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DEVELOPMENT OF AN INTEGRATED BUILDING DESIGN INFORMATION INTERFACE

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ABSTRACT

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. This research is limited to the interface design of the new front-end which is named Integrated Building Design Information Interface.

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 establishes 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.

INTRODUCTION

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 visualiztion, the potential of these tools is largely untapped (Ellis et al., 2002). 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 (Hong et al., 1997). 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 (Ellis et al., 2002).

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 consist 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 the initial design stages (Ellis et al., 2002).

INTERFACE DESIGN OF PROTOTYPE

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 (Petrelli et al., 1999). 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 (Smiley, 2002). 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 (Morbitzer et al., 2001). 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 (Hefley et al., 1993). For the architects to use the tool, it should possess the following characteristics (Gratia et al., 2002):

- To be very user-friendly by using the visual language of architects, mainly based on illustartions.

- To require minimum amounts 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 (Marsh et al., 1995).

The creation of a Domain-Oriented Design Environment 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 and listens to the feedback provided by the environment. And conversely, the DODE listens to the designer's design moves and speaks by providing feedback (Ostwald et al., 1995).

Building design is a multidisciplinary activity involving several professions i.e. architects; 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 (Ellis et al., 2002). 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 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. Building Design Advisor-BDA is one of the projects aiming to provide such an IBDS (Ellis et al., 2002; Hong et al., 2000). An IBDS will act as an integration of databases such as building components, HVAC components, weather data, etc. and applications like CADD (Hong et al., 2000).

After a thorough analysis of the current simulation tools: BDA, MIT 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 front-end. The front-end consists of three distinct parts as shown in Figure 1, 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 that 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 (Papamichael et al., 2002).

Details regarding the interface design for the front-end that was developed using VisualBasic.Net, are now presented. 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, which acts as a replacement for the existing interfaces of simulation tools. The input interfaces for existing tools either accept fixed format text as input, selecting from a hierarchical tree of building description keywords, or entering numerical data.

The created interface is flexible to each individual user's needs. The main start-up screen is where initial project information such as building type i.e. residential, commercial, school, country, state, city, project name, units and default floor to floor height can be entered. After entering the required information on the start up screen, clicking the start button brings the user to the building description screen. 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 i.e. 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. 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 Figure 2. Roof categories and assemblies are displayed when the roof button in the top bar is clicked. The roof categories are as shown in Figure 3. Selecting one or more components from all the three categories and then clicking on the assemble button will create a roof assemblage. In theory, this will add up thermal values of all components in the order of categories, which will be needed for calculating the building design performance. Clicking on the product image will display the product specifications and a link to the manufacturer's website.

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 Figure 4. 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 Figure 4. 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.

USABILITY TESTING & EVALUATION

"Usability can be defined as the ease with which a system/application can be learned and used" (Bury et al., 1986). Usability testing is a generic name for a set of cost effective ways of evaluating user interfaces to find problems pertaining to usability. There are four basic ways of evaluating user interfaces, that are as follows (Nielsen, 1995):

- Automatic: usability measures computed by running a user interface specification through some program.
- Empirical: usability assessed by testing the interface with real users.

- Formal: using exact models and formulas to calculate usability measures.
- 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 (Nielsen, 1995). 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 (Bury et al., 1986).

Some of the strengths of Empirical user testing include (Bury et al., 1986):

- 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.

The purpose of the usability testing is geared towards establishing the usefulness, effectiveness, likeability and learnability of the developed front-end interface design (Rubin, 1994). 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 demonstrates 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 is 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 Department of Architecture, Texas A&M University volunteered to participate in the usability testing. These students were selected as 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 (Rubin, 1994):

- 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?

Procedure for Usability Testing

Each of the participants was given a working copy of the IBDII front-end and an information sheet 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. The six sections of the questionnaire are as follows:

- Interface Design
- Navigation
- Reviewing and Modifying Input
- Saving and Retrieving Input
- Database Creation
- 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.

