Developing a Prototype of Green BIM -based Integrated Design Systems for Small Architectural Design Firms

Sae Jin Woo

Department of Building and Environment Design
Ulsan College, Ulsan, 44022, South Korea

ABSTRACT

Since the importance of eco-friendly architecture is rapidly increasing, BIM   receives significant attention as an alternative that would derive the practical results and apply the design values of eco-friendly design elements to the architectural design process. Therefore, this study establishes an Integrated Design System based on Green BIM by applying the eco-friendly design values logically and systemically. The study also proposes practical case studies to examine the possibility of application. As a result, the framework of Green based Integrated Design System(gbIDS) and a prototype of Web-based gbIDS were developed to improve the working environment of small architectural firms.

Key words*: Building Information Modeling(BIM), Integrated Design System(IDS),gbXML, Architectural Design Process and Building Energy Saving.*

I. INTRODUCTION

As the global world focuses their attention on the severity of climate change, the architectural society's interest in environmental-friendly architecture has been increasing as well [1], [2]. Such trends resulted in the development of the method of planning, as well as a specific technology for the adaptation of surrounding natural environments. However, this development tends to be limited to unit scales such as building envelope, unit technology, windows and doors [3]-[5]. In order to apply those results to the buildings so that the synergy effect would be derived as eco-friendly architecture, the systemic consideration that builds on the early stage of architectural design is needed to create the practical influences. BIM stands out as one of the alternatives. BIM is a third-dimension design technology that consistently manages information of a building's entire life span. Such management, had become possible as communication and computer technologies were improved by combining them with architectural technology. BIM is also a tool that effectively fulfills an integrated design process by a cooperative system [6].

Therefore, the major purpose of the study is to set up Integrated Design System based on Green BIM by logically and systematically applying the design methods and technologies that are related to the environment during the early stage of architectural design. The study also attempts to suggest the practical case studies in order to verify the

possibility of Integrated Design System. Since the objectives of the study are to propose the framework of Green BIM-based Integrated Design System(gbIDS), which can be run by architects at an early stage of architectural design, and to develop the prototype of gbIDS, the following steps are taken to achieve the goals.

First, establish the framework of Integrated Design based on the conclusions of precedent studies and the interviews with the working staffs.

Second, set up the framework of applicable Integrated Design System based on the established framework of gbIDS.

Third, develop a web-based Integrated Design System that can be directly applied by architects at an early stage of architectural design using the established frameworks.

II. THE ESTABLISHMENT OF THE FRAMEWORK OF gbIDS

2.1 Development of eco-friendly design elements and gbIDS Process

The basic information for establishing the framework of gbIDS, which allows architects to process the eco-friendly architectural design beginning at an early stage of architectural design, is developed by the precedent studies [7], [8] of gbIDS process and eco-friendly design elements.

The precedent studies [7] suggest a total of 22 design elements allotted to 5 categories that should be decided by the design plans at an early stage (architectural planning stage) in order to create eco-friendly architecture. The levels of information that those design elements demand such as cases that require exact prediction values, specific plans, appropriate

new technology, and methods of design for the application of structure are set depending on the characteristics of each design element using simulation technology. The gbIDS for the application of eco-friendly design elements is set in accordance with Fig. 1 [9], [10]. Fig. 1 is also set by the researchers' decisions and the interviews with working staffs based on the conclusions of precedent studies [7].
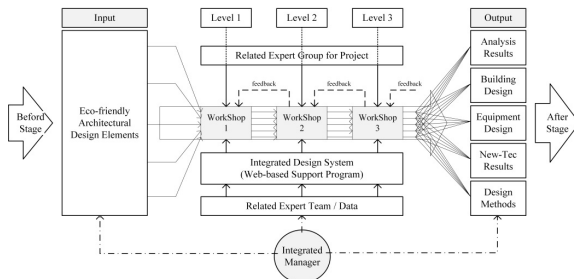

Fig. 1. Integrated Design Process

Fig. 1 shows that the building operation is conducted according to the eco-friendly design element's characteristics and to the level of information correlating each step of the design planning process. The elements that require the stimulation analysis is processed using the Application Program. The elements that require a blueprint of architectural design or a blueprint of facility system as their outputs are processed by the repeating personal efforts and discussions with the expert teams. This process is supported by the Integrated Design System, and the person who is in charge of the design project becomes the core of the process. However, the information obtained from the process and the conclusions which form the discussions, are revised by the integrated manager.

