DEVELOPMENT OF AN INTEGRATED BUILDING DESIGN INFORMATION INTERFACE

A Thesis

by

SONIA ARJUN PUNJABI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2005

Major Subject: Architecture

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Approved as to style and content by:

Valerian Miranda (Chair of Committee)	Larry Degelman (Member)
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ABSTRACT

Development of an Integrated Building Design

Information Interface. (May 2005)

Sonia Arjun Punjabi, B. Arch, University of Mumbai

Chair of Advisory Committee: Dr. Valerian Miranda

This research recognizes the need for building simulation/performance tools that can easily be integrated into the building design process. The study examines available simulation tools and attempts to determine why these tools are not used by building designers/architects. Findings confirm that the complexity of simulation tools created by scientists, who are more technically oriented, discourages use by architects who are more visually oriented people.

The evaluation and analysis of available simulation tools suggests a thorough research methodology for creating a new front-end interface that solves current usage problems. The research is limited to the interface design of the new front-end which is named Integrated Building Design Information Interface (IBDII). The new front end provides an interface that allows designers to make more informed decisions during the design process while providing a front-end that supports AutoCAD and permits a user interface where the mode of input is graphical and not numerical.

Criteria for the new front-end interface enable the development of a series of mock-up interface designs that are responsive to the needs of architects. A working graphical user interface of the building information prototype is created and is then put through an empirical user testing. The usability testing establishs the usefulness, effectiveness, likeability and learnability of the developed interface design. The testing includes six factors which act as indicators of usability and provide suggestions for future developments. The testing evaluation ascertains that the interface is easy to learn and use. Findings also show that the best feature of integrated building design information front-end is its interface design and there is room for improvement in the way input is selected.

DEDICATION

To my Dad for making me who I am today …

I dedicate my thesis to him

I hope I fulfilled your dream daddy

ACKNOWLEDGMENTS

The successful completion of my thesis has been made possible by the support and help of many people who I would like to thank. I thank Dr. Valerian Miranda for helping me throughout – for his guidance, copious assistance and keen interest for my research. He has helped me immensely in establishing clear and well-defined fundamentals for my thesis research. I thank him for just being there for me, which means a whole lot to me.

I would like to give a special thanks to Prof. Larry Degelman, who took time out regularly to guide me and give me his valuable advice. I am honored to have him on my committee. I would also like to thank Dr. Julie Rogers and Dr. Frank Shipman for all their help, support and guidance. I am thankful to Srikar Doddi for his technical help, without which my thesis would not have reached so far.

I am grateful to my Mother, sister and brother-in-law for helping me to get to Texas A&M University all the way from India. I am thankful to my parents for providing me with life long possessions – strength and courage. I thank my baby nephew Aditya for providing me the motivation, by his delightful arrival which I most needed in the last few days of my thesis. I would like to thank Salim for being by my side, through the good and the not-so-good days.

I am thankful to Texas A&M University for all the happy memories, proud moments and special occasions. I thank all my friends at Texas A&M University for all their encouraging words and happy times. And nothing could have gone just the way it did without the special blessings of my Dad.

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INTRODUCTION

Background

Several building design and building performance analysis programs are now available for building designers. Such programs include the Building Design Advisor (BDA) which supports the integrated use of multiple analysis and visualization tools throughout the building design process [24]. All of these simulation tools use sophisticated algorithms that model the physical behavior of buildings under varying environmental conditions. When used during the building design process, these tools can predict the performance of design alternatives with respect to comfort, energy usage, overall life cycle costs, etc., and can thus lead to better informed design decisions.

The aspiration of designers to create sustainable built environments for the future by consciously taking into consideration issues such as energy efficiency, passive building and ecologically friendly design has further added to the complexity of the design process. With such increasing complexity involved in building design and performance evaluation of buildings, the need for the use of computational building performance evaluation and design support tools throughout the process is recognized. Such tools allow the building designers to evaluate the impact of design on the various performance mandates such as thermal, air, acoustic and visual quality [8, 10]. They can

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This thesis follows the style and format of the *Journal of Automation in Construction.*

lead to an improved understanding of the behavior of various climatic agents and thus provide confidence in design. They are also especially important for making preliminary evaluation of complex design strategies [17, 10]. Building designs that focus on energy efficiency and environmental impact from the early, schematic phases of building design can sometimes exceed code requirements by more than 50%, and at the same, even reduce initial cost [16, 22].

Currently, designers are finding it difficult to fully exploit even the basic computer tools available to them. Despite advances in the field of simulation tools for building performance analysis and visualization, the potential of these tools is largely untapped [5]. The complexity of design tools is born out of a growing gap in what researchers and scientists offer as design tools, and what is really used in practice [14, 5]. Researchers and scientists are more technically oriented and require powerful and accurate models that adequately represent real-world complexity. Considering the fact that architects on the other hand are visually oriented people they tend to shy away from inputting numerical data for obtaining building design information. They are more interested in simple, straightforward and intuitive tools [5].

Unfortunately, most of the available simulation programs were originally developed by researchers, for research purposes, and are not easy to use. They require significant amounts of detailed information about the building and its context, usually in the form of input files that consists of keywords and data, following particular syntax and structures. The interface of these tools is typically cumbersome, the output is largely numeric, and the input requires mechanical engineering data that comes at the end of the architectural design process, hence it becomes difficult for the architects to incorporate the energy analysis results during the process of designing.

New tools must therefore be designed in close co-operation with designers so that their requirements can be addressed. A need therefore exists for design tools that are user-friendly and easy-to-use. These tools should be able to provide answers quickly and calculations should require the minimum amount of input so as to be useful during he initial design stages [5].

Problem Statement

The problem of non-usage of simulation/performance analysis tools by building designers exists due to the following reasons: complexity of existing tools, lack of integration with the design process, tools require extensive training, interface is typically cumbersome, input is largely numeric and design projects undertaken have time constraints.

Objectives

The core objective of the research is to develop a visual language for an Integrated Building Design Information Interface, keeping in mind that architects and designers would be the people using this front-end. The new front-end integrates the building design process with existing building performance analysis tools, and is thus named Integrated Building Design Information Interface (IBDII). This research specifically concentrates on the interface design of the created front-end and not any other aspects related to the calculation of performance analysis of existing tools that would be linked to the front-end. Some of the accompanying objectives of this research are listed as follows:

- To provide the designers with a building performance tool that would aide in the design process to make more informed decisions.
- To provide a front-end that supports AutoCAD, so that the relevant building information can be assigned to the drawings thereby reducing the need to redraw and this would also prevent the need to input numerical data.
- To develop a graphical user interface where the mode of input is graphical and not numerical.
- To provide designers with a building design information tool that requires the least amount of training and yet is very easy to learn and use.
- To provide designers with an option to create his/her custom databases of building components with the least amount of effort and skill.

Hypotheses

The main premises for this research can be stated as follows:

- Premise 1 – Architects and designers tend to avoid using simulation tools.
- Premise 2 – Data input is extensive and requires lot of training.
- Premise 3 – There exists very little integration of tools supporting drawing (AutoCAD) and analysis.

Scope and Limitations

Since the 1960's, researchers have been developing extremely sophisticated analysis tools to study the energy performance of buildings. These tools are typically unsuitable for architects, because the interface is cumbersome, the output is largely numeric, and the input requires mechanical engineering data that comes at the end of the architectural design process. The proposed IBDII front-end prototype will be an integration of the extremely sophisticated analysis and simulation tools that have been developed to date. As the prototype will be linked to specialized tools, attention will be paid only to the interface design and development of an architect-friendly front-end. Some of the important features of the proposed front-end will be:

- The research is limited only to the interface design of the front-end and will not investigate the effectiveness of the tool in (calculating output) providing quick performance analysis for design projects.
- IBDII is designed with an emphasis on being used by architects, thereby attempting to solve the problem of non-usage of existing simulation tools. It is an interface designed keeping in mind the skill and knowledge level of architects.
- This research is limited to develop and design an architect-friendly interface and does not include the development of a new energy simulation tool.
- Since the proposed tool operates as a front-end with all the linked tools performing simulations in the background, the designer will not have to input data in various formats as preferred by the different specialized tools.

CHAPTER II

REVIEW OF LITERATURE

The review of the literature focuses on currently available simulation tools. Problems and inadequacies related to the available simulation tools are discussed. This analysis provides a basis of formulating design criteria for developing the new Integrated Building Design Information Interface (IBDII) front-end that can be integrated with sophisticated design and analysis engines.

Currently Available Simulation Tools

A myriad of simulation/performance analysis tools that evaluate energy efficiency, renewable energy, and sustainability in buildings are available today. Unfortunately, most of the available simulation programs were originally developed by researchers, for research purposes, and are not easy to use. They require significant amounts of detailed information about the building and its context, usually in the form of input files that consists of keywords and data, following particular syntax and structures. Moreover, the output generated is usually in the form of alphanumeric tables that are hard to review and decipher. As a result, such programs are very expensive to use, because they require significant knowledge and time for the preparation of their input and the interpretation of their output [24].

Some of the currently available tools include: Building Design Advisor (BDA), ECOTECT, MIT Design Advisor, DOE-2 and ENER-WIN. BDA is developed by the Building Technologies Department the Environmental Energy Technologies Division at

Ernest Orlando Lawrence Berkeley National Laboratory [26]. BDA acts as a data manager and process controller, allowing building designers to benefit from the capabilities of multiple analysis and visualization tools throughout the building design process [31]. ECOTECT is an environmental design tool, which couples an intuitive 3D modeling interface with extensive solar, thermal, lighting, acoustic and cost analysis functions. ECOTECT provides performance analysis which is simple, accurate and most importantly, visually responsive [31]. MIT Design Advisor is a web suite of building energy simulators that can model energy, comfort, and daylighting performance, and give estimates of the long-term cost of utilities [31]. And DOE-2 is an hourly, whole-building energy analysis program, which is capable of calculating energy performance and life-cycle cost of operation [31]. ENER-WIN is an hourly energy simulation model developed at Texas A&M University estimating annual energy consumption in buildings [4].

Usage of Simulation Tools by Building Designers/Architects

Energy analysis tools can enable architects to design more responsive buildings; however the analysis of a building's performance is but one concern facing architects in the initial stages of design. The majority of architects recognize the importance of analyzing a building's performance in the early stages of design; but they lack the time and knowledge to adequately address these concerns given the enormous range of other considerations they face [19]. Architectural design is most often a process of gradual refinement. Many factors have to be considered simultaneously. Resolving competing or conflicting requirements takes time and results in a very dynamic initial definition of the building. If environmental issues are to be factored in appropriately at this early stage, some method of quickly assessing the impact of very non-specific design decisions needs to be provided. This requires tools that work without the need for intricate detail. Architects need tools that provide feedback on the performance ramifications of manipulations of space and form in the early stages of design. They need tools that don't require the tedious input of incompatible design data so common to many architectural science applications [19].

Building designers require energy analysis tools that are quick to use and produce results that are easy to understand. DOE-2 is a program known to building designer's yet rarely used, despite the fact that it is capable of providing accurate performance results. Architects are skilled in the design of buildings and have a good understanding of various issues like costs, energy, and lighting related to the building designs that they create. Designers need expertise and skill in design and building design tools; however it is not necessary that they achieve expertise in highly specialized energy simulation tools. Simulation tools like DOE-2 require extensive specialized training, and architects in the profession rarely use these simulation tools because of time constraints for project completion, the inability to fully understand numerical building analysis, and the inability to devote long hours inputting building information in a numerical form. Hefley says that in order to reduce the complexity of a user's role in complex task, two approaches may be taken: user skill may be increased or the task complexity may be decreased [9]. For the reasons stated above, Hefley's second approach of reducing task complexity shall be adopted for the development of a new integrated energy simulation front-end.

According to a study of the use of performance-based simulation tools for building design and evaluation, the integration of CAD with various performance-based simulation tools will enhance the design process as well as eliminate the major limitations of current discrete simulation tools [10]. This study surveyed 584 firms including 440 architectural firms, 134 engineering consulting firms and 10 government statutory bodies. The results obtained by this study support the need for a tool such as the new IBDII front-end. Of the total number of people surveyed, 69% felt that the main limitation of existing performance based simulation tools is the very extensive data input required. Extensive data input could indeed impose a very serious problem, especially during the initial design stage where design information is very limited. A greater number of the people surveyed (82.3%) felt that to ameliorate the inherent system limitations of the current simulation tools, performance simulation should be integrated with computer-aided design environments [10].

The study also found that a very small fraction (1.6 %) of architecture firms use energy and HVAC sizing tools, while 46.4% of engineering firms use them. As far as the educational background of users is concerned, it was found that a majority of the energy and HVAC sizing software users were mechanical engineers and building services engineers. The users of daylighting and electric lighting software tended to be electrical engineers (71.4%) and building services engineers (28.6%). Architects used the energy and HVAC sizing software the least (14.3%) [10].

Non-Usage

Currently, designers are finding it difficult to fully exploit even the basic computer tools available to them. Designers typically find it difficult to structure their thoughts in a given fixed format. The documenting of thoughts interferes with the thinking process itself, thereby disrupting the design and requires substantial time and effort that the designers would rather invest in design [29]. The complexity of existing tools and their integration into the design process seem to be the biggest barriers. New tools must therefore be designed in close co-operation with designers so that their requirements can be addressed. A need therefore exists for design tools that are user-friendly and easy-to-use. These tools should be able to provide answers quickly and calculations should require the minimum amount of input so as to be useful during he initial design stages [5]. What is important is that the products of environmental science research be translated into a form easily assimilated into the design process. Only then will architects begin to use them early enough in their designs for such research to have any significant impact on the form of new buildings [19].

Interface Design

Concepts of Interface Design

User interface design is a combination of art and science. There are three primary design criteria in that need to be considered for software interface design [32]:

- Usability: can users easily learn and effectively interact with the system?
- Functionality: what functions and controls are available to allow for optimal use of the application/system?

- Visual communication and aesthetics: how does the visual appearance and spatial location of the elements optimize functionality?

Graphical User Interface (GUI)

At a conceptual level, a computer human interface is a “means by which people and computers communicate with each other” [2, 15]. A Graphical User Interface (GUI) is a type of computer human interface. GUI’s usually have common characteristics such as **W**indows, **I**cons, **M**enus, and **P**ush-buttons (WIMP). Collectively, WIMP are pictures that bring forth a certain action or an action space. The user issues commands via the GUI to computer applications [15]. GUI’s have the potential to provide users with a more direct, intuitive means to interact with software applications [1].

Design of GUIs

There is much more to designing usable GUI screens than making them look pretty. The way a screen looks should tell the user how to interact with it, and what behavior to expect from the application. The screen layout of an interface is about communication and usability, not making a screen “pretty” [32]. Graphic design details of the interface are not cosmetic matters or decorative touches, but an aid to communication. Graphic elements are often referred to as the “look and feel” of a software application. Successful layout and design can be achieved through visual harmony, providing cues to functionality and clarity and communication. The following range of principles can be used to achieve these goals and improve the usability of applications [32]:

- Icons: They can make an interface visually more interesting and are appropriate when they communicate better than text.
- Typography: The typography of an interface should be clear, easy to read and should not get in the way of usability.
- Language: The language throughout an application, including messages, should be natural and concise.
- Color: Care needs to be taken to ensure that color does not undermine usability.

Interface Design of Simulation Tools

The interface of the front-end should be designed with a user-centered approach, one that requires the user be involved from the very beginning. First of all, a user-centered approach requires that the researcher understand reality: who will use the system, where, how and to do what. Secondly the system design iterates a design-implementation-evaluation cycle [27]. Finally, according to Smiley the user most often remembers the visual aspect of a computer program. This is the most obvious manifestation of a program. It doesn’t matter how beautiful, eloquent, or brilliant program code is, if the user can’t interact with the interface designed, then ultimately, the program is considered a failure [30]. The interfaces of simulation tools need to reflect typical simulation issues related to the particular design stage and the expertise and background of the user [20]. There are three potential roles for user interface: to assist in the correct and effective use of systems capabilities, to be proactive in the user’s problem solving process, and to provide training [9]. For the architects to use the tool, it should possess the following characteristics [7]:

- To be very user-friendly (thus to use the visual language of the architects mainly based on illustrations).
- To require minimum of data and to be fast (since the use of this tool is integrated with the design process, it should aid the design process and hence needs to have minimum input and offer fast results).

Rather than require that the same data be translated into a multitude of formats, it is possible to use existing 2D and 3D CAD drawings as the basis for comprehensive environmental analysis. Architectural design is most often a process of gradual refinement, and many factors must be considered simultaneously. Hence if environmental issues are to be factored in appropriately at an early stage, a method that quickly assesses the impact of very non-specific design decisions needs to be provided. Linking the simulation front-end tool to a widely used CAD package would not require the building designer to generate the design in a different specified format from the one that he has already generated using the CAD package [19].

