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FRAMEWORK FOR SUSTAINABLE BUILDING DESIGN

Through Sustainable Building Ratings Integration

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Abstract. For sustainable building design, computational tools, mostly in the form of simulations, are employed to determine loads and to predict systems performance typically in terms of energy use. Currently, sustainability, in the building domain, is judged by a *rating system*. Design choices are validated, by measuring against one. The objective of the framework is to provide a general approach to processing the informational needs of any rating system, by identifying, categorizing and organizing relevant data requirements. Aspects of sustainability that designers deal with intuitively will have a structured guideline and gauge as one selects a rating system of choice.

Keywords. Sustainable design: rating system; framework; building information model.

1. Introduction

Designing for green entails consideration of just more than the building itself; tied to it are additional parameters that designers alone cannot intuitively construct. With many quantifiable aspects such as energy, lighting, air flow simulations; efficiency of material and resource use and reuse; green design implementation reaches out to computational tools. Being able to employ requirements, in the early design phase, set out by a *sustainable building rating system*, could offer guidance for designers new to the concepts of achieving sustainability goals.

Rating systems, that are used to evaluate and benchmark sustainability, are constantly evolving— there is, currently, no comprehensive way to accommodate changes to rating systems, let alone consider the possibility of using one for designing buildings within a CAD system. If this can be successfully addressed, there is then potential for having sustainability evaluations being an integral part of a CAD system by incorporating within it. Among the various design processes, building information modelling (BIM), offers promise for integration, which can then provide feedback to users for dynamic assessments of design.

For sustainability evaluations to become part of a design tool, it necessitates the development of a framework that can encapsulate the requirements of different sustainable building rating systems. This paper presents a sustainable information framework referred to as SIF to address the needs of ultimately supporting the integration with a BIM. Several sustainable building rating systems have been examined to identify the measures and elements considered.

2. Background

A major impetus for the green design movement in the United States has been the establishment of the green building rating system, Leadership in Energy and Environmental Design (LEED). (Ahn and Pearce, 2008) In addition to adoption of LEED on the national scale, it is also being required by federal, state, and local level organizations. Organizations such as U.S. General Services Administration (GSA), Environmental Protection Agency (EPA) and U.S Army not only require minimum green building standards, but also mandate that future buildings be green. (http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1852: Dec 2008). To support the demands set by green building construction, many organizations such as the American Institute of Architects (AIA), National Association of Home Builders (NAHB), USGBC and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), to name a few, have made contributions towards promoting green construction and publishing educational materials. (Ahn and Pearce, 2008).

Of the many research areas of green design, such as its cost effectiveness and financial benefits, lifecycle assessment and cost, there has been considerable concentration on green building rating systems. (Kibert, 2005 and Ahn and Pearce, 2008) The adaptation of using rating systems during design is thus becoming a part of practice. BNIM architects have used a sustainability matrix (http://www.bnim.com/newsite/pdfs/2002-Matrix.pdf: Dec 2008) that incorporates rating systems in the early design phase as a guide towards achieving sustainability goals. However, to date, there is no comprehensive way to managing rating system requirements or to guiding designers during design.

3. Sustainable Building Rating Systems

In the US, a commercial green building is generally considered to be one certified by a sustainable building rating system; for example Leadership in Energy and Environmental Design (LEED), which is developed by US Green Building Council (USGBC) to establish a common standard of measurement. (Yudelson, 2008) Claiming to adhere to a standard is not the end of the process; achieving some level of certification demonstrates that the project has attained the green measures set out by the standard. According to Fowler (2006, pp 1) a green/ sustainable building rating system is defined as a tool that examines the performance or expected performance of a 'whole building' and translates that into an overall assessment that allows for comparison against other buildings.

Rating systems differ in the order of reduction in use of resources in the respective areas without causing discomfort to the users of the space. Different rating systems have similar categories, but can be very different in their intent, criteria, emphasis and implementation. (Glavinich, 2008) The ways categories are weighted, scaled and quantified in the various systems differ, and so the same building may have two different ratings when judged by different systems. Actual ecological impacts of rating systems are still yet to be scrutinized and are not within the scope of this paper.

