Designers and information overload: A new approach.

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Introduction

Designers are being asked to handle ever-increasing demands for information about the expected performance of buildings at the design stage. When combined with other information demands, such as those on the available strategies and technologies and the context of the particular design project, the total load becomes almost unmanageable. This article offers a closer look at the information that designers need to handle and an introduction to the Building Design Advisor (BDA), a new software that offers a way of integrating information requirements to facilitate decision-making.

Design decisions

Building design decisions involve the consideration of multiple performance considerations, such as comfort, economics, code compliance, energy requirements, environmental impact, esthetics, etc. Building design can be seen as the process of generating ideas that involve specific strategies and technologies and then estimating and evaluating their performance with respect to the various performance considerations within the specific design context (Figure 1).

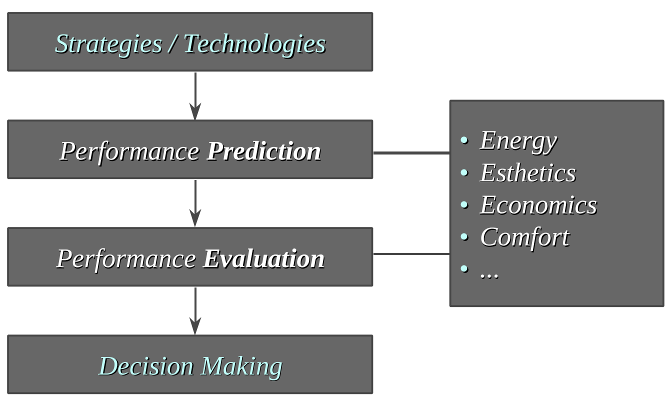

Figure 1. *Decision-making requires performance prediction as well as evaluation with respect to various performance considerations. The BDA software automates performance prediction and facilitates evaluation through its specialized user interface.*

Performance prediction

To estimate the performance of building designs, designers need to simulate the operation of the building using various types of modeling techniques. Traditionally, these techniques have been limited to sketches and drawings of building plans, sections, elevations, perspectives, etc., and computations using hand-held calculators. As the need for additional and more accurate performance considerations is increasing, new simulation techniques are becoming available. For performance considerations such as those related to energy requirements and environmental impact, these techniques involve massive computations that have led to the development of a number of computer-based simulations. Unfortunately, most of these have been 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 is usually generated in the form of alphanumeric tables that are hard to review and interpret. As a result, such programs are very expensive to use, because they require significant knowledge and time for the preparation of the input and the interpretation of the output. Moreover, different simulation programs use different representations of the building and its context, depending on the performance aspect that they address. A thermal analysis program, for example, uses a representation in terms of thermal barriers that are characterized by thermal transmission and capacity properties, while a lighting analysis one uses a representation in terms of polygons that are characterized by light reflectance and texture. As a result, the use of multiple programs requires repetitive descriptions of the building and its context in different formats, which makes the use of such programs even more costly and unattractive.

Performance evaluation

Performance prediction is mandatory but not adequate for decision-making. Once performance has been predicted it has to be evaluated with respect to its goodness or appropriateness. Since “good” and “bad” make sense only when there are at least two of a kind, evaluation requires comparison of multiple alternative design schemes, as well as comparison with the performance of existing buildings. Moreover, evaluation requires concurrent and integrated consideration of all performance aspects.

While performance prediction can be highly automated through the use of computers, performance evaluation cannot, unless it is with respect to a single criterion. The multi-criterion nature of most design decisions requires the direct involvement of humans. However, computers can still facilitate the evaluation process though appropriate user interface schemata that provide graphical presentation of data and allow for direct comparison of multiple solutions with respect to multiple performance considerations.

