

COMPUTER AIDED SUSTAINABLE DESIGN

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Abstract. One of the most important aspects architects need to consider fairly early on is that of energy saving, cost, thermal comfort and the effect on the environment in terms of CO₂ emissions. At present, during the early design stage of a building, different options are assessed using simple tools (tables, graphs and software) that contain a large number of assumptions the very nature of which can bias choice or possibly lead to an inappropriate solution. It can be argued that the only way to provide a rational assessment of options is to use calculation methods that represent in detail the physical processes involved; this usually involves the use of dynamic thermal models. Furthermore if this tool is also used during detailed design it would introduce a consistency that is normally absent from the analytical design process. Many designers are of the opinion that, because not all details are known, then such tools are not suitable for application at early stages in the design. This view can be challenged because, even at the concept stage, a great deal is known about a building. This paper aims to show that a general description of a building can be used to generate sufficient data to drive a valid analysis using a detailed thermal model at the early sketch stage of the design process. The paper describes the philosophy, methodology and the interface developed to achieve this aim. The interface guides the user through the input process using a series of screens giving options for keywords used to describe the building; comprehensive default data built into the software are then attached to these keywords. The resulting data file is a building description that is the best possible interpretation of the design intent. This can then be used to assess options and guide towards a final design.

1. Introduction

In the early stages of building design process, architects need to assess various design alternatives and choose the one which best represent their design intent. One of the important aspects that architects need to consider fairly early on is the aspect of energy saving and thermal comfort.

In this paper, we report on the collaborative work that took place between the School of Architecture and the School of Computing at The Robert Gordon University, which aim was to develop an (online) interface, called Computer Aided Sustainable Design (CASD), that will guide the user through a series of input screens to allow him/her to describe the building and select various environmental and energy saving options. The interface is to be accessed by students at the School of Architecture to allow them to integrate environmental aspects in their designs.

A selection of building specifications from a database is used to generate numerical information that will be used by a calculation engine that uses sophisticated thermal models (CIBSE guide, 1986).

One of the projects main objectives was to develop a tool that assisted in reducing the number of design cycle iterations (revisions). This fits with government policy to improve the effectiveness of the design process and to make procurement of buildings cheaper and more efficient (Bennadji et al, 2002).

In the past people have resisted the use of such simulation programs for a number of different reasons. They felt that it was time consuming to input the necessary data and that the program was not user friendly enough. The team aimed to reduce the amount of input required for each building with the use of extensive, intelligent defaults. To make the program more user friendly, an implementation of a pictorial based input system was used with a minimal amount of data required to describe a building. Users also felt that programs could not be trusted, perhaps because of their complexity and the fact that they could not understand them. The above goes along way to solving this.

At the concept stage of any project the design team already have a significant amount of information regarding the building such as location, number of floors, occupancy, preferred glazed areas, insulation standards, thermal mass and required internal environmental conditions.

This information may seem quite standard but can prove to be invaluable when used along with the correct program and suitable dynamic thermal model. Indeed, there is no reason why such a tools should not suitable for application at early stages in the design process.

2. CASD's Features

CASD is a whole building energy prediction method and a program that allows users to enter a minimum amount of data to produce an energy analysis file. The analysis of this file is performed by a third party analytical program. It is intended to be used to compare the performance of different building's design that the building's actors can choose the best option regarding the thermal point of view.

The originality of this software is that the inputs and the outputs are generated in a building actor's understandable language and it's not necessary that they have good computer skills.

The basic features of the software are as follows:

1. Simple method for evaluating energy performance of alternative plans, section, elevations of a building at the sketch design stage. It is a means to estimate relative energy performance of different options.
2. CASD uses energy performance data from a mathematical model, in which values have been assumed for heating, cooling, lighting energy (data that would not be available at the sketch stage). The user manipulates only a few design variables, mainly related to building form and façade design.
3. CASD is not a precision model for accurate estimation of performance of an actual building. CASD is used to evaluate relative energy performance of a number of options for comparison purposes. In fact, a tool for assessing the environmental quality of a building should be able to deal with two distinct types of reality:
 1. The physical reality of phenomena, expressing the links between sources and environmental effects.
 2. The reality of the progress of a building's operation, with its phases, actors, decisions.

