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Formulation of a Measurement System to Determine Sustainability of Building Projects

U.G.D.Weerasinghe
Department of Civil Engineering, University of Calgary, Calgary, Alberta, Canada
ugweeras@ucalgary.ca

J.Y. Ruwanpura
Project Management Systems
Department of Civil Engineering, University of Calgary, Calgary, Alberta, Canada
janaka@ucalgary.ca

Abstract
During the last two decades, green building movement has come to the forefront of building industry. Consequently, several significant building environmental assessment methods have emerged in different parts of the world providing diverse perspectives on the measurement of environmental impact of building projects. Analysis of current literature and research on green buildings revealed the need for broadening the scope of building performance assessment methods to fall within the main spheres of sustainability – environmental, social and economic norms. This paper examines the possibility of evolving an assessment system of indicators expressing the complex relationships between environmental, social and economic domains of sustainability which would effectively measure the sustainability performance of building projects. It is an exercise involving the development of a definition for sustainable buildings, several root cause analyses of sustainability issues to identify the causes /criteria that require attention in building projects, and the enhancement of these criteria to incorporate sustainability objectives, resulting in a set of indicators. Determination of criteria and value for each indicator would eventually culminate in an index for assessing sustainability of building projects.

Keywords
Green buildings, Sustainable buildings, Building environmental assessment methods, Sustainability indicators

1. Introduction

The impact of the building industry on the natural environment had increased in significant proportions during the last two decades. Worldwide, building construction and operation account for 40% of the world's energy consumption (Worldwatch, 2007), which corresponds to one-third of the carbon dioxide emissions that cause global warming and two-fifths of the sulphur dioxide emissions that cause acid rain. Further, it is estimated that worldwide buildings use 40% of virgin minerals which is associated with landscape destruction, toxic runoff, deforestation, and both air and water pollution. The available statistics indicate contributions being made to environmental degradation by construction and operation of buildings, and the responsibility being entrusted to the building industry towards resolving the same.

As it became apparent that the building industry has a responsibility towards environmental protection, an environmental responsive approach, namely, the green building movement came to the forefront of building industry. With the advent of the green building movement, different building environmental assessment (BEA) methods, with the aid of which the environmental performance of a building could be assessed, began to emerge in different parts of the world. Leadership in Energy and Environmental Design (LEED) in USA and Canada, Building Research Establishment Environmental Assessment Method (BREEAM) in UK, Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan and Green Star in Australia are some widely used methods. One of the most comprehensive and sophisticated building assessment methods developed in recent years has been the Sustainable Building Tool (SBTool), also known as Green Building Tool (GBTool) a system of indicators initiated by Natural Resources Canada.

The introduction of BEA methods opened up a highly controversial debate on the limitations inherent in these systems, including cost implications and long term economic and environmental benefits. Among the views expressed is the need to broaden the scope of building performance assessment systems to incorporate sustainability requirements, which are, environmental, social and economic norms. The inadequacy of the existing building performance assessment systems to address sustainability concerns is a key issue that needs attention, and this research paper proposes a solution for addressing this issue. It consists of a literature review of BEA methods, generation of research objectives, explanation of a methodology and the benefits of such an exercise to the building industry and society.

2. Implications and Benefits of Green Buildings

According to a detailed analysis of sixty LEED rated buildings by Kats (2003), it is clearly demonstrated that green buildings, when compared with conventional buildings, are 25-30% more energy efficient. Lapinski *et al*., (2006) point out that the upfront cost is used to purchase better quality building components, and that this 'investment' can achieve significant operational savings that extend over the life of the building. According to van Paumgartten (2002), environmental measurement systems encourage the industry to look upon buildings as long term investments, and that the approach based solely on initial construction costs is being replaced by a whole building perspective that bases costs on the entire life cycle of a building. Kats (2003) indicates that LEED rating system addresses several measures that help to reduce the pollutants causing sickness and increasing health care costs, improve quality of lighting, and increase tenet control and comfort. Kats argues that most of the buildings that have applied for, or obtained LEED rating include a range of material, design and operation measures that directly improve human health and productivity.

