SUSTAINABLE BUILDING DESIGN: THEORY AND PRACTICE

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SUMMARY

This paper briefly summarizes a range of constructs and methods that have been proposed for assessing sustainability of human activity as a basis for assessing sustainable design alternatives. We provide these as examples of relevant approaches to quantifying sustainability. After a brief, critical comparison of the main proposed theories and their embedded assumptions, we suggest their contextualized applications in building design.

INTRODUCTION: THEORIES AND DEFINITIONS

Global population forecasts for the year 2100 range from $9.6 * 10^9$ to $12.3 * 10^9$ (Gerland et al, 2014). With a modest 3.5% growth in access to technology, by 2100, the simple I=PAT model (Ehrlich and Holdren, 1972) under a business-as-usual model (Levin, 2007) and the most recent UN global population estimate for 2100 ($\sim 11 * 10^9$) results in a >8-fold increase in human environmental impact. Because buildings are responsible for roughly one-third to one-half of anthropogenic material and energy use (Levin *et al*, 1997), reductions in buildings' environmental impacts can substantially improve environmental sustainability.

The widely used term "sustainability" still lacks a consistent meaning and a shared framework (Dobson, 1996; Kundak, 2009; Ostrom, 2015).

According to Hans Carl von Carlowitz, who first mentioned "sustainability" in 1712 in relation to un-controlled consumption of forests, "the idea of sustainability emerges in times of catastrophic events or shortages" (Kundak, 2006). But the most famous definition of the concept came from international law that introduced sustainable development as "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987). Users of this definition cite the "three-legged stool" of sustainability: social, economic and environmental (Holdren, 2008). "Sustainable development" presented as almost synonymous with "sustainability," is challenged by authors who argue that "development" itself is antithetical to sustainability (Daly, 1996) because development is inherently unsustainable: "human development must occur without overwhelming the natural ecosystems that we depend on"(Wood, 2015).

While most definitions of sustainability are too vague to be useful (Dobson, 1996; Kohler, 1998), some have tried to become more specific. "Sustainable" is often used to characterize a technology with a lower environmental impact on a single environmental problem (e.g., climate change, water resource use, etc.), often quantified in terms of reduced resource use or pollution emissions as a fraction or percentage. Sustainability should address the complex interactions among social-ecological systems (Ostrom, 2015).

In this wide and blurred landscape, clearly each definition depends on a set of assumptions and choices of the relevant values and priorities applied to decisions involving trade-offs (Dobson, 1996; 1998). Values and choices drive decisions about trade-offs among alternative building designs. However, most of these value choices are not explicitly shown, but are implicit both in common design practice and in the development and use of building rating systems. A more critical, transparent, and advanced rating system would make these choices apparent and openly discussed, not only in general, but in relation to specific contexts. In this respect, Andrew Dobson's approach to sustainability has the advantage of directly addressing the need to open up the black boxes of assumptions about sustainability (Dobson, 1996; 1997).

PART 1 - FROM THEORIES TO METRICS

Andrew Dobson provides an overview of conceptions of sustainability, based on four questions, 1.What to sustain, 2. Why, 3. for Whom, and 4. Substitutability (Dobson, 1996; 1998). Models to assess and measure sustainability have evolved during the past half century but not all of Dobson's questions have been addressed. The earliest formulation of a simple metric for sustainability is "I=PAT" (Impact equals Population times Affluence times Technology) (Ehrlich and Holdren, 1972). In the early 90s a similar model was elaborated in great detail, suggesting quantitative targets for the Netherlands based on estimates of global and Dutch national "ecocapacity," (the ecological carrying capacity of the Earth) (Wetterings and Opschoor, 1992).

Later, Azar *et al* (1996) presented a quantitative approach to calculate "socio-ecological indicators" for sustainability. Using available data, their method compares consumption rates to known resource reserves to illustrate relationships between resource use and supply. The method is still in common use by corporations and industry as the "Natural Step" (Natural Step, 2015)

Graedel and Klee (2002) went beyond the 1992 Dutch target-based approach to demonstrate a target-based method for assessing sustainability quantitatively, comparing resource consumption and pollution emission (including greenhouse gases) to science-based targets. Wood et al (2015) developed the European EXIOBASE project (model and data base) to quantify environmentally-relevant inputs, outputs, and land use changes.

PART 2 PRACTICE IN BUILDING DESIGN

Which theories and metrics should apply to buildings; how should they be compared, confronted; and their relative values assessed? While these questions are rarely asked, implicit answers to them are embedded in rating systems without a clear account of their validity, just assumed as expert positions. The approaches characteristic of most building rating systems rarely derive from explicit identification of the environmental problems being addressed or a set of criteria for making the inevitable trade-offs among available solutions to environmental problems.