CASD has been designed to capture all the data needed by any thermal model, and as such can be plugged-in any software that uses thermal models to predict annual primary energy consumption as a function of:

- Local climatic conditions
- Orientation of façades
- Area and type of glazing
- Obstructions due to adjacent buildings
- Occupancy and vacation patterns
- Lighting levels
- Internal gains

Examples of such software include, Energy2 and Energy10.

3. CASD's Interface

The interface has been developed using HTML in the Macromedia Dreamweaver MX environment. ASP (Active Server Pages) code was used to link the Web pages with a MS Access Database containing all the data entered by the user, and other default (standard) values related to the building regulations in the U.K. ASP allows you to dynamically edit, change or add any content of a Web page, respond to user queries or data submitted from HTML forms, access any data in the database and return the results to the browser. The images and icons have been manipulated using Adobe Photoshop.

The interface (see Figure 1) is comprised of a sequence of screens (Web pages) in which the user can freely move forth or back. The user is free to start from any screen after completing the first one which relates to the project description. The user can stop at any stage, save his/her work and resume at some other time.

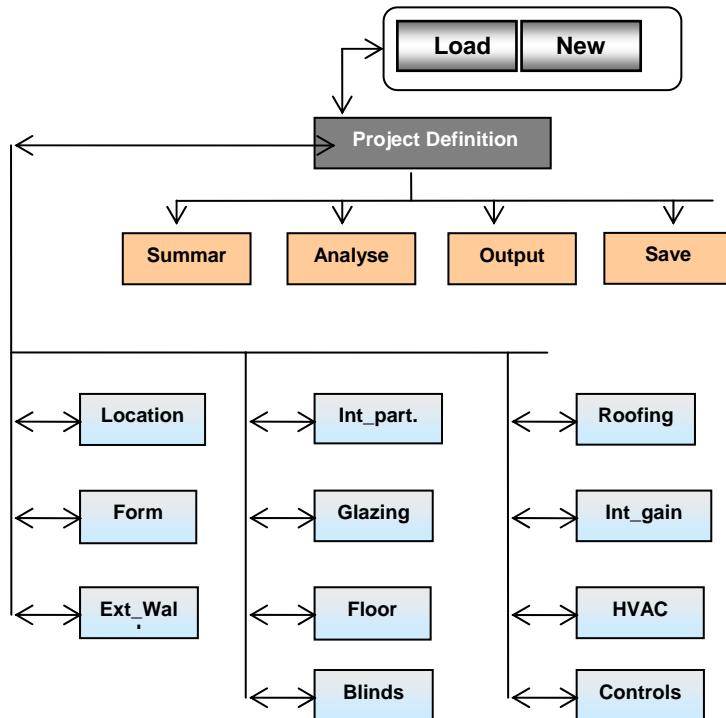


Figure 1. CASD's Interface.

In the following we provide a summarized description of all the screens with some of the options that the user is called to choose from.

3.1. PROJECT SCREEN

This screen enables the user to load an existing project (from the database) or create a new one. For newly created projects, the user can specify a project's name, description and the air conditioning function (standard or prestige), (see Figure 2).

