BUILDING DESIGN AND ITS IMPACT ON THE ECO SYSTEM

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ABSTRACT

Since our earth has finite material resources and biological capacity, human must live within the carrying capacity on the earth.As we exceed the carrying capacity of the earth's ecosystem over the time they stressed, then go into decline and finally collapse. They are expanded further than renewed. The construction and operation of built environment contribute to the environmental loads. Those who design and purchase building have little or no methods to asses the environmental impact of their actions. Thus, there is a need to study the impact of the building design to the ecosystem and finalize the design rule for Green Building.

The qualification of a healthy built environment is judged with respect to several factors and of course parameters where one of them is how it is compatible to the environment with the ecology. Thus while designing a built environment conjoins two disciplines that is subject of architecture and that of ecology. To develop a green building and environmental building is a subject of applied ecology, where the designers understand the constitutions, organization and structure of ecosystems, and their impact of architecture are considered from environmental perspectives. By utilizing the concepts, methods and language of ecology, designers can create architecture that is very much embedded in the site and the surroundings.

To asses on the compatibility of the building with the local or regional environment there should be some criteria for assessment, which implies the definition of building design criteria. If we establish the criteria that are based to our best scientific understanding of environmental capacity that we begin to develop a building stock that is sustainable. To do this one must quantify the linkage between the resulting environmental impacts and their cause in building production and use. This are not done in traditional building environmental impact assessment methods, which are based on qualification assumed negative impacts on man made inventions on the natural environment, typically using a code complaint reference building as a standard and improved upon. These indices lack on ecologically derived base line or standard of measure, under which sustainable development can be analyzed and compared with a universal basis.

Using ecosystem services as a baseline, a duel-criteria frame can determine the sustainability. Evaluation may be done in terms of input and output. In the first case, the quantities absorbed/consumed from the ecosystem during built up process and in last case the emission from the building systems during operation and use.

The input assessment can be defined in terms of mathematical equations considering the ecosystems input and output, are total land, materials, water and energy used. A term ecosystems productivity, i.e. a quantity for carrying earth's environmental carrying capacity will be taken as the reference scale. Those scale will dictate about the quantity of land required to absorb the waste of the materials and ecology from the building to eco systems.

An ecologically derived baselines can be used to qualify both positive and negative impacts of buildings which will allow equal base lines of the vastly different types of projects depending upon their locations, types and sizes. The present paper will derive a tool to evaluate the effectiveness of the building design to the environment. The ecosystems service criteria use an objective to develop a shelter which consume low energy from the conventional sources, generate energy to meet its maximum demand, create a clean and safe environment. The details of the relative ecological impact of energy and materials in the built in environment as well as identification of effective strategies for reducing environmental impacts will be discussed in the text of the paper.

KEYWORDS

Building, Eco-system, Assessment

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INTRODUCTION

Sustainable design at the present time calls for "good neighbor policy", which require actions for the benefit of the global neighborhood. E.O.Wilson philosophically articulates this in his "The Discovery of Life" in 1992 as;

"In amnesiac revelry it is also easy to overlook the services that ecosystems provide humanity. They enrich the soil and create the very air we breathe. Without these amenities, the remaining tenure of the human race would be nasty and brief"

Since our earth has finite material resources and biological capacity, human being must live within the carrying capacity of the earth. As we exceed the carrying capacity of the earth's ecosystem over the time, the earth will be stressed, then go into decline and finally will collapse. They are expended rather than renewed. The construction and operation of buildings in the environment contribute to the environmental loads. Those who design and purchase building have little or no methods to asses the environmental impacts of their actions.

Building is known as the shelter for human being. Thus, shelter should provide living environment for the present and the future generation. To present the shelter as compatible to living conditions the Government has framed many rules and regulations. However, till date very little considerations have been imposed to quantify that the building in the environment as eco friendly and an abode for healthy and wealthy environment.

