Sustainable Design and Construction Strategies for the Built Environment

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Introduction

Over the last few years, a diverse number of public- and private-sector organizations around the world have given increased attention to the problems of excessive natural resource consumption, depletion and degradation; waste generation and accumulation; and environmental impact and degradation. Since the construction industry is a major contributor to these problems, it now faces increasingly restrictive environmental conservation and protection laws and regulations, the emergence of international standards to address environmental quality and performance such as ISO 14,000, and substantial pressures from civic and private environmental groups. As a result, private and public sector owners face new, complex, and rapidly changing challenges imposed by these laws, regulations, standards, and pressures at all life cycle stages of a capital project, from initial planning, design, construction, and operation/maintenance, to ultimate rehabilitation, decommissioning and/or disposal. Furthermore, traditional approaches to capital projects of mere environmental regulatory compliance or reactive corrective actions such as mitigation or remediation have proven to be consistently costly, inefficient, and many times ineffective.

There are strong incentives for the development of a sustainable approach to capital projects. Such an approach goes beyond the traditional focus on cost, time, and quality performance to include the goals of minimal (1) natural resource consumption, depletion and degradation, (2) waste generation and accumulation, and (3) environmental impact and degradation, all within the contextual satisfaction of human needs and aspirations. These goals are explicitly and systematically incorporated within the decision-making process at all stages of the life cycle of a capital project, particularly the early funding allocation, and the planning and conceptual design phases. However, most stakeholders within the capital project delivery process (i.e., owners, planners, designers, vendors/suppliers, constructors, users/operators) face a complex task when attempting to implement a sustainable approach. First, they already face the challenges imposed by increasingly limited resources on the effective and efficient delivery of capital projects. Second, they do not have clear incentives, the proper resources, nor the mechanisms or tools to do so. Finally, there is a lack of awareness and understanding of the actual or potential impact and/or implications of environmental regulations and standards on capital projects; a lack of awareness and understanding of the opportunities and potential benefits to an organization created by a sustainable approach to its capital projects; and finally, a lack of credible and reliable quantitative indicators, metrics, and/or data on the actual benefits and associated costs.

A sustainable approach to capital projects would allow the U.S. construction industry to take a more aggressive role in finding both short-term and long-term solutions for a more effective and efficient use of its increasingly limited and tight capital resources. The anticipated beneficiaries of the results from this research project include: owners, who would directly accrue the economic benefits of the implementation of specific strategies for investment, execution, and management of capital resources within a sustainable framework; designers and constructors, who could significantly enhance environmental quality and performance of capital projects, as a

result of the application of specific guidelines for sustainable design and construction; and vendors and suppliers, who would have a strong incentive to develop and supply sustainable construction technologies, systems, products and materials.

A New Paradigm for Development

The development path that humans have taken, particularly since the industrial revolution, has proven to be detrimental to the health of ecological context of the world. Thus, as the dawn of a new century approaches, the current pattern of unsustainable, inequitable and unstable asymmetric demographic and economic growth has forced many segments of society to come together in facing a critical challenge: how can societies across the world meet their current basic human needs, aspirations and desires, without compromising the ability of future generations to meet their own needs? At the core of this challenge is the question: how can the human race maintain in perpetuity a healthy, physically attractive and biologically productive environment? (Malone 1994)

Sustainable development offers a new way of thinking which reconciles the human drive to improve quality of life with the limitations imposed by the global context. It requires unique solutions for improving 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 for future generations, most interpretations and definitions 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 (National Science and Technology Council 1994). Thus, sustainability is a relationship or balancing act among many factors (economic, social, and environmental and realities and constraints) which are constantly changing. As one expert has defined it "*Sustainable development is a process of change in organizing and regulating human endeavors so that humans can meet their needs and exact their aspirations for current generations without foreclosing the possibilities for future generations to meet their own needs and exact their own aspirations*" (Weston 1995). Because sustainability is a dynamic concept rather than a static state, it requires decision makers to be flexible and willing to modify their approaches according to changes in human needs and aspirations, the environment, or technological advances.