Data requirements

Both performance prediction and evaluation require availability and processing of massive amounts of data about the building and its context. Building performance is described through various *performance parameters*, whose values can be single numbers (e.g., first cost, life-cycle cost, total energy requirements, etc.) or distributions of such numbers (e.g., temporal energy requirements, spatial illuminance distributions, images, etc.). In general, the values of performance parameters depend on the values of two other types of parameters. The first type represents the parameters that building designers have control over (e.g., dimensions of spaces, location and orientation of windows, glazing type) and are usually referred to as *design parameters.* The second type represents the parameters that building designers do not have control over (e.g., weather parameters, cost of materials and services, occupant characteristics and preferences, etc.) and are usually referred to as *context parameters.* In fact, the differentiation between design and context parameters is a design decision and indicates the level at which a particular design decision is addressed. While the orientation of a building, for example, may be considered as a design parameter during the initial, schematic phases of building design, it can then serve as a context parameter for further decisions.

Let’s consider the example of electric lighting savings as a performance parameter for the design of an office space. Electric lighting savings depend on the temporal distribution of daylight work-plane illuminance at the location of the control sensor, as well as the type of the electric lighting system and its controls. In turn, daylight work-plane illuminance depends on a large number of additional parameters, such as room geometry, window location and orientation, reflectance of interior and exterior surfaces, glazing transmittance and reflectance, daylight availability, etc. Some of these may be considered as design parameters while the rest serve as context ones. The exact number and type of design and context parameters depends on the model used to simulate the physical behavior of the building. A simplified daylighting model, for example, may require a single number for the reflectance of surfaces, while a more sophisticated one may require a bi-directional reflectance function.

Inter-dependencies and design complexity

One of the major difficulties in design problems is that the effect of each design parameter depends on the values of the rest. The effect of window width on daylight work-plane illuminance, for example, depends on the reflectance of surfaces, the daylight availability, etc. Another major difficulty comes from the fact that design parameters usually come in "groups." When designers need to specify glazing reflectance and transmittance, for example, they cannot specify any combination they want. Rather, they have to choose from a number of combinations that exist in the form of available glazing systems. Finally, there is also an inter-dependency among performance variables that is mainly responsible for the "wicked" nature of design problems. In the same way that the effect of a design parameter depends on the values of the rest of the design parameters, the goodness or appropriateness of the value of a performance parameter depends on the values of the rest of the performance parameters. The goodness of the value of first cost, for example, depends on the values of life-cycle cost, comfort indices, energy requirements, environmental impact, etc.

Information overload

As the number of performance parameters considered is increasing, along with the demand for "better" buildings, designers are faced with data overload even with the use of the simplest simulation procedures. A simplified energy computation algorithm requires knowledge of the values of more than two hundred design and context variables. Sophisticated models require at least twice as much. Consider now several models for different performance aspects and combine their input requirements. Moreover, consider the large number of available options for each building component and system. Add to it the knowledge of organizing and preparing data so that they are effectively supplied as input to the appropriate simulation routines. Finally, consider the need for knowledge of the performance of existing buildings, as well as the organization and the management of the performance of multiple alternatives for decision making, and you get the picture of design information overload! Not to mention that this information is required from the initial, schematic phases of building design, when detailed issues are not usually addressed… But do designers really need to know all of these data and the relevant methods and procedures for their manipulation? Well not really…

Automation using computers

Let's consider the decision on glazing selection for a single window in a single space, assuming everything else is context information and that we are only concerned with one performance parameter, e.g., energy requirements. The design decision is now reduced to *finding a glazing which will reduce energy requirements to the extend possible.* All of the information seeking and manipulating that is required for this search can be delegated to someone else. In fact, if minimization of energy requirements were the only criterion for glazing selection, the designer would not really be needed at all… Following up on our example, a glazing database can satisfy the need for information about existing glazings and their characteristics. While CAD modeling and weather databases can take care of contextual information, simulation algorithms can be employed to determine energy performance quantities. Moreover, the whole process of preparing the input to and manipulating the output from the simulation routines can be automated. Add an optimization algorithm and the selection of the glazing becomes the equivalent of executing a computer program that draws information from several databases! That would indeed be the case for these types of decisions on selecting a member from a set of known alternatives. The main reason that this is not truly the case is that usually there are more than one performance aspects to be considered. Glazing selection usually involves more than energy considerations, such as comfort, cost, esthetics, etc., in which case it requires a multi-criterion judgement that cannot really be specified and delegated to others, let alone machines… This is the main non-delegable design task, which can only be addressed by the designers themselves. Moreover, it can only be addressed through direct, side-by-side comparison of multiple design alternatives. However, with the exception of this type of multi-criterion optimization, the rest of the design tasks *can* be specified and delegated to others, especially to computers, which can perform them fast and, in principle without errors. This recognition has been the basis for the development of the Building Design Advisor (BDA) software, in an attempt to automate as much as possible of what can be automated and assist decision-makers in as much as possible of what they have to do themselves.