The testing and evaluation of IBDII consisted of distinctive qualitative measures: interface design, navigation, ease of use, learnability, effectiveness and overall user feedback. A majority of 8 out of the 9 participants i.e. 88.9%, preferred the input format of IBDII which was icons with text descriptions, much over the input formats in tools currently available, this is seen in Figure 5. And 8 of the 9 participants i.e. 88.9%, found the interface of the front-end to be user-friendly and thought that navigating the interface was easy, which is seen in Figure 5. 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 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, as seen in Figure 6. Among all of the constructs, learnability and ease of use received the highest score of 100% which is shown in Figure 7. When asked about the best features of the front-end 5 of the participants i.e. 55.6%, found it to be the interface design. An equal number of 3 participants i.e. 33.3 %, found usefulness and easy learnability to be the best feature of IBDII. 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.

CONCLUSION

The previous sections 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 (Ellis et al., 2002). 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 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 the front-end was created with the following focuses:

- 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.

- The visual appearance and the technical aspects should both be paid attention to.
- The interface was designed for easy learnability and usability.
- Input methodology was to be explicit, straightforward, and graphic.

In order to achieve the desired benefits from the research, the following steps were employed:

- the analysis and evaluation of available tools,
- the design of a new front-end interface, and
- 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 helped with evolving criteria for IBDII. In a way, the criteria developed, 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.

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:

- 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.
- 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.
- Look into how building components can actually be assigned to building drawings to obtain accurate results. This could be done by developing a smart recognition system that could not only assign building components appropriately but also calculate accurately. The concepts of a domain-oriented design environment could be looked deeper into.
- Test the interface design with architects i.e. 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, this 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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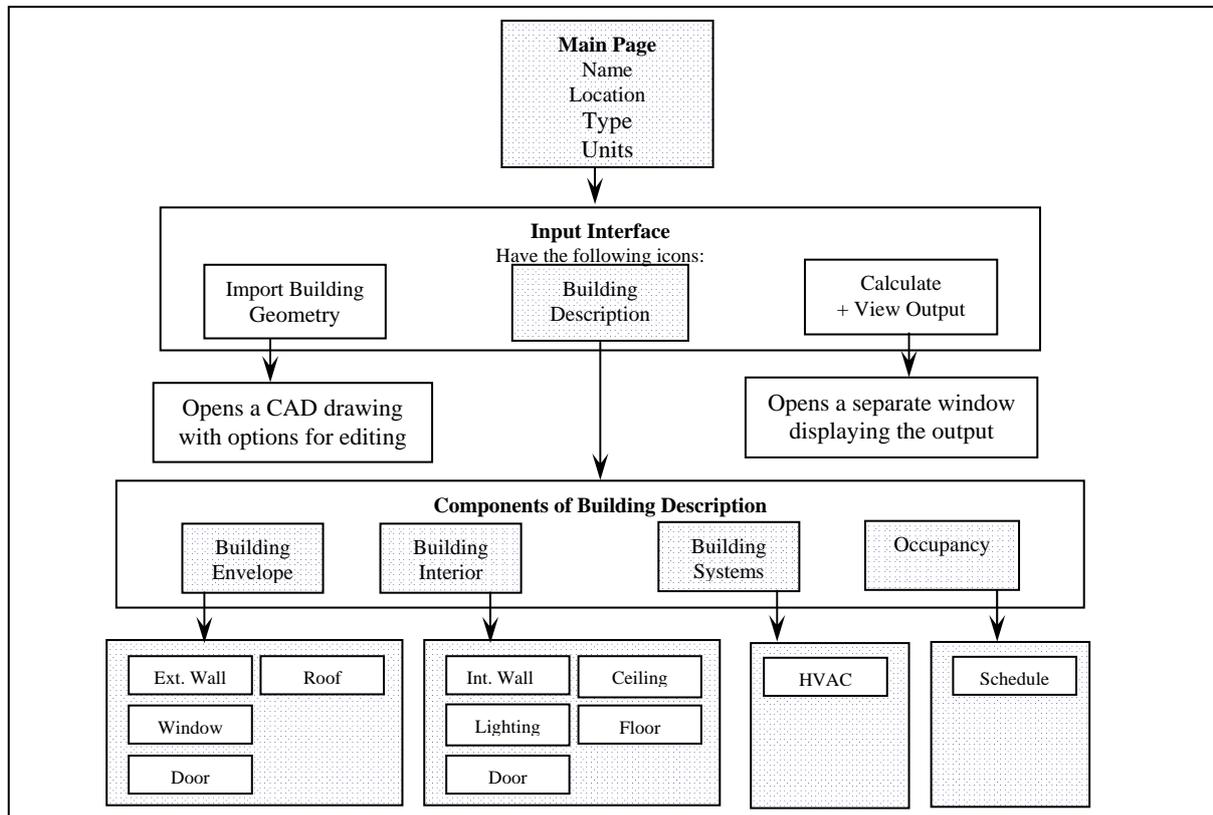J. Smiley, Learn to Program with Visual Basic. Net, McGraw-Hill Osborne Media, 2002.

