THE NATURAL STEP AS AN ASSESSMENT TOOL FOR THE BUILT ENVIRONMENT

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ABSTRACT

The Architecture/Engineering/Construction industry has begun to show an increased interest in the concept of sustainability as a way of improving the performance of facilities throughout their life cycle, in terms of indoor and outdoor environment, economics, and other criteria. Decision makers in the A/E/C industry, along with facility owners and users who are interested in increasing the sustainability of their facilities, need a tool with which to evaluate their buildings in terms of the critical variables of sustainability. Because there has been little agreement over the precise composition of sustainability and the essential elements of a sustainable building, different sets of sustainable building indicators have been developed to satisfy the various schools of thought.

One of the more promising recent approaches to achieving sustainability is The Natural Step (TNS). Many people seem to like the approach of TNS, since its four system conditions are relatively easy to understand and accept and its tenor is non-judgmental. While the system conditions of TNS provide a useful starting point for evaluation, their application to specific technologies such as buildings is difficult because of the complexity of the technologies and the indeterminate nature of the system conditions. This paper seeks to answer the following question: "How can TNS be applied to built facilities, and what does it mean for how we build buildings?" Using TNS as a framework, we have developed a matrix evaluation tool which categorizes building-related indicators according to the four system conditions.

INTRODUCTION

Sustainability offers a way of interacting with our world which reconciles the ubiquitous human desire for a high quality of life with the realities of our global context. It calls for unique solutions for improving our welfare that do not come at the cost of degrading the environment or impinging on the well-being of other people. Although there is no general agreement regarding the precise meaning of sustainability beyond respect for the quality of life of future generations, most interpretations of the term "sustainable" refer to the viability of natural resources and ecosystems over time, and to the maintenance of human living standards and economic development [1].

The Natural Step Approach

One of the more useful frameworks for thinking about sustainability is The Natural Step (TNS). This approach is an attempt to simplify the language and distill sustainability down to critical issues. This framework was developed by Dr. Karl-Henrik Robèrt in 1989 in Sweden.

As an oncologist, Dr. Robèrt began noticing an increase in cancer rates among children. In an attempt to understand the cause of this phenomenon he concluded that children were being impacted by something pervasive in the environment, as opposed to a lifestyle choice which might lead to cancer in adults. This led him to the conception of “molecular garbage” -- the detritus that has accumulated in the environment and is found at the molecular level. We have unearthed persistent metals and unleashed them into the terrestrial environment. We have also created synthetic toxics that can not be broken down by nature. All of these persistent materials linger in the environment and make their way it into the molecular structure of living things, including humans.

Dr. Robèrt was aware that there are very clear parameters which prescribe the conditions a cell must have to live and wondered if a similar set of clear rules could be developed for our environment. He drafted a document outlining potential parameters and after 21 iterations among 50 scientists, the final product was a list of four system conditions that must be met for sustainability to be achieved.

While most environmental frameworks have focused on type and quantity of materials consumed, The Natural Step looks at waste generated as the primary limiting factor. In a speech to Monsanto, Paul Hawken refers to a high school science experiment with bacteria in a petri dish. He points out that the bacteria do not die from lack of food, but are poisoned by their own waste products [2]. The Earth is a closed system just like the petri dish, and our wastes are threatening to poison us:

> *Our resources are being rapidly transformed into useless garbage, some of which is obvious to the naked eye, but most of which escapes awareness. The smaller portion can be seen in garbage dumps and other visible waste. By far the larger portion can be thought of as ‘molecular garbage’ - consisting of the vast quantities of tiny particles that are daily spewed out into the earth’s air, water and soil. [3]*

Basic Principles of The Natural Step

The four conditions shown in Table 1 were the result of the consensus process undertaken by Robèrt. These parameters are seen as non-negotiable conditions required for a sustainable system.

1) Substances from the Earth's crust must not systematically increase in the biosphere.
2) Substances produced by society must not systematically increase in the biosphere.
3) The physical basis for the productivity and diversity of nature must not be systematically deteriorated.
4) In order to meet the previous three system conditions, there must be a fair and efficient use of resources with respect to meeting human needs.

Table 1: Natural Step System Conditions [4]

Although TNS cannot tell us what materials to use, nor how to design, construct, operate, or deconstruct buildings, it can be helpful in the field of the built environment. It can be instrumental in framing our thinking, and can serve as a guide to evaluating the sustainability of a building. TNS does not judge or tell us what to do, but it does guide us in the right direction.

METHODOLOGY

The primary objective of this work was to transform the operational system conditions of TNS into an evaluation tool which could be used to assess the sustainability of built facilities. The methodology consisted of interpreting the TNS system conditions and finding building-specific indicators which represented each condition over the critical phases of the facility life, resulting in a life-cycle assessment matrix.

Developing a Matrix of Sustainability from The Natural Step

Indicators serve to tell us if we are going in the right direction. To be useful they must be easy to understand, relevant, and contain information that is readily accessible. Since they are not definitive they should not be used in isolation. The four Natural Step system conditions were transformed by selecting indicators which together represent the essence of each condition. The indicators were selected from existing building-related indicators based on the following criteria:

- Representativeness of the associated Natural Step system condition;
- Availability of data with which to generate a value for the indicator;
- Generalizeability to other types of built facilities; and
- Applicability to the particular facility type examined [5].

