Industrial Ecology

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Ecological Concepts

Ecology is a science which involves the study of systems, specifically the study of the interactions of organisms, populations, and biological species (including humans) with their living and nonliving environment. The green building movement espouses that the built environment should be created using 'ecological' principles, yet their is little evidence that there is any real understanding of ecology or ecological principles on the part of the various actors in the building process. The reasons for this disconnect are fairly obvious. Foremost among these reasons is that the actors are generally designers, builders, managers, and investors with no environmental or ecological education or training. Consequently, although their intuition is that ecological literacy is an important aspect of creating a high performance built environment, adhering to ecological precepts is strictly by a 'seat of the pants' approach. A deeper understanding of ecology and ecological concepts is essential for a truly effective green building movement. Without it, these efforts are not much more than mere decor or window dressing.

Some have suggested that human industrial systems can and must use both the metaphor and actual behavior of ecological systems as guidance for their design. Current industrial systems are the equivalent of ecosystem r-strategists [pioneer species] that rapidly colonize areas laid bare by fire or other natural catastrophes. Their strategy of maximum mobility and reproduction invests all their energy in seeds and rapid growth and minimizes investments in structure. r-strategists are mobile, surviving by being the first at the scene of a disturbance and securing resources before they are eroded away. However when the resource base has been expended, their populations will diminish to very low levels. They are not competitive in the long run and only excel at outcompeting each other in a loose 'scramble competition,' eventually losing out to better strategies. In natural succession, K-strategist species supplant r-strategist species because they spend less energy on generating seeds and more on systems such as roots that will enable their survival during periods of lower available resources. K-strategists live in synergy with surrounding species and are far more complex than the other the r-strategists. K-strategists, unlike r-strategists, are not mobile but survive longer at higher density by developing highly efficient resource and energy feedback loops. K-strategists invest more in structure than mobility and this is the template around which their complex interrelationships efficiently conserve the flow of energy and resources.

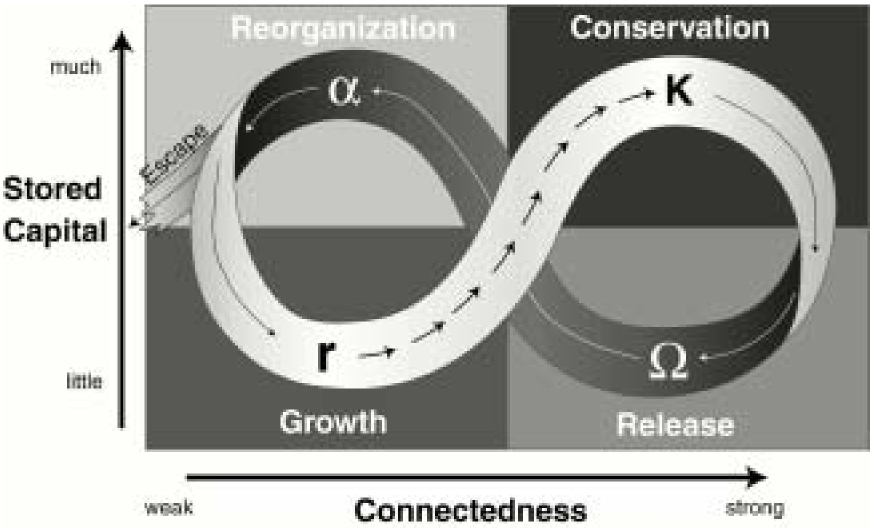

Figure 1 Ecological systems from the point of view of 'adaptive management.' Ecosystems have cyclic behavior starting with a growth, r-strategy in which energy is directed toward growth and reproduction, eventually shifting to a synergistic K-strategy in which species occupy specialized niches. Ecosystems are eventually upset and crash (e.g. through disease or fire), moving rapidly through Ω- and α-stages back to a point where it can cycle back into its original system or exit into a totally new system (the Escape) in the diagram above). A forest can cycle through multiple iterations as a pine forest but exit into a state as a cypress swamp.