The creation of a domain-oriented design environment (DODE) to support design in a specific domain, in this case a building information interface would provide feedback to the designers as they design, rather than requiring the designers to construct a final product before receiving feedback. The interaction between the designer and a DODE could be seen as a conversation where the designer speaks by making a design move (can be considered as input data) and listens to the feedback (can be considered as output) provided by the environment. And conversely, the DODE listens to the designer's design moves (input) and speaks by providing feedback (output) [22].

Building design is a multidisciplinary activity involving several professions (architects, and structural, mechanical and electrical engineers). Different building simulation programs are required at different design stages by different professionals for different purposes of simulation. The concept of linking the central database to various design tools is considered an object-driven approach in the development of integrated building design systems (IBDS) [5]. For a tool of this kind, more attention can then be paid to creating and developing an efficient and easy-to-use front-end rather than paying attention to the intricacies of developing a sophisticated building geometry tool or energy simulation tools. An interface designed on the basis of an Integrated Building Design System (IBDS) that integrates different building simulation programs will enable them to exchange data through a standardized building database. This will prove to be highly desirable for total building design. BDA is one of the projects aiming to provide such an IBDS [5, 13]. An IBDS will act as an integration of databases (building components, HVAC components, weather data, etc.) and applications (CADD) [13].

Evaluation of User Interfaces

Definition of Usability

"Usability can be defined as the ease with which a system/application can be learned and used" [3]. Usability testing is a generic name for a set of cost effective ways of evaluating user interfaces to find problems pertaining to usability [21].

Methods of Usability Testing

There are four basic ways of evaluating user interfaces, which are as follows [21]:

1. Automatic: usability measures computed by running a user interface specification through some program.
2. Empirical: usability assessed by testing the interface with real users.
3. Formal: using exact models and formulas to calculate usability measures.
4. Informal: based on rules of thumb and the general skill and experience of the evaluators.

Empirical methods are the main way of evaluating user interfaces, with user testing probably being the most commonly used method [21]. Since this method of interface testing is empirical and not theoretical; it tells us how the system or application really is used, rather than how it is supposed/assumed to be used [3].

Some of the strengths of Empirical user testing include [3]:

- It incorporates into the system/application the reactions of people other than just the user-interface designer.
- It consciously gets information from many more people.
- It gets information from people who approximate the ultimate end-users.

CHAPTER III

RESEARCH METHODOLOGY

Steps Involved in the Creation of New Front-End Interface Design

Fig. 1 illustrates the methodology of this research. This methodology is adopted from the ten-step guide to successful interface design [30].

1. Learn to use and evaluate available simulation/building performance tools for their advantages and disadvantages.
2. Analyze the available tools for their advantages and disadvantages.
3. Prepare a list of requirements/criteria for the new front-end after assessing the current version of BDA.
4. Sketch a mock-up design of all the interfaces on paper keeping in mind the guidelines for the new front-end. Devise a flow chart indicating how all the interfaces are linked to each other.
5. Develop related user interfaces using the Visual Basic Integrated Development Environment.
6. The interface design is an iterative process and changes to the properties of the form or controls will necessitate design modifications.
7. Modified program is then run in Visual Basic. Net.
8. Finally write code to enhance the default behavior of the interface.
9. The working interface is then tested by a fixed number of architecture students.
10. Report the research findings of the developed and tested front-end.

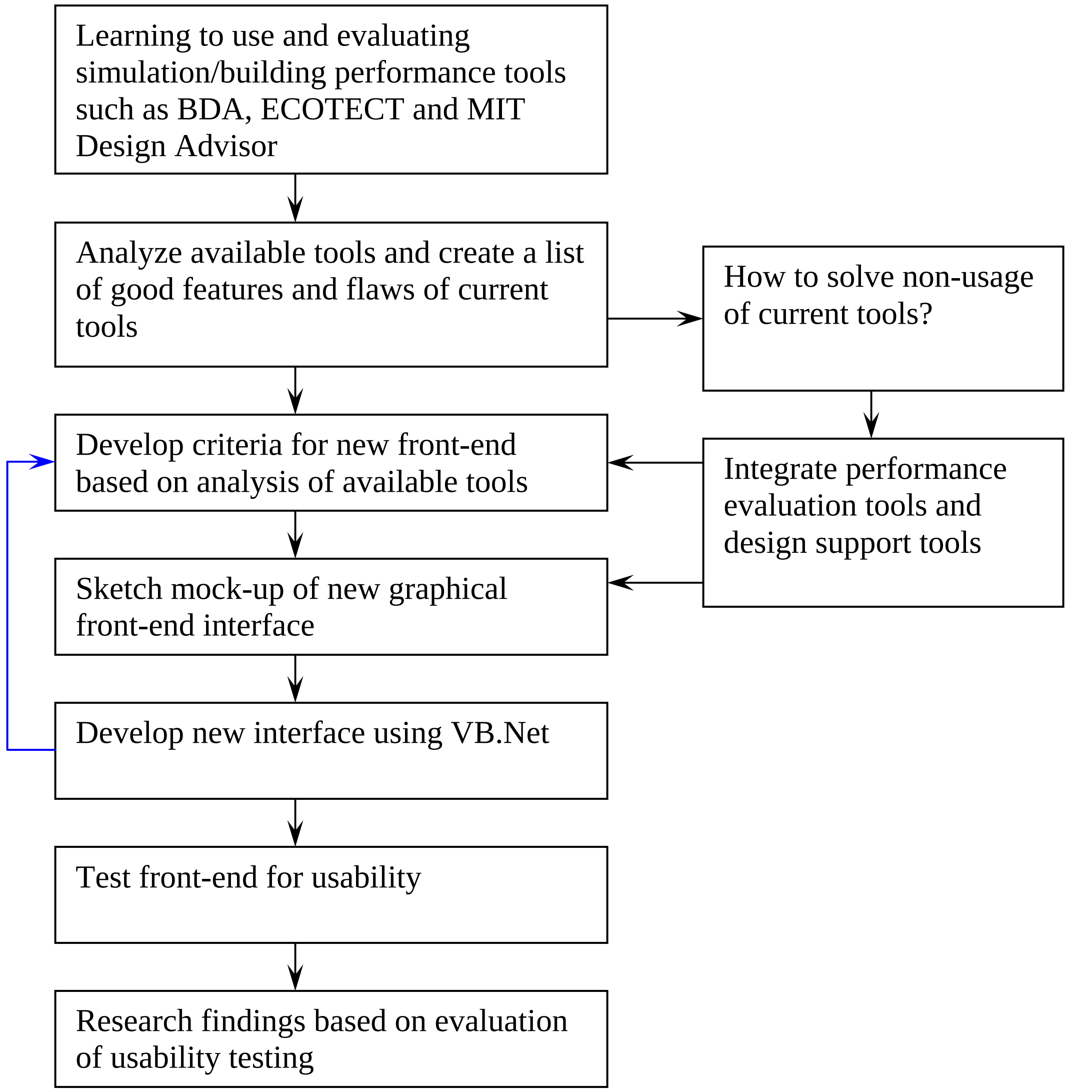

Fig. 1. Research methodology flowchart

Learning to Use and Evaluating Available Building Simulation/Performance Tools

Simulation tools such as BDA, ECOTECT and MIT Design Advisor were experimented with for several months before they were analyzed for their good features and flaws. Some of the simulation tools and reasons of their selection for this research stated as follows:

- Building Design Advisor (BDA) – The BDA simulation tool supports the integration of multiple building models and databases used by analysis and visualization tools, through a single, object-based representation of building components and systems [31].
- ECOTECT – ECOTECT allows for integration of drawing tools such as AUTOCAD and also is one of the few visually oriented simulation tools.

  These tools are analyzed and discussed in detail below.
- MIT Design Advisor – MIT Design Advisor offers users great ease-of-use and speed. The tool can be easily and quickly mastered by non-technical designers, and runs fast enough to allow them the scope to experiment with many different versions of a design during a single sitting [31].

Building Design Advisor (BDA)

Building Design Advisor (BDA) was developed by the Building Technologies department of the Environmental Energy Technologies Division at Ernest Orlando Lawrence Berkeley National Laboratory. One of the unique features of BDA is that it integrates building design and building performance analysis tools that are currently available. A large number of tools (DOE-2, RADIANCE) serve only as building performance analysis tools (RADIANCE is a lighting and rendering simulation program). For the designer, their use is tedious during the initial design phases, as these programs do not support the schematic design (SD) and design development (DD) phases in the design of buildings. The BDA is a computer program designed to integrate the sophisticated DOE-2 and RADIANCE simulation tools while allowing for a more designer friendly program – one that produces outputs with the same accuracy as, the stand alone simulation tools. BDA acts as an integrated interpretation front-end interface, with tools like DOE-2 and RADIANCE actually performing the real-time simulations in the background. BDA is a software environment designed to make use of and integrate various simulation tools. Since it is linked to other sophisticated simulation tools, it becomes easier to compute energy performance analysis for buildings from the early schematic phases of building design. BDA is designed to allow for transparent, integrated, and concurrent use of multiple simulation tools and databases, through a single graphical user-interface that supports multi-criterion decision-making [25].

BDA provides a graphical user interface that consists of two main elements: the Building Browser (BB) and the Decision Desktop (DD). The Building Browser, as shown in Fig. 2, allows for quick navigation of descriptive and performance parameters that are addressed by the simulation tools linked to BDA. The default values of input parameters can be edited in the Building Browser and the selected parameters can be displayed in the Decision Desktop as seen in Fig. 3. The Decision Desktop provides a comparison of the performance analysis of multiple design alternatives created by building designers.

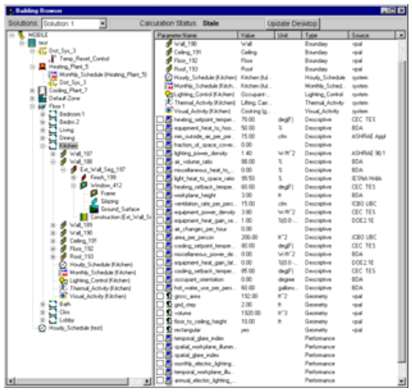

Fig. 2. Building Browser in BDA

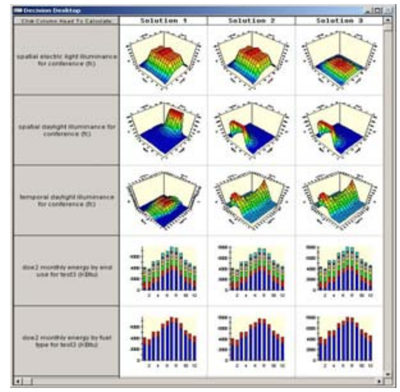

Fig. 3. Decision Desktop in BDA

BDA is also linked to Schematic Graphic Editor (SGE), which allows for quick and easy specification of geometric characteristics of building components and systems. Fig. 4 shows the SGE interface [26].

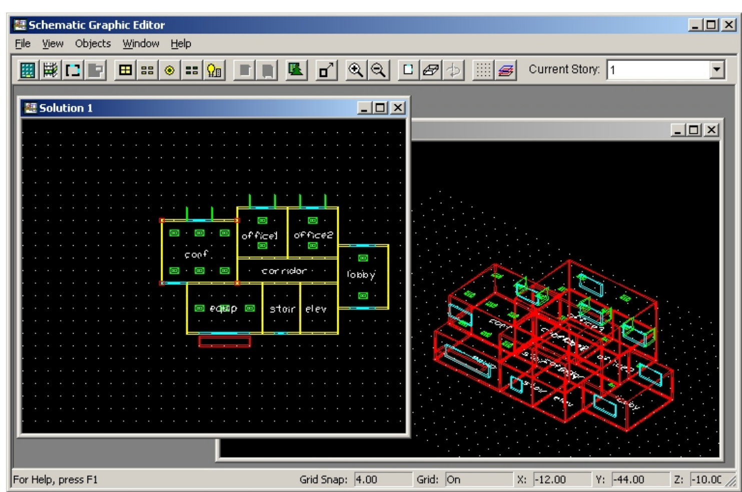

Fig. 4. Schematic Graphic Editor in BDA

BDA makes comparative analysis of different design alternatives easier as it provides a matrix of the different design alternatives. BDA breaks away from the creation of fixed format text files used in DOE-2, as shown in Fig. 5 that make building performance issues more tedious to compute. Inputting in BDA is far less complicated and because the output is non-alphanumerical, it is easy for architects to understand.

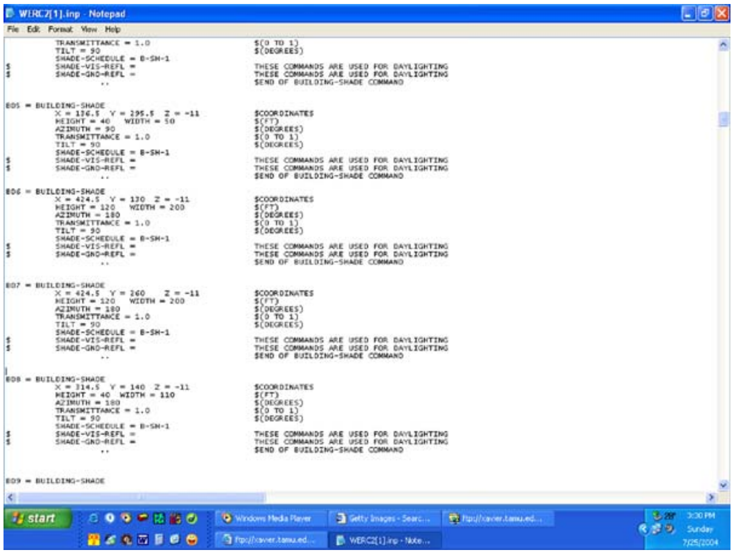

Fig. 5. Interface of DOE-2, (fixed text format input)

ECOTECT

ECOTECT is a building design & building performance analysis tool, developed by Dr. Andrew Marsh and Caroline Raines of Square One research and the Welsh School of Architecture at Cardiff University [18]. ECOTECT is comparable to BDA as an integrated design and analysis tool that allows for performance analysis during the initial stages of design. Both applications have a similar approach as far as the generation of simultaneous analysis of thermal performance, environmental impact, overall costs and lighting levels. Thus the ramifications of design decisions can quickly be compared on many different levels without having to input the same data in different formats to a number of different tools [19].

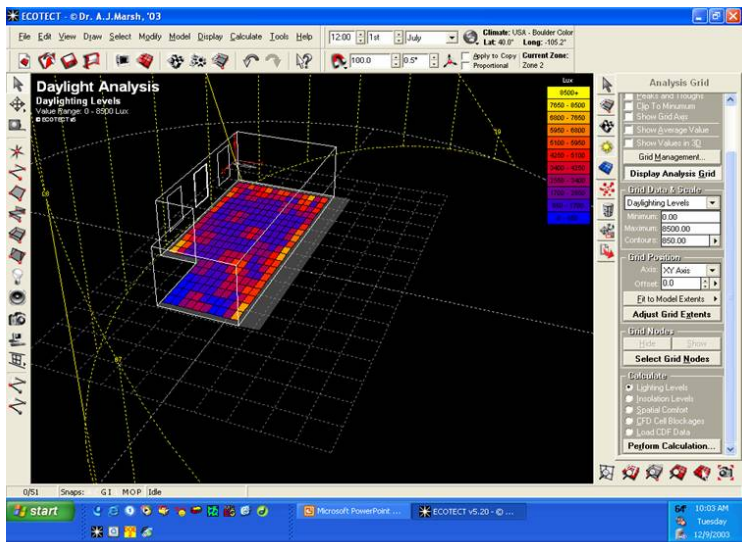

Fig. 6. Graphic 3D interface of ECOTECT

One of ECOTECT's significant features is its interactive approach to analysis and its innovative 3D interface, which is shown in Fig. 6. BDA is considered as a front-end, whereas ECOTECT is a simulation tool in itself. ECOTECT has been designed to serve as a complete building design and environmental analysis tool. ECOTECT's unique features - interoperability, interactivity, a 3D cursor system, a sketch like environment, easy editing of the model, visual feedback during calculations - make it a superior tool for building designers.

MIT Design Advisor

Design Advisor is a web suite of building energy simulators that model energy, comfort, and daylighting performance, and give estimates of the long-term cost of utilities. It has been designed by the Building Technology Group, Department of Architecture at Massachusetts Institute of Technology. Design Advisor is designed with the intention of it being so simple enough that a new user would not need to consult documentation in order to learn to use it [6]. The start up interface a user has to deal with consists of basic rudimentary input controls which are displayed in Fig. 7.