3. Integration of BEA's with Project Managemeent and Design Process

Environmental assessment methods encourage greater communication and interaction between members of the design team and various sectors within the building industry (Cole *et al*., 2005). In fact, BEAs assist in re-shaping project management framework and the design process, as it requires a multi-disciplinary and integrated approach to design with all parties involved from commencement of the process. Matthiessen *et al*., (2004), while emphasizing that sustainability is a program issue rather than an added requirement, recommend that it could be achieved by, a) establishing team goals, b) including specific goals to the program, c) aligning budget with the program, and d) staying on track through design and construction. Integration of LEED decision with Project Definition Rating Index, a project management tool for scope definition at pre planning stage, is demonstrated by Weerasinghe *et al*., (2007), an approach that could be enhanced to encompass the project life cycle.

Kibert (2008) suggests the adoption of Integrated Design Process (IDP) as having the necessary characteristics for delivery of high performance green buildings. "In green design, the integrated design starts much earlier in the project development compared to conventional design, involving interaction with the owner to define issues and set goals prior to schematic design and continuing through construction and commissioning" (Kibert, 2008. p 85). In fact, he is highlighting essential factors necessary for successful project management but modified to meet challenges of green building.

3.1 The Integrated Design Process (IDP)

The development of IDP is based on the experience gained from a Canadian demonstration program for high performance buildings designed in 1993. It is the name given to the high levels of collaboration and teamwork that help differentiate a sustainable building design from the design process found in a conventional project.

"The traditional process has a mainly linear structure due to the successive contributions of the members of the design team" (Larsson, 2004. p 1). According to Larsson (2004), the IDP process contains no elements that are radically new, but integrates well-established and accepted approaches into a systematic total process. According to Zimmerman (2006), IDP describes and intentional way of approaching sustainable building and community design that offers a much higher likelihood of success than any other approach. While emphasizing IDP as an appropriate tool for sustainable building design, Zimmerman (2006) describes it as a collaborative process that focuses on the design, construction, operation and occupancy of a building over its complete life-cycle. It is designed to allow the client and other stakeholders to develop and realize clearly defined and challenging functional, environmental and economic goals and objectives requiring a multi-disciplinary design team that includes or acquires the skills required to address all design issues flowing from the objectives. Prowler (2008) explains that the IDP asks all the members of the stakeholder community, and the technical, planning, design and construction team to look at the project objectives, and building materials, systems, and assemblies from many different perspectives.

4. Analysis, Limitations and Future of BEA Methods

Gu *et al*., (2006), in analyzing three most widely used BEA methods, which are, BREEAM EcoHomes 2005, LEED-New Construction 2.2 and SBTool 2005, observe that with time, rating systems have become more comprehensive as well as complicated. "EcoHomes has the fewest indicators and GBTool has most, which reflects the more recent the development period, the more complex the method is. In fact, GBTool has more sub-indicators to cover the whole range of building design and planning, not only environmental issues, but also social and economic issues" (Gu *et al*., 2006, p 180).

The credits in both BREAM and LEED are highly segregated and distinct, so that the attainment of one credit does not meet another credit's prerequisites, which limits double counting. The detriments of this approach are highlighted by Fenner and Ryce (2008), who point out that it encourages the installation of systems and technologies to meet specific credit requirements, and does not account for, nor foster the holistic point of view that is required for the efficient design of a green building.

Lack of post-construction auditing and performance reporting requirements is a major drawback in the successful commissioning of a green building. Wener and Carmalt (2006) suggest several solutions that could easily be incorporated into a building assessment tool. BREEAM does have a post-construction option, although it is not widely used. Fenner and Ryce (2008) suggest several possibilities exist for modification that would overcome this deficiency, such as the introduction of mandatory post-construction audits to ensure adherence to certified designs.

4.1 Emerging Trends

The building rating systems currently in use have not been considered to foster the creation of sustainable buildings, nor a sustainable future (Fenner and Ryce, 2008). Pope and Morrison-Saunders (2004) express similar opinions by stating that typical integrated assessment tools such as building rating schemes currently seek to minimize 'unsustainability' and that such systems explicitly seek to minimize environmental impacts, but often fail adequately to take into account social and economic indicators. Cole *et al*., (2005) emphasize on the need for recasting environmental assessment methods under the umbrella of environmental, social and economic sustainability.

Gu *et al*., (2006) point out that BEA methods are now shifting towards assessment of more specialized structures while there is general consensus that the next generation of assessment tools should be developed to analyze a wider range of structures than just single buildings. Fenner and Ryce (2008) agree that future assessment tools should be developed to address sustainability in its entirety rather than focus on environmental indicators. But they caution on the need to be sensitive in carrying out this change of focus. "This realignment will have to be carefully orchestrated , however, as a dramatic, unmonitored increase in assessment focal points runs the risk of diffusing public awareness of, and professional interest in, improving environmental performance of buildings" (Fenner and Ryce, 2008. p 61).