The Building Design Advisor

The main objective of the Building Design Advisor (BDA) software is to provide an environment where designers can answer design, context and performance questions as fast as possible and integrate the answers in ways that facilitate multi-criterion judgement and decision-making. This would allow not only for more informed decisions, but for the consideration of many more design alternatives within the same amount of time. To meet this objective, the BDA supports the integrated use of multiple simulation tools and databases from the initial, schematic phases of building design to the detailed specification of building components and systems. The BDA uses a single, object-oriented representation of the building and its context, which is mapped to the representations used by the various simulation tools and databases that are linked to it (Figure 2). Through a specialized graphical user interface it allows designers to quickly and easily review and edit the specifications of building components and systems, as well as request information from the databases and the simulation tools that are linked to the BDA. Moreover, the BDA allows the maintenance of multiple alternative designs and their side-by-side comparison with respect to multiple performance parameters.

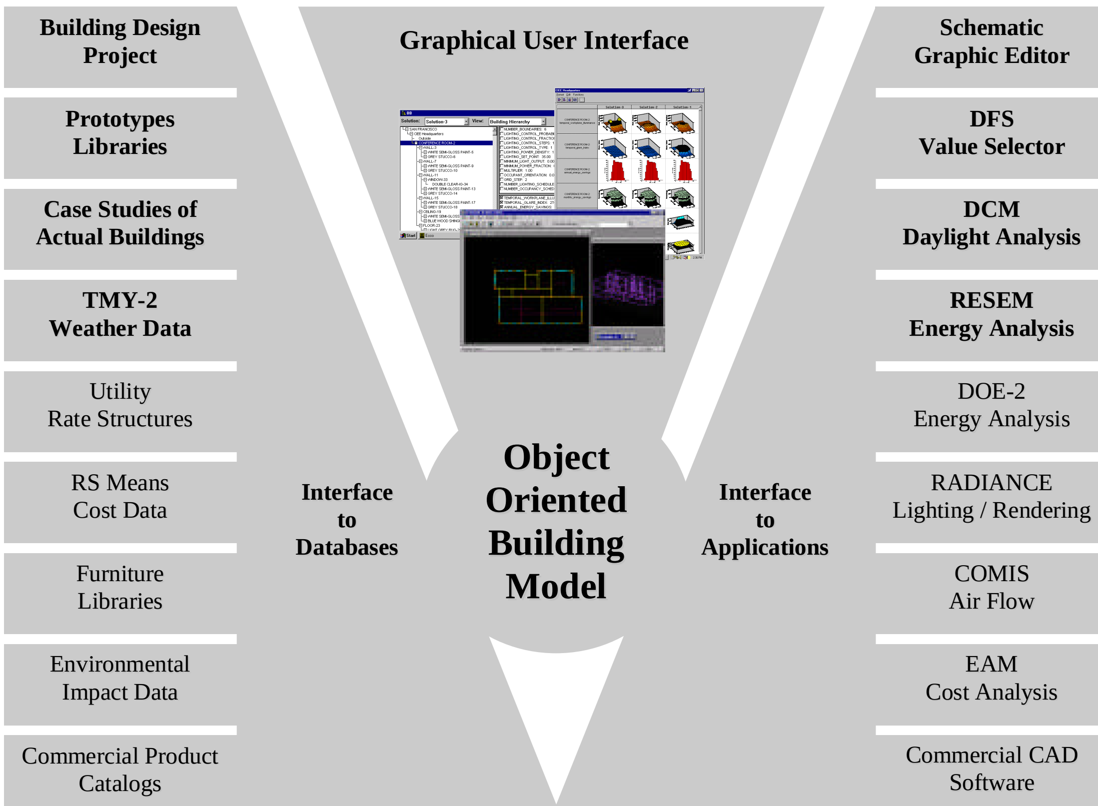

Figure 2. *A schematic diagram showing the Building Design Advisor software environment.* **Bold face text** *indicates databases and applications that are part of the 1.0 release. The rest of the modules will be linked in future BDA versions.*

