INTEGRATING SUSTAINABLE BUILDING RATING SYSTEMS WITH BUILDING INFORMATION MODELS

TAJIN BISWAS, TSUNG-HSIEN WANG AND RAMESH KRISHNAMURTI

Carnegie Mellon University, Pittsburgh, PA 15213, USA
tbiswas@andrew.cmu.edu, tsunghsw@andrew.cmu.edu
ramesh@cmu.edu

Abstract. The transition from conventional to sustainable building depends on a number of factors— technological, environmental, economic and social. From a computer-aided design perspective, the first two are perhaps the most significant. We are working on a project with an emphasis on developing tools, to evaluate environmental consequences for design decision-making. Our current thrust is given to reducing energy usage as well as carbon emissions in buildings.

Keywords. Sustainable building rating system, Building information model

1. Introduction

Evaluating a building to be certified as "sustainable," according to a rating system, is a multifaceted and multi-phase process, which ensures that measures have been taken for the building to achieve certain performance levels in aspects such as energy consumption reduction, conservation of resources, low carbon footprint etc. To produce designs that fulfill certain sustainability rating requires much more than mere designer assumptions and intuitions.

The advent of building information modeling (BIM) has engendered a shift in the way we think of and represent the built environment. BIM facilitates model change and propagation via parametric object oriented representation; in it, we see an ideal place for integrating sustainable building ratings. Our project examines different sustainability rating systems through the lens of their inherent categories, criteria, scopes and assessment methods.

This paper briefly illustrates how a sustainable building rating system can be adopted into a building information model to offer designers an environment to integratively enhance awareness of different sustainability factors. The sustainable building information model (SBIM) application is created to aid designers to the different design aspects that they need to keep in mind from the early design phases. To address, in a cohesive manner, the issues of the changing nature of different rating systems and all fragments of information, we propose a general framework of sustainable measures to encompass the different rating systems. For the purpose of this study, for prototyping, we employed Revit as the BIM model, and the leadership in energy and environmental design (LEED NC 2.2) developed by the United States Green Building Council as the exemplar sustainable building rating system.

1.1 WHAT IS A SUSTAINABLE BUILDING RATING SYSTEM?

The term, *sustainable building rating system,* is defined as a tool that examines the (expected) performance of a 'whole building,' translating this into an assessment scheme for comparison with other buildings (Fowler, 2006). However, worldwide, there are a number of rating systems and tools, which focus on different aspects of sustainable building design. Although sustainable rating systems vary from country to regions in the same country, there are common categories that they cover in differing degrees. A generalization of categories shows that most sustainable rating systems consider site, water use, energy use, material and resource use, indoor air quality and emissions. All these differ in the order of reduction in use of resources in the respective areas without causing discomfort to the users of the space. The way categories are weighted, scaled and quantified in the various systems falls outside the scope of this paper. “However, in spite of their differences some are being adopted over others due to their relative ease of use and acceptable costs.” (Kibert, 2005)

1.2 WHY IS COMPLIANCE TO A BUILDING RATING SYSTEM USEFUL?

Compliance with a sustainability rating system is not mandatory, although, increasingly, it is becoming a goal that many designers and authorities would like to achieve. Unlike say, building codes, compliance to a chosen rating system is a way of showing that certain measures have been taken to ensure the mandates of sustainability in the building domain. There are of course limitations in adhering to rating systems; it is a way to objectively align project goals to sustainable requirements. Whether it is meeting minimum criteria for certification, or is in pursuit of making a positive contribution to the environment, there is a need to have benchmarks that can be referenced for comparison.

2. Background

Sustainable rating systems constantly evolve (Walker, 2006). Currently, within design software, there is no efficacious way of accommodating for change, let alone in using them while designing. Where there is intention to design sustainable structures, integration begins with awareness and interest. “Though barriers to sustainable design are often said to be economic-evidence indicates that such buildings can be made cost effective.” (Kibert, 2005) The main obstacles are lack of design competences and tools to aid in the process of creating sustainable designs. It is essential to consider, fairly early on in design, the strategies to ensure some of the key components of sustainable design. (Bennadji, 2004)

2.1 EVALUATION OF BUILDINGS

Buildings can be evaluated in terms of codes, energy performance, aesthetics, and, now, a sustainability point of view. Once mandatory codes have been met, evaluating for sustainability essentially looks at the building, holistically, in terms of energy and resource use. These comprise yet another set of requirements, most of which are measured objectively.