5. Research Inspiration: Expanding the Scope of BEA Methods

The existing BEA methods primarily address environmental issues, which restricts the scope within which the performance of a building could be assessed. The forgone discussion highlights the need to broaden the capacity to BEA methods /tools to encompass the main spheres of sustainability – environmental, social and economic – as the next stage of development. It could pave way for a more comprehensive assessment of the impact of the buildings, providing corrective measures concurrently. On of these measures is to consider the Integrated Design Process as a means of achieving sustainable buildings in the formulation of sustainability assessment methods, thus incorporating a life cycle approach with multi-disciplinary collaboration right from project initiation. Another possibility is to re-structure the project management framework to accommodate project delivery system for sustainable buildings, and examination of the impact of sustainability objectives on the project management constraints, namely, time, cost, quality and scope.

6. Research Objectives

The main objective of this exercise is the development of a measurement system to assess sustainability of a building project addressing the environmental, social and economic attributes of the building life cycle. It should be incorporated with the design and project management processes so that appropriate strategies could be adopted during the planning, design and construction stages of a project.

The other sub-objectives are to: i) Formulate a working definition for sustainability, ii) Identify decisions taken during the project management phases and IDP of a building project that could cause sustainability implications throughout its life cycle, iii) Establish a set of categories made up of indicators from the decisions taken during the integrated design process that could address sustainability effects of the building throughout its entire lifecycle, iv) Develop qualitative/quantitative standards/requirements and assign values for sustainability indicators and v) Establish a system of measurement by merging all the indicators together.

The final deliverable of this exercise would be a comprehensive measurement system in the form of an index to assess sustainability of building projects.

7. Methodology

The research methodology consists of several phases as explained below.

7.1 Defining Sustainability

The definition for sustainable development as proposed by the Brundtland Commission Report, which is, "Development that meets the needs of the present without compromising the needs of the future generations" (WCED.1987, p 8), is generally acknowledged, and is recognized as the acceptable definition for this research. In order to define sustainability for the purpose of this research, numerous definitions for 'sustainability' that have come into being during the last two decades have been examined, based on which, a working definition for Sustainability has been derived, which reads as:

"*A state in which a system can be socially, environmentally and economically self reliant indefinitely*".

A sustainable building could be achieved through an integrated design process and sustainable construction process, as indicated in Figure 1. The decisions taken during the IDP determine the sustainability of the end product, that is, of the building created.

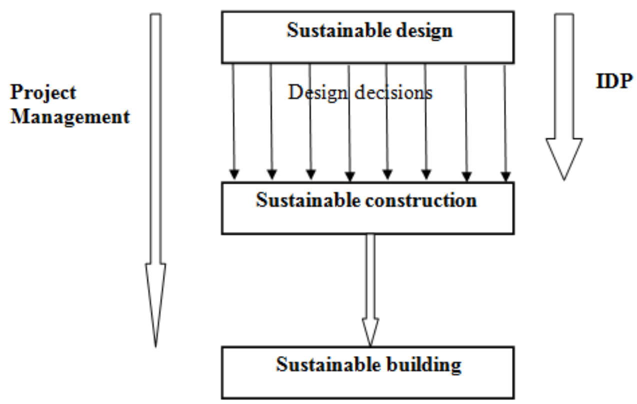

Figure 1: Realizing Sustainable Buildings

Accordingly, a sustainable building could be defined as a building which remains in a state of social, environmental and economical self reliance within the context of the built environment throughout its life cycle.

7.2 Theoretical Formulation of Indicators

Several approaches are being taken to identify potential indicators, and the research framework for this sub-phase is shown in Figure 2.

7.2.1 Identification /Determination of potential indicators

Being one of the most crucial tasks of this research, several paths, as described below, and indicated in figure 2 will be adopted to identify the potential indicators for sustainable buildings.

i) The point of origin for path 1 is Agenda 21, which was adopted by the United Nations in 1992 at conclusion of the Rio Earth summit. It is a comprehensive blueprint of action for sustainable development for the 21st century, to be taken at globally, nationally and locally by organizations of the UN, governments, and major groups in every area in which humans impact on the environment. It marked the beginning of a new global partnership for sustainable development

(UN, 2004). An exploratory study to determine root causes of global environmental issues as identified by Agenda 21 has already been carried out. Through this analysis, it is possible to identify the effects of building related activities on the environment. The main global issues considered are climate change, land degradation, pollution (indoor and outdoor), resource depletion, ecosystem damage, acid rain and ozone depletion. Further, the effects of proposed actions of Agenda 21 on the design, construction and operation of buildings will be examined to ascertain any other potential indicators.