In a similar manner it could be said that industrial systems behave in a similar fashion. r-strategist industries employ the typical industrial processes of today, linear systems with little or no recovery of materials from the waste stream. Closed-loop K-strategist industrial ecosystems with full materials recovery do not exist at present, partially due to a lack of technology, partially due to poor product design, partially due to thermodynamic reasons and partially due to the lack of adequate economic incentives. It is only very recently that industrial products such as automobiles are being 'designed for the environment,' that is designed for reusing or recycling components and with full consideration of how to reduce the impacts on ecological systems. Today's r-strategist industrial system is simply a primitive stage in a process of never ending evolution of human designed systems that evolve in a manner similar to nature. The question for humankind emerging from this observation of nature is how to move as rapidly as possible from our r-strategy global economy to an advanced, closed materials cycle K-strategy.

The primary lesson construction industry can learn from nature is to cycle its materials in a closed-loop manner, the goal being a 'zero waste' system. This could be achieved by designing all components from recyclable materials and for quick disassembly. For example, when its useful life has ended, an air handler in a large commercial building would be returned to its producer who would then be able to quickly separate all steel, copper, and aluminum components for recycling, compost the organic insulation, and throw away essentially nothing. Building structural elements would be designed to be unpinned or unscrewed rather than demolished in place. Integrated with a similarly functioning industrial system, builders and manufacturers of building materials and products would exchange resources with automobile industry, computer chip manufacturers, and consumer products on an as-needed basis. Today's building curtain wall system may be comprised largely of yesterday's washing machine, Ford transmission, and other artifacts, all designed as part of a larger human ecosystem.

The outcomes of applying these natural system analogues to construction would be a built environment [1] that is readily deconstructable at the end of its useful life; [2] consists of components that are decoupled from the building for easy replacement; [3] is comprised of products that are themselves designed for recycling; [4] whose bulk structural materials are recyclable; [5] whose metabolism would be very slow due to its durability and adaptability; and [6] that promotes health for its human occupants.

Industrial Ecology as a Starting Point

Perhaps the most serious and developed effort at applying ecological principles to human systems is industrial ecology. Industrial Ecology can be defined as the application of ecological theory to industrial systems or the ecological restructuring of industry. In its implementation it addresses materials, institutional barriers, and regional strategies and experiments. Industrial Metabolism is the flow of materials and energy through the industrial system and is directed at understanding the flows of materials and energy from human activities and the interaction of these flows with global biogeochemical cycles. The rejection of the concept of 'waste' is one of the most important outcomes of Industrial Ecology. In an ideal industrial system, nonrenewable materials would be utilized in a closed loop to minimize the input of virgin resources. Products degraded by age or service would be designed to be reverse-distributed back to industry for recycling or remanufacturing. The processes creating the loops would be designed for zero solid waste to include zero emissions to water and air. Renewable resources would also be used in a closed loop manner to the maximum extent possible and follow the same zero waste rules as for nonrenewables. Renewable resources, being biological in origin, could be recycled by natural processes as simple biomass which could serve as nourishment for biological growth.

According to Deanna Richards and Robert Frosch, "..industrial ecology views environmental quality in terms of the interactions among and between units of production and consumption and their economic and natural environments, and it does so with a special focus on materials flows and energy use." They also go on to note that the integration of environmental factors can occur at three scales:

- microlevel (the industrial plant)
- mesolevel (corporation or group operating as a system)
- macrolevel (nation, region, world).

It is interesting to note that these three levels are identical to the levels at which natural systems are studied for their function.

Industrial Ecology has evolved in several major directions since it became well-known in the late 1980's. The first direction is the evolution of the concept of eco-industrial parks (EIP) in which waste and by-products from a group of companies are shared as resources. Sometimes referred to as 'industrial symbiosis,' the grouping of industries with compatible energy and materials waste and needs helps minimize the emissions of the industrial cluster. Extending the concept of waste energy/materials sharing to regional scale can hypothetically result in 'islands of sustainability.' The Kalundborg EIP in Denmark is the most frequently cited success story of industrial symbiosis but detailed knowledge of the materials, energy, economic, environmental, and social effects of this industry cluster are not well-known.