The recent global attention to the issues and challenges of sustainable development is forcing industries to conduct self-assessments to identify where they stand within the framework for sustainability, and more importantly, to identify drivers, opportunities, strategies and technologies that support achieving this goal. However, in order to understand the changes that need to be made to achieve sustainability, it is useful to look at the paradigm which is currently being employed. Despite a wide range of positions and opinions on the subject, there is general agreement that the current paradigm of development, which disregards constraints to material resources and/or energy consumption, is unsustainable. This paradigm, which has prevailed over the last few centuries, is based on an unsustainable linear approach to development that begins with the extraction and use of primary natural resources, both renewable and non-renewable natural resources such as air, water, soil, mineral or biological resources. These resources are then used for energy production and use, and as inputs to resource processing and manufacturing processes. The results of these processes are industry-specific products or services that are eventually transported and commercialized, and ultimately used and consumed across all segments of society. The process is linear because from an initial extraction of resources, all inputs and outputs move in one direction until disposed, going through the system only once with

no recovery of materials. Aggravating this situation even more is a continuous increase in the demand, use, and consumption of products and services, which creates pressures for further extraction of natural resources, and for continued expansion of energy production, resource processing, and manufacturing capabilities. This unrelenting growth has created three serious problems: excessive natural resource consumption, depletion, and degradation (both renewable and non-renewable); waste generation and accumulation (including organic and inorganic, and hazardous and non-hazardous); and environmental impact and degradation (on the air, water, land, biota). These are the challenges that must be overcome to achieve sustainability.

Conversely, a sustainable approach to development is not a linear process, but rather a closed cyclical system, such as the one for the manufacturing industry shown next in Figure 1. The total integrated system includes the same elements described earlier as a part of the unsustainable linear development approach (mining, material processing, product manufacture, distribution, and use). However, it additionally incorporates four new elements, each a response to a specific sustainability challenge: (1) *natural resource management* addresses the need to manage the extraction of renewable natural resources from the environment (air, sea, land) in a way that ensures that the supply will always exceed the demand, and at the same time, monitors and controls the use of non-renewable natural resources to prevent their total depletion; (2) *resource recovery* addresses the need to reduce the amount of waste that requires disposal by recovering selected resources and products from waste, including direct reuse, remanufacture of reusable components, reprocessing of recycled material, and monomer/raw material generation; (3) *waste disposal* recognizes that a certain amount of waste is inevitable, and thus will require disposal in ways that are not detrimental to the environment; and (4) *environmental technologies* address the need to incorporate proactively, within every element of the system, strategies and mechanisms that mitigate environmental impacts at the root (i.e., before the impact happens, through the application of preservation, pollution prevention, avoidance, monitoring, assessment and control strategies and mechanisms), and also to implement corrective actions such as remediation or restoration when some damage to the environment already has been done.

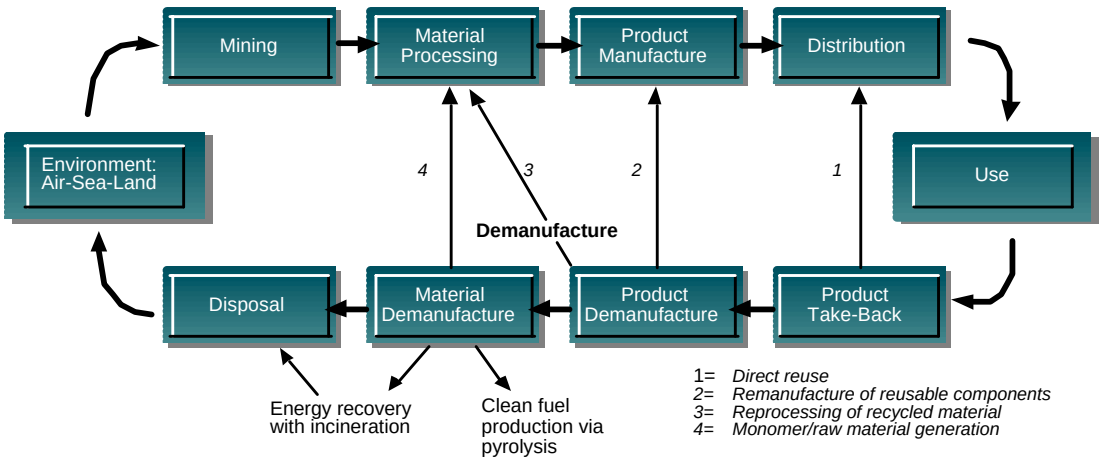

Figure 1.– A Sustainable System for Manufacture
[developed from material found in (Bras, 1996)]