2.1.1 Evaluation of Building Code Adherence

Precursors to the notion of sustainable building rating systems integration have been mostly in the domain of code checking. For example IAI’s IFC (Industry Foundation Class) has been implemented in several different AEC CAD packages, which can consistently export valid IFC files that describe the building design. BCAider (Sharpe and Oakes, 1995) from Australia is one such package. It uses interactive communication and provides services for building classification and compliance checking. Another is BP-Expert developed in Singapore, and is relevant for codes in that country (CORENET, 2000).

2.1.2 Evaluation of Energy Performance

Energy simulations can be used to assess energy conservation measures early and throughout the design process. “Simulation is credited with speeding up the design process, increasing efficiency, enabling the comparison of a broader range if designs. Simulations thus provide a better understanding of the consequences of design decisions" (Augenbroe, 2001).

The expanded design team collaborates early in conceptual design to generate alternative concepts for building form, envelope and landscaping, focusing on minimizing peak energy loads, demand and consumption. Simulations are used: to refine designs and ensure that energy-conservation and capital cost goals are met; and to demonstrate compliance with regulatory requirements. However, detailed simulations are often tedious, expensive and are not generally available to every designer who has sustainability in mind.

Although there is a wide range of simulation tools, interoperability with the design environment is not seamless. For instance, a tool such as the Building Design Advisor (BDA) is built around an object-oriented representation of the building and its context, which is mapped onto corresponding representations of multiple tools and databases (Papamichael, 1999). It however has its own drawing interface which creates redundant work of redrawing. Avoidance of this extra labor is mitigated in Revit MEP, as IES VE can be accessed directly, but its effective use still remains in the domain of the mechanical engineer.

2.1.3 Evaluation of Building to Sustainable Building Rating Systems

A holistic approach to sustainability relies on a vision of the designing team; for this, tools need to be accessible and easy to use. Unlike successful implementations of code checking, evaluations for sustainable design have not been likewise captured to be designer accessible. The different criteria for sustainable buildings are disparate requirements distributed across different domains of the building industry.

3. Methodology

Our goal is to integrate requirements of rating systems with a BIM, which enables a designer to gauge the project in terms of a chosen rating. Research objectives were; to determine and develop a framework to encompass the categories and subcategories of commonly used rating systems; find the related objects of query in a BIM; and create a prototype application that could provide sustainability related information to the user.

3.1 GENERAL FRAMEWORK

Similar to other building industry-related schemas there needs to be a framework to contain the categories that pertain to sustainable building rating systems. The framework is an attempt to capture broad categories and group them according to their inherent scopes. Figure 1 shows how the categories of common rating systems overlap and conform to one another.