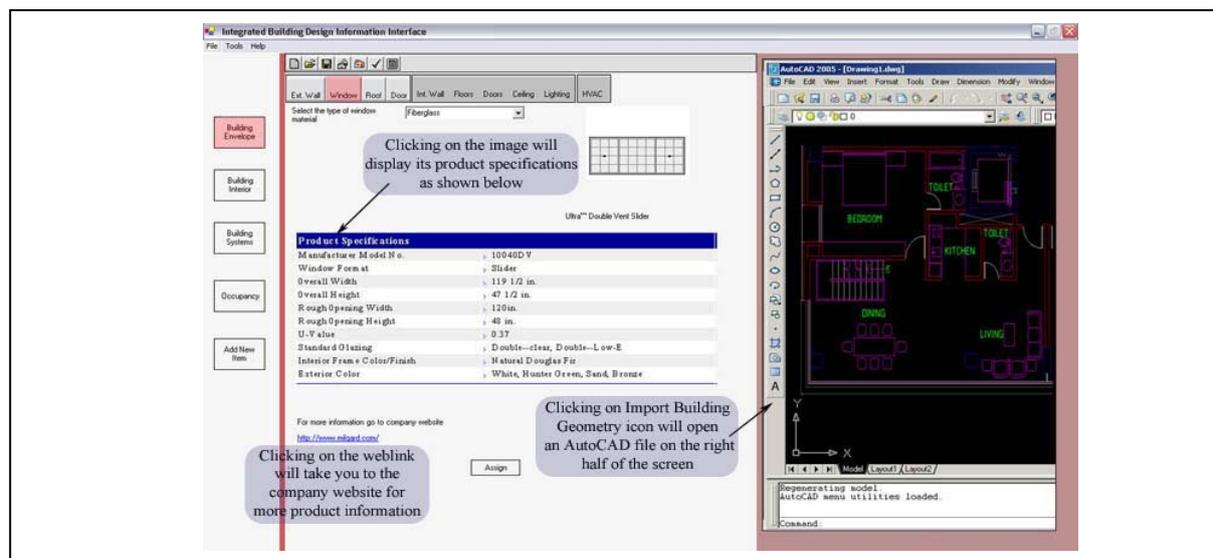*Figure 1 Flow chart showing interface links of IBDII*