Indicators were selected to comprehensively represent each TNS system condition (Table 2), according to the interpretations discussed in the following subsections. The indicators were kept to a minimum, due to the prototypical nature of the study. If the Natural Step metric proves to be a useful and valid tool, then the number of indicators and their precision could be increased as necessary to improve the reliability and usefulness of the metric.

	Construction	Operation & Maintenance	Deconstruction
System Condition 1			
Percent of total materials from Lithosphere			
Percent of Lithospheric materials from recycled sources			
Percent of Lithospheric materials which are recycled			
System Condition 2			
Percent of total materials which are Synthetic			
Percent of Synthetic materials from recycled sources			
Percent of Synthetic materials which are recycled			
System Condition 3			
Percent of virgin Natural materials from sustainable sources			
Percent of Natural materials from recycled sources			
Percent of Natural materials out which are recycled			
Percent of total materials out which are not recycled			
Level of Site Ecosystem Disturbance			
System Condition 4			
Resource Efficiency			
Resource Fairness			
Satisfaction of Human Needs			

Table 2: Natural Step Condition Indicators over a Facility Life Cycle

System Conditions One and Two: Lithospheric and Synthetic Materials

System Conditions One and Two are based on avoiding accumulation of particular types of materials in the biosphere—those parts of the Earth where life exists. System Condition One states that materials from the Earth's crust (lithosphere), such as metals, should not be allowed to accumulate in the biosphere. System Condition Two states the same for substances produced by society, and includes synthetic and pervasive materials such as plastics. To evaluate built facilities in terms of these two conditions, we need to account for the types of materials and energy which comprise and pass through the building over the three primary phases of its existence: construction, operation/maintenance, and deconstruction or demolition.

The matter which flows into a building can be classified as being from three primary sources: Natural, Synthetic, or Lithospheric (Table 3). Natural materials are substances which occur naturally within the biosphere. While they may be processed in some way by humans before incorporation into buildings, these materials could be returned to the biosphere and be reassimilated by nature. Synthetic materials, on the other hand, cannot be metabolized by cells and therefore become molecular garbage. While lithospheric materials occur naturally, their presence in the biosphere is problematic because they are persistent and often toxic. Although there are natural processes that redeposit these materials into the Earth's crust, the rate is significantly slower than current rates of extraction.

Natural	**Lithospheric**	**Synthetic**
Wood	Steel	CFCs
Bricks	Mercury	Pesticides
Glass	Lead	PCBs
Jute	Aluminum	Plastic
Soil	Gypsum	Ceramics
Cellulose Insulation	Mineral Wool Insulation	Polystyrene Insulation
Stone	Bituminous Pavement	Solvents
Rubber	Concrete	Synthetic Paints/Finishes

Table 3: Classification of Typical Building Materials

The Natural Step does not dictate which materials should be used; the system conditions state only that we must avoid the *systematic accumulation* of Synthetic and Lithospheric materials in the biosphere. Recycling of materials is an important strategy for minimizing their accumulation in nature. Using recycled Synthetic or Lithospheric materials in place of virgin materials causes comparatively little systematic increase; however some of these materials will still accumulate because recycling is not 100 percent efficient.

In selecting indicators for System Conditions One and Two, we chose to take account of Synthetic and Lithospheric materials which flow into and out of a facility over its life cycle, as well as to assess the source and destination of materials in terms of recycling. No attempt was made to consider the rate at which lithospheric materials are reassimilated by the Earth. It was assumed that this rate was so slow as to have an insignificant effect.

System Condition Three: Productivity and Diversity of Nature

System Condition Three is based on avoiding deterioration of the physical life support system of nature by maintaining the productivity and diversity of ecosystems. An important consideration for built facilities with respect to this condition is the sources of Natural materials used in buildings. Also important are impacts caused by the flows of materials and energy out of the facility and direct and indirect disturbances caused by the presence of the facility on its site.

The flow of Natural materials into the facility over its life cycle is important in terms of whether or not those materials are virgin or recycled, just as for the previous system conditions. Virgin materials can be categorized into two classes: those which come from sustainably harvested sources, and those which do not.

In addition, the flow of substances out from the facility is an important consideration for System Condition Three. What becomes of the waste which is not recycled or composted is important due to the potentially significant environmental impacts resulting from disposal methods such as landfilling or incineration. According to Condition Three, all waste materials should be either completely reused or recycled by humans, or be of a quantity and nature assimilable by natural ecosystems without damage to the productivity of those systems.

Finally, built facilities have impacts to ecosystems directly by virtue of their existence on a site. These impacts include direct displacement of ecosystems by the building footprint, erosion, process residuals and emissions, noise, pesticides, changes in biodiversity due to landscaping practices, and reduced soil permeability. To capture the multitude of potential on-site disturbances, we chose to include a single subjective qualitative measure, Level of Site Ecosystem Disturbance. By trying to capture the essence of on-site disturbance in one subjective rating, we hope to maintain the generalizability of the matrix to other facilities while allowing factors important to specific facilities to be incorporated as necessary. Some examples of indicators which could be included as part of this subjective rating are changes in water, soil, or air quality, landscaping maintenance requirements, volumes of emission or soil erosion, and percent of site disturbed during construction.