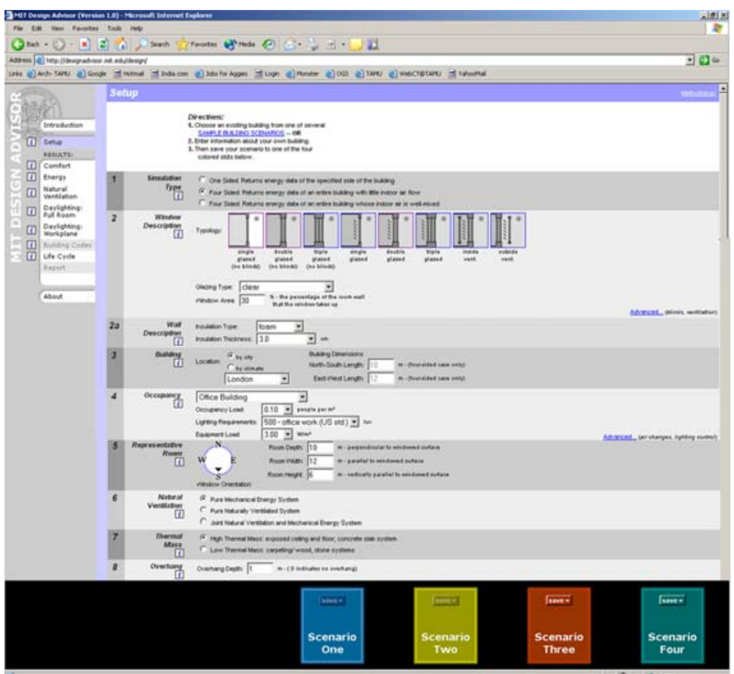

Fig. 7. Interface of MIT Design Advisor (text fields and buttons only input)

One of the interesting features of this tool is that the users can compare their own buildings with other well-known energy-efficient buildings around the world from a list that has been provided under the “existing scenario” function. This web tool is divided into three main modules: “Energy”, “Comfort”, and “Daylighting”. The output generated is in the form of graphs showing monthly and yearly energy consumption, graded color charts showing comfort zones in a room, 3-D perspective sketches showing daylighting effects, and a text-based page showing a comprehensive listing of inputs and outputs [6].

Analysis of Tools Under Consideration

After learning and evaluating BDA, ECOTECT and MIT Design Advisor, these performance analysis tools were analyzed. Functionality, usability and visual communication were the three main aspects kept in mind for the analysis of these tools. The advantages and disadvantages of these tools are shown in detail in Table 1.

Table 1
Analysis of BDA, ECOTECT and MIT Design Advisor

	BDA	**ECOTECT**	**MIT Design Advisor**
Intended Use	Can be used for early schematic phases of building design to the detailed specification of building components and systems.	Intended for use during the earliest most conceptual stages of design.	Intended for use as an approximate tool for comparing early building design concepts.
Advantages	Supports the drawing of specific building components and systems with the help of Schematic graphic Editor, Graphical user interface, good concept of the hierarchical tree of building description keywords, visual and easy to comprehend output, input fairly easy to understand, can generate comparisons between design options.	Supports 3D modelling and editing, also supports AutoCAD, 3D Graphical user interface, good interactivity, input in the form of keywords-text fields-buttons, output is displayed in the actual building model hence very easy to comprehend.	Web based interface, quick and easy to understand, easy to learn and get results, input in the form of text fields and buttons, can easily generate comparisons between different scenarios.
Disadvantages	Has a rudimentary drawing tool (SGE), does not support superior design tools like CAD. Hierarchical tree for selecting input is confusing and tedious, could have a better visual interface, no provision for custom databases	No provision for real life building components, results are not validated as per American standards, user needs to aware of user needs to be aware of the different modeling and data requirements making input hard to understand at times.	Does not support any drawing of modeling tools, simulations restrict flexibility and accuracy restricted to 10-15%, an approximation tool, not integrated with the design process. No provision for adding custom databases.

Further Assessment of BDA

BDA is the tool chosen for assessment as opposed to ECOTECT and MIT Design Advisor because it is a front-end and not a simulation like the other two. Since BDA is a front-end, its assessment would be more appropriate for creating the proposed

IBDII tool, which is also a front-end. Hence BDA was thoroughly assessed and a detailed list of all input parameters was compiled. Advantages and disadvantages of BDA with respect to its use in building design were noted and categorized. These further aided in the mock-up of the new interfaces.

Currently BDA acts as a front-end, with simulation tools like DOE-2 [11] & DElight [12] performing the simulations and Schematic Graphic Editor (SGE) [26], a building geometry tool. The SGE currently supports only rudimentary building geometries. Graphical tools like AutoCAD help designers generate both complex as well as simple geometries more easily. The SGE currently in BDA does not support multiple geometries and if the proposed IBDII prototype is linked to a sophisticated CAD tool, it will be able to support multiple geometries.

Since a myriad of computer applications already exist, the proposed IBDII tool, would act solely as a front-end and could be linked to all other sophisticated tools. This concept of linking the central database to various design and simulation tools is considered an object-driven approach in the development of integrated building design systems (IBDS) [5]. For a tool of this kind, more attention can then be paid to creating and developing an efficient and easy-to-use front-end rather than paying attention to the intricacies of developing a sophisticated building geometry tool or energy simulation tools. The premise of this research is that specialized tools such as AutoCAD for building geometry, DOE-2 for energy performance analysis, RADIANCE for lighting & day lighting analysis are already available, and can be integrated into a new front-end which is capable of being architect-friendly.

Advantages and Disadvantages of BDA

1. BDA provides a matrix of the different design alternatives, making comparative analysis of different design alternatives easier.
2. The Building Browser in BDA has a hierarchical tree of parameters, which serve as the input for output generated in the Decision Desktop. The hierarchical tree sounds good in theory but in reality it is very confusing to select the exact building component you are trying to locate. The concept of a child object being linked with a parent object is good, but this concept needs to be worked on more to make it easy for architects to understand.
3. Each child object is linked to a parent object, e.g. a window is linked to the exterior wall. BDA breaks away from the creation of fixed format text files (DOE-2), which make the building performance issues more tedious to compute. The inputting is far less complicated and the output being non-alphanumerical easy to read for architects.
4. The creation of BDA is partly leaning towards a Graphical User interface which is definitely a plus; since architects are visually oriented people they can understand visuals better than numericals.
5. The Schematic Graphic Editor, which is the drawing tool as part of the BDA interface is very rudimentary. Especially today where tools like AutoCAD offer far more advanced drawing options, SGE is definitely something that could be replaced by an existing CAD tool.

6. The concept of linking the BDA front-end with sophisticated tools like DOE-2, DElight and RADIANCE would provide results which are validated.

Criteria for New Front-End Design of **I**ntegrated **B**uilding **D**esign **I**nformation **I**nterface (IBDII)

Based on the analysis of the tools under consideration i.e. BDA, Design Advisor and ECOTECT, a list of guidelines trying to overcome their shortcomings was developed. These would serve as guidelines for the design of the new front-end. Some of the guidelines for the interface design of IBDII are as follows:

1. The new front-end will be designed with an emphasis of being used by architects.
2. The input will be such that it is easily understood and entered by users.
3. Building information will be presented as real life images of building components associated with product specifications as opposed to just keywords or text descriptions.
4. The interface would support design tools like AutoCAD, thereby reducing the need to redraw using other tools.
5. It would provide the user with an option to create and update custom databases of building components.
6. The front-end will be developed in a way that is intuitive and easy to use and learn effective, and at the same time integrated with the design process.
7. The interface design should be such that no training is required to learn its usage yet it should provide quick and accurate results.

Sketch and Develop Interface Design of IBDII

Based on the guidelines evolved for the development of the new interface design for IBDII the mock-up interface was sketched. This was an iterative process and the mock-up underwent numerous changes to match up the guidelines. The developed interface is illustrated in detail in the following Chapter IV, where all the aspects considered for the design of the interface are discussed and illustrated elaborately.

Test Front-End for Usability

The usability of the developed front-end is then determined by testing the interface with real users, who in this case are architecture students. The testing is not in the pursuit of real architectural projects but with a view towards the graphic qualities of an acceptable user-friendly interface. This usability testing is geared to architecture students because they are the ones who turn design professionals and hence it is assumed they will be carrying their education further into profession. However, further testing by architects/building designers would prove to be beneficial and would help to strengthen the present research.

A usability test for IBDII is conducted to check the usefulness, effectiveness, learn ability and likeability of the newly developed front-end interface [28]. This kind of usability testing will best establish the usefulness and friendliness of the developed front-end and to better understand the advantages and disadvantages of the designed interface under consideration. Chapter V is completely dedicated to explaining in detail the procedure for testing, user’s feedback and comments obtained while conducting the usability testing of IBDII.

Research Findings Based on Evaluation of Usability Testing of IBDII

After conducting the usability testing of IBDII, the user's feedback and comments are evaluated. This evaluation provides answers about the effectiveness, usefulness and learnability of the newly developed front-end interface. The evaluation of the findings also helps to establish and understand better the advantages and disadvantages of the developed interface design. The research findings are reported in Chapter VI.

CHAPTER IV

INTERFACE DESIGN AND DEVELOPMENT OF IBDII

Introduction

After a thorough analysis of the current simulation tools discussed in Chapter III, BDA, Design Advisor and ECOTECT, a mock-up design of all the interfaces of IBDII was sketched on paper keeping in mind the requirements for the new front-end. A flow chart indicating how all the interfaces are linked to each other was devised. The emphasis of the research is on interface design of the input section of the interface. The front-end consists of three distinct parts as shown in Fig. 8, Import Building Geometry, Building Description and Calculate + View Output. The input section of IBDII is the "Building Description" part where various building components can be assembled and selected. These components can later be assigned to an already existing AutoCAD drawing of a design project and which would help to generate the required output analysis. Rapid geometry definition can be achieved efficiently via a link to a CAD tool. It will thus be possible to use existing architectural drawings to create the geometry definition of thermal models. This will reduce input error risks and time requirements [23]. Also by selecting the specific building components the designer can express his/her intentions or make design moves, for a given task [22].

This chapter will provide details regarding the interface design for the front-end that was developed using VB.Net. The interfaces will be displayed and described in sequential order to show the graphical user interface which consists of real life images of building components as input as a replacement for the existing interfaces of simulation tools. The input interfaces for existing tools either accept fixed format text as input (DOE-2), selecting from a hierarchical tree of building description keywords (BDA), or entering numerical data (ECOTECT, MIT Design Advisor).

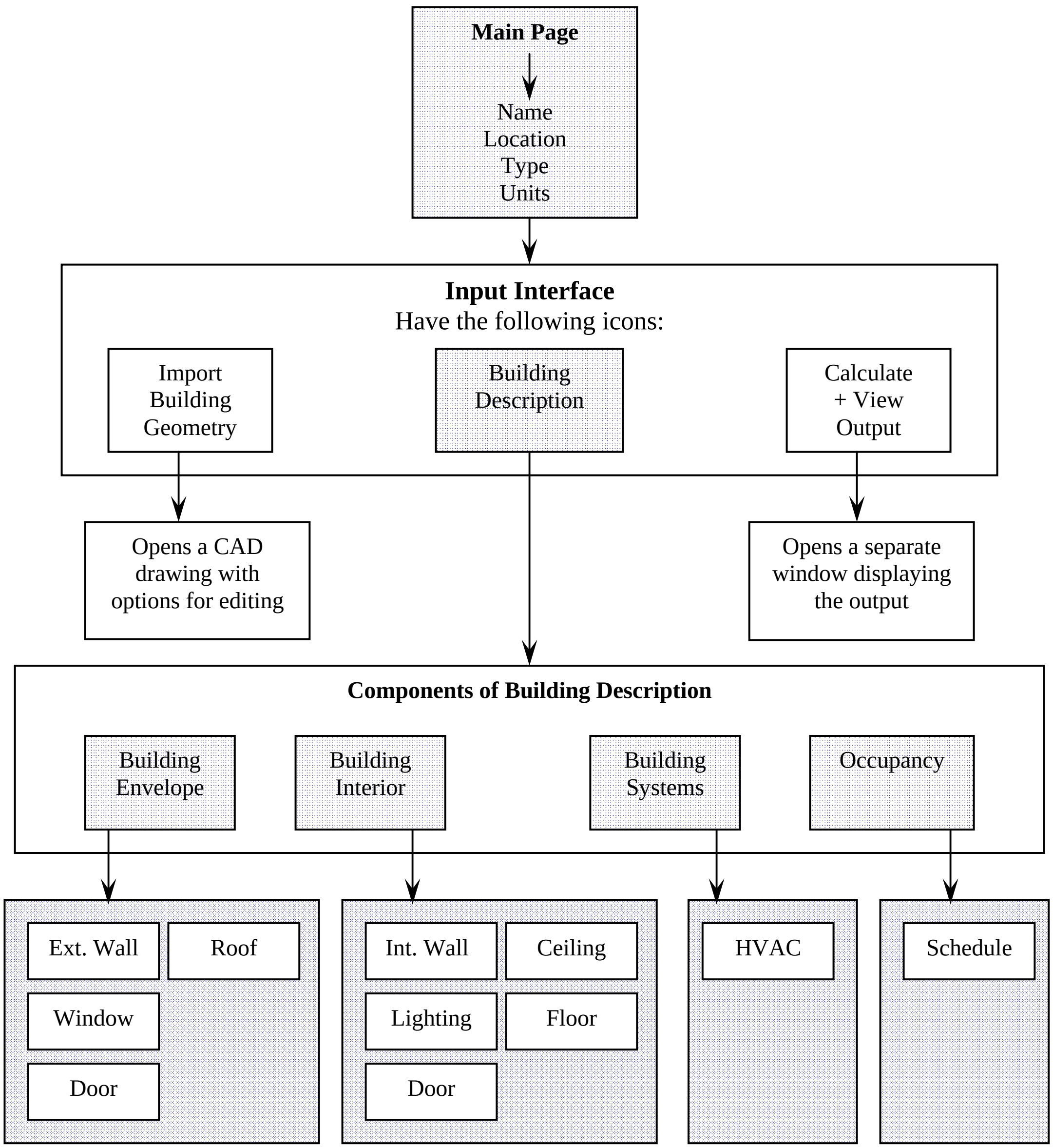

Fig. 8. Flow chart showing interface links of IBDII

Interface Design of IBDII

The following pages illustrate the design of the Integrated Building Design Information Interface in a sequential order that is meant for illustration only. The created interface is flexible to each individual users needs. IBDII starts up with an image displaying its name and the creator's information, as shown in Fig. 9.

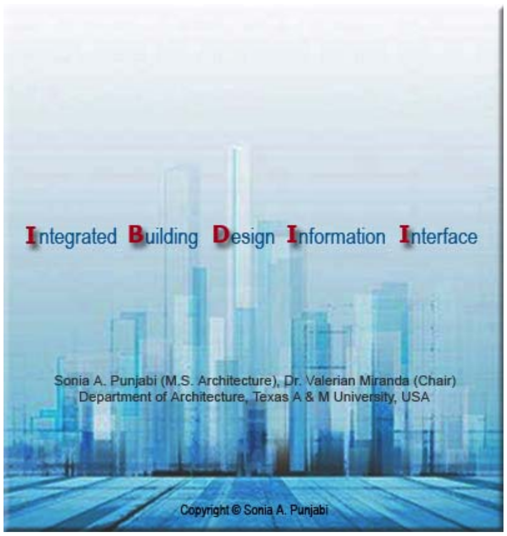

Fig. 9. Image seen while IBDII's start-up

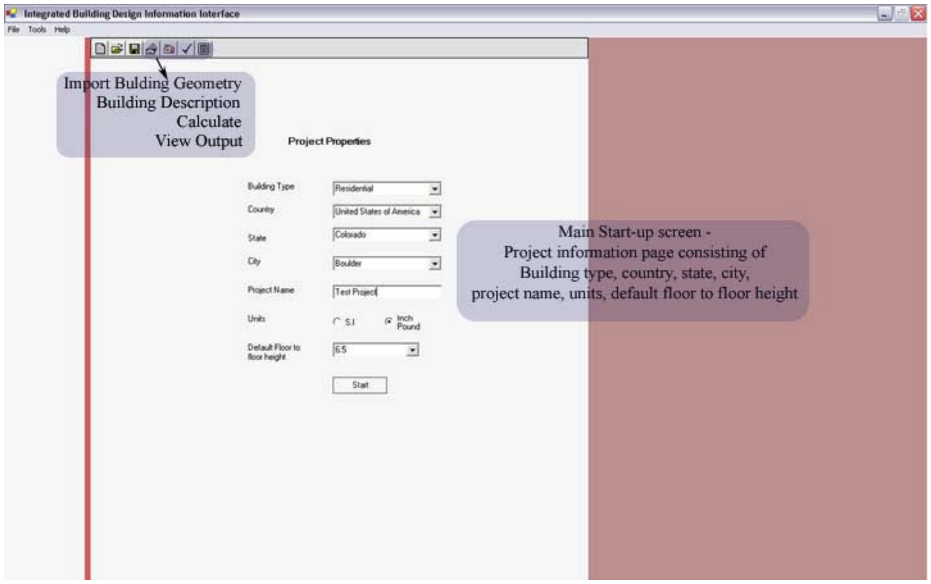

Fig. 10. Start-up screen of IBDII for entering basic project information

The main start-up screen (as shown in Fig. 10) is where initial project information such as building type (residential, commercial, school), country, state, city, project name, units (S.I., Inch Pound) and default floor to floor height can be entered. This information can be edited by the choosing the option project properties under the file menu.