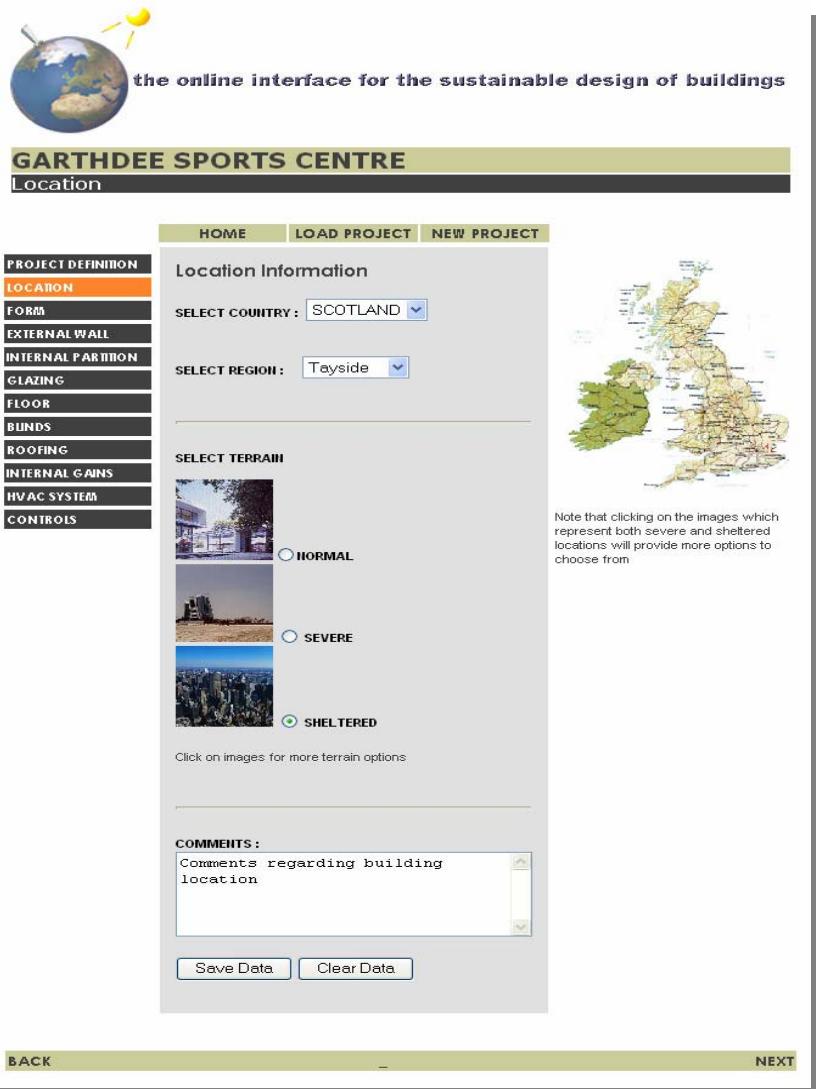
The screenshot shows the 'Project Definition' screen of the online interface for sustainable building design. At the top, there is a logo of a globe with a yellow sun-like icon above it, followed by the text 'the online interface for the sustainable design of buildings'. Below this, the title 'GARTHDEE SPORTS CENTRE' is displayed in a green bar, with 'Project Definition' in a black bar underneath. A navigation menu at the top includes 'HOME', 'LOAD PROJECT', and 'NEW PROJECT'. On the left, a vertical sidebar lists categories: 'PROJECT DEFINITION' (highlighted in orange), 'LOCATION', 'FORM', 'EXTERNAL WALL', 'INTERNAL PARTITION', 'GLAZING', 'FLOOR', 'BUNDS', 'ROOFING', 'INTERNAL GAINS', 'HVAC SYSTEM', and 'CONTROLS'. The main form area contains fields for 'PROJECT NAME' (empty), 'USER FIRST NAME' (empty), 'USER SURNAME' (empty), 'USER LOCATION' (set to 'Austria'), 'AIR CONDITIONING FUNCTION' (set to 'Standard'), and a 'COMMENTS' text area (empty). Below the form are 'Submit' and 'Clear Fields' buttons. To the right of the form, under 'Supporting information', is a detailed explanatory text about the purpose of the screen and the initial air conditioning function.

In addition to data entry regarding the main elements of the building the user must firstly fill in the project definition screen, as the purpose of this screen is to identify the user and the country they are working from. The user must also define the initial air conditioning function although this is gone into in more depth later on.

Figure 2. Project Definition Screen

3.2. LOCATION SCREEN

It enables the user to select the country in which the building will exist (at the moment restricted to the U.K.), then select an area within that country, given that in many cases (such as in the U.K.) building regulations differ from place to place. And finally, the user can enter the terrain in which the building is to be built, i.e., normal, severe or sheltered (see Figure 2). If one of the two last options is selected, the user will be asked to specify further whether the terrain is “rough open”, “farmland”, “urban” or “sub-urban”, (see Figure 3).



