LIFE CYCLE ASSESSMENT OF CONSTRUCTION MATERIALS USING EIO-LCA

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Abstract

Sustainability has been a major parameter in evaluation of construction industry. Sustainable construction can be defined simply as the application of methods which fulfill the needs of the present generation without compromising the needs of the future generation [1]. One of such methods used is LCA. Life Cycle Assessment of a construction material is done to get a broader picture of the environmental impact of the particular material in terms of carbon footprint. LCA Methods helps in pointing out the specific process of the material procurement or usage during which cynically affects the environment. The analysis of the results may help in informing the consumer or producer to reduce the life cycle greenhouse gas emissions. In this paper, EIO-LCA software is discussed and alternative construction materials are analyzed against conventional materials thereby, suggesting the better one between them. Necessary incentives to enhance the use of LCA were also discussed.

***Keywords –** Sustainability, Life Cycle Assessment, carbon footprint, EIO-LCA*

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1. INTRODUCTION

All basic processes of Life Cycle Assessment are established on the principle of "cradle to grave", where all mass and energy flow inputs and outputs are considered and all possible negative effects on environment ARE evaluated. LCA involves four major steps as follows [2]:

1. Establishing the goals and scope of LCA.
2. Constructing an inventory table which comprises of all energy and material inputs as well as outputs in all stages of the life cycle of the particular material.
3. Assessment of all pertinent impacts to the environment based on the inventory table.
4. Perceiving the available results to achieve a satisfactory result.

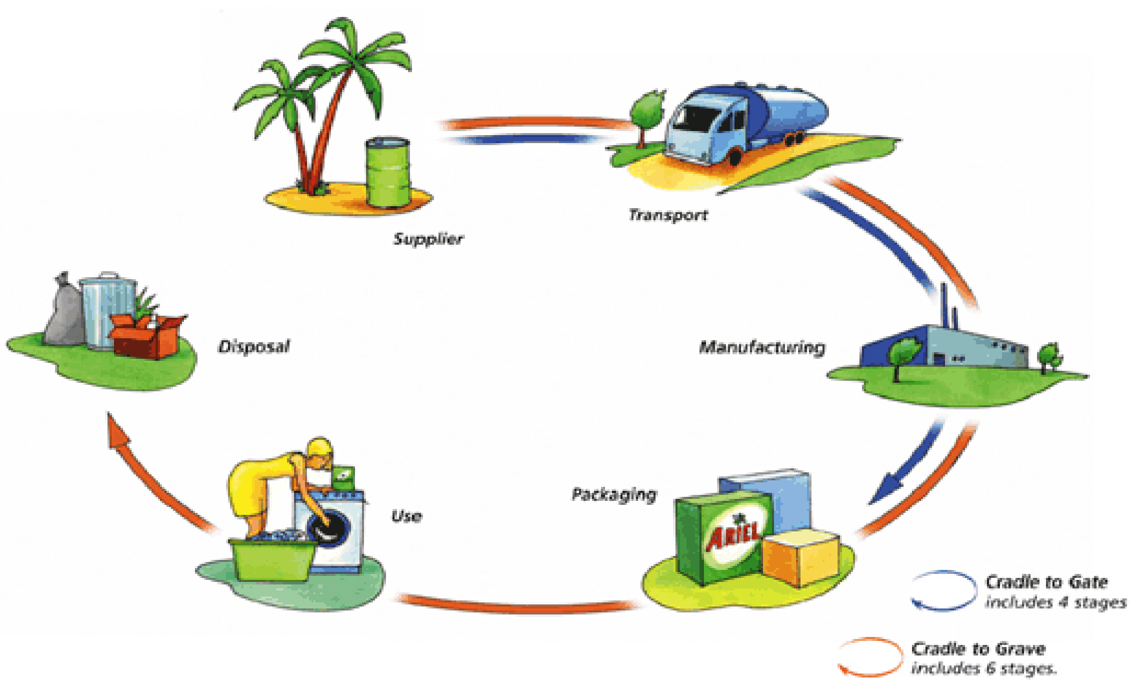

Fig 1 [3]

By referring to life cycle stages [4], there are five distinct stages:

1. Acquisition of the raw materials (consists of operations which involve extracting raw materials).
2. Manufacturing (consists of operations converting the extracted materials to final products).
3. Distribution (transportation and storage of products for utilization of the consumer).
4. Use/ Reuse (Consumption of the finished products).
5. End of Life Stage (Goods cannot be reused anymore and have to be strategized according to waste management).