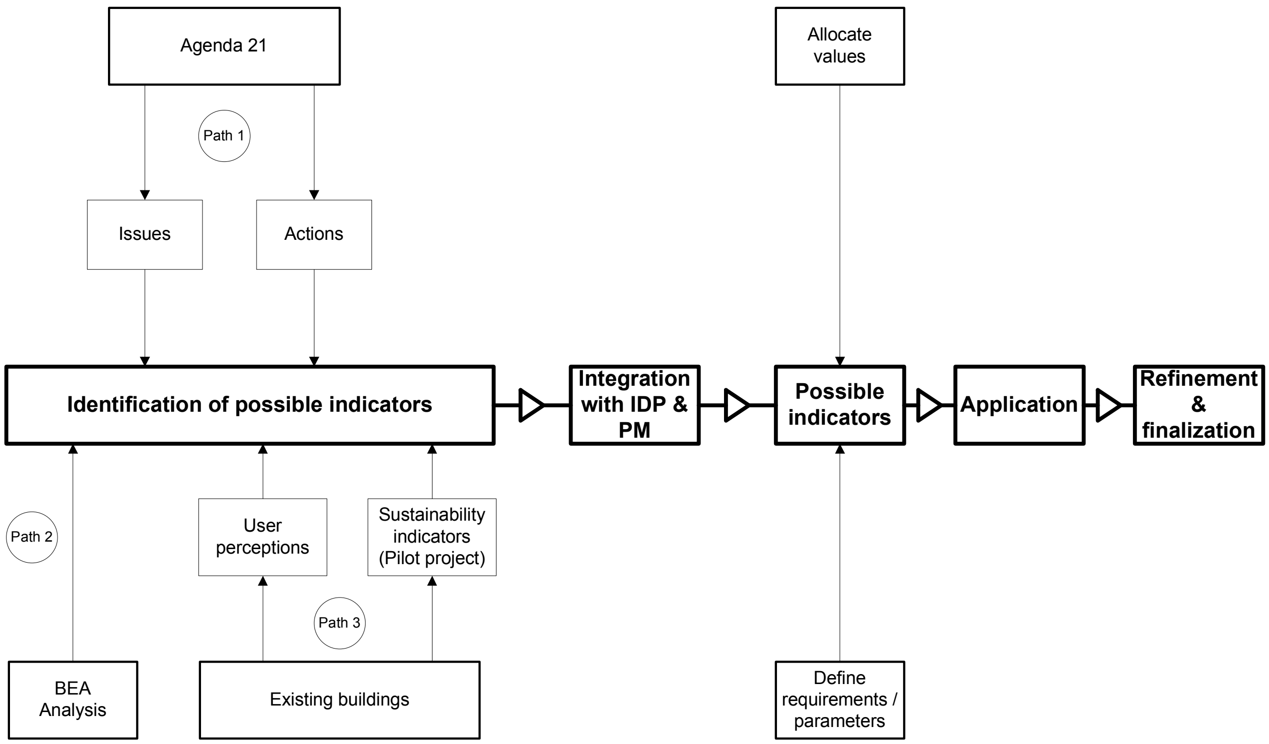

Figure 2: Framework for Theoretical Formulation of Indicators

ii) Examination of the most widely used BEA methods is path 2 in the identification of potential indicators. This exercise will be aided by previous research, such as the analysis of three of the most widely used BEAs, LEED, BREEAM and GBTool done by Gu *et al*., (2006) through which some of the common indicators could be identified.

iii) Path 3 for determination of indicators is through a pilot project being undertaken to formulate a sustainability index for existing buildings. Existing buildings are vital sources of ascertaining how the buildings and occupants respond to the decisions taken during design stage. As such, a set of indicators for existing buildings is an excellent means of informing the design process.

Once the potential indicators are finalized, the most critical indicators which have to be allocated appropriate values will be shortlisted. The requirements and parameters for each indicator will be determined through review of previous research on the relevant subject areas.

The applicability of each critical indicator to the project management and IDP process will be determined by analyzing each activity of the process and identifying the decisions that have an impact on the indicator. Please refer Figure 3.