To achieve the goal of reduced environmental impact (and increased sustainability), there are often conflicts (and trade-offs) among design alternatives, and decision-makers must choose among alternatives. There are often complex inter-relationships among the problems, e.g., global warming affects biodiversity, water availability, natural resources, etc., (Miller, 2005). Various aspects of a building contribute to environmental problems. Identifying the magnitude of the contribution of each design alternative to each environmental problem enables systematic sustainability assessment of alternative design options. Comparing impacts and weighting them according to a set of consistent priorities reduces the potential for conflicting design choices (e.g., increasing ventilation to improve indoor air quality versus reducing energy use to minimize emissions of greenhouse gases; using "natural" materials to reduce human health impacts vs. reduced deterioration of habitats that maintain biodiversity). Systematic Evaluation and Assessment of Building Environmental Performance (SEABEP) proposes prioritization (weighting) of environmental problems and specific, contextualized criteria to enable a consistent and systematic trade-off based, decision-making process (Levin, 1997).

The magnitude of the impact depends on the characteristics of a building's burden on the environment. Resource consumption, pollution emissions, and land encroachment are each forms of buildings' impacts. Additionally, buildings contribute to human health problems by the environmental conditions within them and by their larger environmental burden. The following are important to determine a building's environmental performance:

- Size and types of resource consumption, pollution emission, and land encroachment – (data are available).
- Scarcity of resources - what is left after we use some; how long it will last (some data are available).
- Environmental consequences of withdrawal: pollution, resource consumption, land encroachment and habitat destruction (varying quality and quantity of data).
- Some way to normalize the various types and quantities of harm so that different impacts can be compared across categories (diverse alternatives exist)
- Some weighting (or prioritization) of environmental problems (types of harm) so that some comparison can be made that includes the importance of the problem (depends on more scientific knowledge than is available and on considerable value-based judgment.

Following is an example of weighting criteria, based on USEPA (1995) and Levin (1996):

- S*patial Scale of Impact* (global, regional, local - large worse than small)
- *Severity of The Hazard* (more toxic, dangerous, damaging being worse)
- *Degree of Exposure* (well-sequestered substances less concern than readily mobilized substances); *Penalty for Being Wrong* (Longer remediation times of more concern)
- *Status of Affected Sinks* (already overburdened sinks more critical than less-burdened ones; sinks = receptors, or environmental compartments).

Designers wishing to maximize buildings' overall environmental performance must identify the contribution of various building components and performance on the environment. Such analysis begins by listing environmental problems, their causes, and evaluating alternative design solutions to eliminate, minimize, or avoid exacerbating the environmental problems as follows: 1) Habitat destruction / deterioration (biodiversity loss); 2) Global climate change; 3) Stratospheric ozone depletion; 4) Soil erosion; 5) Depletion of freshwater resources; 6) Acid deposition; 7) Urban air pollution / smog; 8) Surface water pollution; 9) Soil and groundwater pollution; 10) Depletion of mineral reserves (especially oil and some metals).

Analysis based on these data can be used by all relevant players (e.g., clients, occupants, communities) and in decision-making procedures to calculate a score for various design alternatives. The analysis should encompass the facility's entire life cycle, using targets for sustainable consumption, emission or land use based on best available science, and on comparison of building performance against the targets. This can produce a dimension-less value representing a building's environmental performance that can be used to compare design alternatives integrated across environmental problem categories.

In contrast, current green building practices use points or credits available from rating or certification systems to encourage environmentally friendlier behavior by favoring design choices deemed preferable by those experts developing the rating systems. These systems support certain design solutions without making apparent the weighting of the environmental problems being addressed. Thus conceived, these systems fail to relate directly to a sustainable level of consumption, pollution emission, or land use. While merely conveying the experts' conclusions, they also make it more difficult to maintain awareness of the need for specific flexibility, contextuality, and necessary revisions.

CONCLUSION

Target-based approaches establish limits based on local and regional (Holdren *et al*, 1995) as well as global ecosystem capacity. Open weighting of problems creates a consistent foundation for data-based, systematic evaluation of building sustainability. Environmental problems should be prioritized by disclosing and discussing implicit assumptions and by adopting project- and location-specific "weights" for various issues tailored to a particular project, organization and location. A process to establish such priorities and examples of available metrics have been described. Changes in the weights reflecting the decision-makers' values can significantly affecting the outcome of the analysis and design process, and should be made explicit.

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