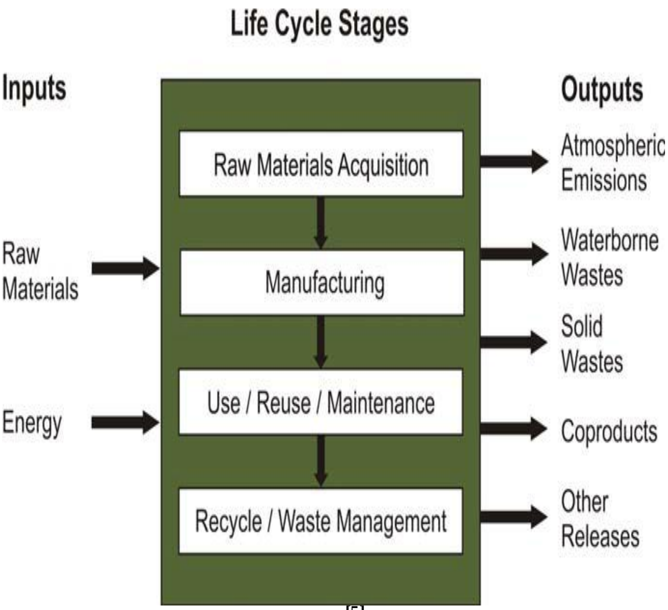

Fig 2 [5]

2. METHODOLOGY

Initially, all energy changes and mass changes are categorized according to inputs and outputs. These inputs and outputs may be in different stages of the product life cycle. But for easier evaluation, they are categorized as inputs from nature, inputs from techno sphere, outputs from nature and outputs from techno sphere. There are many other terms such as time-related coverage which emphasizes on the age of data, geographical coverage, which focuses on the area where data was obtained, technology coverage, the efficiency of technology used for data collection, reproducibility and consistency denote the effectiveness of data. In the identification of goal and scope of LCA, product will be analyzed and is categorized and the required data is collected. In the next step of inventory data, all energies and materials, emission to atmosphere are calculated for each individual process. Energy evaluation has played and will always play a crucial role in building construction evaluation especially in green building rating systems. One such example is "Operational Energy" [6] which quantifies all energy used by the building in a time period of one year.

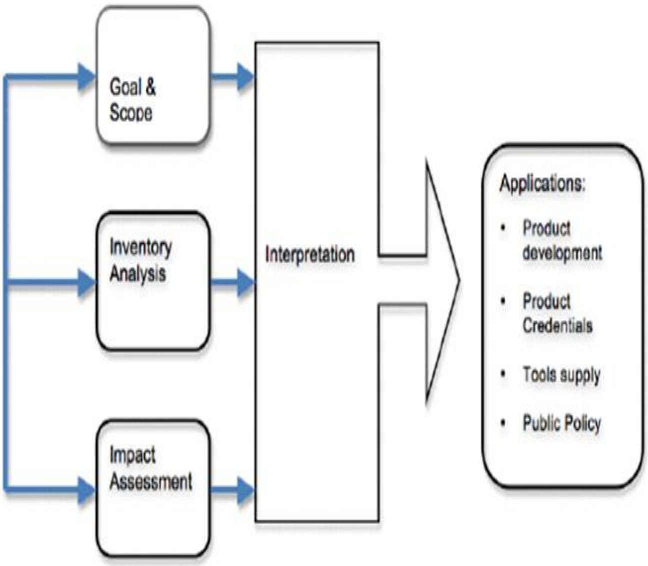

Fig 3 [7]

In the impact assessment, the adverse effects of emissions, the energy and emission inputs and outputs generated are grouped together and are pegged under their relevant categories. In the interpretation stage, the results are reported in the most detailed manner and all opportunities available to reduce the adverse impact are noted. This step of interpretation is most advantageous and accommodating when two products are analyzed against each other. Tools which are used for the LCA process use the above method. Some examples are GaBi, OpenLCA, SimaPro [8]. One such notable example is the EIOLCA method which additionally considers a feature of economic inputs into the assessment process. EIOLCA stands for Economic Input Output Life Cycle Assessment [9].