The quantification of a healthy built environment is judged with respect to several factors and of course parameters where one of them is how much it is compatible to the environment with the ecology. Thus, while designing a building in the environment the process conjoins two disciplines that is the subject of architecture and that of ecology. To develop a green building and environmental building is a subject of applied ecology, where the designers understand the constitutions, organization and structure of eco systems, and their impact of architecture are considered from environmental perspectives. By utilizing the concepts, methods and language of ecology, designers can create architecture that is very much embedded in the site and its surroundings.

To asses on the compatibility of the building with the local or regional environment there should be some criteria for assessment, which implies the definition of building design criteria. If we establish the criteria that are based to our best scientific understanding of environmental capacity that will begin to develop a building stock that is sustainable. To do this one must quantify the linkage between the resulting environmental impacts and their cause in building production and use. These are not done in traditional building environmental impact assessment methods, which are based on the quantification assumed negative impacts of man made interventions on the natural environment, typically using a code compliant reference building as a standard and improved upon. These indices lack on ecologically derived base line or standard of measure, under which sustainable developments can be analyzed and compared with an universal basis.

An ecologically derived baseline can be used to quantify both positive and negative impacts of the buildings which will allow equal base lines of the vastly different types of the projects depending upon their locations, types and sizes. The present paper consists of a tool to evaluate the effectiveness of the building design in the environment. The ecosystems service criteria uses an objective to develop a shelter which consume low energy from the conventional sources, the shelter generates energy to meet its maximum demand, shelter create a clean and safe environment. The relative ecological impact of energy and materials in the built environment as well as identification of effective strategies for reducing environmental impacts are the topics covered in the text of the paper.

Building and Ecosystems

It has already been discussed in the previous section that building serves as a shelter when it maintains healthy ambience. The construction materials those are used for construction have significant impact on the environment. According to the report of Worldwatch Institute*, construction of building consumes about 40% of raw stone, gravels and sand in each year and 25% of raw wood. World wide building construction also consumes 40% of energy and 16% of the total water.Regular consumption of these items have negative impacts on the environment and eco-systems. Raw material extracted from the nature leads to resource depletion and biological diversifications. Construction material manufacturing and transportation consume energy, which are sources for the emission of Green House Gases (GHG) contribute for global warming and acid rain. Landfill from the demolition of building waste contaminate air and water and ultimately produce unhealthy indoor environment which is responsible for respiratory problem with the increase of misery, suffering and ultimately death.

Thus, selection of preferable eco-friendly building materials is a way for providing quality environment to the buildings and its surroundings. In real sense the environmental performance must be balanced with the affordability of the developers and purchasers. Thus building designers and building material

manufacturers should provide the weight age of the environmental benefit with the minimum cost. It may be projected in a fashion that one should identify building materials those have little or no bad impact to the environment with the little or no increment in cost.

Environmental Performance Assessment

The impact of building to the environment is measured in terms of a tool known as Life Cycle Assessment (LCA). The real concept of LCA is to measure the environmental impact of all parameters those are associated with the building. LCA is a four steps assessment procedure as follows;

Identification of possible impact according to the local situations.

Quantification of environmental impacts of the materials used in the building.

Quantification of input and output. The input may be the followings a. Land, b. Water, c. Energy and d. Other Natural Resources. The output may be a. Water, b. Air c. Refuses and d. Other additional Items.

Evaluation of input and output over the local and global environment.

Building Indices

In recent years several assessment indices specific to the buildings have emerged. The Building Research Establishment Environmental Assessment Method (BREEAM) was launched in the UK in the year 1990 to provide an environmental assessment and labeling scheme for the building. BREEAM, a voluntary market-oriented assessment of a building's environmental performance allows licensed assessors to perform assessments to maintain a consistent level of quality and objectivity. Buildings are assessed for both construction and operation. Matrices include environmental impact, energy efficiency and compatible to health and hygiene. Assessment are scored in terms of "Credit Earned" for good performance on water conservation, carbon dioxide emission, energy generation etc. In the USA similar types of assessment systems are also in operation which is known as "Leadership in Energy and Environmental Design" (LEED). Internationally the "Green Building Tools" (GBT) is an evolving assessment system sponsored by National Resources Canada that has generated substantial interest. The scoring systems each used code compliant built environments as base lines to evaluate the environmental performance of the building being assessed. This skews the evaluation and has no direct correlation to environmental impacts. No indicators of environmental health are measured to asses the effect of a built in environment. Accordingly the rating like platinum, gold, silver and bronze have been instituted.