The second major direction of Industrial Ecology is the optimization of materials flows by increasing resource productivity or dematerialization. The notion of a service economy which sells services instead of the actual material products is considered the sine qua non of this strategy, alternatively referred to as 'systemic dematerialization.' One of the questions facing Industrial Ecology is whether corporations can profit more from closing materials loops and behaving environmentally responsibly or through built-in obsolescence and open materials cycles.

Rules of the Production-Consumption System

With respect to the system that produces the components for construction, the question remains as to how this system and, for that matter, the overall industrial system should behave if it is to follow ecological principles. A set of rules of conduct that translates or converts James Kay, an ecologist and professor at the University of Waterloo, Ontario, Canada, suggests a set of rules for use in considering how to transition today's industrial system, which would of course include construction industry, to one that is consort with ecosystems. These four rules are:

(1) *Interfacing*: the *interface* between man-made systems and natural ecosystems reflects the limited ability of natural ecosystems to provide energy and absorb waste before their survival potential is significantly altered, and that the survival potential natural ecosystems must be maintained.
(2) *Bionics*: the behavior and structure of large-scale, man-made systems should be as similar as possible to those exhibited by natural ecosystems.
(3) *Appropriate Biotechnology*: whenever feasible the function of a component of a man-made system should be carried out by a subsystem of the natural biosphere. This is referred to as *using appropriate biotechnology.*
(4) *Renewable Resources*: non-renewable resources be used only as capital expenditures to bring renewable resources on line.

The Golden Rules of Eco-Design

Stefan Bringezu of the Wuppertal Institute in Germany suggests an alternative set of rules for the industrial systems to follow in shifting course to one that adheres to ecological principles. He labels them the Golden Rules of Eco-Design and they are as follows:

(1) Potential impacts to the environment should be considered on a life cycle basis or from cradle-to-grave.
(2) The intensity of us of processes, products and services should be maximized.
(3) The intensity of resource us (materials, energy, and land) should be minimized.
(4) Hazardous substances should be eliminated.
(5) Resource input should be shifted towards renewables.

Construction Ecology

Clearly a new concept for materials and energy use in construction industry is needed if sustainability is to be achieved. As noted at the start of this paper, industrial systems in general are beginning to take the first steps toward examining their resource utilization or metabolism, and beginning the process of defining and implementing Industrial Ecology. In this same spirit, a subset of these efforts for construction industry would help accelerate the move toward integrating in with nature and behaving in a 'natural' manner. It is proposed that a Construction Ecology be considered as the development and maintenance of a built environment (1) with a materials system that functions in a closed loop that is integrated with eco-industrial and natural systems; (2) that depends solely on renewable energy sources, and (3) that fosters preservation of natural system functions. Construction Metabolism is resource utilization in the built environment that mimics natural systems metabolism by recycling materials resources by employing renewable energy systems. It would be a result of applying the general principles of Industrial Ecology and the specific dictates of Construction Ecology.

The outcomes of applying these natural system analogues to construction would be a built environment (1) that is readily deconstructable at the end of its useful life; (2) whose components are decoupled from the building for easy replacement; (3) comprised of products that are themselves designed for recycling; (4) whose bulk structural materials are recyclable; (5) whose metabolism would be very slow due to its durability and adapatability; and (6) that promotes health for its human occupants.

Cardinal Rules for the Construction Materials Cycle

Applying the ideas of industrial ecology and construction ecology would suggest that four cardinal rules can be hypothesized that should govern the flow of materials in the built environment along the lines of how ecological systems function. These rules are referred to here as the Cardinal Rules of the Construction Materials Cycle:

(1) Buildings must be deconstructable.
(2) Building products must be disassemblable.
(3) Building product materials must be recyclable.
(4) The dissipation effects of materials recycling must be harmless.

Questions for the Session Participants

- How can ecology inform building design and construction?
- What lessons can be learned from industrial ecology for application to building design and construction?
- How can ecology and industrial ecology be applied to building products and materials?
- How can we now define ecological design?
- How do we design building to be deconstructable?
- How must building products change to be able to be reused and be recyclable?
- How do we treat the concept of downcycling versus recycling?
- What are the current Best Practices and Best Available Techniques for closing materials loops?
- Are the Cardinal Rules of the Construction Materials Cycle acceptable or should they be modified?
- Which incentives must be established to encourage principles of industrial ecology in market driven economies?