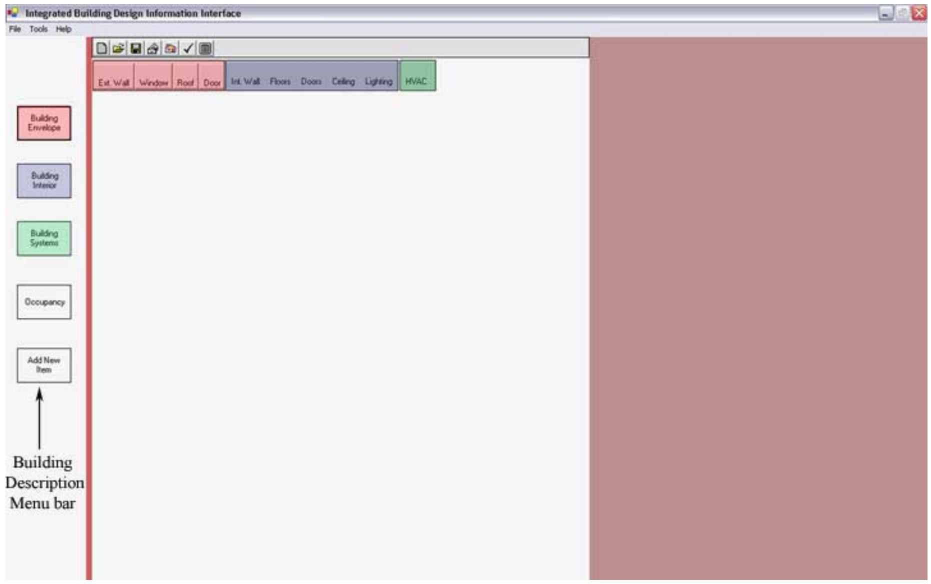

Fig. 11. Building Description screen with building description components in the left menu bar

After entering the required information on the start up screen, clicking the start button brings the user to the building description screen (as shown in Fig. 11). The Building Description Components are placed in the left menu along with the occupancy profile and add new item icons. The Building Description Components have three distinct sections, starting from the skin of the building to the inside (the Building Envelope), the Building Interior and the Building Systems. The Building Envelope consists of exterior walls, windows, roof, and doors. The Building Interior consists of interior walls, floors, doors, ceiling, and lighting. The Building Systems consists of HVAC equipment. Clicking on any of these three buttons will respectively activate a set of buttons in the top bar. Components like walls, roofs and floors are made up of a number of products, and hence these components create an assemblage of products.

Structure of Building Description Components

The following is the structure of Building Description Components:

Building Envelope

Exterior Wall
- Category I - Exterior Surface Material
- Category II – Intermediate Wall Cavity
- Category III – Interior Surface Material

Window

Roof
- Category I - Decking/Sheathing
- Category II - Underlayment
- Category III - Exterior surface material

Door

Building Interior

Interior Wall
- Category I - Surface Material I
- Category II – Intermediate Wall Cavity
- Category III – Surface Material II

Floors
- Category I – Finished Flooring
- Category II – Floor Support Structure
- Category III – Sub-flooring
- Category IV – Insulation and Waterproofing

Door

Ceiling

Lighting

Building Systems

HVAC

Building Envelope

Exterior wall

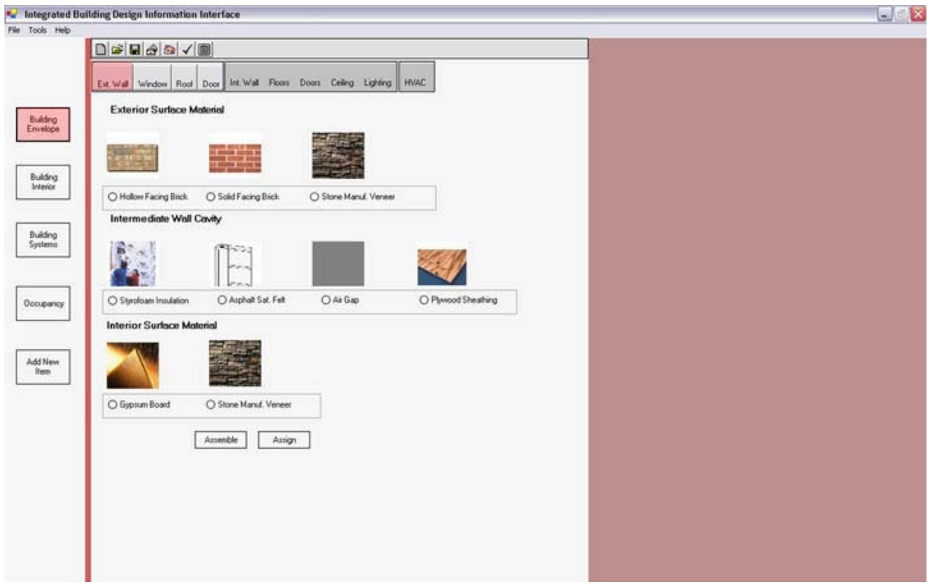

Fig. 12. Building Envelope - exterior wall assembly page

Exterior wall categories and assemblies are displayed (as shown in Fig. 12) when the exterior wall button in the top bar is clicked. Since building components like walls, floors and roofs are made of a number of building products; these components have provisions for creating custom assemblies. Selecting one or more components from all the three categories and then clicking on the assemble button will create a wall assemblage. In theory, this will add up thermal values of all components in the order of categories, which will be need for calculating the building design performance.

Window

Clicking on the window button will open up a list of windows stored in the database. This list is based on material types (as shown in Fig. 13). Clicking on any one name in the list will open a real life image of the respective product. For information and product specifications of a particular window the user has to click on the image of the product. Clicking on the image will provide product specifications for the window assembly and a web link to the manufactures website for further detailed information. Information for all other products (doors, ceiling, lighting, and HVAC) has a similar structure.

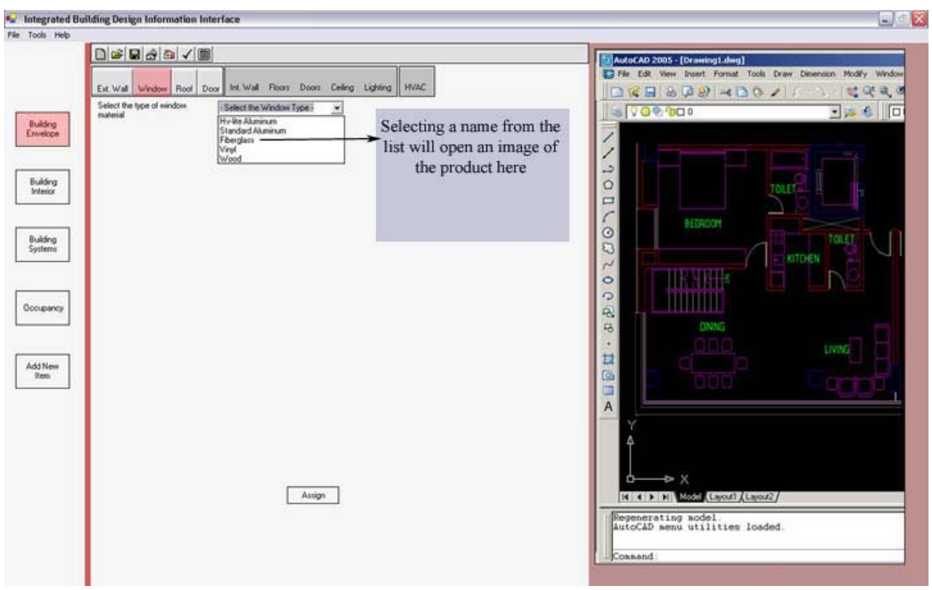

Fig. 13. Selecting a window from the IBDII database by clicking on a name in the list box

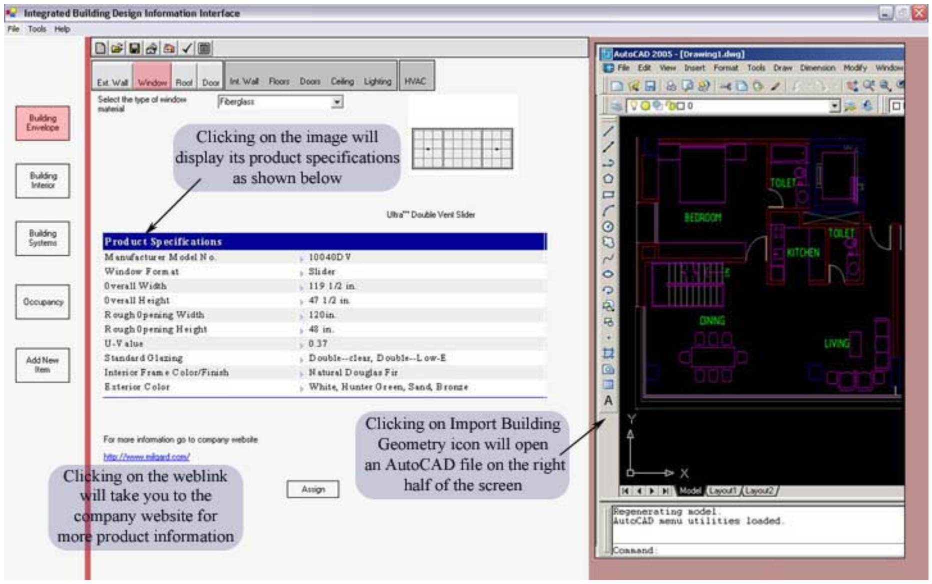

Fig. 14. Screen displaying window (building component) specifications, manufacturer's web link and AutoCAD image on right which opens on clicking the Import Building Geometry button

The building components can all be assigned to an AutoCAD drawing in the future. For now since the emphasis is on interface design, an AutoCAD image is displayed for purposes of representation. Clicking on the Import Building Geometry will open up an AutoCAD drawing on the right half of the screen as shown in Fig. 14.

Roof

Roof categories and assemblies are displayed by when the roof button in the top bar is clicked. The roof categories are as shown in Fig. 15.

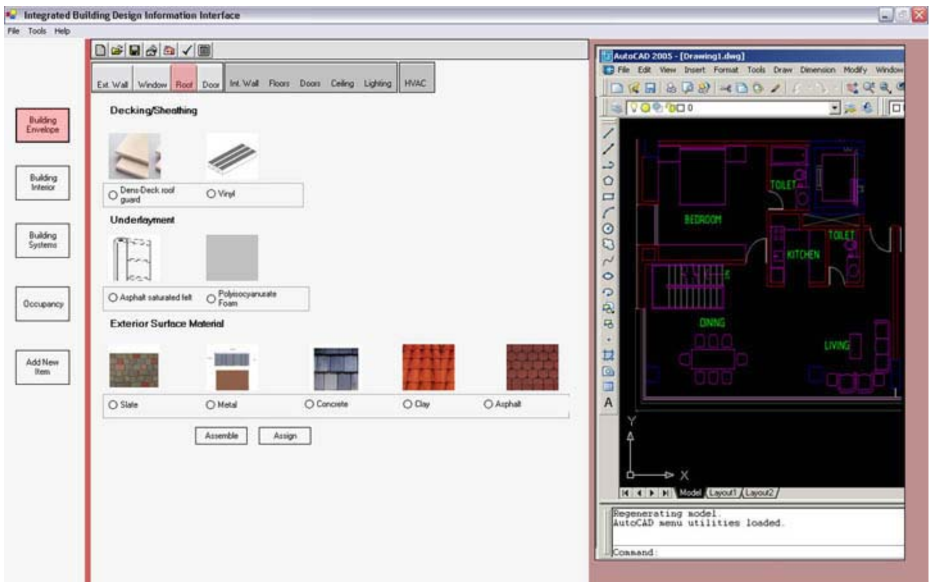

Fig. 15. Building Envelope - roof assembly page

Exterior Door

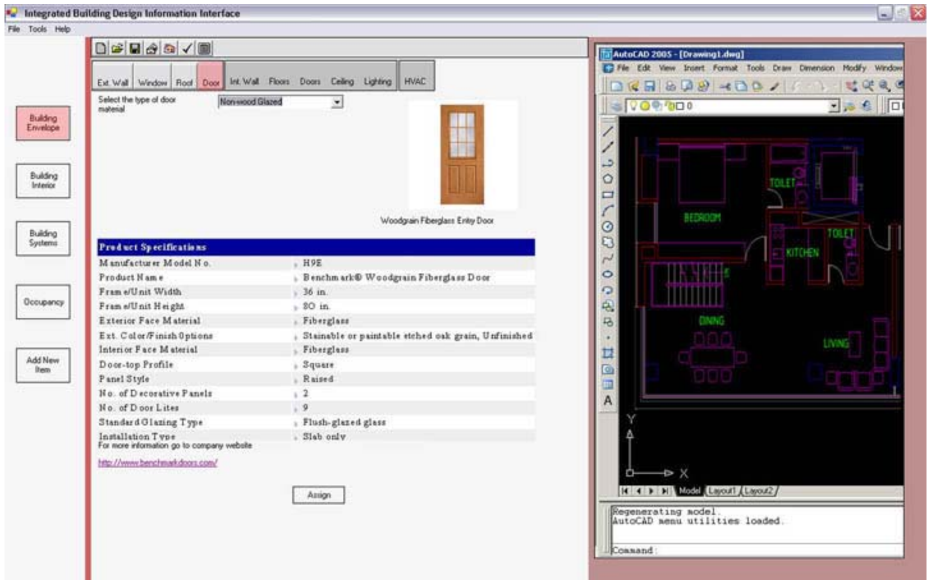

Fig. 16. Exterior doors listing and images, product specifications and manufacturers web link

A listing of exterior doors based on materials is made available in IBDII and is shown in Fig. 16. This follows the same structure as is described under windows. Clicking on a name in the list will open its image; clicking on the image will display the product specifications and a link to the manufacturer’s website. All product information is courtesy of http://ebuild.com – the professionals guide to building products (Feb 2001).

Building Interior

Interior Wall

Interior wall categories and assemblies are displayed (as shown in Fig. 17) when the exterior wall button in the top bar is clicked. This follows a structure similar to exterior walls as described earlier on.

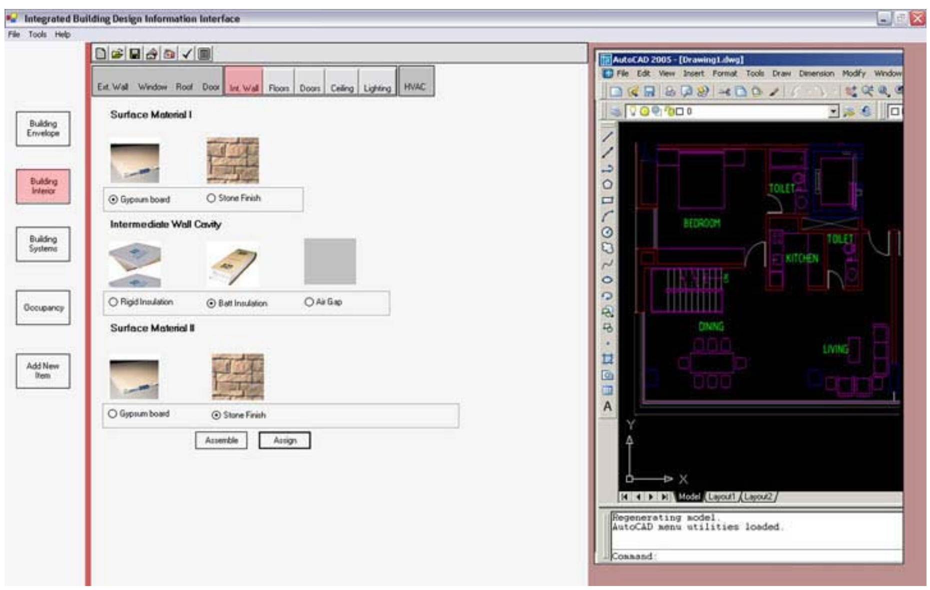

Fig. 17. Building Interior - interior wall assembly page

Floors

Floors consist of a series of layers and selecting one or more components from all the four categories that complete a floor structure will create a floor assembly (as shown in Fig. 18). The selecting and assigning of floors to an AutoCAD drawing is the same as for exterior walls, interior walls and roof.