3.1. COMPARISON OF RATING SYSTEMS

In the changing process of design, adoption of "sustainable building rating systems offer a roadmap that lead to sustainability goals and help align requirements"(BNIM). There is, however, the task of choosing a particular rating system and following its requirements as they constantly evolve. Table 1 shows the general assessment areas that can be laid out to categorize the various rating systems. Studies done by Fowler (2006, pp 45-47) looks at rating systems with an emphasis on energy reduction, Indoor Air quality and use of environmentally preferable products, along with other criteria for selecting the rating system to be used by the US GSA.

TABLE 1. Rating Systems by Assessment Areas

Assessment Area	**LEED**	**GreenGlobes**	**SBTool**
1. Management		Management	
2. Energy and Atmosphere	Energy and Atmosphere	Energy	Energy and Resource Consumption
3. Emissions to the environment		Emissions	Environmental Loadings
4. Sustainable sites	Sustainable sites	Site	Site Selection
			Economic Aspects
5. Water Efficiency	Water Efficiency	Water	
6. Indoor Air Quality	Indoor Air Quality	Indoor Environment	Indoor Environmental Quality
7. Quality of Service			Service Quality
8. Materials and Resources	Materials and Resources	Resources	
9. Innovations	Innovations		
10. Culture and Heritage			Cultural and Perceptual Aspects

The AIA evaluates rating systems from sixteen broad categories, to give the user a deeper understanding of the three chosen rating systems. (AIA, 2008) Four categories are summarized in Table 2. Other studies on comparison of rating systems (Smith, et al, 2006) aim at finding the content, priorities and processes for adaptation and implementation. The American Institute of Architects (AIA) supports the development and use of rating systems and standards that promote the design and construction of communities and buildings that contribute to a sustainable future (AIA), provided that the rating systems follow certain qualities, of which, one ensures that standards are updated on a regular basis. It is a challenge for experienced designers to keep up with all the change, let alone for novices. To address these unique requirements of rating systems, we envision a sustainable information framework as an organizer, and bridge, ultimately, to cater for multiple rating systems when implemented with design software making it amenable to computation.

TABLE 2. Rating Systems by Categories adapted from AIA (AIA, 2008)

Categories	**GreenGlobes**	**LEED NC 2.2**	**SBTool**
1. Renewed on a consensus based process	Renewed by the ANSI Technical Committee	USGBC members vote on the versions before they are released and updated	Renewed on a biannual basis led by the members of (International Initiative for a Sustainable Built Environment (iiSBE)
2. Require design documentation	Third party reviewer evaluates construction documents, energy models, wastewater systems, material data	It uses web templates for documentation compliance	Does not need documentation but encourages the completion on an online questionnaire
3. Requires third party validation	Third party verification through Canadian Standards Association (CSA) America Inc.	Compliance and certification are validated through a third party review system	The iiSBE provides a quality audit of a submitted assessment and issues certification.
4. Require significant reductions in energy use	Energy Credits are achieved through performance based and prescriptive paths using the US EPAs Target Finder System	Requires all projects must exceed ASHRAE 90.1 2004 by at least 14%, which may lead to significant energy reduction	Encourages specific goals for energy reductions by weighting local climate, energy operating costs, and case study models.

4. Framework for Sustainable Information

In a broad sense, a framework is a "conceptual structure used to solve or address complex issues" (http://en.wikipedia.org/wiki/Framework: Dec 2008). In sustainable design it is seen and used mainly in the form of matrixes, (Weerasinghe, et al 2007, Hassan, 2008 and Gething, 2007). In this paper the characteristics associated with a framework will be used more specifically as a structure to map rating system requirements to their comprising elements; identify processes involved; identify missing information and manage changes in rating systems in a cohesive way.

4.1 STRUCTURE OF SUSTAINABLE INFORMATION FRAMEWORK

To organize evolving rating system requirements, we are developing a flexible sustainable information framework (SIF) to accommodate rating system changes and designer needs. The objective of the SIF is to provide a general approach to processing the informational needs of any rating system, by identifying, categorizing and organizing relevant data requirements. The explicit formulation of such an exhaustive list of data requirements for rating systems enables designers to rate a building design according to the chosen system.