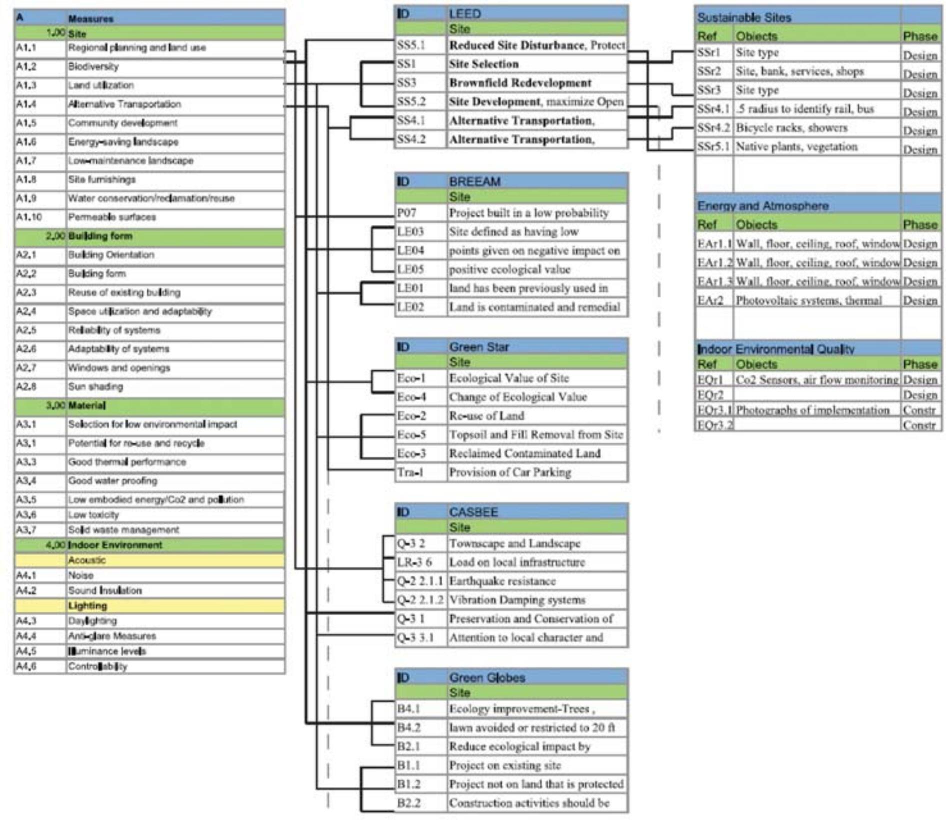

Figure 1. General Framework of Measures

However, methods used to reach quantification of the measurables differ in each. A list of measures, given on the far left side, aim to cover a gamut of categories and subcategories of the different rating systems. Working towards the right these categories map to the rating systems and ultimately to objects in the BIM. To create a framework for representing a flexible sustainable rating system the user will be able to either choose from the available systems, or define changes as required. Relationships of objects have emerged as we discover limitations in the building information model. Information relevant to the evaluating a building in sustainable terms often needs to be supplemented by external databases. Although the framework development is an ongoing process in parallel with the application, it provides a vital basis for incorporating different categories considered in sustainable design. The framework is a placeholder, and bridge, ultimately, to cater for multiple rating systems.

3.2 USER INTERFACE

The SBIM has an easy to use interface based on the following major elements: a) Sustainable building information modeling environment; b) Calculating engines; c) Database; and d). Evaluation output. The system architecture, depicted in Figure 2, shows the relation among these elements.

Figure 2. System Architecture

For our prototype, the building design environment is an external application built on Revit . All geometry information created in this environment forms the basis for the evaluation process. Calculating engines comprise two major parts: the external energy simulation engine, which runs the baseline performance; and the internal estimation engine, which checks values from building information against corresponding LEED requirements. Currently, three databases have been constructed. These correspond to LEED, Embodied Carbon and Building assumptions. The evaluation output shows the results. Figure 3 illustrates the interface of the system. Once a project is opened in Revit then the external application can be initialized. Necessary project information such as location and building type are entered, as these are required for the energy and lighting simulations later on.

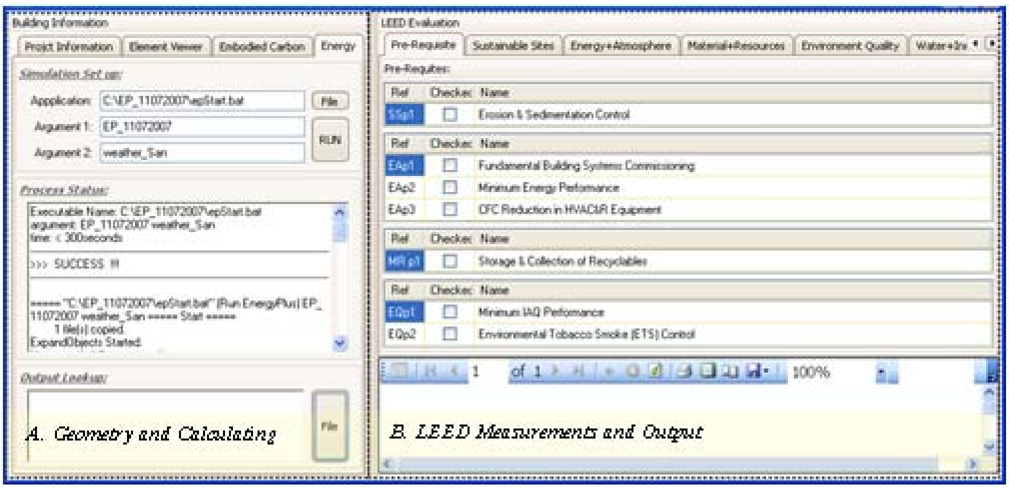

Figure 3. Main System Interface

The left hand side panel holds geometry information and calculation-required estimations. The right hand side contains the LEED credits in a tabular format and evaluation results. Available credits are categorized by prerequisites, design and construction requirements. These are manually checkable where applicable, and invoke domain specific information where the model is unable to provide them. If the user enables the prerequisites, then the rest of the available credits can be updated for results. This informs the user as well as starts giving feedback of the project in terms of the sustainable criteria that the design meets at that time. Once this application is run, it scans through all the objects in the model and checks them against the rules and threshold values required to satisfy the LEED credits. At this stage the application gives a static view of the model and is updated when opened.