2. 2 The Concept and Components of gbIDS

The gbIDS process that is previously mentioned, suggests that Integrated Design System works as the platform for the design process of eco-friendly architecture. In other words, the gbIDS process is an Analysis-Application Program that is needed for setting the design values of eco-friendly design elements. This process is also BIM-based Design Platform that consistently manages inputs and outputs of the data from the discussions with the experts. The abridged components and systems of gbIDS is referred in Fig. 2. Fig. 2 is consisted of 4 different factors: data input means, data formation means, data management means, and data output means.
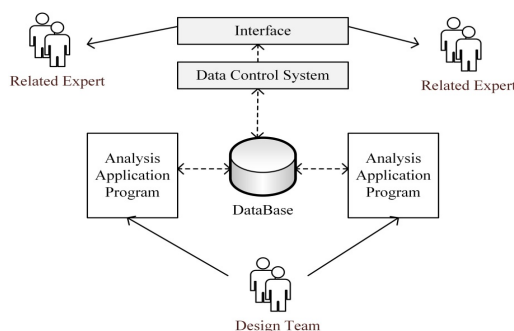

Fig. 2. The elements and structure of gbIDS

Data input means are for the design teams to enter necessary data for processing architectural design using BIM-based Design Tools such as Revit or AchiCAD [11], [12]. Therefore, the convenience of entering the data and creating an input guideline to maintain the consistency are essential regarding the data input means. Data formation means are for saving and revising the new data formed by BIM Design Tools and Analysis-Application Programs. Thus, it is important to make sure that the different data formed by other tools and programs are compatible. Data management means are the managements of design values that satisfy related experts' needs in Integrated Design Process. Therefore, keeping the consistency of the data so that the building would be available for its entire span is crucial in the data management means. Finally, the data output means are for providing an interface that allows the experts to utilize the information conveniently and to save the decided design values from the perspective of the users.

2.3 The Establishment of the Framework of gbIDS

Based on the components and the system set in Fig. 2, the researchers' experiments and judgement, as well as the results of interviews with the related experts, are mainly used to establish the framework of gbIDS as expressed in Fig. 3.
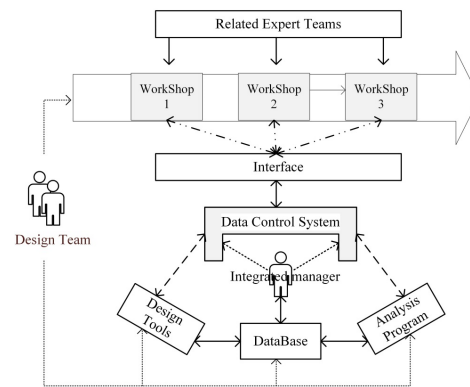

Fig. 3. The Framework of gbIDS

Fig. 3 shows that the work is done with the support of the information and the design values, which are needed for both the discussions with experts and for the analysis of eco-friendly architectural elements (these are the results of the process of the architectural design teams who are in charge of the project). In this process, IFC [13] or gbXML [14], the data-compatible file formats, is considered as the driving force of Integrated Design System and is employed for the mutual compatibility. The integrated manager manages and maintains the data of systems, and should provide the design information and the design values to the design teams and to the experts so that eco-friendly design elements' values can be applied in accordance to the level of step-by-step information starting from the early stage of architectural design.

III. CASE STUDY : DEVELOPMENT OF THE PROTOTYPE

3.1 Development of a Model of gbIDS Prototype

In order to analyze the possibility of a system that satisfies the developed framework and to utilize such a framework as a prototype of gbIDS, the study now focuses on the development of gbIDS that small to medium sized architectural design firms can use. In general, smaller architectural firms consist of one architect and one to two employees, and do not have sufficient equipment and programs for architectural design [15], [16]. Due to the limitation of human resources and investments in facilities, the designing works are processed by a qualified architect who is a representative of the office. The qualified architect participates in the overall process of architectural design, starting from pre-design and construction documentation to the supervision of the project, and also manages the floor plan and the work process. As a result of such limited working conditions, the management of data, consistency of the work, and discussion with the experts are rather inefficient. In order to overcome the limitations presented by small architectural firms and to increase the efficiency of the design process, this study suggests a system that can be utilized in all processes by applying gbIDS.