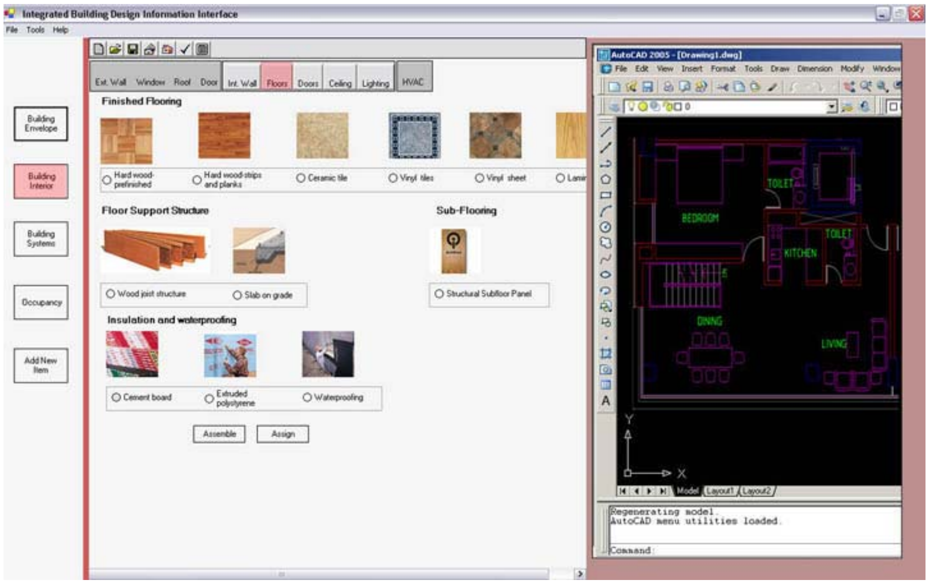

Fig. 18. Building Interior - floors assembly page

Interior Doors

These are specifically interior doors and are categorized based on materials. Interior doors can be assigned (see Fig. 19) in the same way as exterior doors as described under 4A.

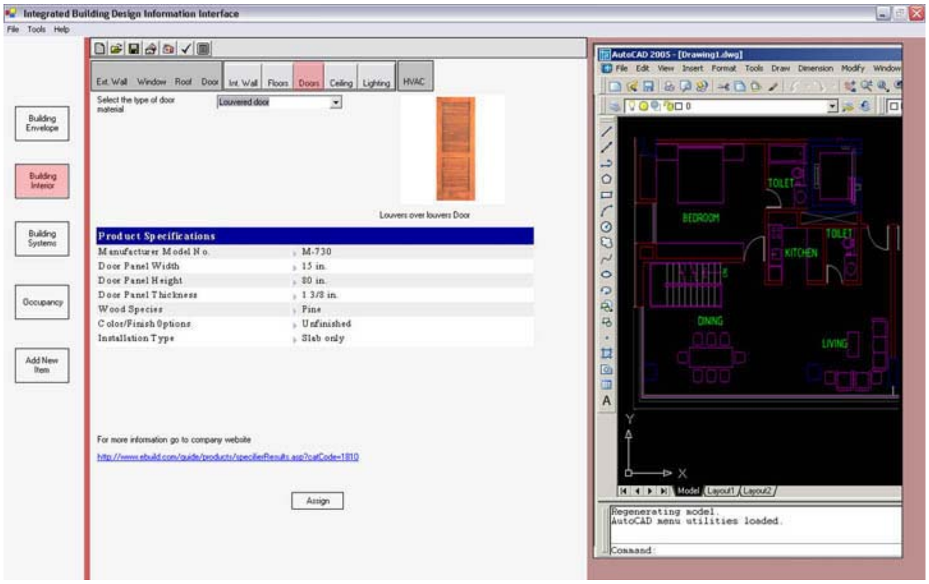

Fig. 19. Interior doors listing and images, product specifications and manufacturers web link

Ceiling

The different type of ceiling can be accessed by clicking on the ceiling icon in the top bar, which opens their listing based on material types. More information for each of the products can be acquired by clicking on the product image on the top right as shown in Fig. 20.

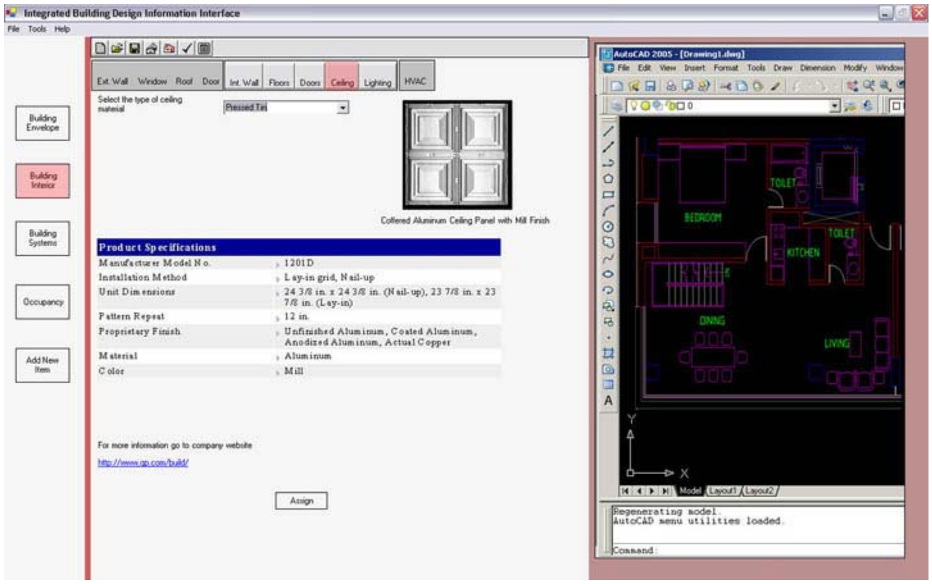

Fig. 20. Ceiling listing and images, product specifications and manufacturers web link

Lighting

Lighting fixtures are classified based on the kind of light source type. The product specifications for all products consist of the manufactures model number, so that more information for the specific model can be looked up on the manufacturer’s website (as shown in Fig. 21).

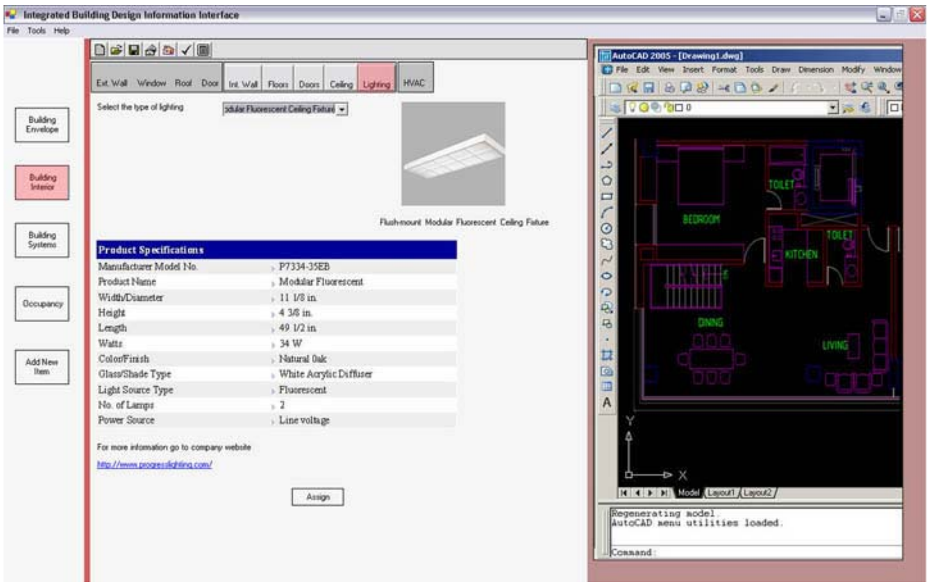

Fig. 21. Lighting listing and images, product specifications and manufacturers web link

Building Systems

HVAC

Clicking on the Building Systems button in the left bar will activate the HVAC button on the top bar which gives access to a listing of HVAC equipment (as shown in Fig. 22) that can be installed in buildings. The HVAC equipment consists of all-air systems, all-water systems, air-water systems, direct expansions systems and heat pumps. For a complete listing of all building components and their assembly structures refer to Appendix A.

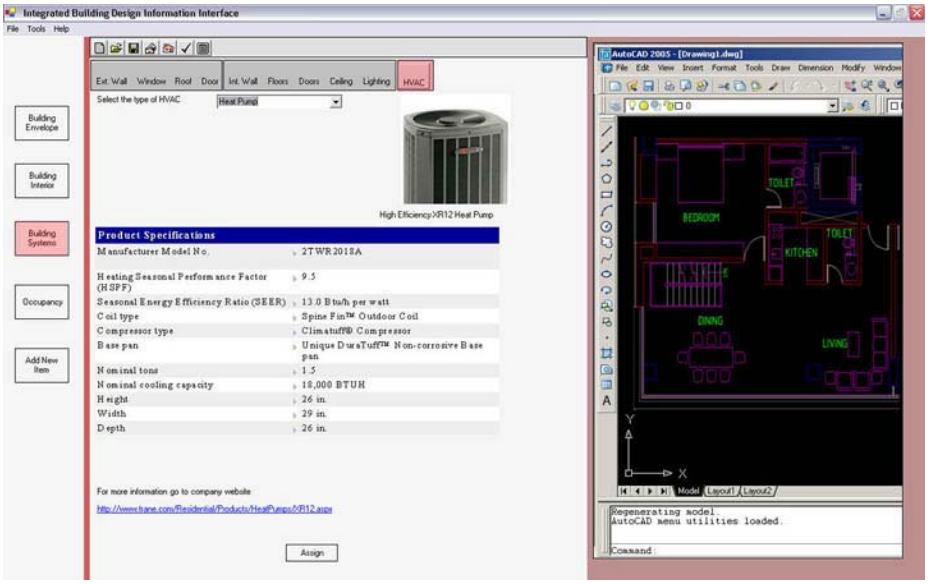

Fig. 22. HVAC listing and images, product specifications and manufacturers web link

<u>Occupancy Profile Setup</u>

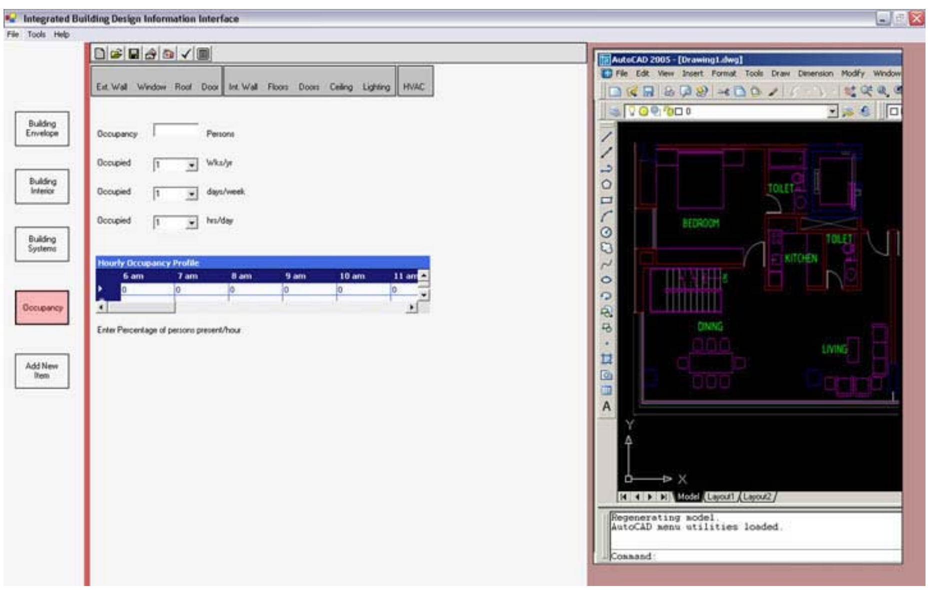

Fig. 23. Occupancy profile screen in IBDII

Clicking on the occupancy button will open the occupancy profile screen (as shown in Fig. 23), where the user can give details about the occupancy profile depending upon the usage pattern of buildings. Details such as: the number of people in a building, the number of weeks/days/hours in a year the building is occupied, and the percentage of people present per hour, need to be input to calculate performance analysis of the buildings. Ventilation, lighting and temperature setting profiles can be added in the future, following the same principles as that of the occupancy profile.

<u>Add New Building Components to Existing Database</u>

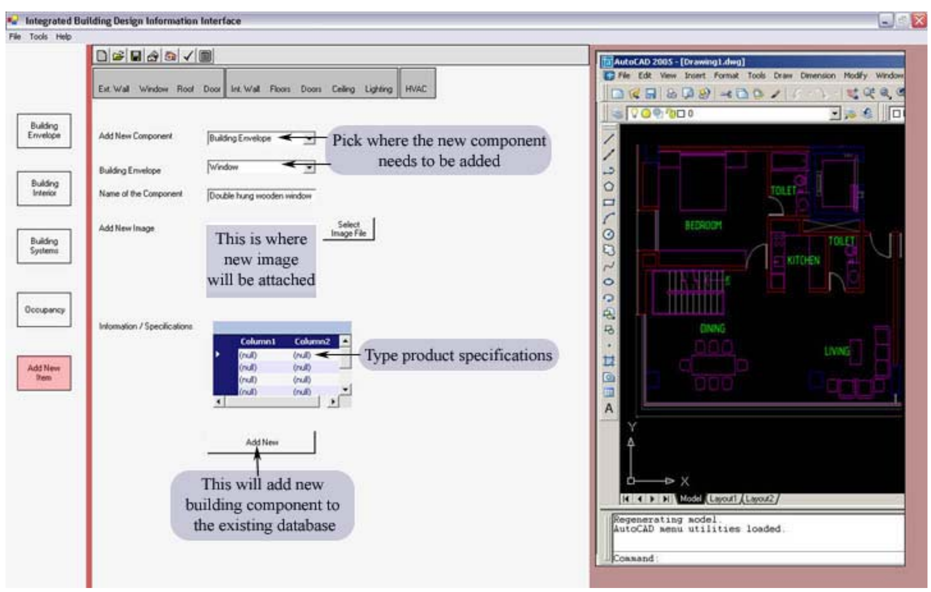

Fig. 24. Add new building component screen in IBDII

IBDII has a provision for adding new building components to the existing database. Clicking on the “add new item” button on the left menu bar will open a screen where instructions about adding a new building component are provided. The user first has to select the category under which the new building component is to be added. Next a name for the building component needs to be typed in the space provided as seen in Fig. 24. The product image can be attached by browsing and then the product specifications known to the user, regarding the building component need to be typed in the space provided as shown in Fig. 24. Completing all of the steps described above and clicking on the “add new” button at the bottom of the screen will add the new building component to the already existing database of building components. Thus by this provision, the user can create his/her own custom database of building components which could be used for various purposes. Products in the database can be assigned to AutoCAD drawings to obtain performance analysis for buildings. They can be used to create custom building component assemblies, can be useful for maintaining building inventories, and can serve as manufacturer databases, aiding in the designing process.

CHAPTER V

USABILTY TESTING AND EVALUATION OF IBDII

Purpose of Usability Testing

The purpose of the usability testing is geared towards establishing the usefulness, effectiveness, likeability and learnability of the developed front-end interface design [28]. This evaluation establishes the advantages and disadvantages of the interface design. The testing allows that the following aspects concerning IBDII are better understood: interface design, navigation, reviewing input, saving input, database creation and general assessment.

Analysis of the questionnaire will demonstrate whether the visual selection of building components that can be attached to existing CAD drawings is preferred over the existing forms of numerical or keyword input to describe building geometry.

Participants

The usability of the developed front-end will be determined by testing the interface with a selected sample of users, who in this case are architecture students. A total of 9 Master's of Architecture students enrolled in the Sustainability Design Studio from the College of Architecture, Texas A&M University volunteered to participate in the usability testing. These students were selected as the target since they are conversant with energy simulation/building performance tools and are also primarily designers. This testing is not in the pursuit of real architectural projects but with a view to verify the graphic qualities of an acceptable user-friendly interface. This usability testing is aimed at architecture students because they are the ones who will become design professionals, and hence it is assumed they will be carrying their education further into profession. Usability testing of the interface by architects/building designers would help to further strengthen and validate the research.

Rationale of Usability Testing

Usability Testing of IBDII will answer the following essential questions [28]:

- In the approach followed by IBDII, how does the user find navigating through the interface?
- What are the best and worst features of the front-end application?
- What kind of format does the user prefer for data input: icons with text description, fixed format text, or keywords describing parameters?
- What are the stumbling blocks for the user?
- For which tasks is help required?
- How does the user find reviewing, saving, and retrieving input?
- What kind of written information will be required? For example, will training, procedural, or theoretical information be required?
- Does the user like the provision of creating and adding a custom database?
- Dose the user have any comments or suggestions about the interface design?