Sustainability and the Building Construction Industry

For the construction industry specifically, achieving true sustainability will require a paradigm shift, similar to the one facing the manufacturing industry, that strives toward a sustainable approach to development by integrating sustainable strategies at all phases of a facility's total life cycle. First, instead of thinking of the built environment as an object separate from the natural environment, it should be viewed as part of the flow and exchange of matter and energy which occurs naturally within the biosphere. In addition to the non-living components which make up the built environment, planners, designers, and constructors of sustainable facilities must also consider the living components of the built environment (flora, fauna, and people) which operate together as a whole system in the context of other ecosystems in the biosphere (Yeang 1995). Furthermore, people who make project decisions with sustainability as an objective will need to evaluate the long-term as well as short-term impacts of those decisions to the local and global environments. And those who take a sustainability approach to planning, design, and construction will be rewarded with reduced liability, new markets, and an earth-friendlier construction process, which will help future and current generations to achieve a better quality of life (Kinlaw 1992, Liddle 1994).

Planners, designers, and constructors of sustainable facilities need to approach each project with a focus on the entire life cycle of the facility, not just the initial capital investment. Life cycle considerations are particularly important because each phase builds upon, and is constrained by the decisions made on the preceding one. Also, choices of more costly design alternatives or features may be offset by cost, resource, and energy savings realized over the life cycle of the facility. Finally, changes are easier to make during the planning and design phases or a project, and their costs are lower, since the facility exists only "on paper" as opposed to being a physical artifact which exists in reality after construction begins and ends. Thus, the primary responsibility for creating sustainable built facilities falls to the planners, designers, and constructors of such facilities.

Figure 2 illustrates the primary paradigm shift to sustainability within the building design and construction industry. This model of the new sustainability paradigm shows issues which must frame the decision-making at all stages of the life cycle of the facility. While traditional design and construction focuses on cost, time, and quality objectives and performance based on the functional and formal requirements of the facility, sustainable design and construction goes beyond these criteria. It incorporates explicitly and proactively within the decision-making process, the goals of minimal natural resource consumption, depletion and degradation; minimal waste generation and accumulation; and minimal environmental impact and degradation. At the base of this new paradigm is the contextual satisfaction of human needs and aspirations.