The model of the system is based on the interviews with the working staffs (the heads of small architectural firms) and is analyzed in Fig. 4. Fig. 4 contains four categories: BIM-based Design Program, Design Program, Analysis Program, and Database. The work platform is set to make BIM-based Design Program as the core of the design process. At each stage of architectural design, the design drawings and the information of BIM-based Design Program are produced. Based on those products, the team members of the design team, as well as other related experts, cooperate with each other to process the design. In order to decide the design values and the design information (for BIM-based Design Program) of the eco-friendly design elements, the related designing programs and analysis programs are mutually utilized to make use of the design data. Database is for controlling the design information of the elements, and it is directly accessible and manageable for an architect.
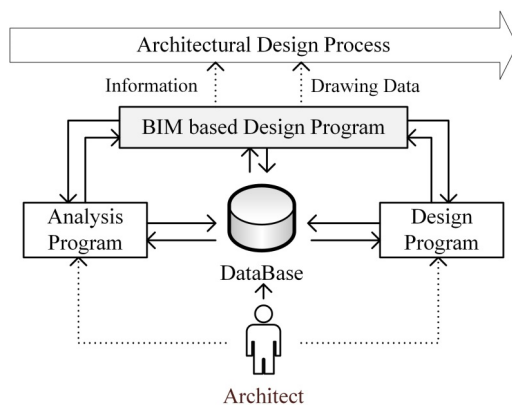

Fig. 4. The model of gbIDS Prototype

3.2 Development of a Framework of gbIDS Prototype

The research shows that the essential eco-friendly factors that must be applied in the designing process with design programs are dependent on external resources since small to medium sized architectural firms lack the professional knowledge and supervisions. The framework of the prototype is based on this conclusion, and expressed in Fig. 5.

Revit Architecture is used as a platform of the designing process because the frequency of its use is high, and is applicable for small firms. Also, for the Design Program, AutoCAD is conjugated since it is the most commonly used program among the architects. Analysis Program contains Application Program for the analysis of a building's energy because building energy-saving designs are grasping an increasing amount of attention. Such programs should have an eco-friendly design element that constitutes the same direction as the nation's policy [17], [18]. Database, a section that manages the design information of the system, is consisted of a Data/information Control System with three major functions. Through this control system, an architect directly maintains the design information such as Revit Architecture, AutoCAD, and Application Programs that is related to a building's energy analysis. Also, the architect provides this information to the design team's members and to the experts.
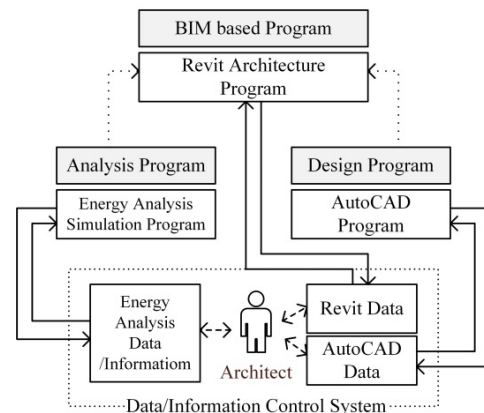

Fig. 5. The Framework of gbIDS Prototype

3.3 Development of gbIDS Prototype

3.3.1 Regarding Data/Information Control System

The Data/ Information Control System that supervises operation of gbIDS and management of data are developed in consideration of the architect and the environment of small architectural firms. In other words, small architectural firms have limitations of investment and human resources [15], [16]; therefore, the development of the system should acknowledge the fact that the majority of architects do not have professional IT knowledge. In addition, the architect is in charge of architectural design and the integrated management simultaneously. The program is designed based on a web system so that one would utilize it conveniently. For the convenience of the users it is interfaced mainly for the non-professionals.

As mentioned in Fig. 5, the Data/Information Control System is consisted of three sections that provide design data

and information: Revit Architecture, AutoCAD, and Building Energy Analysis Simulation Application Program (BEAsap). Fig. 6 shows details of the elements and of the system.