Procedure for Usability Testing

Each of the participants was given a working copy of the IBDII front-end and an information sheet briefly describing the purpose of the usability testing. They were then instructed to start the front-end application, experiment and run through it and perform tasks such as: start new project, select building components, review information, attach components to CAD drawing, create building component assemblies, fill occupancy profile, add new components, save and retrieve project. After completion of these tasks they were asked to fill out a questionnaire.

Questionnaire

The questionnaire had six distinct sections, all of which act as indicators of usability and provide suggestions for future developments/improvements. As seen in Appendix B, all the questions have a qualitative scale. The six sections of the questionnaire are as follows:

1. Interface Design
2. Navigation
3. Reviewing and Modifying Input
4. Saving and Retrieving Input
5. Database Creation
6. Assessment and Comments

The last part of the questionnaire was allotted for comments from participants and each participant was encouraged to write his/her comments about improvements recommended for IBDII.

Evaluation of Usability Testing

The questionnaire determines the participant's background with regard to ability in using energy simulation/building performance tools. 7 of the users have used energy simulation/building performance tools before, and hence are considered to be adept at the use of such tools to aid building design.

Interface Design

Three constructs are used to represent the interface design premise:

1. The interface ease of use,
2. The building component icons usage,
3. The input format preferred.

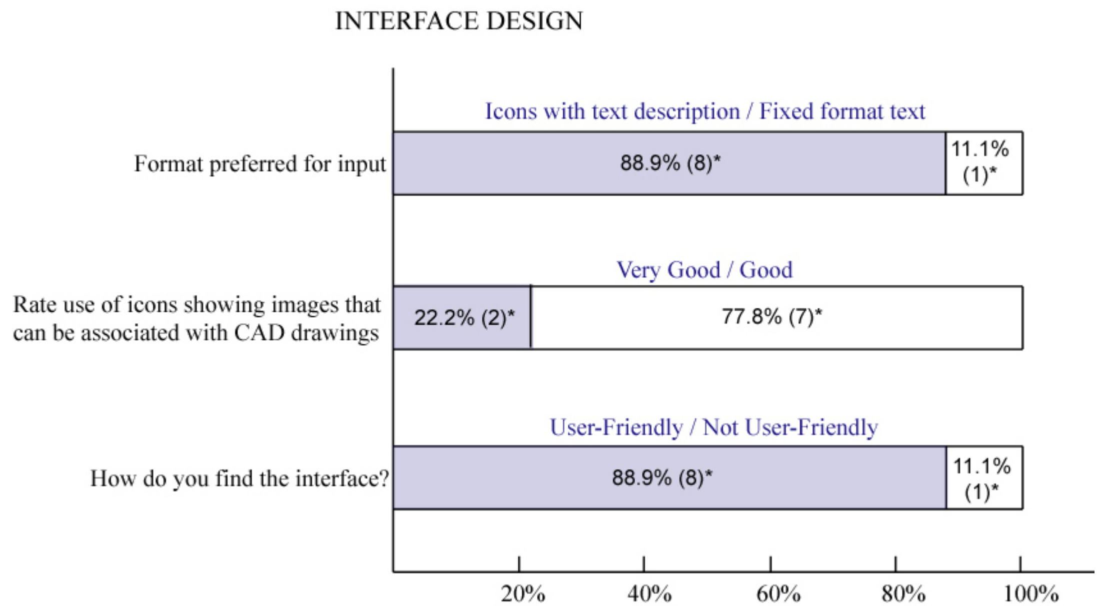

Fig. 25. Overall user reaction to interface design of IBDII.
( )* - No of participants

Fig. 25 shows that 8 out of the 9 participants found the interface user-friendly, thereby authenticating the proposed hypothesis of designing a user-friendly interface design for IBDII. The use of icons showings real-life images of building components was found to be very good by 2 participants, good by 7 participants and not good by none of the participants. This finding illustrates that the graphic icons used in IBDII were liked by the users. When asked about what kind of input format was preferred, 8 out of the 9 participants chose the option of icons with text descriptions which is made available in IBDII. Only 1 of the participants chose the option of fixed format text for input data and neither chose the option of keywords describing the parameters of building design. This clearly shows that a graphic (icons) are preferred over text for input methods.

<u>Navigation</u>

Two constructs are used to represent the premise of navigation:

1. Help required using the front-end
2. Navigating the interface

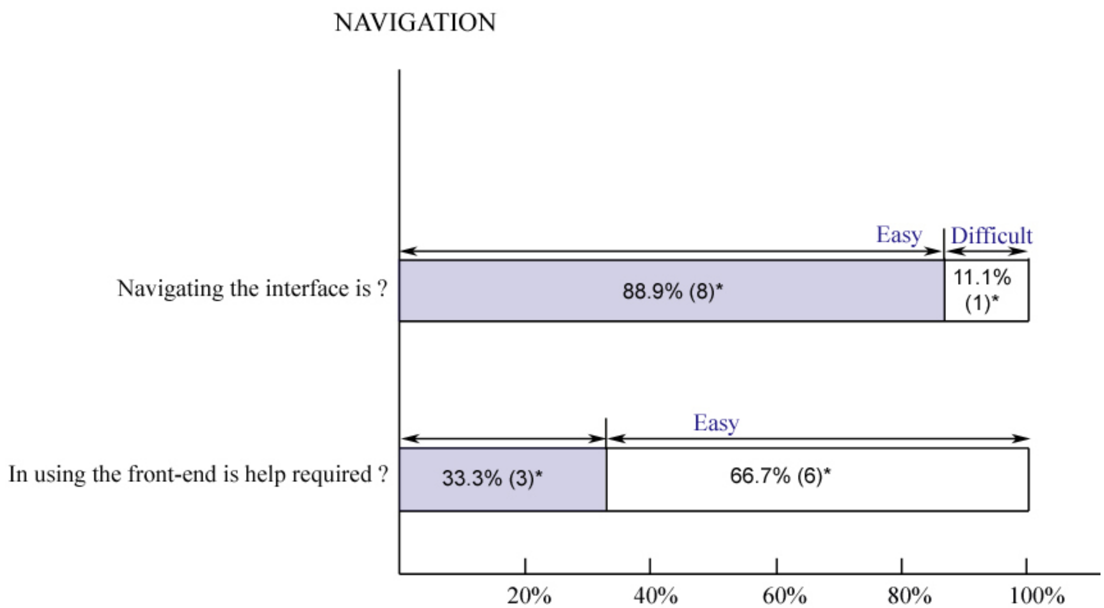

Fig. 26. Overall user reaction to navigating through the interface of IBDII.
( )* - No of participants

Fig. 26 reveals that 6 of the 9 participants declined the use of any help for implementing and navigating through the interface, thus establishing the ease of navigating through the interface. Of the 3 participants who requested for help with the front-end, a majority of them said they would like to have an interactive tutorial. A small fraction of them thought that providing examples of projects would be a better way of guiding them through the front-end. A total of 8 participants found the interface easy to navigate through, and only 1 out of the 9 participants found it difficult to navigate through and neither of the participants found it very difficult to navigate through the interface.

Reviewing and Saving Input

Two constructs are used to represent the premise of reviewing and saving input:

1. Modifying and reviewing input
2. Saving and retrieving input

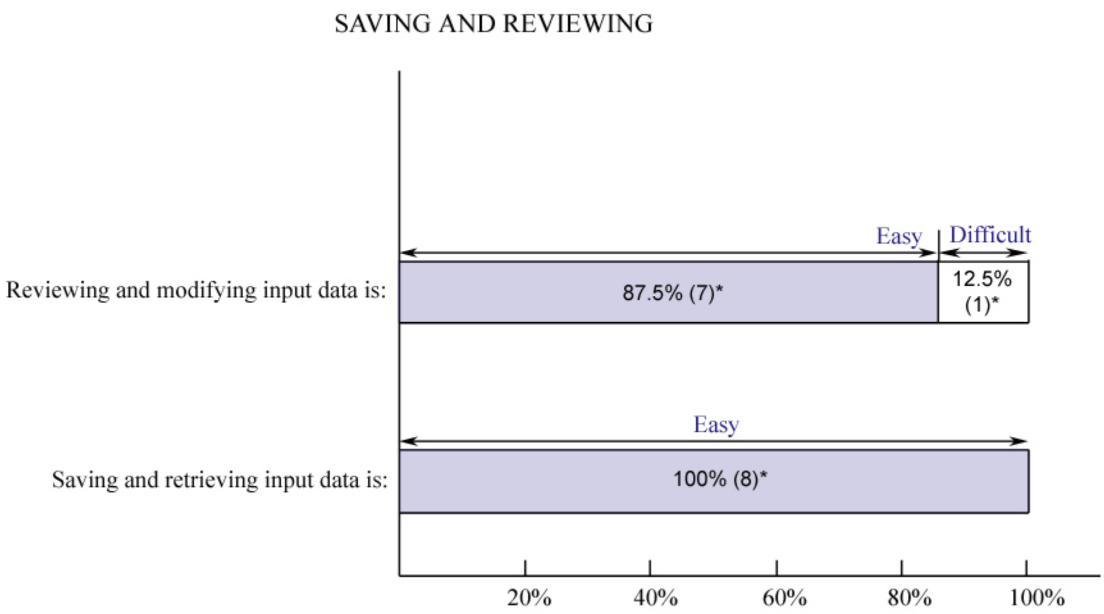

Fig. 27. Overall user reaction to modifying and saving input within IBDII.
( )* - No of participants

A larger majority of the participants found reviewing and modifying the input data easy. Fig. 27 reveals that 7 out of the 9 participants found the method of modifying and reviewing input in IBDII easy and only 1 found it to be difficult (1 of the participants did not respond), and neither of them found it to be very difficult. When asked about saving and retrieving input, all of the 9 participants agreed that it was easy to do so. These results show that saving and reviewing input was chiefly easy to use and understand thereby making the use of the interface effective.

<u>Database Creation</u>

Two constructs are used to represent the database creation premise:

1. Adding a custom database
2. Provision of custom database in IBDII

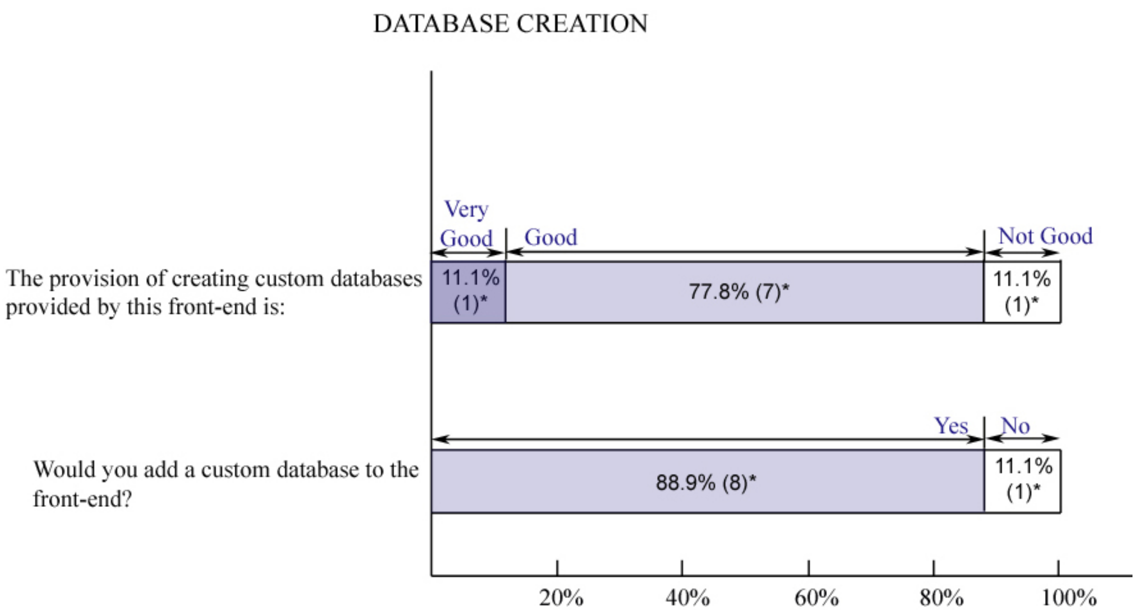

Fig. 28. Overall user reaction to creating custom databases within IBDII.
( )* - No of participants

A greater part of the participants would want to create their own custom database and add it to the existing database of building components. Fig 28 shows that 8 out of 9 participants would like to have an option to create new a new database to add to the existing one. Only 1 out of the 9 participants responded negatively and would not want to add a custom database. From the total of 9 participants: 1 voted for the provision of creating and adding new building components to the ones already existing in IBDII as very good, 7 out of the 9 found this option good and only 1 out of the 9 found it not good.

Assessment

Three constructs are used to represent the database creation premise:

1. Use of the front-end
2. Use the front-end to get a quick energy analysis for design projects
3. Learning to operate the front-end

In the overall assessment of the front-end, all of the 9 participants confirmed that IBDII was easy to use and also easy to learn. Fig 29 reveals that 8 of the participants would use IBDII for getting a quick energy analysis for a design project. Only 1 out of the 9 participants, refused to use IBDII for getting a quick energy analysis for the reason that current options for building components provided in IBDII seem limited.

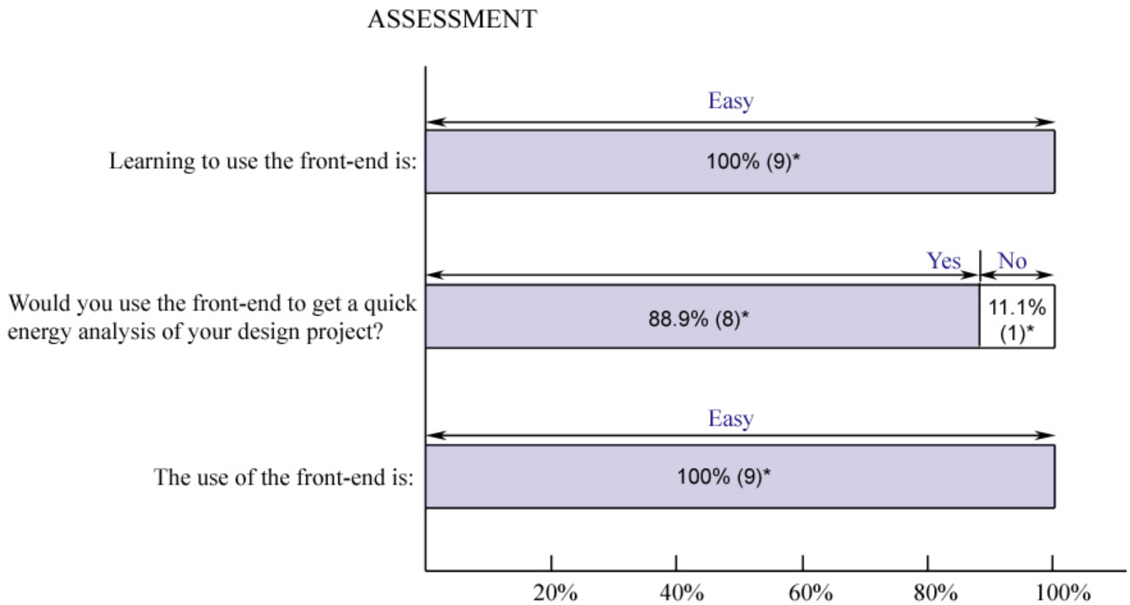

Fig. 29. Overall user assessment of IBDII.
( )* - No of participants

Recommended Improvements and User Comments

Some of the improvements suggested by users were as follows. Additional details can be seen in Appendix B:

1. Participants thought the addition of more building component materials would make the front-end execute better work and results.
2. The "add new item" should not be placed in the left bar along with the other main building parameter components.
3. The occupancy profile input should be expanded.

Users also thought IBDII is a good graphic interface for otherwise boring software's and perceived it as a much more user-friendly tool than some of the currently available energy analysis/building performance tools. The product information and the building component information could be updated by manufacturers as needed. The interface in relation to AutoCAD needs to be tested to check if the building design elements are correctly recognized when assigned to the drawing.

Additional Comments

A demonstration of the working interface of IBDII was informally presented to the audience at the Graduate Student Research Symposium, Department of Architecture, Texas A&M University on November 11th 2004. After the demonstration, the audience was asked to comment on the interface design of IBDII. The comments offered by the people attending the symposium served as additional means for evaluating and validating both the created interface design and the comments of the survey participants. Since a vast majority of the audience was from the field of architectural design and was comprised of architectural design professors, architecture students and architectural designers, this increases confidence in the findings.