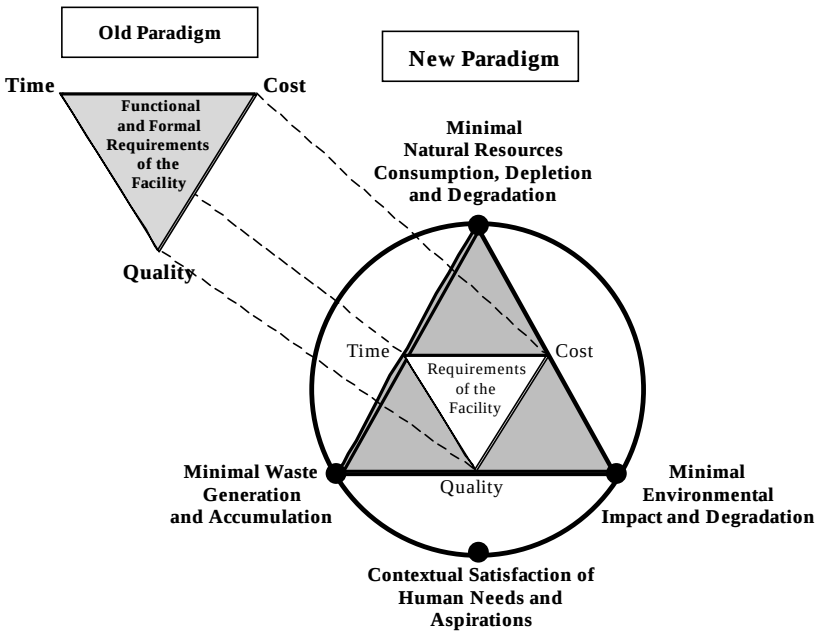

Figure 2.– Paradigm Shift from Traditional to Sustainable Design and Construction
[developed from (Vanegas et al., 1996)]

Specific Strategies

Within this new paradigm, specific strategies emerge to support each of the four goals described above. The are briefly listed next.

- *creating a healthy built environment:* a healthy facility requires consideration of the interfaces between the built environment and the natural environment, use of materials that are non-toxic in their manufacture, use, and disposal, and incorporation of design features which convey aesthetic or spiritual values conducive to the tasks and activities which occur within the facility.
- *integrating the built environment into ecological systems:* designing resource and energy flows into and out of the built environment to fit within the yield and assimilative capacities of its ecological context creates a symbiotic relationship between the two, which can be mutually beneficial to humans and nature, provided that humans do not exceed the assimilative capacity of natural systems.
- *revising economic valuation of projects:* developing better tools for cost-benefit analysis, financial forecasting, and long term prediction, and also revised economic valuation schemes which assign meaningful values to reserves of natural resources and ecological habitats can prove essential to assess the economic viability of sustainable projects.
- *avoiding the need for new infrastructure:* making better use of sites and facilities which have already been used, rather than greenfield sites for new development, reduces negative impacts on the natural environment, minimizes costs related to extending utility and transportation systems to greenfield facilities, and reduces travel time for users.

- *reusing, rehabilitating, and retrofitting existing facilities:* by using techniques such as adaptive reuse, rehabilitation, or retrofitting, old facilities can be modified or improved to meet new use criteria, at a much lower consumptive cost than building a new facility.
- *recovering waste: reducing, reusing, recycling:* by using techniques such as reduction, reuse, or recycling, resources and energy that would traditionally be considered waste can be used in new productive ways.
- *improving effectiveness and efficiency of existing construction technologies:* improving the technological efficacy and efficiency of construction materials, construction equipment, and construction methods and processes can minimize the consumption of resources and energy.
- *adapting historical building technologies:* combining the knowledge of historical building techniques, especially those that are benign to the environment, with selected aspects of new technologies may lead to a new generation of sustainable technologies.
- *developing new sustainable technologies:* creating innovative sustainable technologies which do not rely on traditional types, sources, or quantities of materials and energy, yet still meet performance requirements, can significantly reduce consumption of resources and energy.
- *incorporating users in the decision-making process:* actively involving users in the decision-making process at all phases of the facility life cycle creates an awareness among the users of the interfaces of the facility with its environmental context, and a respect for the flows of energy and material through the built environment over time.
- *reshaping human aspirations:* by improving education and increasing awareness of the impacts of their choices for the built environment on the ecosystems of which they are a part, people may select alternatives that support sustainability.

Conclusion

The principal conclusion of this paper is that the area of sustainable strategies for the built environment is one of increasing interest which has many levels and complex dimensions. In this paper the authors have tried to stress the importance of adopting a new paradigm for development which goes beyond the traditional focus on cost, time, and quality performance. Goals of minimal natural resource consumption, depletion, and degradation, waste generation and accumulation, and environmental impact and degradation, need to be explicitly addressed and incorporated at all stages of the life cycle of a project. Above all, the contextual satisfaction of human needs and aspirations should be a driver. In order to achieve sustainability for society as a whole and for the Architecture, Engineering, and Construction (A/E/C) industry in particular, intelligent decision making is required which includes full consideration and knowledge of the many trade-offs and impacts associated with each alternative available to be chosen. Sustainability is a desirable state towards which to strive, but the journey is not easy.

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