ESTABLISHING PRINCIPLES AND A MODEL FOR SUSTAINABLE CONSTRUCTION

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Introduction

A newly and rapidly emerging arena of construction industry concern and interest is sustainable or "green" construction. Projects such as the Recycled House in Odense, Denmark, ReCraft 90 in Montana, Florida House in Sarasota, Florida, and the Green Builder Program in Austin, Texas, and many other projects in Europe and elsewhere mark the start of a new era that has sustainability as perhaps the major objective in creating the built environment. Construction industry senses the need to be more environmentally responsible and is seeking to conduct its operations to minimize negative environmental impacts. To the traditional criteria of performance, quality, and cost for building materials, products, and systems must be added a set of criteria and principles that center around environmental impacts, described here as sustainability criteria.

The present day greening of construction has its roots in the oil crises of the 1970s. These traumatic events resulted in a major movement towards energy conservation, energy efficiency, and alternative energy sources. A second series of crises over local water shortages in the recent past has spurred the development of more water conscious design. Indoor air quality, sick building syndrome, and groundwater contamination have forced us to remove toxics from our interior spaces and reconsider the use of chemicals on our landscaping. The notion presented in this paper is that all these issues are interconnected, that they can and should be covered under the heading of "sustainable construction."

The purpose of this effort is to establish the sustainability criteria for construction, define the issues and principles of sustainable construction, and create a model for the construction industry to use a tool for understanding and evaluating alternative approaches to achieving a more environmentally sound built environment.

Traditional versus Sustainable Criteria

The concept of sustainability is not a new one but became a part of the environmental vernacular in 1987 when Gro Brundtland, the Prime Minister of Norway authored the Brundtland Report in which she described sustainability as "leaving sufficient resources for future generations to have a quality of life similar to ours." An environmental movement oriented toward sustainability emerged about this time and began affecting all segments of society and commerce, including, albeit slowly, construction industry. In the description provided here we have included the two sustainable environment criteria, minimizing resource depletion and preventing environmental degradation, and added a third criteria connected to providing a healthy environment. This last criteria connects extensive efforts to provide good indoor environmental quality and the elimination of toxics from the building outdoor environment (pesticides, fungicides, herbicides, fertilizers) with the first two sustainability criteria (Table 1).

Traditional Criteria	Sustainability Criteria
• Performance • Quality • Cost	• Resource depletion • Environmental degradation • Healthy environment

Table 1 Traditional and Sustainability Criteria for Building Materials, Products, and Systems

A major challenge at present is to provide a means for construction industry to act on its obligations to achieve sustainability. This is not an easy task because the wide variety of issues causes us to formulate several varieties of criteria that do not easily indicate the interconnectedness or coupling of the issues. The criteria for energy and water sustainability are reasonably straightforward to state. At present there is significant effort underway to establish what may be termed technical criteria as a means of quantifying the environmental effects of our materials choices for creating the built environment. The challenge is how to present all the criteria and options in a model or tableau that can serve as a tool for the industry to use in assessing the wide range of alternative materials, products, and systems.

The Issues of Sustainable Construction

The first step in the process of establishing evaluation tools is to set forth the issues that are encompassed by sustainable construction. Although we have alluded to some of these earlier, the proposed set is shown below (Table 2).

Resources	• Energy Consumption • Water Use • Land Use • Materials Selection
Healthy Environment	• Indoor Environmental Quality • Exterior Environmental Quality
Design	• Building Design • Community Design
Environmental Effects	• Construction Operations • Life Cycle Operation • Deconstruction

Table 2 The Issues of Sustainable Construction

Indoor Environmental Quality (IEQ) includes the provision of good Indoor Air Quality (IAQ), lighting, noise control, and temperature/humidity control. Exterior Environmental Quality (EEQ) seeks to remove fertilizer and toxics such as pesticides, herbicides, and fungicides from landscape maintenance and minimize the need for landscape irrigation.

Excellence of design at all levels is crucial for several reasons. First, the creation of passive heating, cooling, and lighting systems cannot be accomplished without good design and adequate tools to carry it out. Second, buildings and communities need to be well-designed to induce the occupants to maintain and care for them. There have been many cases of failed communities and buildings that have their roots in poor design. Additionally community scale design must consider transportation, infrastructure, and other issues for the community to be successful.