Figure 2 Screen displaying window (building component) specifications, manufacturer's web link and AutoCAD image on right which opens on clicking the Import Building Geometry button
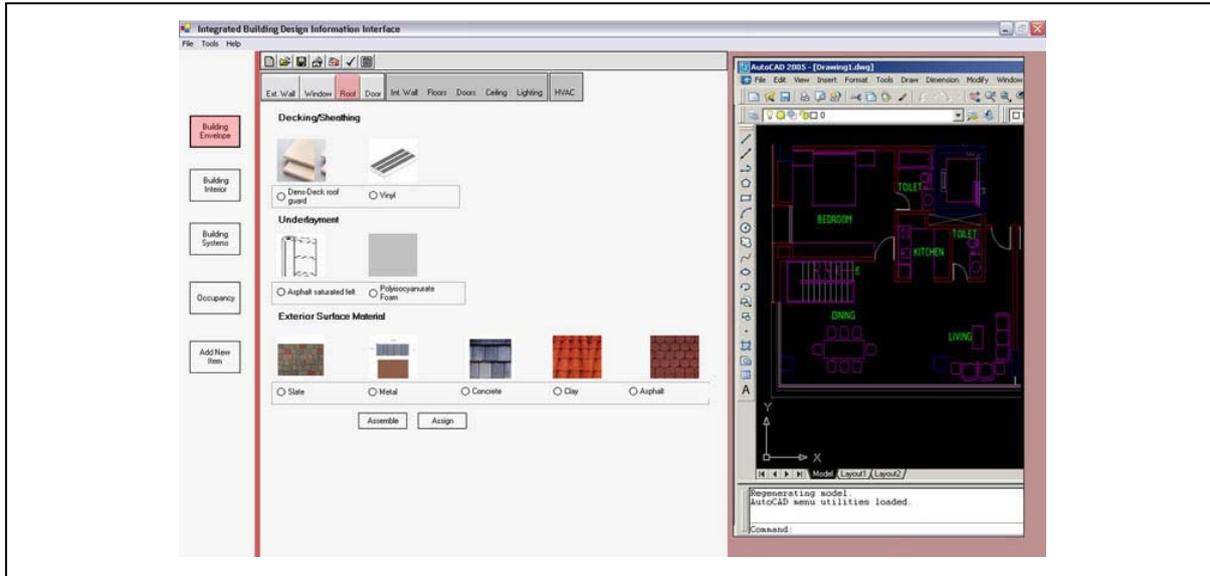
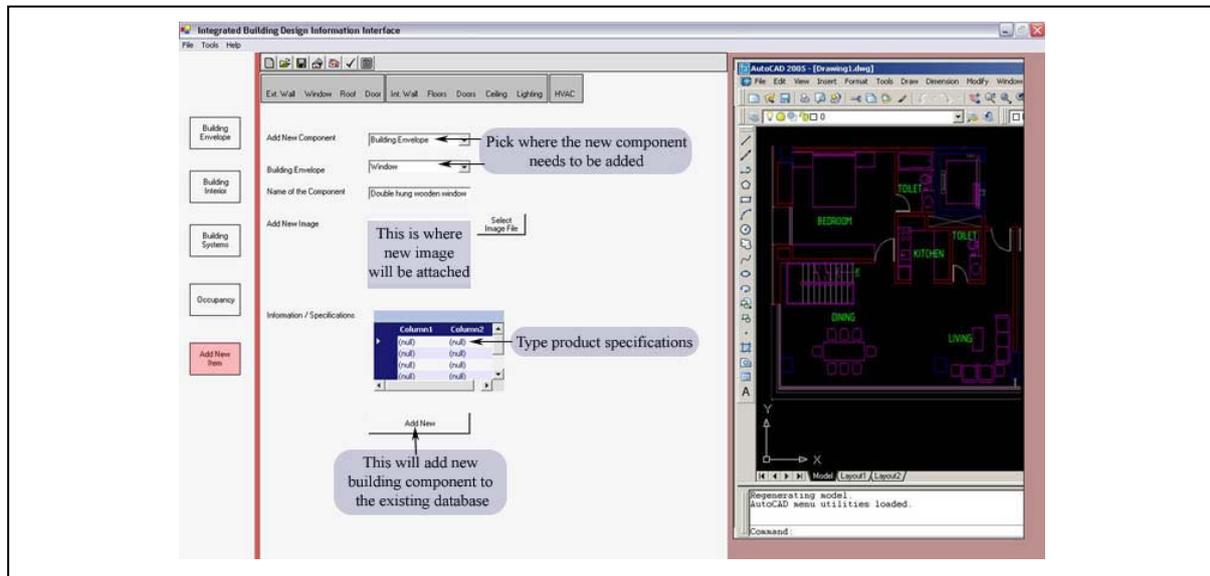*Figure 3 Building Envelope - roof assembly page*