However, there is another category of assessment method which is referred to as the nature based checklist. All these methods share the concepts of the natural systems provide the services we desire and we should rate our intervention for their ability to also provide those services. In addition, each of the checklists provide the ability to rate an intervention positively as well as negatively, setting the stage for regenerative design rather than only reducing impacts.

The checklist methods are less developed than the other assessment methods. However, the standard methods have the advantages as they are design specific, i.e. they are providing direction and information for designers in the design stage. Although they are simple, and do not require extensive research or involve costs to complete the desired level. On the other hand, they lack quantification and they are inherently biased towards the achievement of the highest rating.

While constructing a building envelope many stages are there like conceptualization, pre-design, design, estimation, construction and occupancy. An ecologically matching design process includes the elements to quantify the building as the eco-friendly building or green building. These are;

Building input like, Land, Materials, Water, Energy

2. Building output like, Conventional and Additional. The conventional output are Water, Air and other refuses. The additional output like, a. Energy Efficiency and site for Clean Energy production, b. Site for Resource Conservation and recycling,

Evaluation Methodologies

Using ecosystem service as a baseline, a dual-criteria frame can determine the sustainability. As already pointed out in the previous sections that evaluation can be done in terms of input and output. In the first case, the quantities absorbed / consumed from the ecosystems during built up process and in last case the emission from the building systems during operation and use.

The input assessment can be defined in terms of the following equation;

$$E_{SI} = \Sigma T_L, T_M, T_W, T_E \quad \text{----------} \quad (1)$$

$$E_{SO} = [E_{SP} \times B_i] / t \quad \text{----------} \quad (2)$$

where, E_{SI}, E_{SO} are the ecosystems input and output, T_L, T_M, T_W, T_E are total land used, total materials used, total water used, total energy used. E_{SP} stands for ecosystems productivity, B_I land area used for the built up systems, t is the time and it can be assessed for a year.
The ratio of equations of equation (1) and (2) indicate the ecological efficiency (η) of built up systems

$$\eta = [E_{SO} / E_{SI}] \times 100\ \% \quad \text{----------} \quad (3)$$

$$\eta = [E_{SP} \times B_I] \ / \ t \sum T_L, T_M, T_W, T_E \quad \text{----------} \quad (4)$$

Equation 4 indicate that land has an important role in indicating ecological efficiency.
The total ecological efficiency (η_T) of a building is the algebraic sum of the efficiency at the construction and commissioning level (η_0) and operation and maintenance level (η_1)

$$\eta_T = \eta_0 + \eta_1 \quad \text{----------} \quad (4a)$$

The value of η_T can be compared to the calculated value of ecological efficiency at the design and planning level (η_D).The degree of deviation will have a tolerance level to the designer as well as the purchasers/users.

$$\eta_D \geq \eta_T \quad \text{.....} \quad (4b)$$

The value of ecological efficiency will indicate about rating earned by the building.
Use of ecosystem services assessed in terms of three matrices these are a. Constructional Impacts, b. Operational Impacts and c. Site Capacity.
Construction Impacts are divisible into the material and energy components along with subcategories.
Site capacity consists of the initial assessment, any detrimental effect incurred through construction and the addition of any capacity as provided through the generation of supplementary ecosystems services on site. Ecosystems services must be contextually defined relative to impacts. As for example building construction and operation impacts consist largely of material and energy consumption as well as production of associated waste. Therefore, ecosystems capacity to absorb waste is an appropriate method. This metric provides several key elements. Using site-specific values of ecosystem productivity one can generate a regionalized assessment. Regional specific data allows for the possibility of restoration of local ecosystem productivity with the accompanying decrease in negative environmental impact. This is inherently more accurate and relevant to context. Once these quantities are established, an ecological preformance can be created, which shows return on investment, ecological profit, ecological deficit or mortgage created during construction, and time required to break-even, etc.
To normalize the results, following metrics are compared on an absolute basis and per unit area basis. A Global average ecosystem productivity was used to measure carrying capacity. This quantity of land required to absorb the waste of the materials and energy was taken from M.Wackernagle* and assumed to be 100 GJ/hr/yr. Most of the material impacts can be translated into energy embodied in the materials with additional land areas required for the production of the renewable materials used**.
While one goes for evaluation of the eco compatibility,assessment should have to be done from the two aspects.These are i) Perspective aspect ii) Performance aspect.

