing methods that require three-dimensional modeling of an existing architectural model.

The energy analysis module is arranged for the use of the EnergyPlus engine, which uses dynamic energy simulation. The comparison with the building energy efficiency rating evaluation porgram(ECO2) shows similar results. In praticular, source energy consumption is within 5% error range, when compared to WebGBS.

More than half of the energy consumption of a building is fixed in the schematic design stage. It is expected that this method, which uses a Web-based sun-hour analysis and energy performance analysis of diverse design options, will work for the objective of energy use reduction.

Further research is required concerning IFC conversion of diverse BIM programs, errors in extraction of configuration information, and ensuing versions of IFC.

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6. Reference

Dong-Hwan Ko, 2010, A Study on BIM-based Sustainable Design Process using Building Performances and Energy Dfficiency Evaluation, Architectural Institute of Korea

Woo-Shin Jeung, Young-Don Kim, Yong-Yee Kim, Kyoo-Dong Song, 2010, A Study on the Extraction of Data from gbXML Format BIM for Heating and Cooling Load Calculation. The Society of Air-conditioning and Refrigerating Engineers of Korea

Jin-Sung Jo, Seung-Yeon Choo, Moo-Hyuck Choi, 2011, A Study on Applying Green BIM to Sustainable Architecture at Early Design Stage, Architectural Institute of Korea, Vol. 27, No. 4.

Hyeun-Jun Moon, Sa-Kyum Kim, 2010, BIM-based Energy Performance Evaluation for a Building Shape Study in an Early Design Stage for High-rise Buildings, Architectural Institute of Korea

Myoung-Chul Yoon, Seong-Lyong Koh, 2011, A Comparative Study on Possibility of Applying BIM based Simulation Compared to Web-based Energy Tool, Architectural Institute of Korea, Vol.13 No. 02

Jae-Hyuk Lee, Ki-Hyoung Yoo, Dong-Woo Jo, 2009, An Analysis of Comparison Between the Evaluation Tool for building Energy Efficiency Rating System and Detailed Analysis Programs, The Society of Air-conditioning and Refrigerating Engineers of Korea

Bazjanac, V., 2008, Pesponse to the OGC Request for Technology in Support of the AECOO Testbed, Technical document, Building Technologies Department, LBNL, Berkeley, CA