The large volume of information required by a rating system in order to evaluate building designs stems from a combination of direct and performance data [1]. Direct data is inherently integral to a building information model; however, tools such as ATHENA, EnergyPlus and Radiance are typically required to generate the necessary performance data. These tools are uniformly data oriented, objective and, mostly, adhere to formal standards and guidelines such as ISO, ASTM, or ASHRAE. (Trusty, 2000) It is clear that to integrate rating system evaluations into a CAD system, for example, Revit™, with possibly automating much of the process, there needs to be access to both direct and performance data.

A representative list of categories and consequently sub categories have been developed through literature investigation of the different rating systems, mainly for new construction, commercial building types. The current list of sub categories aims to satisfy the requirements of the different rating systems from the point of a project's lifecycle (Figure 1). The subcategories are comprised of elements (Figure 2) that are required for assessment by a rating system.

It may be noted that gaps will emerge as requirements change. When types of buildings change, requirements will have variations and more than often require additional sub categories or even categories. For example in LEED for residential building type, it is seen that there are categories/credits that are specific to residential development such as community resources, type of development and non toxic pest control, to mention a few. To address the missing subcategory, say, 'type of development', then this needs to be added and extended to match the credit requirements within a sub category of measures. In a case where there is no match, a new sub category needs to be created, for instance, for low toxic pest control management.

[1] *Direct data* refers to data that constitutes the building description, while not necessarily a product of user specification. *Performance data* are derived performance metrics of specific domains that characterizes a building.

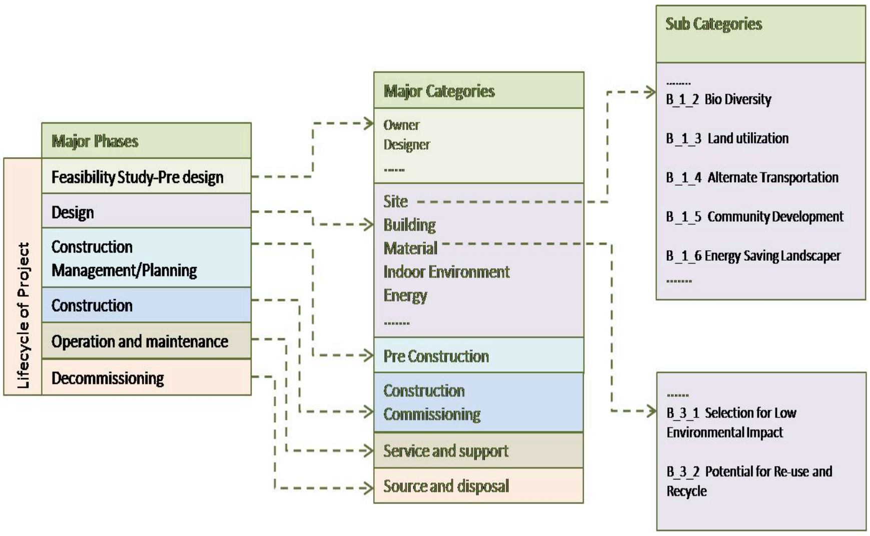

Figure 1. Classification of the building lifecycle addressing phases and transitions adapted from Gielingh