3.3 ENERGY ANALYSES

In general, energy estimation requires detailed information about geometry, material, heating ventilating and air conditioning (HVAC) systems specifications, location, weather data and schedules. To provide the designer with a quick view, our approach here has two stages: an assumption stage and a tuning stage. In the first stage, the user needs to specify project information: location and building type. Other information such as material or HVAC system assumptions is supplied for the base run of thermal simulation performance. In Figure 4, the left panel shows where users can specify project geographical information and the right panel illustrates the estimated energy simulation for the current project. For the prototype, Energy plus was used to do the base run; however, it requires several steps of preparation before it can be initiated. The results of the base run will be stored to compare the next run when the design is modified or updated with different building materials or elements that effect energy calculations.

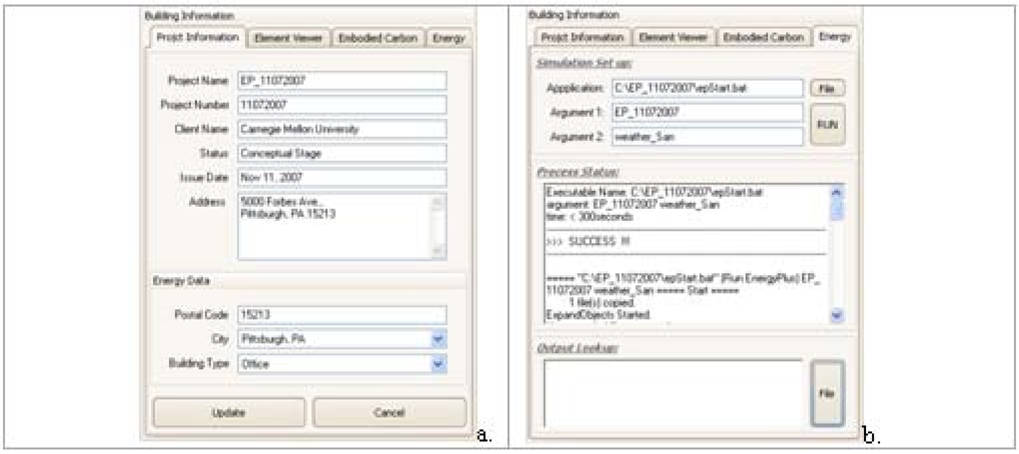

Figure 4. a. Project information for building assumption; b. Energy simulation for base run.

3.4 EMBODIED CARBON QUANTIFICATION

Thermal energy simulation software typically provides the amount of operational carbon. To compute the carbon footprint of the building we need the embodied carbon component this is retrieved from the building materials. From the geometry information we are able to extract the volumes of each material and calculate embodied carbon content. Figure 5 illustrates the elements in the selected project from which carbon quantity is calculated.

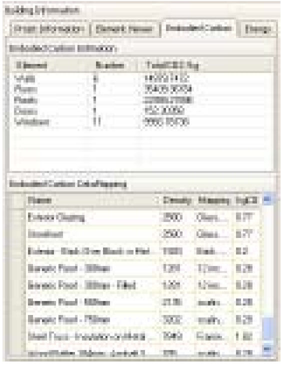

Figure 5. Embodied Carbon Estimation Tab

The embodied carbon database was adopted from that compiled by researchers at Bath University (Hammond and Jones, 2006). This Inventory of Carbon and Energy (ICE) provides data on average CO_2 emitted in the manufacture of most common building materials. Although the BIM holds information on material quantities, it does not necessarily contain all material properties. To calculate carbon we mapped design elements to corresponding carbon emission rates in our database. Densities of respective materials were needed to convert from volume to output the CO_2 in terms of weight. At this stage we are considering basic building material types of walls, floors, doors, windows and roof. We have yet to refine composite building assemblies and their carbon quantification.

4. Future Direction

Teams experienced in sustainable design address sustainability ratings by bringing diverse expertise together and by developing a work process that involves multiple iterations of schematic design to come up with feasible options in terms of initial performance, cost and environmental impact. What is second nature to them is unattainable to novice design teams without sufficient guidance. Our tool seeks to provide designers relevant information as indicators, give suggestions and strategies for making a building project earn and fulfill more rating points. Other LEED categories such as water, sustainable sites and indoor air quality are currently in the process of being implemented following the method presented in the paper.

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