As Fig. 6 describes, the section of Revit Architecture is composed of three major parts: Modeling Data (which is data needed for operating BIM-based Design Program) and Family Data (which is design information) as well as Template Data. Modeling Data arranges the building types and collects the floor plans written by Revit Architecture. Modeling Data is also a portion that provides architects web-based and saved design data for the architectural design process. Family Data collects and organizes families that are needed for Revit Architecture's modeling process. These families are arranged in accordance to Family Types such as structure (wall, floor etc) and furniture. This information then goes to the design teams. Template Data is the data regarding the establishment of designing the environment of Revit Architecture. Template Data revises existing data so that it fits the working environment of small firms. It is also designed to be used in the modeling process based on the data from the interviews with the working staffs. AutoCAD is a design program for drawing 2D floor plans in the architectural design process. AutoCAD contains Drawing Data, Block Data, and Working Environment Data. Drawing Data collects and organizes 2D floor plans (drawn by AutoCAD) so that it fits the working environment of small firms. Drawing data also manages the floor plans created during the design process and provides the design teams with results. Block Data is needed for drawing floor plans by AutoCAD online. This data collects appropriate data for small firm working environments, and is arranged by specific types such as wall, floor, roof, and furniture. Work Environment Data offers the design teams data that constitutes the working environment of AutoCAD. Work Environment Data corrects the existing data to make it fit the working environment, or contains the data created by the researchers.
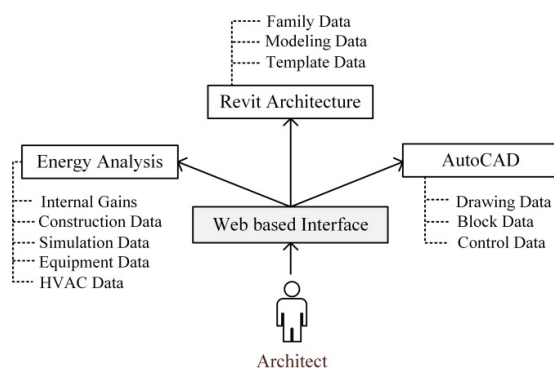

Fig. 6. The elements and structure of gbIDS Prototype

BEAsap analyzes both proper design values and Building Energy-saving Design; it also supports the data and information that must apply Analysis Stimulation Tool to the design process. BEAsap contains Internal Gains Data, Construction Data, Equipment System Data, and Stimulation Data. Internal Gains Data deals with the conditions of internal environments for analyzing Building Energy, and consists of People, Light and Electric Equipment. The following data values are formed by organizing the proper values of internal spaces according to

their building types and the interviews with the staffs [19]-[21]. Construction Data is for maintaining the data of building structures. Depending on the type of building, Construction Data differentiates between floor, wall, roof, window, and door so that the Design Detail Data can be formed and managed according to the types of materials, thickness, and number of layers. Equipment System Data deals with controlling the data which is correlated with the Heating & Cooling System. The subparts are then allocated to plant and HVAC System. Plant collects information about Equipment Type of heating and cooling (Boiler, District, Chiller etc), and HVAC System creates and manages Equipment Type (CAV, VAV, FCU etc) data to support and apply Analysis Stimulation Tool.

3.3.2 Regarding Analysis System

Among various eco-friendly design elements, the branch that attracts the most attention is Building Energy Saving Design [22], [23]. Building Energy Saving Design should concentrate on making energy-saving buildings during the pre-design phase, but small to medium sized architectural firms cannot secure the technology to do so due to the limitation of their working environments. As a result, they only receive support from external experts, their architect's experience, and the simple codes when they process the design. In order to overcome the limitations of small architectural firms and to test the possibility of gbIDS, the study developed Building Energy Analysis Simulation-Application Program (BEAsap) by using Analysis System.

Fig. 7 shows the model of BEAsap which is set based on the framework of the prototype that was previously mentioned.
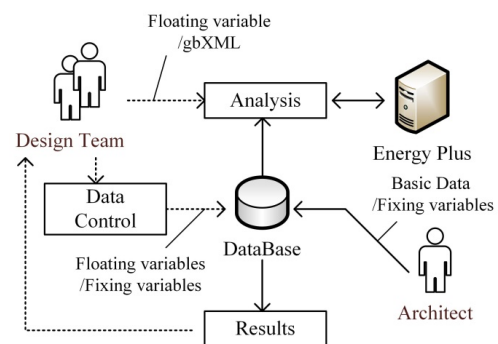

Fig. 7. The model of BEAsap

Fig. 7 refers to a web-based model that users can access easily in the design process. The model develops three major functions: analysis, output management, and data management. Data management includes data manager, which is supervised by the users, and Data/Information Control System, which is supervised by the manager. The core point of this subpart division is to allow the user and manager to enter, revise, and choose the design variables for analysis online. Analytical function is the most essential portion of the development tool. It consists of an interface and an analytical engine that are developed to process the analytical function fitting the purpose of the user. Analytical engine is applied by EnergyPlus (Ver. 6.0.0) [24] which is globally certified. Result management function constructs an interface which organizes types of users

according to types of analysis (plan and basic design) in relation to the analyzed building. The results of the analysis are in graphic forms to provide simplicity to users (architects).