Some of the comments and improvements suggested by the audience included the following. The audience suggested linking IBDII with a 3D building geometry instead of 2D CAD. This might best be integrated with parametric design tools like KINETIX REVIT instead of CAD, which is a "dumb" object environment as opposed to an "intelligent" object environment. The audience also saw the need for more options for building materials need to be added to the existing database. The research has a good point about technical vs. visual inclinations. IBDII has a very interesting program concept but seems a bit cumbersome at present, though this is definitely a minor issue.

Suggestions for Future Work

Some of the suggestions for future work for the development of IBDII included: It will be useful if information about building cost analysis and energy performance comparison between a building defined by user and the standard building energy performance, would be added. Immediate result comparisons with codes (IECC- International Energy Conservation Code and ASHRAE Standards 90.1 and 90.2) and LEED could be considered for future development. In order to do an effective energy analysis, more work will have to be done with building assemblies. The aspect about how information can effectively be used in the design process needs to be looked into further. Design tools other than AutoCAD could be explored for their use and can be integrated with the developed front-end.

CHAPTER VI

CONCLUSIONS

Summary of Research Findings

The previous chapters analyze the pros and cons of current energy simulation tools, and discuss why architects are reluctant to use these tools during the design process. This non-usage may be due to the fact that researchers, who are more technically oriented, develop the tools. These researchers require powerful and accurate models that adequately represent real-world complexity. Designers on the other hand are more interested in simple, straightforward and intuitive tools [5]. In addition to this, the current tools are difficult to integrate with the design process, they require tedious input methods, and require extensive training. These tools are not quick enough to be used during the design process, and require technical expertise.

After realizing all of the above shortcomings of available tools, the underlying principle of the research was to develop a design tool specifically for architects. The interface design of IBDII was created with the following focuses.

1. The interface should have an integration of simulation/performance analysis and design tools like AutoCAD. It should not be a stand alone building simulation/performance analysis tool, thus isolating it from the design process.
2. The visual appearance and the technical aspects should both be paid attention to.
3. The interface was designed for easy learnability and usability.
4. Input methodology was to be explicit, straightforward, and graphic.

In order to achieve the desired benefits from the research, the following steps were employed: (1) the analysis and evaluation of available tools, (2) the design of a new front-end interface, and (3) the testing of the new front-end to check for validity of the research hypothesis. All the above three steps would prove mutually beneficial for the preceding steps. The analysis and evaluation of the available tools (BDA, ECOTECT, & MIT Design Advisor) helped with evolving criteria for IBDII. The criteria developed, and in a way, served as answers to the problems faced by available tools. In order for the developed front-end to stand true to what is said about it in theory, it underwent usability testing by architecture design students. The purpose of the usability testing was to establish and validate the premises of the research.

The testing and evaluation of IBDII consisted of distinctive qualitative measures: interface design, navigation, ease of use, learnability, effectiveness and overall user feedback. Among all of these constructs, learnability and ease of use received the highest score of 100%; all 9 participants found the interface easy to use and easy learn. This ascertains the learnability and effectiveness of IBDII. 8 out of the 9 participants found saving and retrieving input easy (1 did not respond) and 7 of the 9 found reviewing and modifying input easy, a total score of 93.75% was given to saving and reviewing input data in IBDII. A majority of 8 out of the 9 participants (88.9%) preferred the input format of IBDII (icons with text descriptions) much over the input formats in tools currently available. And again 8 out of the 9 participants (88.9%) found the front-end interface of to be user-friendly and thought that navigating the interface was easy. When asked about the best features of the front-end 5 of the participants (55.6%) found it to be the interface design. An equal number of 3 participants (33.3 %) found usefulness and easy learnability to be the best feature of IBDII. Details about the evaluation can be found in Chapter V. Consequently all the above factors make the front-end, a tool that enhances an architect's creativity by enabling experimentation without having to be completely dependant on the advice of the consultant. Also it does not require the architect to undergo extensive training, making the front-end of IBDII a tool that is easy and quick to learn and use.

Directions for Future Work

Although the evaluation of IBDII validated and confirmed the hypothesis of the research, there is still the need for future research to inspect some of the following:

1. Further study is needed to improve the data selection method. This could be done by refining the current method and coming up with a more intuitive and flexible way of data selection.
2. To look into other computer aided design tools that could be integrated with the interface instead of AutoCAD. Further research may look into other tools that support sketches and 3D modelling, or design tools which are "intelligent" would allow for easy recognition when building components are assigned to the drawing directly.
3. Look into how building components can actually be assigned to building drawings to obtain accurate results. This could be done be developing a smart recognition system that could be able not only to assign building components

appropriately but also calculate accurately. The concepts of a domain-oriented design environment (as discussed in Chapter II) could be looked deeper into.

4. Test the interface design with architects (real end-users) to validate and strengthen present research findings.

The scope of the research could be extended to various fields in the designing and construction of buildings. IBDII could serve as a tool for providing lifecycle cost analysis and energy analysis/performance for building design projects. The existing database of IBDII could serve as a database for various building material manufacturers. The existing database could also be changed by adding or deleting components depending on each users/manufacturers needs. It could also be helpful in maintaining building inventories. And most of all if the algorithms of all components are added to IBDII so that it becomes capable of calculating the performance of buildings; it would definitely aide architects in the design process to make more informed decisions.

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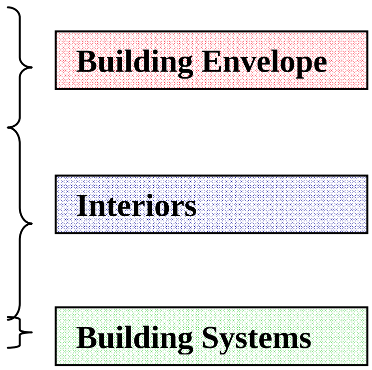
APPENDIX A

Comprehensive listing of IBDII building component input parameters

List of input materials

1. Ext. wall
2. Windows
3. Roof
4. Doors
5. Int. Wall
6. Floors
7. Doors
8. Ceiling
9. Lighting
10. HVAC
11. Occupancy



Types based on materials

1. Exterior wall assembly list
   Category I – Exterior finish
   i. Hollow facing brick
   ii. Solid facing brick
   iii. Stone manufactured veneer
   Category II – Wall assembly
   i. Styrofoam insulation
   ii. Asphalt saturated felt
   iii. Air gap
   iv. Plywood sheathing
   Category III – Interior finish
   i. Gypsum board
   ii. Stone facing

2. Windows
   i. Aluminum: Aluminum Frame Fixed Unit with Clear Block Glazing & Aluminum Standard Single hung Venting Unit
   ii. Wood: Double-hung Wood Window
   iii. Vinyl: Classic Vinyl Venting Single-hung
   iv. Fiberglass: Double Vent Slider

3. Roof Assembly list

    Category I – Decking/Sheathing

    i. Dens-Deck roof guard decking
    ii. Vinyl decking

    Category II – Underlayment

    i. Asphalt saturated felt (non-perforated)
    ii. Polyisocyanurate Foam Roof Insulation

    Category III – Exterior covering

    i. Roof shingles – slate
    ii. Roof Shingles – Metal
    iii. Roof tiles – concrete
    iv. Roof tiles – clay
    v. Roof shingles – asphalt

4. Door

    i. Non-wood, glazed: Wood grain Fiberglass Entry Door
    ii. Non-wood, unglazed: 22-gauge Steel Entry Door
    iii. Wood, glazed: 1-lite Half-view Entry Door
    iv. Wood unglazed: Classic 7-panel Square-top Entry Door

5. Interior wall assembly list

    Categories I – Surface finish 1

    i. Gypsum board
    ii. Stone finish

    Category II – Wall assembly

    i. Rigid insulation
    ii. Batt insulation
    iii. Air gap

    Category III – Surface finish 2

    i. Interior stone finish
    ii. Gypsum board

6. Floor Assembly list

    Category I – Finished flooring

    i. Hard wood
    ii. Ceramic tile
    iii. Vinyl
    iv. Laminate

    Category II – Sub flooring

    i. Wood sub floor

    Category III – Floor support structure

    ii. Wood joist structure
    iii. Slab on grade

    Category IV – Insulation and Weatherproofing

   i. Cement board flooring Underlayment
   ii. Extruded polystyrene Underlayment
   iii. Waterproofing

7. Doors
   i. Non-wood, bi- fold unglazed: Smooth 8' Bi-fold Door (2-panel)
   ii. Wood unglazed bi-fold: Classic 4-panel Bi-fold Door
   iii. Wood, glazed: 9-lite Full-view French Door
   iv. Wood, unglazed: Louvers over louvers Door
   v. Passage door wood: Classic 6-panel Raised panel Interior Door
   vi. Passage door non – wood (MDF): Router Carved 1-panel Door

8. Ceiling
   i. Pressed tin: Coffered Aluminum Ceiling Panel with Mill Finish
   ii. Acoustic panel: 2' x 2' Acoustical Ceiling Panel with Square Edges
   iii. Gypsum board: ToughRock™ Gypsum Board -- 5/8 in. Thick

9. Lighting
   i. Fluorescent: Compact Fluorescent Ceiling Fixture, Recessed Fluorescent lamp & Flush-mount Modular Fluorescent Ceiling Fixture
   ii. Halogen: Halogen Wall/Bath Fixture
   iii. Incandescent: Flush-mount Ceiling Fixture

10. HVAC
   i. Heat pumps: High Efficiency XR12 Heat Pump
   ii. Direct Refrigerant (DX) systems: Packaged XL 1200 Air Conditioner
   iii. All – water systems (4-pipe fan coil): Horizontal Fan Coil
   iv. All – air systems (Single duct, Variable air volume): Single-Duct VAV Terminal

11. Occupancy
   i. No of persons
   ii. No of weeks/year
   iii. No of days/week
   iv. No of hours/day
   v. Percentage of persons present/hour

APPENDIX B

Questionnaire - 1

Purpose of Study

The purpose of this study is to establish the usefulness, effectiveness and learnability of the newly developed front-end interface. This questionnaire will help to establish and understand the advantages and disadvantages of the developed interface design.

Instructions

Please put a check mark against the option you select.

1) Have you ever used any energy simulation/building performance analysis tools before?

- ■ Yes
- ☐ No

If YES, please write down the names: Doe-2, Enerwin

Section A – Interface Design

2) After having used the front-end, do you find the interface:

- ■ User-friendly
- ☐ Not User-friendly

3) Would you rate the use of icons showing images of components that can be associated with your drawings:

- ☐ Very Good
- ■ Good
- ☐ Not Good

4) Which of the following formats do you prefer for input data:

- ■ Icons with text descriptions
- ☐ Text description (fixed format text)
- ☐ Keywords describing the parameters

Other, please explain:

Section B - Navigation

5) Do you require help using the front-end?

- ☐ Yes
- ■ No

If YES, then what kind of help would you prefer:

- ☐ Training
- ☐ Interactive tutorial

☐ Examples

☐ Theoretical information

6) Do you find navigating the interface:

■ Easy

☐ Difficult

☐ Very Difficult

Section C – Reviewing and Modifying Input
7) Would you rate modifying and reviewing the input data:

■ Easy

☐ Difficult

☐ Very Difficult

Section D – Saving & Retrieving Input
8) Would you rate saving and retrieving the input data:

■ Easy

☐ Difficult

☐ Very Difficult

Section E – Database Creation
9) Would you like to add your own database of building components to the front-end (i.e. customizable database)?

■ Yes

☐ No

10) Do you find the provision of creating your custom database of building components provided by this tool:

☐ Very Good

■ Good

☐ Not Good

Section F – Assessment & Comments
11) Do you consider the use of this front-end:

■ Easy

☐ Difficult

☐ Very Difficult

12) Would you use this tool to get a quick energy analysis for your design project?

- ■ Yes
- ☐ No

If NO, then why:

13) After using this front-end, do you consider learning it to be:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

14) The best feature of this front-end application is:

- ■ Interface design
- ☐ Usefulness
- ☐ Easy learnability
- ☐ Easy to use

Other:

15) The main problem regarding the use of this front-end application is:

- ☐ Interface design
- ■ Workability of the front-end
- ☐ Hard to learn
- ☐ Difficult to use
- ☐ Input data methodology
- ☐ Time consuming

Other:

16) Improvements you would recommend for this front-end application
Comments:

17) Any other comments you may have related to user-interfaces for energy analysis software's in building design:

Questionnaire - 2

Purpose of Study

The purpose of this study is to establish the usefulness, effectiveness and learnability of the newly developed front-end interface. This questionnaire will help to establish and understand the advantages and disadvantages of the developed interface design.

Instructions

Please put a check mark against the option you select.

1) Have you ever used any energy simulation/building performance analysis tools before?

- ■ Yes
- ☐ No

If YES, please write down the names: Enerwin, RADIANCE

Section A – Interface Design

2) After having used the front-end, do you find the interface:

- ■ User-friendly
- ☐ Not User-friendly

3) Would you rate the use of icons showing images of components that can be associated with your drawings:

- ■ Very Good
- ☐ Good
- ☐ Not Good

4) Which of the following formats do you prefer for input data:

- ■ Icons with text descriptions
- ☐ Text description (fixed format text)
- ☐ Keywords describing the parameters

Other, please explain:

Section B - Navigation

5) Do you require help using the front-end?

- ☐ Yes
- ■ No

If YES, then what kind of help would you prefer:

- ☐ Training
- ☐ Interactive tutorial
- ☐ Examples

- ☐ Theoretical information

6) Do you find navigating the interface:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section C – Reviewing and Modifying Input
7) Would you rate modifying and reviewing the input data:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section D – Saving & Retrieving Input
8) Would you rate saving and retrieving the input data:

- ☐ Easy
- ☐ Difficult
- ☐ Very Difficult

Section E – Database Creation
9) Would you like to add your own database of building components to the front-end (i.e. customizable database)?

- ■ Yes
- ☐ No

10) Do you find the provision of creating your custom database of building components provided by this tool:

- ☐ Very Good
- ☐ Good
- ■ Not Good

Section F – Assessment & Comments
11) Do you consider the use of this front-end:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

12) Would you use this tool to get a quick energy analysis for your design project?

- ■ Yes
- ☐ No

If NO, then why:

13) After using this front-end, do you consider learning it to be:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

14) The best feature of this front-end application is:

- ■ Interface design
- ☐ Usefulness
- ☐ Easy learnability
- ☐ Easy to use

Other:

15) The main problem regarding the use of this front-end application is:

- ☐ Interface design
- ☐ Workability of the front-end
- ☐ Hard to learn
- ☐ Difficult to use
- ■ Input data methodology
- ☐ Time consuming

Other:

16) Improvements you would recommend for this front-end application
Comments: Right now the data stored is minimal. Once the data is increased, I am sure this software will work better. However, a good graphic interface for otherwise boring softwares.

17) Any other comments you may have related to user-interfaces for energy analysis software's in building design:

Questionnaire - 3

Purpose of Study

The purpose of this study is to establish the usefulness, effectiveness and learnability of the newly developed front-end interface. This questionnaire will help to establish and understand the advantages and disadvantages of the developed interface design.

Instructions

Please put a check mark against the option you select.

1) Have you ever used any energy simulation/building performance analysis tools before?

- ■ Yes
- ☐ No

If YES, please write down the names: Visual Doe, Enerwin, RADIANCE, ECOTECT

Section A – Interface Design

2) After having used the front-end, do you find the interface:

- ■ User-friendly
- ☐ Not User-friendly

3) Would you rate the use of icons showing images of components that can be associated with your drawings:

- ☐ Very Good
- ■ Good
- ☐ Not Good

4) Which of the following formats do you prefer for input data:

- ☐ Icons with text descriptions
- ■ Text description (fixed format text)
- ☐ Keywords describing the parameters

Other, please explain: as well as maybe, all dimension

Section B - Navigation

5) Do you require help using the front-end?

- ☐ Yes
- ■ No

If YES, then what kind of help would you prefer:

- ☐ Training
- ■ Interactive tutorial
- ■ Examples

- ☐ Theoretical information

6) Do you find navigating the interface:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section C – Reviewing and Modifying Input
7) Would you rate modifying and reviewing the input data:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section D – Saving & Retrieving Input
8) Would you rate saving and retrieving the input data:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section E – Database Creation
9) Would you like to add your own database of building components to the front-end (i.e. customizable database)?

- ■ Yes
- ☐ No

10) Do you find the provision of creating your custom database of building components provided by this tool:

- ☐ Very Good
- ■ Good
- ☐ Not Good

Section F – Assessment & Comments
11) Do you consider the use of this front-end:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

12) Would you use this tool to get a quick energy analysis for your design project?