The Default Value Selector

To support the use of simulation tools form the initial, schematic phases of building design, without distracting designers with all details required for simulations, the BDA uses a Default Value Selector mechanism. While the BDA user specifies the geometry of spaces and apertures in a Schematic Graphic Editor (Figure 3) the BDA automatically creates the building representation and assigns default values to all parameters that are required as input to the simulation tools linked to it. The Schematic Graphic Editor was developed specifically for use with the BDA and can be replaced with other graphic editors in the future, as CAD software follows the paradigm of object-oriented representation of building components and systems. The default values are selected from libraries of building components and systems, based on building location, building type and space type. The sources for the default values and the rules that are used for their selection include design guidelines and recommended procedures by major building associations and organizations, such as the American Society of Heating Refrigerating and Air-conditioning Engineers (ASHRAE), the California Energy Commission (CEC), etc. The default values can be easily identified and altered at any point through the BDA's graphical user interface.

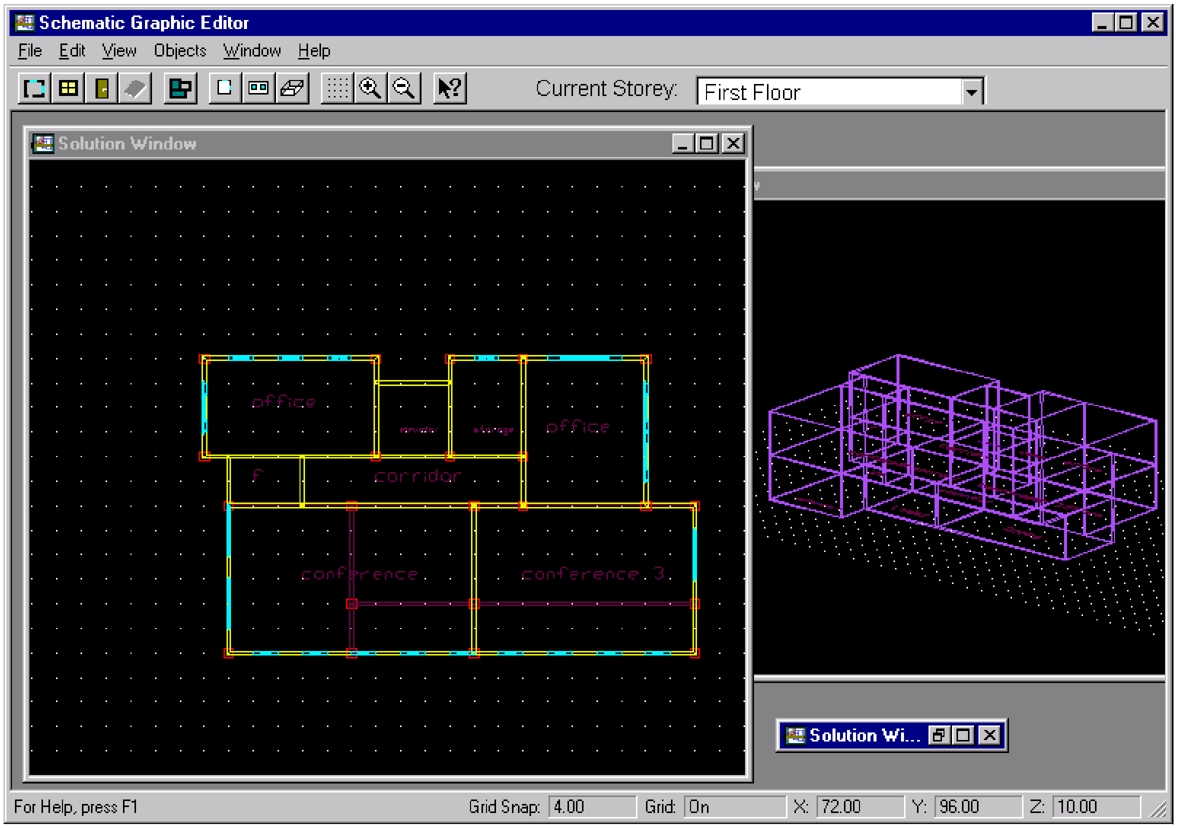

Figure 3. *The Schematic Graphic Editor allows the user to draw and modify the geometry of building objects, and supports the display of multiple design alternatives, in their own windows.*

The Building Browser

The BDA supports the review and modification of the building specifications through a graphical user interface element called Building Browser, which is very similar in concept to the Window 95's Explorer (Figure 4). In the same way that the Explorer allows navigation through directories and files, the Building Browser allows navigation through building objects and parameters. Moreover, it allows modification of the values of objects and parameters, and automatically maintains a record of *who changed what and when*. The values of building objects are modified by selecting from expandable libraries of alternatives (Figure5).

In addition to viewing the building model and modifying the values of descriptive parameters, the BDA users can use the Building Browser to specify which variables (descriptive or performance) they want to consider for decision-making and display their values in the Decision Desktop (Figure 6).

The Decision Desktop

The Decision Desktop is a graphical user interface element that facilitates multi-criterion decision-making by allowing direct, side-by-side comparison of multiple alternative solutions with respect to multiple performance parameters. When the user selects performance parameters whose values need to be calculated by one or more of the linked simulation tools, the BDA automatically prepares the required input, activates the required simulation tools and displays the results graphically in the Decision Desktop. The BDA can handle most known data types, such as strings, integers and real numbers, one- and two-dimensional arrays, images and video.