According to the model suggested in Fig. 7, the fundamental factor of the analytical tool is the analytical engine. In order to achieve the goal of the web-based analytical tool, BEAsap, (which predicts the amount of consumption of building energy and CO_2 production) the reliability of the engine should be a priority. To increase the reliability, this study used EnergyPlus because its quality is officially proven; also idf file must be formed as the analytical input method. The process of forming idf file is the algorithm of analytical tool. Analytical algorithm is set as shown in Fig. 8.
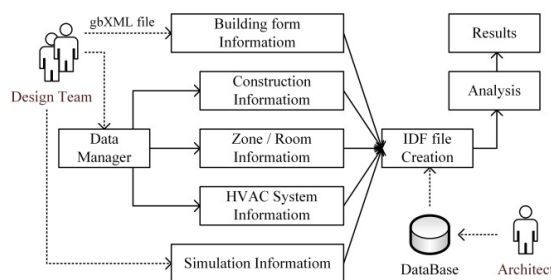

Fig. 8. The analysis algorithm of BEAsap

Fig. 8 classifies the components of forming an idf file for each module as followings: building massing information, structure information, heat-resource equipment information, building's analytical simulation information, and constant variables. Building massing information is about building's size, measurement, and shape. From this information, one can derive modeling data of BIM-based Design Program (Revit Architecture). If one can use this directly during the designing process, it is possible to omit the rewriting in analysis of the existing buildings, so time and effort are saved. For this efficiency, the development attempted to cross-brows Revit Architecture with gbXML.

Structure information is about the building materials that consist envelope structures (external wall, roof, windows and doors) and internal structure (floor, internal wall, windows and doors) as well as their material properties. This information can be created directly in modeling process of Revit Architecture, but since current technology is limited, Data Manager Interface is developed to form the structure information for design environment and securing diversity. Among other variables that constitute idf file, Constant variable and other extra information clarify design values of computer simulation variables that cannot be decided by architects in analysis as well as the variables that architects cannot comprehend and apply easily in basic planning phase. The zone information (internally generated heat, application of air conditioning etc), the heat-resource equipment information (detail design values of air conditioning) and the simulation information of analyzed building (meteorological data, location, size, surrounding environment etc) are generated by Data Manager Interface.

3.3.3 Establishment of an Alternative for Data Compatibility

The contents and composition of Building Form Information that is needed in Building Energy analysis by EnergyPlus should be in form that structure that idf file requires. For this, the structure of idf file is set as a frame of Building Form Information, and the structure of Building Form Information is developed so that other required contents must be readable from gbXML as Fig. 9 shows [25].

In Fig. 9, Building Form Information has two components: the structure information (Building Surface: Detailed) which is also a structure of idf file and fenestration information (Fenestration Surface: Detailed). The content of the Building Form Information are adjusted based on the structure information of gbXML file (Surface id = " " Surface type = " ") and on fenestration information (Opening id = " " Opening type = " ") so that it fits the expression and structure of idf file. Considering the content of gbXML file, several important principles of idf formation can be deduced as follow:

First, diction, content, and principles of Building Form Information must be written by the standards of idf file.

Second, among the types of structures that were decided by gbXML, Shade and Air should not be applied, and Interior Floor is consisted of the lowest floor, the interlayer floor, and the pilotis.

Third, the coordinates for expressing the form of structure is process in counterclockwise by the left, low point.