Perspective Aspect : In case of perspective aspect the designer should have to incorporate the eco friendly items as well as energy conservation and energy conversion components in the building at the design and planning stages as per the prescription provided in the Annex.As a result purchasers/users have the ideas about the building envelope and its compatibility to environment.Thus it will be an essential component for the building at the planning and design stage.

Performance aspect:

During construction and commissioning period building consumes a number of items from the environment like air water, energy which in turn emits something to the atmosphere to increase the fragileness of the ecosystems.Among these major components consume from the eco systems are water and energy. The water in turn emits CO_2 and other Green House Gases (GHG) to the eco systems.These require accountability in terms of pay back.Same things happen during the operation and maintenance period of the building envelope.During construction and commissioning period care should be taken so that items indicated in the prescriptive planning must be incorporated and the equipment has been commissioning following their best performance rate.

Evaluation of impacts at Construction and commissioning Stage:

Before building comes into operation builder can quantify the eco services consumed by the building as follows.This can be considered as the impact at the 'Zeroth' year and can be formulated as :

Ecosystems Services Consumed (E_{SCO}) (ha/yr.) = [Construction Materials quantity (M_T)x Embodied Energy of the material (E_1) used] / [Ecosystem productivity in GJ/ha/yr] .This can be written as

$$E_{SCO} = [M_T \times E_i] / 100 \quad \text{---------- (5)}$$

The value of E_{SCO} in equation 5 in ideal case to be considered as 1.In real case it will be always > 1.This means that the building has consumed a lot from the environment.Thus steps require to repay to the environment and eco systems.

Evaluation of Impacts at Operational Stage:

When the purchaser/user enter into the building major component use by the building is water and energy.

Impacts at operation and stage of water and energy can also be calculated using the same method;

Ecosystems Services Consumed(E_{SCW})(ha/yr.) = [Effective Water(E_W) Consumed (in terms of equivalent energy/ L) in that year] / [Ecosystem productivity in GJ/ha/yr]

Effective Energy Consumed = Total Energy Consumed – Energy generated by the building

$$E_{SCW} = EW / 100 \quad \text{------ (6)}$$

Similar for energy consumption, it can be calculated by similar way ;

Ecosystems Services Consumed(E_{SCW})(ha/yr.) = [Effective Energy(E_E) Consumed in that year] / [Ecosystem productivity in GJ/ha/yr] ------ (6)

Effective Energy Consumed = Total Energy Consumed – Energy generated by the building.Thus,

$$E_{SCE} = E_E / 100 \quad \text{------ (7)}$$

Thus, total eco systems consumed (E_{SCT}) by the building throughout the year during the operation and maintenance period will be

$$E_{SCT} = E_{SCO} + E_{SCW} + E_{SCE}$$

$$E_{SCT} = 0.01 \times [M_T \times E_1 + E_w + E_1] \quad \text{------ (8)}$$

Thus the pay back period (P_{BT}) by the building (in year) to the environment will be 1/ E_{SCT} i.e

$$P_{BT} = 100/ [M_T \times E_1 + E_w + E_E] \quad \text{------ (9)}$$

From the above equation , one can justify the credit to be earned by the building in terms of its eco compatibility.

Approach for Evaluation:

Fill up the formats as in Annex to evaluate various parameters
Evaluate constructional impacts
Evaluate operational impact

Results and Assesment.

A systematic study on the various parameters is being carried out at the 'Energy Efficient Built Environment lab' in the department of Architecture, Jadavpur University, Kolkata, India. A portion of results were obtained and the remaining part will be presented at the conference .

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