Construction operations consume energy, create substantial noise, and can cause significant damage and product large quantities of waste. Changes in process are needed to protect the environment during these operations. Life Cycle operation must carry forward the intent of the design, maintaining the performance of the systems and renovating and retrofitting in the same sustainable mode. Finally the deconstruction or demolition of the building, hopefully after many years of use, should result in a source of materials for new construction. This implies that materials and products that were utilized in creating the structure were selected for either their recyclability or ability to be composted and returned to the earth as biomass.

Technical Criteria

At the present time, in order to determine appropriate decisions that will improve the creation of the built environment, technical criteria are often applied to the materials selection process. Reducing these to easily manageable information produces essentially three overarching criteria (Table 3).

1. Embodied energy content
2. Greenhouse warming gases
3. Toxics generated/content

Table 3 Technical Criteria for Materials Selection

Each of these technical criteria are fraught with difficulties that make their application on other than an academic level quite difficult. Embodied energy, a quantification of the amount of energy needed to extract resources, manufacture products, install them into the building, and transport them between the various phases, gives us a tool for comparing the amount of a single resource, energy, in products. Thus we can determine which of several structural systems (wood, steel, concrete) has the lowest energy inputs. Unfortunately embodied energy provides us with no information about whether the resource is recyclable or renewable and it varies greatly depending on assumed transportation distances.

A second common criterion now appearing in the literature is the quantity of greenhouse warming gases emitted during manufacture of materials. Greenhouse warming gases such as carbon dioxide and methane are created in the production of materials, with the implicit assumption that fossil fuels are the energy sources. However nuclear energy produces no greenhouse warming gases per se. If greenhouse warming gas quantity were a major criterion, France, which produces in excess of 80% of its energy via nuclear power plants, may have to be considered as the source for all construction products. On the other hand nuclear power plant construction has massive greenhouse gas emissions associated with the huge quantities of concrete and steel that comprise them. The complexities of these conditions make reliance on this parameter very difficult and perhaps unjustifiable.

This same notion holds true for the third criterion. When toxics are considered in the materials creation processes, the assumption is that fossil fueled energy systems will be used, resulting in the presumed generation of sulfur and nitrous dioxides and other substances. Again, given a wide variety of processes for most materials, the assumptions of toxics generation quantities are very speculative and not very useful.

When selecting a material or system we are then forced to examine the mix of these technical criteria to make a decision. A classic one in the U.S. is the selection of wood or steel framing for the structure of single family housing. A quick reaction might be to state that wood has low embodied energy and generates only small quantities of greenhouse gases. However what if the steel is 100% recycled and the wood comes from a poorly managed monoculture forest? Which is the better choice? Further we can argue that removing the tree from its carbon dioxide absorption role is in fact a huge net contributor to greenhouse warming gas contribution. The situation becomes murkier the deeper we probe.

The problem presented here is a classic one: how to reflect environmental impacts in the costs of the products, whether it be groundwater pollution, waste disposal, toxics generation or others. Many of these costs are externalities, that is, air and water serve as sinks for waste and pollution with no assessments made against the polluters (Pigou, 1935). Society as a whole must absorb the costs via health impacts, lowered quality of life, and environmental remediation. The ultimate goal in this regard must be to internalize these costs and reflect them in the price of the product. "Tax pollution, not production" must be the creed of this new order (Hawken, 1993). Another approach to articulating this situation is to note that production can be said to be in private hands and the depletion of resources, the owner's wealth, motivates stewardship or conservation of resources. Pollution, an outcome of production, occurs to environmental sinks of air and water, that are not privately owned, with no motivation for stewardship on the part of the producers (Daly, 1993). The sources for resources, the wealth, can be divided up and fenced while the sinks, the destinations for pollution, cannot.

Principles for Sustainable Construction

Technical criteria for materials selection are too difficult to apply in the real world of construction. In the past the criteria for energy and water resources were not connected to one another, to materials selection, or to the other issues of sustainable construction.

In this light a major challenge is establishing the principles of sustainable construction and creating a common vocabulary that can be used to exchange information, define methods, create appropriate materials, transition technology, and accomplish other related activities. The principles must be sufficiently broad to cover the issues of sustainable construction and flexible enough to adapt to evolving technologies. They must also be easy to utilize to evaluate alternatives. Creating the built environment with environmental awareness and sensitivity would be the outcome of using the principles.