Fourth, the division of structures (wall, floor and roof) should be done based on the zones that are touching the structure with consideration of pathway of heat transfer.
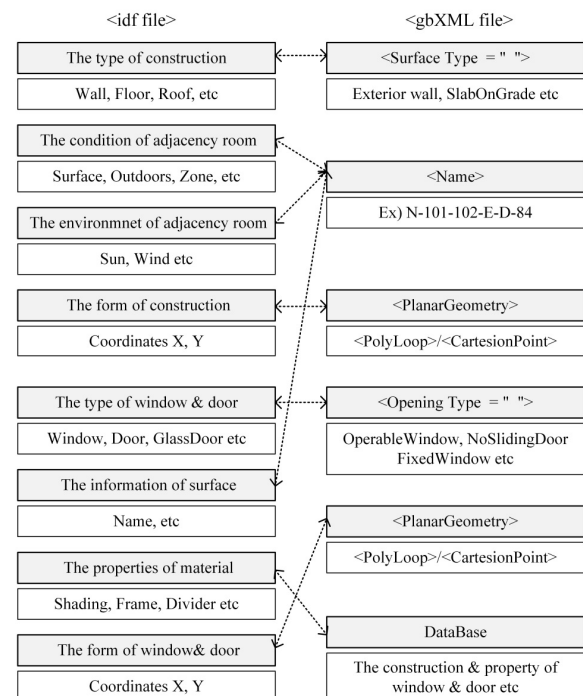

Fig. 9. The compatible construction of building form information

3.3.4 Development of gbIDS Prototype

The prototype of gbIDS is web-based, and it is constructed using C# (MS Visual Studio 2010) [26], [27] and MS Access [28], [29]. The constructed gbIDS contains Data/Information Control System that can be utilized to operate gbIDS, and it also contains BEAsap that is used to analyze and to predict building energy which is an eco-friendly design element.

Fig. 10 is the start-up screen of Web-based Data/Information Control System which is established based on Fig. 6. It is consisted of two parts: "Building Energy & CO_2 Database" which administers design data and information related to BEAsap (see Fig. 11) and "Architectural Design Database & Library" that oversees Revit, data of AutoCAD, and information. Through those web-based systems, the integrated governing of related data that design teams are currently utilizing such as Revit, AutoCAD, and BEAsap becomes available.

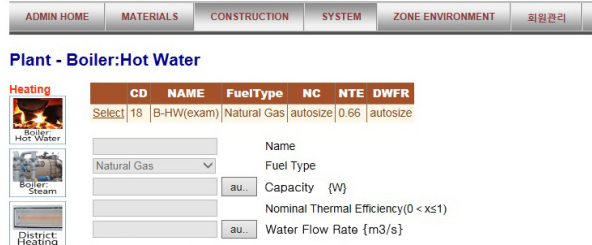Fig. 10. The main screen of Data/Information control system

Fig. 11. The screen of Building Energy & CO_2 DataBase

If you look at Fig. 12 which is the starting screen of BEAsap which is developed based on Fig. 8 and 9, it contains, five factors: Home, Data Manager, Analysis, Result, Help & Contact.
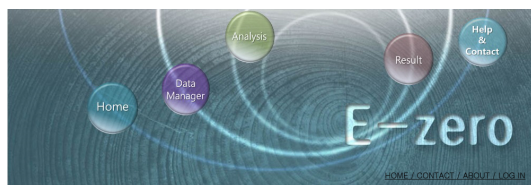

Fig. 12. The main screen of BEAsap

Data Manager which is developed by the results mentioned earlier has construction information, zone information, and plant information so that users can handle it directly. The system of Data Manager is expressed as Fig. 13 describes.
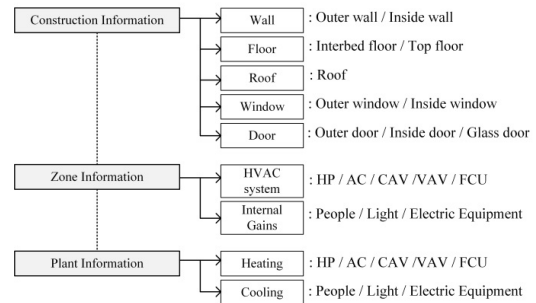

Fig. 13. The elements and structure of Data Manager Interface

Construction information provides components and material property of each structure of subject of analysis. In order to achieve this, users are supposed to be able to choose the materials of Database according to the types of wall, floor, roof, window and door; also users create and manage the formed structures based on their choices.

Zone information provides information about internal gains and HVAC System of Heating and Cooling Zones. Zone HVAC System selects five general types so that users can set few variables by themselves, internal gains contains three types of manageable design values. Plant information provides information regarding plant equipments for cooling and heating such as boilers and chillers. Based on the types that are used in architecture frequently, three types of boilers are selected, and four types of chillers are selected. Each plant's design variables are directly manageable for users just like other zone information. Analysis is an interface developed for comfortable prediction of building energy consumption and CO_2 production. This interface can be process directly by users using analytical development tool. Analysis Interface considers the difference in levels of design values that are required in designing process.