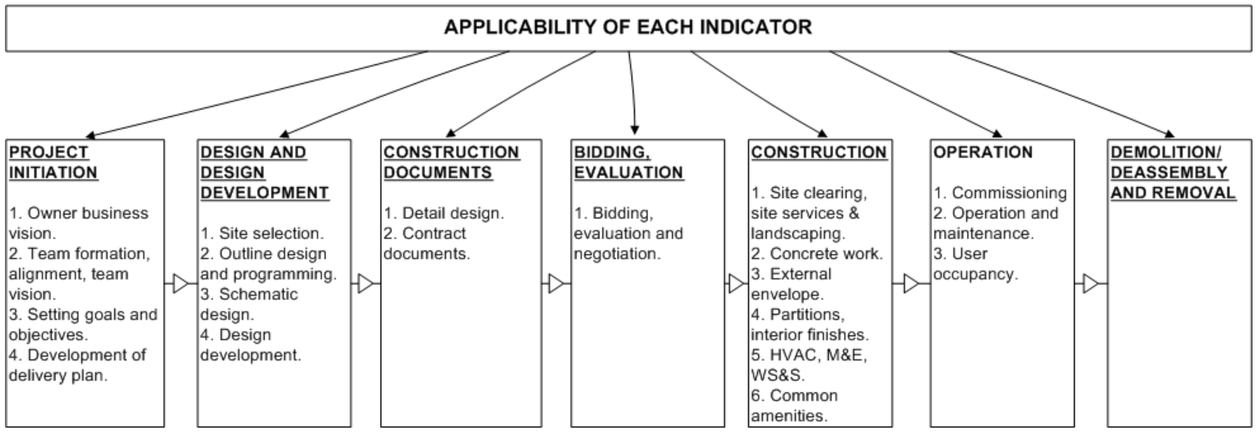

Figure 3: Incorporation of Indicators with Project Life Cycle and Building Life Cycle

7.3 Assignment of Values/Weights to Indicators

A web based survey of experts in the building industry, preferably architects and LEED accredited professionals will be carried out to establish weights to each indicator. A questionnaire listing out the indicators requesting the experts to assign weights to each indicator based on their own experience and knowledge will be used for this purpose. The preference will be based on Likert scale, and final weights for indicators could be assigned by obtaining the weighted mean value of all values received for each indicator.

Accordingly, for each indicator,

$$\mathbf{v} = \frac{\sum_{i=1}^{5} n_i v_i}{\sum_{i=1}^{5} n_i}$$

Where, v = value allocated for each indicator, n = number of respondents (for each value) and v = value range from 1 to 5. Conclusion of this phase will be the finalization of a set of indicators and the ensuing sustainability index.

8. Application and Refinement of the Index

The final stage of the research is the refinement of the index by applying it to selected building projects. It will be conducted as multiple case studies, as opposed to a single case study. Since no projects clearly defined as meeting sustainable requirements exist on record, it would be prudent to select LEED rated projects as case studies. The reason for selecting LEED projects is that at least some environmental considerations are fulfilled and recorded in such projects, as opposed to non-LEED buildings. Therefore, two LEED projects, representing as many LEED credits as possible, will be selected as case studies. The archival data about each case, or project would be reviewed initially, after which the design process will be re-enacted with the sustainability indicators being applied. It would enable to determine feasibility of each indicator, as well as the requirements/parameters for their application in building projects. After values are allocated for relevant indicators, the final value (V) for the particular building could be calculated by

$$V = \frac{\sum_{i=1}^{n} v_i}{\sum_{i=1}^{n} \mathrm{v}_i} \times 100\ \%$$

Where, v is the value obtained by each indicator, v is the value allocated for each indicator, and n is the number of indicators. The final value of the sustainability of a building project will be derived as a percentage, thus providing the level of sustainability of the end product. During the process of application each indicator and the requirements would be reviewed and refined, so as to minimize complications in its application, thus making it a user friendly tool.

9. Conclusion

The final outcome of the research would be a Sustainability Index that could be applied by owners and design teams seeking high quality, sustainable buildings as the final output of their endeavours. The research will contribute towards formulating a best practices methodology for sustainable buildings, developing on the existing design processes incorporating BEA methods. The product will be a highly specialized derivative from the existing building rating systems: a tool to be used effectively in practice. Major allied fields that will benefit are Architecture, Project Management and Engineering (building services engineering). The challenges of sustainable construction could enhance the building trades, with the emergence of innovative and sustainable technologies and products into the market to fulfill expanding needs of the industry. Further, this exercise opens up several new avenues for further research on the architecture and project management of sustainable buildings.

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