- ■ Yes
- ☐ No

If NO, then why:

13) After using this front-end, do you consider learning it to be:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

14) The best feature of this front-end application is:

- ■ Interface design
- ■ Usefulness
- ■ Easy learnability
- ■ Easy to use

Other:

15) The main problem regarding the use of this front-end application is:

- ☐ Interface design
- ☐ Workability of the front-end
- ☐ Hard to learn
- ☐ Difficult to use
- ☐ Input data methodology
- ☐ Time consuming

Other:

16) Improvements you would recommend for this front-end application
Comments: It's perfect. Add more parameter. Results should be in the form of charts charts, tables, pie-charts.

17) Any other comments you may have related to user-interfaces for energy analysis software's in building design:

Questionnaire - 4

Purpose of Study

The purpose of this study is to establish the usefulness, effectiveness and learnability of the newly developed front-end interface. This questionnaire will help to establish and understand the advantages and disadvantages of the developed interface design.

Instructions

Please put a check mark against the option you select.

1) Have you ever used any energy simulation/building performance analysis tools before?

- ■ Yes
- ☐ No

If YES, please write down the names: Enerwin, ECOTECT

Section A – Interface Design

2) After having used the front-end, do you find the interface:

- ■ User-friendly
- ☐ Not User-friendly

3) Would you rate the use of icons showing images of components that can be associated with your drawings:

- ☐ Very Good
- ■ Good
- ☐ Not Good

4) Which of the following formats do you prefer for input data:

- ■ Icons with text descriptions
- ☐ Text description (fixed format text)
- ☐ Keywords describing the parameters

Other, please explain:

Section B - Navigation

5) Do you require help using the front-end?

- ■ Yes
- ☐ No

If YES, then what kind of help would you prefer:

- ■ Training
- ■ Interactive tutorial
- ■ Examples

- ☐ Theoretical information

6) Do you find navigating the interface:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section C – Reviewing and Modifying Input
7) Would you rate modifying and reviewing the input data:

- ☐ Easy
- ☐ Difficult
- ☐ Very Difficult

Section D – Saving & Retrieving Input
8) Would you rate saving and retrieving the input data:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section E – Database Creation
9) Would you like to add your own database of building components to the front-end (i.e. customizable database)?

- ■ Yes
- ☐ No

10) Do you find the provision of creating your custom database of building components provided by this tool:

- ☐ Very Good
- ■ Good
- ☐ Not Good

Section F – Assessment & Comments
11) Do you consider the use of this front-end:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

12) Would you use this tool to get a quick energy analysis for your design project?

- ☐ Yes
- ■ No

If NO, then why: Options seem limited

13) After using this front-end, do you consider learning it to be:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

14) The best feature of this front-end application is:

- ■ Interface design
- ☐ Usefulness
- ☐ Easy learnability
- ☐ Easy to use

Other:

15) The main problem regarding the use of this front-end application is:

- ☐ Interface design
- ☐ Workability of the front-end
- ☐ Hard to learn
- ☐ Difficult to use
- ■ Input data methodology
- ☐ Time consuming

Other:

16) Improvements you would recommend for this front-end application
Comments:

17) Any other comments you may have related to user-interfaces for energy analysis software's in building design: The interface with AutoCAD – on recognition of elements of the building structure – has to be fully tested.

Questionnaire - 5

Purpose of Study

The purpose of this study is to establish the usefulness, effectiveness and learnability of the newly developed front-end interface. This questionnaire will help to establish and understand the advantages and disadvantages of the developed interface design.

Instructions

Please put a check mark against the option you select.

1) Have you ever used any energy simulation/building performance analysis tools before?

- ■ Yes
- ☐ No

If YES, please write down the names:

Section A – Interface Design

2) After having used the front-end, do you find the interface:

- ■ User-friendly
- ☐ Not User-friendly

3) Would you rate the use of icons showing images of components that can be associated with your drawings:

- ☐ Very Good
- ■ Good
- ☐ Not Good

4) Which of the following formats do you prefer for input data:

- ■ Icons with text descriptions
- ☐ Text description (fixed format text)
- ☐ Keywords describing the parameters

Other, please explain:

Section B - Navigation

5) Do you require help using the front-end?

- ☐ Yes
- ■ No

If YES, then what kind of help would you prefer:

- ☐ Training
- ☐ Interactive tutorial
- ☐ Examples

- ☐ Theoretical information

6) Do you find navigating the interface:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section C – Reviewing and Modifying Input
7) Would you rate modifying and reviewing the input data:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section D – Saving & Retrieving Input
8) Would you rate saving and retrieving the input data:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section E – Database Creation
9) Would you like to add your own database of building components to the front-end (i.e. customizable database)?

- ■ Yes
- ☐ No

10) Do you find the provision of creating your custom database of building components provided by this tool:

- ■ Very Good
- ☐ Good
- ☐ Not Good

Section F – Assessment & Comments
11) Do you consider the use of this front-end:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

12) Would you use this tool to get a quick energy analysis for your design project?

- ■ Yes
- ☐ No

If NO, then why:

13) After using this front-end, do you consider learning it to be:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

14) The best feature of this front-end application is:

- ☐ Interface design
- ☐ Usefulness
- ☐ Easy learnability
- ■ Easy to use

Other:

15) The main problem regarding the use of this front-end application is:

- ☐ Interface design
- ☐ Workability of the front-end
- ☐ Hard to learn
- ☐ Difficult to use
- ☐ Input data methodology
- ☐ Time consuming

Other:

16) Improvements you would recommend for this front-end application
Comments:

17) Any other comments you may have related to user-interfaces for energy analysis software's in building design: Have products updated by manufacturer's as needed

Questionnaire - 6

Purpose of Study

The purpose of this study is to establish the usefulness, effectiveness and learnability of the newly developed front-end interface. This questionnaire will help to establish and understand the advantages and disadvantages of the developed interface design.

Instructions

Please put a check mark against the option you select.

1) Have you ever used any energy simulation/building performance analysis tools before?

- ■ Yes
- ☐ No

If YES, please write down the names: Enerwin 5

Section A – Interface Design

2) After having used the front-end, do you find the interface:

- ■ User-friendly
- ☐ Not User-friendly

3) Would you rate the use of icons showing images of components that can be associated with your drawings:

- ☐ Very Good
- ■ Good
- ☐ Not Good

4) Which of the following formats do you prefer for input data:

- ■ Icons with text descriptions
- ☐ Text description (fixed format text)
- ■ Keywords describing the parameters

Other, please explain:

Section B - Navigation

5) Do you require help using the front-end?

- ☐ Yes
- ■ No

If YES, then what kind of help would you prefer:

- ☐ Training
- ■ Interactive tutorial
- ■ Examples

■ Theoretical information

6) Do you find navigating the interface:

■ Easy

☐ Difficult

☐ Very Difficult

Section C – Reviewing and Modifying Input
7) Would you rate modifying and reviewing the input data:

■ Easy

☐ Difficult

☐ Very Difficult

Section D – Saving & Retrieving Input
8) Would you rate saving and retrieving the input data:

■ Easy

☐ Difficult

☐ Very Difficult

Section E – Database Creation
9) Would you like to add your own database of building components to the front-end (i.e. customizable database)?

■ Yes

☐ No

10) Do you find the provision of creating your custom database of building components provided by this tool:

☐ Very Good

■ Good

☐ Not Good

Section F – Assessment & Comments
11) Do you consider the use of this front-end:

■ Easy

☐ Difficult

☐ Very Difficult

12) Would you use this tool to get a quick energy analysis for your design project?

■ Yes

☐ No

If NO, then why:

13) After using this front-end, do you consider learning it to be:

■ Easy

☐ Difficult

☐ Very Difficult

14) The best feature of this front-end application is:

■ Interface design

☐ Usefulness

■ Easy learnability

☐ Easy to use

Other:

15) The main problem regarding the use of this front-end application is:

☐ Interface design

☐ Workability of the front-end

☐ Hard to learn

☐ Difficult to use

☐ Input data methodology

☐ Time consuming

Other:

16) Improvements you would recommend for this front-end application
Comments:

17) Any other comments you may have related to user-interfaces for energy analysis software's in building design:

Questionnaire - 7

Purpose of Study

The purpose of this study is to establish the usefulness, effectiveness and learnability of the newly developed front-end interface. This questionnaire will help to establish and understand the advantages and disadvantages of the developed interface design.

Instructions

Please put a check mark against the option you select.

1) Have you ever used any energy simulation/building performance analysis tools before?

- ☐ Yes
- ■ No

If YES, please write down the names:

Section A – Interface Design

2) After having used the front-end, do you find the interface:

- ■ User-friendly
- ☐ Not User-friendly

3) Would you rate the use of icons showing images of components that can be associated with your drawings:

- ☐ Very Good
- ■ Good
- ☐ Not Good

4) Which of the following formats do you prefer for input data:

- ■ Icons with text descriptions
- ☐ Text description (fixed format text)
- ☐ Keywords describing the parameters

Other, please explain:

Section B - Navigation

5) Do you require help using the front-end?

- ☐ Yes
- ■ No

If YES, then what kind of help would you prefer:

- ☐ Training
- ☐ Interactive tutorial
- ☐ Examples

- ☐ Theoretical information

6) Do you find navigating the interface:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section C – Reviewing and Modifying Input
7) Would you rate modifying and reviewing the input data:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section D – Saving & Retrieving Input
8) Would you rate saving and retrieving the input data:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section E – Database Creation
9) Would you like to add your own database of building components to the front-end (i.e. customizable database)?

- ■ Yes
- ☐ No

10) Do you find the provision of creating your custom database of building components provided by this tool:

- ☐ Very Good
- ■ Good
- ☐ Not Good

Section F – Assessment & Comments
11) Do you consider the use of this front-end:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

12) Would you use this tool to get a quick energy analysis for your design project?

- ■ Yes
- ☐ No

If NO, then why:

13) After using this front-end, do you consider learning it to be:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

14) The best feature of this front-end application is:

- ☐ Interface design
- ☐ Usefulness
- ■ Easy learnability
- ☐ Easy to use

Other:

15) The main problem regarding the use of this front-end application is:

- ☐ Interface design
- ■ Workability of the front-end
- ☐ Hard to learn
- ☐ Difficult to use
- ☐ Input data methodology
- ☐ Time consuming

Other:

16) Improvements you would recommend for this front-end application
Comments: Work on occupancy input times

17) Any other comments you may have related to user-interfaces for energy analysis software's in building design:

Questionnaire - 8

Purpose of Study

The purpose of this study is to establish the usefulness, effectiveness and learnability of the newly developed front-end interface. This questionnaire will help to establish and understand the advantages and disadvantages of the developed interface design.

Instructions

Please put a check mark against the option you select.

1) Have you ever used any energy simulation/building performance analysis tools before?

- ■ Yes
- ☐ No

If YES, please write down the names: Enerwin

Section A – Interface Design

2) After having used the front-end, do you find the interface:

- ■ User-friendly
- ☐ Not User-friendly

3) Would you rate the use of icons showing images of components that can be associated with your drawings:

- ■ Very Good
- ☐ Good
- ☐ Not Good

4) Which of the following formats do you prefer for input data:

- ■ Icons with text descriptions
- ☐ Text description (fixed format text)
- ☐ Keywords describing the parameters

Other, please explain:

Section B - Navigation

5) Do you require help using the front-end?

- ■ Yes
- ☐ No

If YES, then what kind of help would you prefer:

- ☐ Training
- ■ Interactive tutorial
- ☐ Examples

- ☐ Theoretical information

6) Do you find navigating the interface:

- ☐ Easy
- ■ Difficult
- ☐ Very Difficult

Section C – Reviewing and Modifying Input
7) Would you rate modifying and reviewing the input data:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section D – Saving & Retrieving Input
8) Would you rate saving and retrieving the input data:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section E – Database Creation
9) Would you like to add your own database of building components to the front-end (i.e. customizable database)?

- ■ Yes
- ☐ No

10) Do you find the provision of creating your custom database of building components provided by this tool:

- ☐ Very Good
- ■ Good
- ☐ Not Good

Section F – Assessment & Comments
11) Do you consider the use of this front-end:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

12) Would you use this tool to get a quick energy analysis for your design project?

- ■ Yes
- ☐ No

If NO, then why:

13) After using this front-end, do you consider learning it to be:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

14) The best feature of this front-end application is:

- ☐ Interface design
- ■ Usefulness
- ☐ Easy learnability
- ☐ Easy to use

Other:

15) The main problem regarding the use of this front-end application is:

- ☐ Interface design
- ■ Workability of the front-end
- ☐ Hard to learn
- ☐ Difficult to use
- ☐ Input data methodology
- ☐ Time consuming

Other:

16) Improvements you would recommend for this front-end application
Comments: Make “Add New Item” look like it’s not a main link

17) Any other comments you may have related to user-interfaces for energy analysis software’s in building design: Much more user-friendly than Enerwin

Questionnaire - 9

Purpose of Study

The purpose of this study is to establish the usefulness, effectiveness and learnability of the newly developed front-end interface. This questionnaire will help to establish and understand the advantages and disadvantages of the developed interface design.

Instructions

Please put a check mark against the option you select.

1) Have you ever used any energy simulation/building performance analysis tools before?

- ☐ Yes
- ■ No

If YES, please write down the names:

Section A – Interface Design

2) After having used the front-end, do you find the interface:

- ☐ User-friendly
- ■ Not User-friendly

3) Would you rate the use of icons showing images of components that can be associated with your drawings:

- ☐ Very Good
- ■ Good
- ☐ Not Good

4) Which of the following formats do you prefer for input data:

- ■ Icons with text descriptions
- ☐ Text description (fixed format text)
- ☐ Keywords describing the parameters

Other, please explain:

Section B - Navigation

5) Do you require help using the front-end?

- ■ Yes
- ☐ No

If YES, then what kind of help would you prefer:

- ☐ Training
- ■ Interactive tutorial
- ☐ Examples

- ☐ Theoretical information

6) Do you find navigating the interface:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section C – Reviewing and Modifying Input
7) Would you rate modifying and reviewing the input data:

- ☐ Easy
- ■ Difficult
- ☐ Very Difficult

Section D – Saving & Retrieving Input
8) Would you rate saving and retrieving the input data:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

Section E – Database Creation
9) Would you like to add your own database of building components to the front-end (i.e. customizable database)?

- ☐ Yes
- ■ No

10) Do you find the provision of creating your custom database of building components provided by this tool:

- ☐ Very Good
- ■ Good
- ☐ Not Good

Section F – Assessment & Comments
11) Do you consider the use of this front-end:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

12) Would you use this tool to get a quick energy analysis for your design project?

- ■ Yes
- ☐ No

If NO, then why:

13) After using this front-end, do you consider learning it to be:

- ■ Easy
- ☐ Difficult
- ☐ Very Difficult

14) The best feature of this front-end application is:

- ☐ Interface design
- ■ Usefulness
- ☐ Easy learnability
- ☐ Easy to use

Other:

15) The main problem regarding the use of this front-end application is:

- ☐ Interface design
- ☐ Workability of the front-end
- ☐ Hard to learn
- ☐ Difficult to use
- ■ Input data methodology
- ☐ Time consuming

Other:

16) Improvements you would recommend for this front-end application
Comments: More material

17) Any other comments you may have related to user-interfaces for energy analysis software's in building design: N/A

VITA

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EDUCATION

2002 - 2005	Master of Science in Architecture, 2005 Texas A&M University, College Station, USA
1997-2002	Bachelor of Architecture, 2002 Sir J. J. College of Architecture, University of Mumbai, India

EXPERIENCE

Sept 03 - May 04	Graduate Assistant for Dr. Valerian Miranda, Associate Dept. Head Dept. of Architecture, Texas A&M University
June 03 - Aug 03	Visiting Researcher Ernest Orlando Lawrence Berkeley National Laboratory (LBNL), Environmental Energy Technologies Division, Berkeley, California
Feb 03 - May 03	Research Assistant for Dr. Roger Ulrich, Director of Centre for Health Systems and Design (CHSD), Dept. of Architecture, Texas A&M University
Oct 01 - April 02	Trainee Architect Upasani Design Cell, Bombay, India

HONORS

2003	Awarded Graduate Assistantship through Dept. of Architecture, Texas A&M University
2003	Awarded The R. J. Reeves Endowed Memorial Scholarship for academic excellence, Texas A&M University
2004, 2003, 2002	Awarded Graduate Scholarship at Texas A&M University
1997	Displayed design project in Sir Claude Batley Art Gallery, Bombay, India
1997	Secured 5th position in All India Architecture Entrance Examination

POSITIONS HELD

2004 – 2005	Elected as the Vice President - ASHRAE Student Chapter, Texas A&M University

PUBLIC PRESENTATIONS

2004	SimBuild 2004, University of Colorado, August 4-6, 2004 Presented poster on “Enhancing Interfaces of Building Performance Analysis Tools”
2004	2004 Graduate Student Research Symposium, Texas A&M University, November 11, 2004 Presented thesis research on “Integrated Building Design Information Interface”