The screenshot shows the 'GARTHDEE SPORTS CENTRE' project page under the 'Location' tab. The top navigation bar includes 'HOME', 'LOAD PROJECT', and 'NEW PROJECT'. A sidebar on the left lists project categories: PROJECT DEFINITION, LOCATION (highlighted in orange), FORM, EXTERNAL WALL, INTERNAL PARTITION, GLAZING, FLOOR, BLINDS, ROOFING, INTERNAL GAINS, HVAC SYSTEM, and CONTROLS. The main content area is titled 'Location Information'.

SELECT COUNTRY: SCOTLAND (dropdown menu)

SELECT REGION: Tayside (dropdown menu)

SELECT TERRAIN:

- NORMAL:** Represented by a small image of a modern building.
- SEVERE:** Represented by a small image of a coastal area with waves.
- SHELTERED:** Represented by a small image of a city skyline.

A note below the terrain selection says: "Note that clicking on the images which represent both severe and sheltered locations will provide more options to choose from".

COMMENTS: Comments regarding building location

At the bottom are 'Save Data' and 'Clear Data' buttons, and navigation buttons 'BACK' and 'NEXT'.

Figure 3. CASD-Project location

3.3. FORM SCREEN

The user describes the building's size (length, width, floor to floor height, floor to ceiling height, number of floors...), orientation (using a diagram that the user can rotate) and to describe the façades (in particular, the percentage of façade area that is glazed).

3.4. EXTERNAL WALLS SCREEN

Here the user describes the building's external walls. The user has three different ways of completing this section: Standard, Custom or load other walls. We describe here the first method, which is to simply choose from the standard specification shown for thermal response time and insulation standard.

There are three possible values for the thermal response time:

- Slow: corresponds to a lightweight external cladding with insulation in the centre and a solid internal wall.
- Medium: corresponds to a solid external cladding with insulation in the centre and a solid internal wall.
- Fast: corresponds to a solid external cladding with insulation in the centre and internal plasterboard finish.

The insulation standard provides the user with three choices:

- Standard UK building regulations value
- 20% better than building regulations value
- 50% building regulations value.

3.5. INTERNAL PARTITIONS SCREEN

Here the user is to describe the building's internal partitions and layout. The description includes the type of internal partition (high mass, medium mass or low mass internal wall) and the type of cell structure (mostly open plan or mostly cellular) for each of the sides of the buildings.

3.6. GLAZING SCREEN

This screen enables the user to describe the building's glazing. The user is offered two options: standard or custom specification. The standard option prompts the user for the number of panes of glass (two or three), the type of glass (clear, heat absorbing, reflecting or low E). If the user opts for the custom option, he/she needs to provide the U-Value of the glass, the short and long wave shading coefficients and the light transmission, (see Figure 4). Some specificity needs more than one screen to be clearly described, the glazing description is one of them, (see Figures 5 and 6).



the online interface for the sustainable design of buildings

GARTHDEE SPORTS CENTRE

Glazing

HOME LOAD PROJECT NEW PROJECT

PROJECT DEFINITION LOCATION FORM EXTERNAL WALL INTERNAL PARTITION GLAZING FLOOR BUNDS ROOFING INTERNAL GAINS HVAC SYSTEM CONTROLS

Click on appropriate image for more options

Click on either the double glazing icon or the triple glazing icon to view a detailed choice of glazing specifications.

DOUBLE GLAZING



DOUBLE GLAZING



DOUBLE GLAZING

CUSTOM GLAZING OPTION

BACK NEXT

Figure 4. CASD – Glazing screen



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GARTHDEE SPORTS CENTRE

Glazing - Two Panes

HOME LOAD PROJECT NEW PROJECT

PROJECT DEFINITION LOCATION FORM EXTERNAL WALL INTERNAL PARTITION GLAZING FLOOR BUNDS ROOFING INTERNAL GAINS HVAC SYSTEM CONTROLS

The diagram below shows the various types of glass to choose from. Select the type of glass corresponding pane of glass. If the pane is to be a double glazing unit, please choose the custom option at the bottom of the page.