System Condition Four: Fair and Efficient Use of Resources

System Condition Four specifies a fair and efficient use of resources with respect to meeting human needs. Three general categories of indicators emerge as important with respect to this system condition: Resource Efficiency, Resource Fairness, and Satisfaction of Human Needs. For the matrix, we elected to include these categories as qualitative indicators, using specific quantitative indicators as appropriate to support each rating within the context of individual facilities.

The first category, Resource Efficiency, is based on the quantity of matter and energy which are used to achieve the desired objectives of the facility. The objective reflected by this category is to maximize the return per unit of resources consumed in terms of the building's ability to meet human needs. Quantitative indicators include materials or energy used per square foot of facility area, or per unit product produced. Another possible indicator is the quantity of waste materials out per unit of materials in to the facility system.

The second category, Resource Fairness, was harder to operationalize in terms of specific building indicators. The question "Fairness to whom?" resulted in lengthy discussion about the role of technology in achieving ethical ends, especially the scope of impacts for which a technology could be held responsible. For example, is a resource-rich building in the United States a fair use of resources when there are humans whose basic needs are not being met in other parts of the world? Should we be constructing facilities to create “luxury” products when the resources used by those buildings could be used to fulfill unmet human needs?

We concluded that the most useful indicators of the quality of resource fairness were reflective of the appropriate scaling and design of the facility to meet anticipated needs. For example, is the facility overdesigned in terms of its expected use? For commercial or residential facilities, what is the percent occupancy of the facility? To what degree is the building actually being used? We felt that judging the facility on the basis of its relevance to meeting basic human needs, especially needs of people who are not direct users of the facility, was unreasonable because of the unlikeliness of the resources used in the facility actually being redirected to needy people if the building were not to be built. Thus, Resource Fairness is based on how well the capabilities of the building are actually being used.

The third category, Satisfaction of Human Needs, is based on how well the building meets the needs of humans who are affected by it. In considering indicators for this category, we realized again that scope of consideration was critical. Obviously the degree to which the building meets the needs of its direct users is of primary importance, but what about the needs of humans who are involved in its construction, or in the harvesting and processing of the materials which comprise it? For the purposes of this analysis, we elected to limit the scope of consideration to direct users of the facility. Quantitative indicators to support this category include indoor environmental quality, health and safety indicators, accessibility to building amenities, and other indicators such as aesthetics or facility pleasantness. Traditional indicators of building performance such as level of service, indoor air quality, code compliance, and structural serviceability also fall into this category.

CONCLUSIONS

Although the matrix approach simplifies building-related data, evaluating facility sustainability is still a complex issue. The subjective and intelligent human mind is still necessary to interpret and amalgamate the information. We see this contribution as a work in progress, and hope that others will provide suggestions for how to improve the matrix. Undoubtedly new indicators will arise, which may prove to be more accurate in measuring sustainability. The primary purpose of compiling these familiar indicators into a matrix evaluation tool was to provide a framework for building evaluation based on The Natural Step. Our contribution is the particular configuration of indicators and the way they support The Natural Step.

To apply The Natural Step to a specific domain, such as the built environment, requires care in interpretation to ensure that indicators provide a complete representation of each system condition. Careful indicator selection also helps to ensure that other objectives such as data availability are met. With some of the System Conditions, especially Condition Four, context sensitivity is critical to selecting appropriate indicators. To maintain generalizeability, we chose to summarize in the form of qualitative indicators. However, the particular configuration of artifact context and stakeholder information requirements should be taken into consideration when selecting quantitative indicators for these conditions.

ACKNOWLEDGMENTS

Grateful acknowledgment is given for the financial support of this effort by Interface Research Corporation, Georgia Institute of Technology, and the National Science Foundation. The application of this matrix is currently being tested on Prince Street Technologies' facility in Cartersville, Georgia and has been made possible by the gracious assistance of Adam Longino and Randy Hatch of Prince Street and Ken Ackerman of Weeks Construction.

REFERENCES

[1] National Science and Technology Council. (1994). *Technology for a Sustainable Future: Framework for Action*. Office of Science and Technology Policy, Washington, DC.
[2] Hawken, P. (1995). Presentation to Monsanto Global Forum, June 29.
[3] Robèrt, K.H. (1991). “Educating the Nation: The Natural Step,” *In Context*, 28, Spring, 10-15.
[4] Robèrt, K.H., Holmberg, J., and Eriksson, K.E. (1994). “Socio-ecological Principles for a Sustainable Society - Scientific Background and Swedish Experience”. *Ecological Economics*.
[5] Zachary, J. (1995). *Sustainable Community Indicators: Guideposts for Local Planning*. Community Environmental Council, Inc., Gildea Resource Center, Santa Barbara, CA.