For the purposes of this discussion, we must first define what is meant by "construction industry." We will use the broad definition: all parties that design, build, alter, or maintain the built environment over its life cycle: developers, planners, architects, engineers, builders, and operators. We can further separate the industry into two layers. Layer 1 are those agencies who most influence the physical content and creation of the built environment because they have design and execution roles: architects, engineers, and builders. This triumvirate uses the sustainability principles to specify and lay out the structures and infrastructure of the built environment and then bring the resources to the site to construct the structures. Layer 2 are those units who influence the built environment on either end of the construction process: developers, planners, and operators. Developers have powerful influence over the location of elements of the built environment and the fate of the land that will be utilized. Planners spell out the details of the interaction of the individual components or units of the built environment. Operators or facility managers begin a huge investment of energy and other resources over the life cycle of the building and need to be integrated into the process so that they will insure the principles of sustainable construction are kept in mind.

To begin the development of these principles we must first understand that sustainable construction is just one component of creating an overall sustainable environment. This latter overarching goal has the direction of insuring that we leave the world in a condition that will allow future inhabitants to enjoy at least the quality of life we have experienced. Simply put this can be accomplished by eliminating (1) resource depletion, and (2) environmental degradation. As noted earlier we can add (3) create a healthy environment, accounting for the need to have good interior and exterior environments. Sustainable construction principles must also focus on these three goals in order to make sense and have merit.

We will define the resources to create the built environment as: energy, water, materials, and land. There are arguably other resources such as human energy and creativity, waste materials, and information. Water may also be considered to be a material. However for our purposes the division of resources into these four categories is logical and useful. We can then propose Six Principles of Sustainable Construction (Table 4).

1. Minimize resource consumption (Conserve)
2. Maximize resource reuse (Reuse)
3. Use renewable or recyclable resources (Renew/Recycle)
4. Protect the natural environment (Protect Nature)
5. Create a healthy, non-toxic environment (Non-Toxics)
6. Pursue quality in creating the built environment (Quality)

Table 4 The Principles of Sustainable Construction

Each of the Six Principles has huge ramifications that need exploration. The Sixth Principle is a repeat of one of the traditional criteria but is included because of a new sense and importance attached to it. The following sections cover the principles in sufficient detail to underscore their importance and the range of their application.

Principle 1: Conserve
Another label for the First Principle might be the Conservation Principle because this is its essence. It is the starting Principle because it contrasts the major problem that forces us to address sustainability in the first place: overconsumption. It leads us to the use of passive measures to provide heating, cooling, ventilation, and lighting for our structures because the minimization of energy consumption is an absolutely essential. It forces us to consider high efficiency systems, high levels of insulation, low flow fixtures, and high performance windows. It also leads us to the use of durable materials that have long lifetimes and require low maintenance.

Principle 2: Reuse

In addition to reducing resource consumption to the minimum we need to consider that it is highly desirable to reuse resources we have already extracted. Reuse contrasts to recycling in that reused items are simply used intact with minimal reprocessing while recycled items are in essence reduced to raw materials and used in new products. A significant business in architectural items such as windows, doors, and bricks that can be reused in new construction and renovation has proven to be profitable as owners and architects strive to recapture a sense of the past in new spaces. Other resources such as water can be reused via use of graywater systems and use of third main systems. Land can be used by creating new spaces in "gray zones," areas formerly used for buildings.

Principle 3: Recycle/Renewable

If resources must be used then it resources that are recyclable, have recycled content, or that are from renewable resources must have priority over others. This Principle applies to energy where renewable sources such as solar and wind power are available for use. It applies to materials such as wood. This common construction material can be supplied from certified sustainable forests that provide the buyer with a reasonable level of assurance that the suppliers are managing their resources in a manner that protects the environment. A wide range of materials have recycled or waste content from engineered wood systems, agriboard panels, tiles with recycled tire or glass content, roofing shingles made of recycled plastics, and many others. One of the problems that must be sorted out with respect to recycled materials is to determine if their content is simply convenient waste from other industries or bona fide recycled content. Products that consist of the former may be said to be downcycled or cascaded uses with the built environment serving as a convenient dumping ground for otherwise difficult to dispose of materials. Some schools of thought would place the onus on each industry to solve its own "end of pipeline waste" problems and not simply seek out convenient large dumping grounds such as construction materials as a repository for their industrial residue. This is not a simple problem, however, nor should it be treated tritely. Fly ash, a post-industrial waste, is successfully utilized to displace cement in concrete, a high energy content material and one of the largest generators of carbon dioxide. An inevitable by-product of steel production and power generation, it is a major disposal headache for these industries, and a waste that will be produced for many decades as a consequence of dependence on fossil fuels as an energy source. One could cite several other examples that make sense at the present time but that as technical evolution and innovation occur, may be relegated to their proper place.