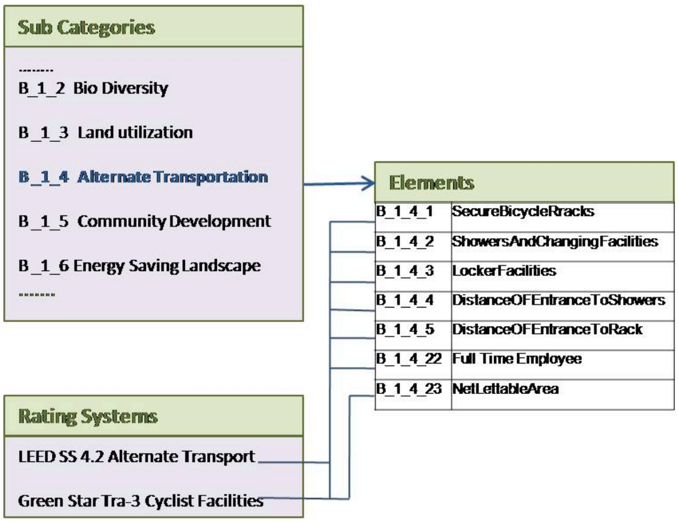

Figure 2. Mapping Rating System Requirements to Elements

A SIF is created through a list of general measures, which captures the categories and sub-categories of sustainable rating systems. The framework can also be used as a decision-making matrix in its own right, "as seen in existing practice-based method that had been developed to assist a dialogue between design team members and their clients–first setting priorities and targets for sustainability and then assisting later reviews and progress reports." (Gething, 2007) For flexibility, the SIF is developed by schema that represents modular components. These components are further broken down into sub-components that eventually map to required objects. From past experience, not all required objects are found in the BIM. This necessitates identifying missing BIM objects with the possibility of accommodating external data.

Implicit in the task of putting together a complete set of data are the following: 1. Formulation of a comprehensive and general ontology that: a) can accommodate and classify all informational requirements of the different rating systems; and b) lends itself easily to computation. 2. Identification of protocols required for carrying out specific processes for such evaluation. 3. Mapping rating system requirements to elements in a BIM, for example, Revit™ to [a)] find missing capabilities in the BIM, which will help identify the necessary external data that [b)] needs to be accommodated. Figure 3 depicts the system flow.

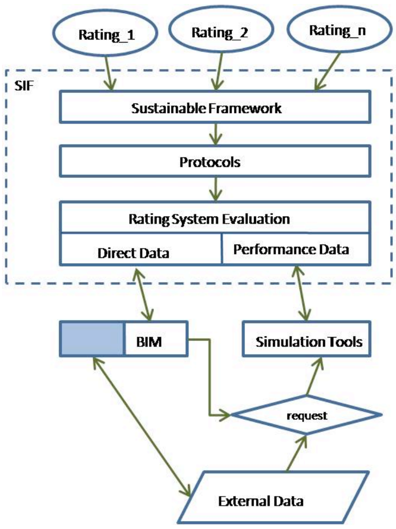

Figure 3. Sustainable Information Framework

Among the various design processes in use, building information modelling (BIM) offers promise for integration. Current efforts in integrating a building model with rating systems, for example, (Biswas et al, 2008), are attempts at providing such capability. Figure 4 illustrates the interaction between the sustainable information framework and a BIM application.

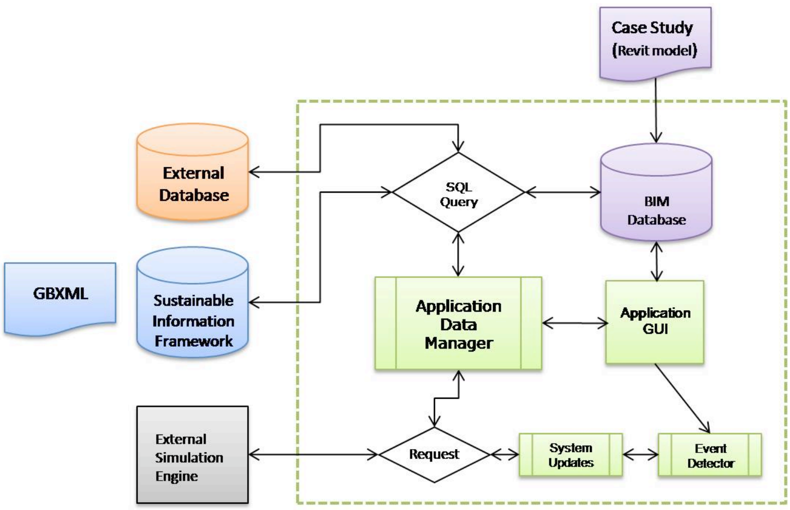

Figure 4. Workflow using framework with a BIM application

Challenges arise when unwarranted assumptions on data availability are made; as such, data related to rating systems are, sometimes, neither accessible nor present in the building model. The intention is to build a common platform that different rating systems can plug into and be used by designers from the early design phases to the completion of the project. The emphasis is on creating the framework to enable the use of information collated from a buildings life cycle in a sustainable manner.