Fig. 14 shows that pre-design and schematic design is separated from each other, regarding such consideration.
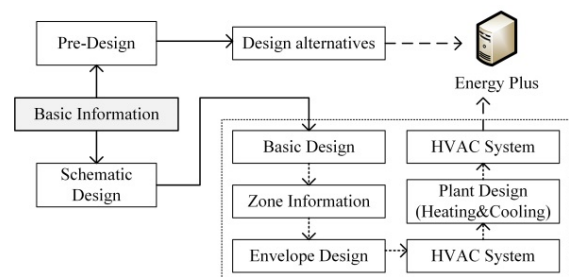

Fig. 14. The elements and structure of Analysis Interface

In Fig. 14, the basic information for processing detailed building energy analysis by EnergyPlus which is an analytical engine is entered first through Information Interface. This basic information contains simulation variables including local meteorological data, simulation period, and gbXML file that have Building Form Information. Pre-Design Interface processes analysis in planning stage. Scrutinizing the characteristics of planning stage, there are three sections of design elements' types so that one can compare different design alternatives. Those three sections are composition of structure types, HVAC System types, and design values of internal gains.

Each section's detailed variables are set by users through Data Manager Interface. Schematic Design Interface processes analysis at early stage of design successively. First, the standard value of analytical variables (heat resources, each zone's internal gains etc) are set within basic plan and zone information. Based on those standard values, the characteristics and the design conditions are taken into account, and revision and reset of the design values of analytical variables are processed step-by-step.

IV. CONCLUDING REMARKS

As a result of systemic effort to apply the values of eco-friendly design elements as well as to develop gbIDS that supports design teams who builds eco-friendly buildings, the following points are abridged to convey the main focuses of the study.

First, From Green BIM-based Integrated Design Process (gbIDS), the function and elements of gbIDS are established, and the framework of gbIDS is also constructed. In other words, gbIDS is a platform of eco-friendly design process that supports the design teams and the experts, and it manages and maintains related design data and information. The framework of gbIDS is established based on four components (element of data input, element of data formation, element of data management and maintain, and element of data output) and gbIDP.

Second, For the examination of possibility of application of established gbIDS and for the development of prototype, a model and a framework of gbIDS prototype are developed to improve the limitation of design environments of small and medium sized architectural firms. In other words, the framework of gbIDS prototype is based on small firms' operation status (human composition, work equipments, etc) in accordance to the established model's components such as BIM-based Design Program, Design Program, Analysis Program, and DataBase .

Third, Based on the established framework, a web-based gbIDS prototype which architect can directly run is developed. In other words, Data/Information Control System that works as a platform of gbIDS prototype is a system that architects directly manage Revit Architecture (BIM-based Design Program), AutoCAD, and the data and information of a developed building-energy analytical tool, BEAsap.or on the lower halves of the backs of the pages.

Fourth, in order to develop gbIDS that can be utilized throughout the entire designing process from planning to working design, this study had obtained the ideas and basis that support the theories. Also, by developing a prototype that applies to the designing process of small architectural design firms, the study checked and confirmed the possibility of real-life application, and the study suggested the feasibility of gbIDS that is closely attached to the actual field based on obtained data and case studies of various scenes.

REFERENCES

[1]   S. W. Shin, *Sustainable Building Technology*, Sustainable Building Research Center, South Korea, 2007.

[2]   G. Peter, *Sustainable Energy System in Architectural Design*, McGraw-Hill, New York, 2006.

[3]   S. J. Woo and Y. D. Yu, "A Study on the Model of a Building-Envelope Structural Modification System to Increase Energy Efficiency at the Schematic Design Stage," Journal of Asian Architecture and Building Engineering, vol. 12, no. 2, 2013, pp. 189-196.

[4]   N. E. Lee, H. S. Han, and B. L. Ahn, "A Study on Cooling Energy Saving Measures using Simulation and Metered Data of Existing Building," Journal of the Architecture Institute of Korea (Planning & Design), vol. 29, no. 4, 2013, pp. 235-242.

[5]   Y. H. Lee and J. Y. Chun, "Selection and Process for the Applicable Performance Items of Remodeling Apartment Project," Journal of the Architecture Institute of Korea (Planning & Design), vol. 25, no. 11, 2009, pp. 79-88.

[6]   C. Eastman, P. Teicholz, R. Sacks, and K. Liston, *BIM Handbook*, John Wiley & Sons, Inc: Hoboken, New Jersey, 2008.