GLASS TYPE

UNIFORM PANE 1: CLEAR



UNIFORM PANE 2: CLEAR



U-VALUE: [input field]

COMMENTS: Comment in regarding building location

Save Data Clear Data

CUSTOM GLAZING OPTION

BACK NEXT



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GARTHDEE SPORTS CENTRE

Glazing - Three Panes

HOME LOAD PROJECT NEW PROJECT

PROJECT DEFINITION LOCATION FORM EXTERNAL WALL INTERNAL PARTITION GLAZING FLOOR BUNDS ROOFING INTERNAL GAINS HVAC SYSTEM CONTROLS

The diagram below shows the various types of glass to choose from. Select the type of glass corresponding pane of glass. If the pane is to be a triple glazing unit, please choose the custom option at the bottom of the page.

GLASS TYPE

UNIFORM PANE 1: CLEAR



UNIFORM PANE 2: CLEAR



UNIFORM PANE 3: CLEAR



U-VALUE: [input field]

COMMENTS: Comment in regarding building location

Save Data Clear Data

CUSTOM GLAZING OPTION

BACK NEXT

Figure 5. CASD - Double glazing

Figure 6. CASD – Triple Glazing

3.7. FLOOR SCREEN

It enables the user to describe the building's floors. Again, three options are offered: standard, custom or load other floors. The standard option, for example, prompts the user to select the weight of the internal floor (light or heavy), the type of the internal floor and the type of the ground floor (solid or suspended). The custom option, however, requires the response time, insulation, solar absorbivity, external and internal emissivity and the internal reflectance.

3.8. BLINDS SCREEN

The user can describe the building's blinds and shading devices. The type of blinds includes external blinds, internal blinds and mid-pane (between two panes of glass). The shading devices include overhangs, side protection, outlook protection, loggia, roof protection to protect not only the glazed areas but the exposed walls as well. The dimensions of these devices are illustrated in a diagram within the screen to allow the user to visualize the device and input the dimensions.

3.9. ROOFING SCREEN

It enables the user to describe the roofing specifications of the building. Again, three options are on offer, namely standard, custom and load other roofs. The standard option requires the selection of the type of the roof (solid, solid with suspended ceiling and lightweight with suspended ceiling) and its insulation (the default option is set to comply with the building regulations, and if needed the user can select a better U-value).

3.10 INTERNAL GAIN SCREEN

This screen enables the user to input data which determine the internal gain of the building (Brown et al, 1991). There are two sections in this screen, occupancy and loads. For occupancy, the user must input the schedule showing when the building is occupied (this determines the heating or the cooling schedule and its intensity). The user selects an entry from a list of five choices:

- Very high occupancy: 24hrs, 7 days/week
- High: 12hrs, 7 days/week
- Medium: 12hrs, 6 days/week
- Low: 12hrs, 5 days/week
- Very low: 8hrs, 5 days/week.

The density of the building should be given in terms of number of people per square meter:

- Very high density: 5m^2 per person
- High: 7m^2 per person
- Medium: 8m^2 per person
- Low: 10m^2 per person
- Very low: over 15m^2 per person.

The loads section of the screen describes the power used in the building, and the power used to run the machines inside the building. Again, the user can select from a range of “very high” to “very low”.

3.11. HVAC (HEATING, VENTILATION AND AIR CONDITIONING) SYSTEM SCREEN

It enables the user to input data which determines the type of heating, ventilation and air conditioning system to be used within the building. For example, the user selects the type of frost coil, the type of heat recovery system, the type of cooling coil and the type of humidifier.

3.12. CONTROLS SCREEN

Here the user can describe controls related to elements within the building including blinds, lighting, temperature, boiler, perimeter heating and electrical equipment such as computers. Talking about the blinds for example, the user selects how the blinds are operated (profiled, automatic or manual), and if the profiled option is selected, the user chooses from: blinds up all of the time, blinds down all of the time, or blinds down during the day.

4. Conclusion

CASD is being designed to suit the following aspects of building design: the iterative nature of the ‘real-world’ design process, the language of actors involved, and to supply results which can be interpreted by a multi-professional team.

The assessment criteria of the method, which consider the actors’ point of views, are related to the thermal performance of the building. The development of a method for assessing the thermal performance of a building is a difficult task because of the complex requirements to be met. The final output profile, which represents the building’s performance according to different criteria, can then be useable by architects and other consultants.

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