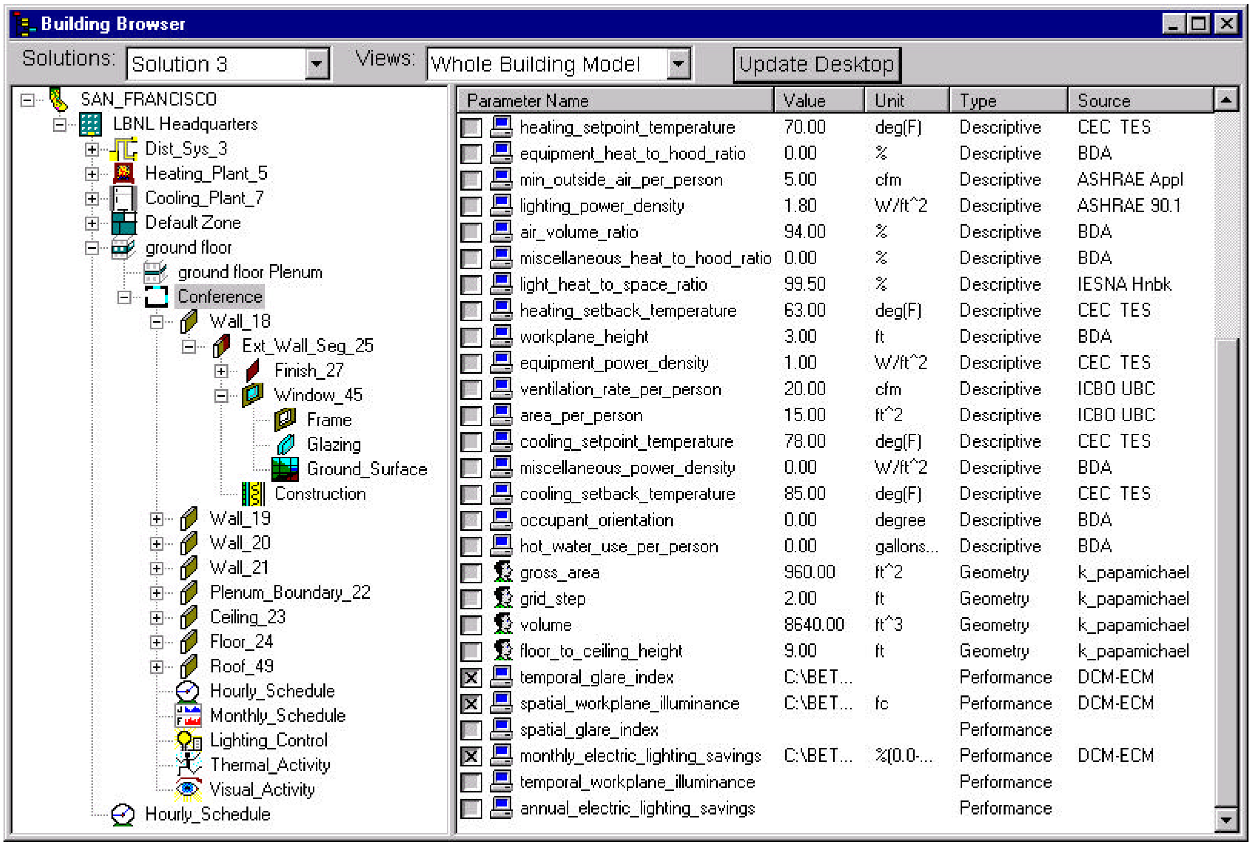

Figure 4. *The Building Browser allows the user to quickly navigate through the object-based representation of the building and its context, and select any number of input and output parameters for display in the Decision*

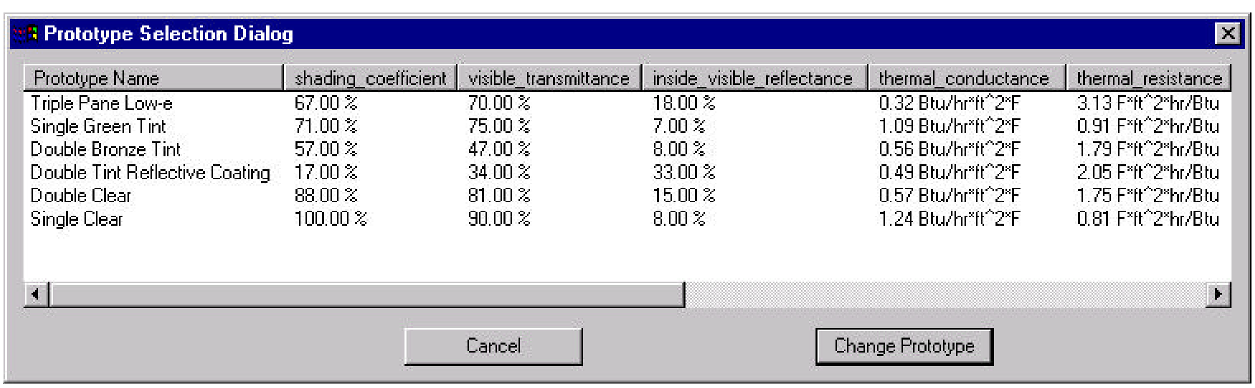

Figure 5. *Through the prototype selection dialog box the user can change the value of a building object by providing a list of all alternative library entries known to BDA.*