[7]   S. J. Woo, "A Study on the Systematization and Establishment of Constituent Design Element of Integrated Design Process for BIM at Early Design Stage," Journal of the Architecture Institute of Korea (Planning & Design), vol. 27, no. 1, 2011, pp. 65-72.

[8]   S. J. Woo, S. M. Yoon, and J. W. Choi, "A Study on the Development of gbXML and Web based Analysis Tool(E-Zero) for the Estimate of Building Energy Needs and CO2 Emissions," Journal of the Architecture Institute of Korea (Planning & Design), vol. 29, no. 8, 2013, pp. 251-258.

[9]   J. Yudelson, *Green Building Through Integrated Design*, McGraw-Hill, New York, 2009.

[10] E. Krygiel and B. Nies, *Green BIM*, Wily Technology Pub, Indianapolis, 2008.

[11] Autodesk (Building Design Suite). Available online: http://www.autodesk.com/suites/building-design-suite/overview

[12] Autodesk (AutoCAD). Available online: http://www.autodesk.com/products/autocad/overview

[13] buildingSMART. Available online : http://www.buildingsmart-tech.org/specifications/ifc-verview

[14] gbXML. Available online: http://www.gbxml.org/

[15] Y. S. Jung and M. H. Joo, "Building information modeling(BIM) framework for practical implementation," Automation in Construction, vol. 20, no. 2, 2011, pp. 126-133.

[16] M. J. Kim, K. H. Lee, and C. B. Son, "An Status Analysis on the BIM Utilization and Improvement Measures in Domestic Architects," Journal of the

Architecture Institute of Korea (Planning & Design), vol. 30, no. 8, 2014, pp. 79-86.

[17] A. Yezioro, B. Dong, and F. Leite, "An applied artificial intelligence approach toward assessing building performance simulation tools," Energy and Building, vol. 40, no. 4, 2008, pp. 612-620.

[18] N. Ghrab Morcos, "CHEOPS: a simplified tool for thermal assessment of Mediterranean residential building in hot and cold seasons," Energy and Building, vol. 37, no. 6, 2005, pp. 651-662.

[19] Y. Ho. Kim and J. W. Park, *HVAC System 2nd ed*, BoSung Ga, South Korea, 1999.

[20] H. William, *HVAC, 2nd ed*, R.S. Means Company, USA, 1994.

[21] K. N. Lee and S. J. Lee, "A Study on the Improvement of HVAC System Design and Operation Strategies through Thermal Environment Assessment of an Office Building," Journal of the Architecture Institute of Korea (Planning & Design), vol. 30, no. 2, 2014, pp. 277-284.

[22] S. Y. Song and S. J. Lee, "Cost Efficiency Analysis of Design Elements for an Energy efficient Apartment Complex and Establishment of Design Models," Journal of the Architecture Institute of Korea (Planning & Design), vol. 24, no. 11, 2008, pp. 329-340.

[23] F. Chlea, A. Husaunndee, C. Inard, and P. Riederer, "A new methodology for the design of low energy buildings," Energy and Building, vol. 41, no. 9, 2009, pp. 982-990.

[24] EnergyPlus Energy Simulation Software. Available online: http://apps1.eere.energy.gov/buildings /energyplus/

[25] S. J. Woo, "A Study of Decision Algorithm for Optimum Envelope Part in Energy Saving Design by Envelope Changing of Apartment Housing," Journal of the Architecture Institute of Korea, vol. 25, no. 10, 2009, pp. 297-305.

[26] Y. G. Choi, *Novel C# 3rd ed*, JABOOK, South Korea, 2009.

[27] H. L. Cho, *Beginer C# 200*, Information Publishing Group, South Korea, 2010.

[28] J. H. Lee, *SQL Server*, Young Jin, South Korea, 1999.

[29] J. Y. Ahn and L. A. Lee, *MS Access 2000*, Dea Moung, South Korea, 2004.

Sae Jin Woo
He received the B.S., M.S. and Ph.D degree in Department of Architectural Engineering from Pusan National University, Pusan, Korea in 1987, 1989 and 2001 respectively. Since 1995, he has been with Department of Building and Environment Design at Ulsan College, where he is currently a professor. His research interests are Eco-Friendly Architectural Designs on the base of Building Information Modeling and AI (Expert System, Fuzzy System).