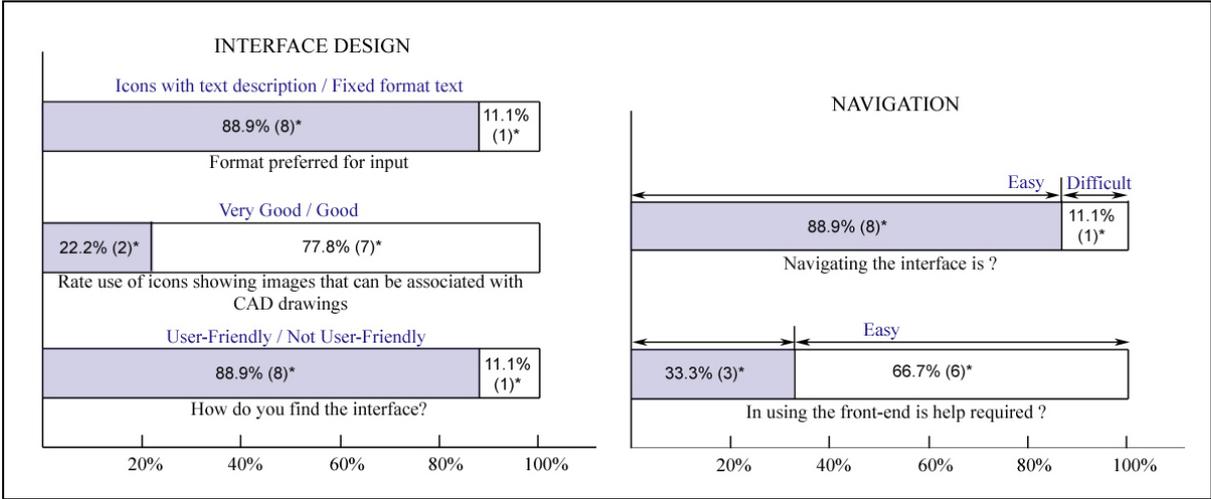*Figure 4 Add new building component screen in IBDII*

Figure 5

INTERFACE DESIGN

Icons with text description / Fixed format text

| 88.9% (8)* | 11.1% (1)* |

Format preferred for input

Very Good / Good

| 22.2% (2)* | 77.8% (7)* |

Rate use of icons showing images that can be associated with CAD drawings

User-Friendly / Not User-Friendly

| 88.9% (8)* | 11.1% (1)* |

How do you find the interface?

20% 40% 60% 80% 100%

NAVIGATION

Easy | Difficult

| 88.9% (8)* | 11.1% (1)* |

Navigating the interface is ?

Easy

| 33.3% (3)* | 66.7% (6)* |

In using the front-end is help required ?

20% 40% 60% 80% 100%

Figure 5 Overall user reactions to interface design and navigating through the interface of IBDII.
(   )* - No of participants

Figure 6

SAVING AND REVIEWING

Easy | Difficult

| 87.5% (7)* | 12.5% (1)* |

Reviewing and modifying input data is:

Easy

| 100% (8)* |

Saving and retrieving input data is:

20% 40% 60% 80% 100%

DATABASE CREATION

Very Good | Good | Not Good

| 11.1% (1)* | 77.8% (7)* | 11.1% (1)* |

The provision of creating custom databases provided by this front-end is:

Yes | No

| 88.9% (8)* | 11.1% (1)* |

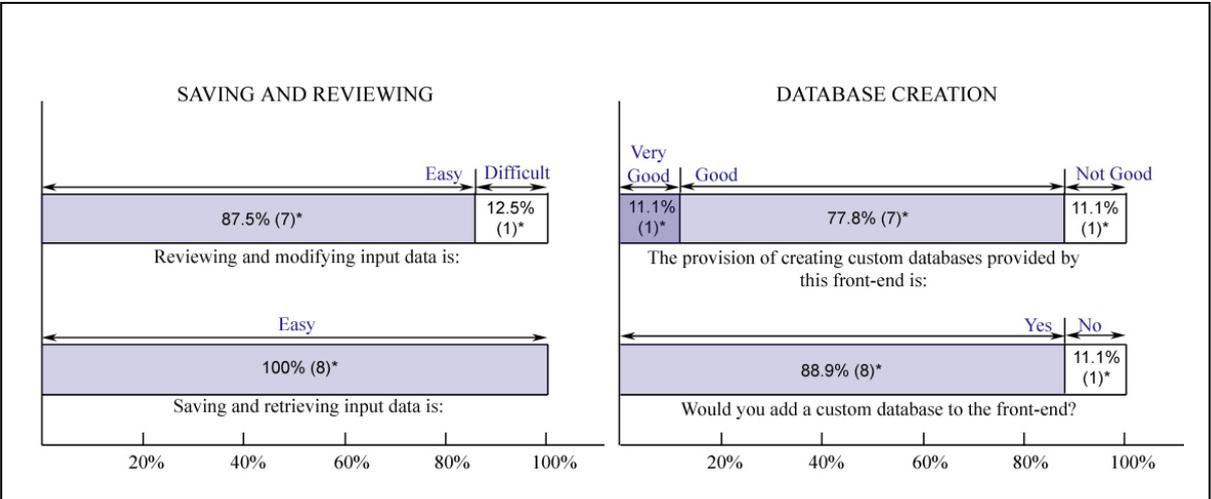Would you add a custom database to the front-end?

20% 40% 60% 80% 100%

Figure 6 Overall user reactions to saving, reviewing and creating custom databases within IBDII.
(   )* - No of participants

Figure 7

ASSESSMENT

Easy

| 100% (9)* |

Learning to use the front-end is:

Yes | No

| 88.9% (8)* | 11.1% (1)* |

Would you use the front-end to get a quick energy analysis of your design project?

Easy

| 100% (9)* |

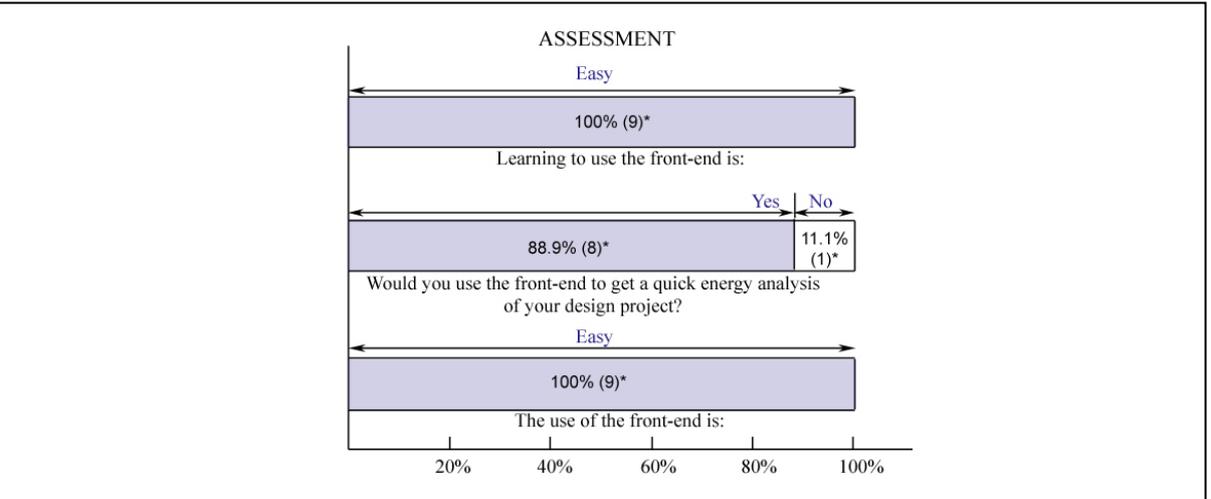The use of the front-end is:

20% 40% 60% 80% 100%

Figure 7 Overall user assessment of IBDII
(   )* - No of participants