Principle 4: Protect Nature

Inevitably our actions in creating the built environment will impact the natural environment and its ecological systems. Considering the past negative effects on the natural environment, perhaps it is time to do better than just "sustain," but to "restore" where possible. Gray zones can be remediated, detoxified and returned nearly to their original state. The abuses of river straightening, marsh draining, and deforestation can be remedied by intelligent intervention in creating the future built environment. In our quest for materials we can scrutinize the impacts of materials acquisition practices, whether logging, mining, or consuming energy, to minimize environmental effects. Some of the choices are not easy but will be inevitably be forced on us by global environmental effects, scarcity, or other reasons.

Another expression of Principle 4 is to exercise environmental stewardship. This acknowledges the human power to destroy the world's complex ecological systems and reminds us that we must tread carefully less we destroy ourselves in the process. The complex tapestry of earth's many natural resources evolved over many thousands of centuries and the interdependence of life forms on one another and on other resources is barely understood. Clearly we have no notion of what extinction of one life form may do to others nor do we have the smallest grasp of what the results of man's genetic engineering experimentation may be. Our recent experience with both pesticides and antibiotics are merely preliminary warnings to what disasters may lay ahead. Creating the built environment, while perhaps not having these same complex impacts, can lead to resource depletion, destruction of plants and wildlife, water and air pollution.

Principle 5: Non-Toxics
Modern industry has created a wealth of miracle products, drugs, chemicals, and machines that have had many positive contributions to the quality of life of man. One of has been the proliferation of toxic substances produced by these industries that have invaded the environment and had inevitable negative effects on humans. Lead, mercury, asbestos, and dioxins come quickly to mind. The products constituting the built environment and the actual construction of the built environment are accompanied by a wide variety of hazardous and toxic substances that ultimately threaten human health and well-being. This is another area, similar to the appropriateness of downcycling, that is not easily defined. Clearly toxic materials must be handled with care and eliminated to the greatest extent possible. One approach is to consider the ultimate elimination of these materials except in cases where the manufacturers can keep them in a closed system. An example of this is mercury, used in thermostats, fluorescent light bulbs, and television sets. Reverse Distribution, a procedure in which products are returned to the manufacturer for extraction of toxic materials for recycling into other products, is a new idea that the US EPA and others are beginning to consider for implementation.

The outcome of this Principle in a practical sense is the elimination of toxics in the indoor and exterior built environment. One of the major objectives is to achieve good indoor air quality by selecting materials that will not off-gas or contribute particulate loading to the environment. Relative to the exterior environment, landscape design should provide for the use of plants and vegetation that are hardy, drought tolerant, and insect resistant. These qualities are usually provided by vegetation native to the region. Using this so-called "xeriscaping" strategy will minimize and perhaps eliminate the application of pesticides, herbicides, fungicides, and fertilizers that ultimately end up polluting groundwater.

Principle 6: Quality
Although often cited and equally often abused, the notion of quality as a component of sustainable construction is vital. It includes planning of communities to reduce automobile trips, increase interpersonal activity, and provide a good quality of life. It includes excellence in design of buildings as an absolutely essential component of sustainable construction because spaces that are not valued by their occupants will, by their very nature, fall into disuse, disrepair, and disorder, contributing to the exact antithesis of what sustainability strives to achieve. Selection of materials, energy systems, design of passive energy and lighting systems, and a host of other decisions rest on the idea that significant analysis and design are required to lay out spaces, build the spaces, and occupy them.

The outcome of stating and exploring these principles is to acknowledge just how interconnected all these matters are and how badly integration of this knowledge is needed. Issues of energy crises, water shortages, air pollution, sick building syndrome, crumbling neighborhoods and infrastructure, and many others are all tightly coupled, not independent events as usually portrayed. Perhaps it may be said that one of the problems of recognizing how tightly interwoven these matters are is that the specialists in these issues have treated each of them in isolation. To solve the problems of the built environment we must discover how to integrate these isolated and compartmentalized areas of interest. Only then will we be well on our way to creating sustainable construction as an important component of a sustainable environment.