5. Conclusions and Future Direction

This paper presents a way of creating a flexible framework to be ultimately integrated with a design system to facilitate endeavours in sustainable design. Determination of data requirements and methods mapping to different rating systems are ongoing. Analysis of different rating systems show that requirements are often met by responding to multiple processes that span across rating system categories. With respect to the variation of methods referenced, there is an underlying operating assumption that there are commonalties of requirements that can be used to compute specific rating evaluations.

The framework lays the groundwork for a process of ultimately analyzing a given building with respect to the requirements given by different rating systems. We plan to test and validate the sustainable information framework through case studies of real buildings, which have been certified by a known rating system. Flexibility is considered by evaluating the same building by several rating systems. These exercises will allow us to find gaps in the proposed framework.

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References

Ahn, Y. H. : 2007, Green Construction: Contractor Experiences, Expectations, and Perceptions. *Journal of Green Building* , **2**(3), 106-122.

AIA, S. D.: 2007, *50to50.* Retrieved 12 08, 08, from American Institute of Architects (AIA): http://www.aia.org/SiteObjects/files/50to50_050307.pdf

AIA, S. D.: n.d., *Quantifiying Sustainability.* Retrieved 12 08, 08, from American Institute of Architects (AIA): http://www.aia.org/SiteObjects/files/Quantifying%20Sustainability.pdf

Biswas, T. ,W-H. Wang and Krishnamurti, R.: 2008, Integrating sustainable building rating systems with building information models. *CAADRIA.* Chiang-Mai, Thailand. pp 193-200

Fowler, K. R.: 2007, *Sustainable BuildinRating Systems Summary.* Pacific Northwest National Laboratory, Department of Energy.

Gielingh, W.: 1988, *General AEC Reference Model (GARM).* Delft, Netherlands: ISO TCI184/SC4 Document 3.2.2.1 TNO Report B1-88-150.

Glavinich, T. E.: 2008, *Contractor's Guide Green Building Construction.* New Jersey: John Wiley & Sons, Inc.

Hassan, M.M.:2008, SDFLex:A Framework for the Assessment and Construction of Sustainable Flexible Pavements. *Journal of Green Building* , **3**(3), 108-118.

Keysar, E. and Pearce, A.R.: 2007, Decision Support Tools For Green Buildings: Facilitating Selection Among New Adopters On Public Sector Projects. *Journal of Green Building* , **2**(3), 153-171.

Kibert, C.: 2005, *Sustainable Construction Green Building Design Delivery.* Hoboken, New Jersey: John Wiley & Sons.

Krygiel, E. and Nies, B.: 2008, *Green BIM Successful Sustainable Design with Building Information Modeling.* Indiana: Wiley Publishing, Inc.

McLennan, J. F. : 2004, *The Philoshophy of Sustainable Design.* Washington: Ecotone Publishing.

Smith, T. F.: 2006, *Green Building Rating Systems.* Minnesota: University of Minnesota.

Tinker, A. and Burt, R.: 2004, Greening the Construction Curriculum. *International Journal of Construction Education and Research* , **9**(2), 26-33.

Trusty, W.: 2000, *Introducing an assessment tool classification system.* Retrieved September 17, 2008, from ATHENA: http://www.athenasmi.ca/publications/docs/AssessTypologyTool.pdf

USGBC. : n.d., *LEED initiatives in Government and Schools.* Retrieved 12 08, 08, from US Green Building Council: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1852

Walker, S.: 2006, *Sustainable by Design Explorations in Theory and Practice.* Earthscan.

Weerasinghe, G. S.: 2007, LEED -PDRI Framework for Pre Project Planning of Sustainable Building Projects. *Journal of Green Building* , **2**(3), 123-143.

Williams, D. E.: 2007, *Sustainable Design: Ecology, Architecture and Planning.* Hoboken, NJ: John Wiley & Sons.

Yudelson, J.: 2008, *Marketing Green Building Services Strategies for Success.* Oxford, UK: Architectural Press