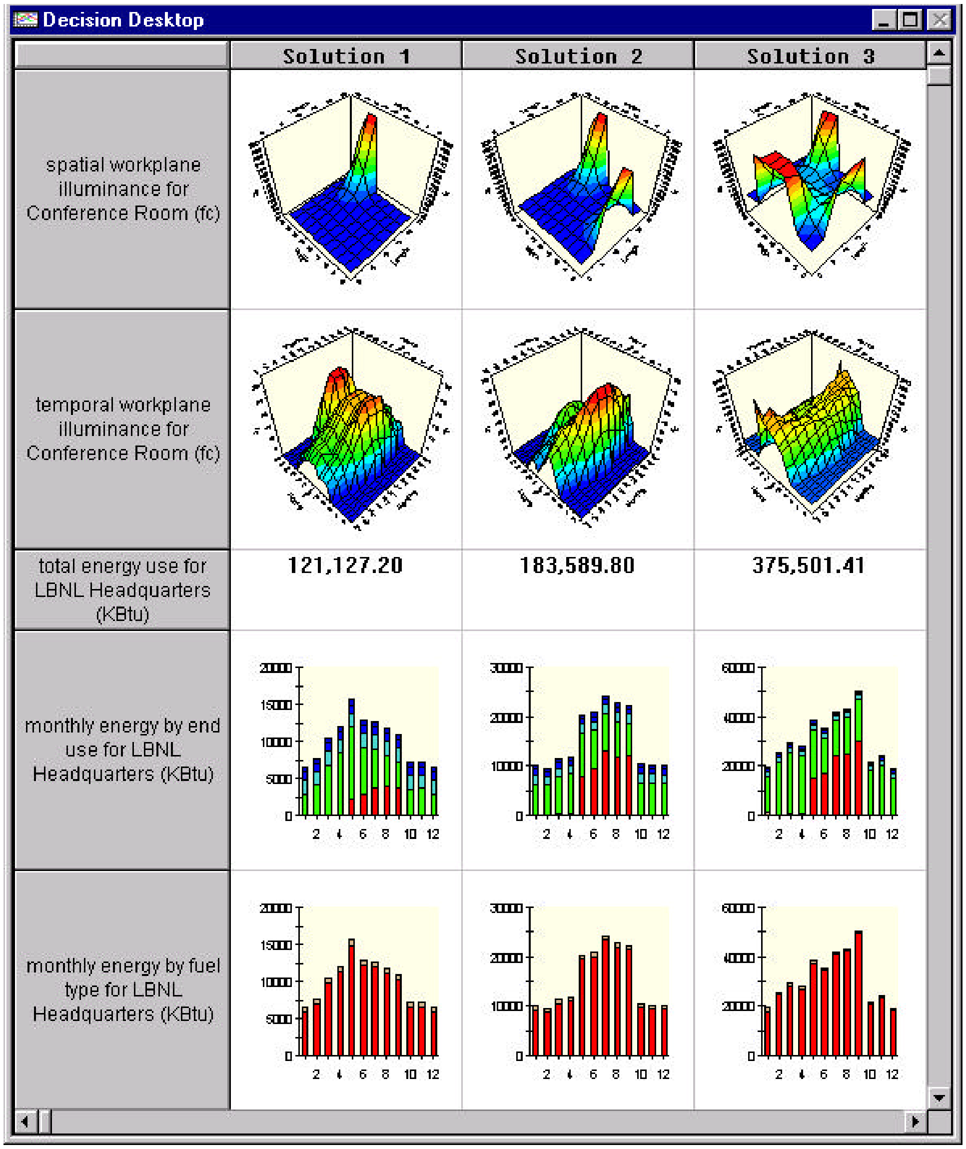

Figure 6*. The Decision Desktop allows the user to compare multiple alternative designs with respect to any number of input and output parameters addressed by the simulation tools linked to the BDA.*

Current status and future directions

The initial version of the BDA, currently in Beta testing, is linked to two simulation tools, one for daylighting and one for energy computations. The daylighting tool computes daylight work plane illuminance and glare index at any point in time and space within rectangular rooms. Moreover, it computes potential electric lighting savings considering an electric lighting power density and several control schemes. The energy tool computes monthly energy requirements by source and end use, for the whole building. This initial version will be released later this year as the 1.0 version. Work for the 2.0 version is already under way for the development of links to the DOE-2 energy analysis program. Future versions of the BDA will be linked to additional analysis and visualization tools, such as RADIANCE (day/lighting and rendering) and COMIS (airflow and indoor air quality). Moreover, the BDA will be linked to cost estimating and environmental impact modules, building rating systems, CAD software and electronic product catalogs.

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