A Conceptual Model for Sustainable Construction

We can combine the Principles with the resources and the time dimension to create an easily understood model of sustainable construction. The simple version would have the three axes shown below in Figure 1. In each case the intersection Principle, Resource, and Time is a decision point for determining what should be accomplished with regard to minimizing resource consumption and preventing environmental damage. For example, during Design, when examining potential materials resources to be used, the Six Principles should be followed to minimize the materials required, reuse materials if at all feasible, use recycled or renewable materials, insure the materials used did not harm the environment in their extraction, that toxics were not generated in the materials creation nor are they potential contributors to indoor environmental problems, and that the design of the materials layout and details is of high quality, with attention paid to all these issues. The design stage should also lay the foundation for future stages so that during construction and operation the excellent environmental intent of the space is able to be maintained.

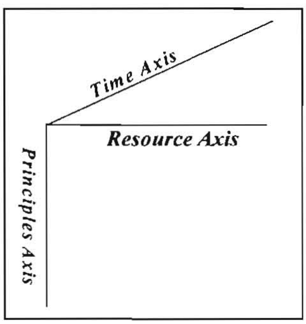

Figure 1 A Simple Conceptual Model for Sustainable Construction

Figure 2 is a more detailed version of the conceptual model and shows the principles, the resources to which the principles must be applied, and the stages of the built environment during which this must occur. For the sake of simplicity, the stage entitled *operation* also includes activities such as renovation and refurbishment.

The model can serve many functions, the first of which is the articulation of the many issues of sustainable construction. It distills a wide range of complex issues into a simple graphic that allow us to grasp, at least in a reasonable fashion, the overall idea of sustainable construction. It allows the debate to be engaged over the appropriateness of activities meant to build or maintain the built environment. A second application is a decision making tool for use in examining the options that may occur during the creation, operation, or deconstruction of buildings. In this regard it can also serve as a checklist for the sustainability issues that should be considered by the construction professions in their activities.

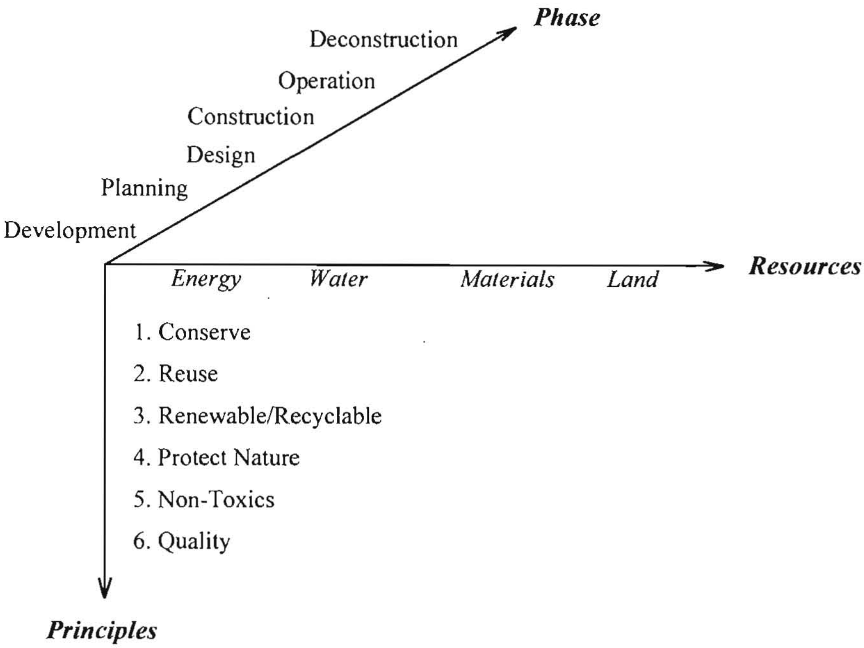

Figure 2 A Conceptual Model for Sustainable Construction

Summary and Conclusions

Construction industry must inevitably change its historic methods of operating with little regard for environmental impacts to a new mode that makes environmental concerns a centerpiece of its efforts. Construction industry has suffered a similar change with regard to safety with dire consequences. A proactive, involved industry that addresses environmental effects squarely will have a far better chance of addressing issues and finding solutions prior to government involvement on a scale that has negative consequences for the industry. The issues, principles, and model described here can be used as a means for establishing the goals of sustainable or green construction and for understanding the connection of a wide range of issues that have been treated as independent matters in the past. The era of sustainability, perhaps more than anything else, is establishing that we need to synthesize and integrate information to provide future generations with their own sustainable environment.

References

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