LCA has been disparaged seldom due to the following issues:

1. Lack of consistent data for LCA.
2. Controversial and judgmental boundaries for LCA.
3. Too expensive and time taking process.
4. No consistent method which can be followed throughout the world.
5. Different processes of LCA for same product tend to give contradictory results.
6. LCA is not adopted for eco-labeling due to its controversial results for same product by different processes.

To provide a solution to the boundary limits of traditional Life Cycle Assessment, researchers have founded a new technique which employs economic input and output analysis. This Economic Input Output Assessment takes a deep approach and considers the whole problem from an economic point of view. This strength of EIOLCA helps the inputs to be modeled as a set of linear simultaneous equations. This representation of equations can be found in the cited reference [9].

By following this proposed software, we have found a solution to the consistent boundary problem prevailing in LCA. However, EIOLCA has also got its own limitations such as the product inputs are varied according to its need in commodity which is different according to the area. As a result, EIOLCA is only consistent when comparing a product and its substituting alternative solution in the same area but not for comparing two homogenous products in different environments. Another prevailing problem in EIOLCA is that only the raw material acquisition and manufacturing stages are only considered, whereas end of life options are seldom considered only in effective cases.

This paper tries to emphasize on EIOLCA as a pragmatic tool for life cycle assessment which can be used by companies and corporations and consumer groups to conduct swift and cost effective life cycle assessments.

3. RESULTS

3.1 Tables

Table 1

Parameter	Sand and Gravel	Wood and Sawmill	Gypsum
Economic Activity	1 million $	1 million $	1 million $
Carbon Dioxide Emissions	0.034 metric tons	0.036 metric tons	0.022 metric tons
Sulphur Oxides Emission	0.014 metric tons	0.002 metric tons	0.016 metric tons
Ammonia Emissions	0.002 metric tons	0.001 metric tons	0.001 metric tons
VOC Emissions	0.004 metric tons	0.021 metric tons	0.001 metric tons
Particulate matter (<10 microns)	0.247 metric tons	0.011 metric tons	0.007 metric tons
Particulate matter (<2.5 microns)	0.054 metric tons	0.007 metric tons	0.003 metric tons
Energy used	0.0839 terajoules	0.139 terajoules	0.099 terajoules
Hazardous waste	0.029 short tons	0.0228 short tons	0.075 short tons
Water Withdrawal	575 kilo gallons	7.67 kilo gallons	0.733 kilo gallons

Table 2

Parameter	Iron and Steel	Asphalt Mixture	Bio Asphalt Mixture
Economic Activity	1 million $	1 million $	1 million $
Carbon Dioxide Emissions	0.150 metric tons	0.011 metric tons	0.006 metric tons
Sulphur Oxides Emission	0.017 metric tons	0.007 metric tons	0.003 metric tons
Ammonia Emissions	0.001 metric tons	0.001 metric tons	0.0002 metric tons
VOC Emissions	0.005 metric tons	0.004 metric tons	0.001 metric tons
Particulate matter (<10 microns)	0.006 metric tons	0.005 metric tons	0.002 metric tons
Particulate matter (<2.5 microns)	0.005 metric tons	0.002 metric tons	0.002 metric tons
Energy used	0.342 terajoules	0.051 terajoules	0.0345 terajoules
Hazardous waste	0.138 short tons	2.44 short tons	1.06 short tons
Water Withdrawal	43.9 kilo gallons	0.517 kilo gallons	0.322 kilo gallons

As evident in the above table, we can observe six main building constituent materials were analyzed for life cycle assessment. Every building constituent had carbon dioxide emissions, sulphur dioxide emissions, ammonia emissions, particulate matter (<10 micron) emissions, particulate matter (< 2.5 micron) emissions, energy and water categories. Bio asphalt mixture and asphalt mixture were taken into analysis so as to find the better suggestive alternative material. We can clearly understand that bio asphalt mixture had less hazardous waste production and relatively fewer emissions compared to conventional asphalt mixture.

4. EIO-LCA METHOD FEATURES

Due to the data requirement limitations and expensive methods which do not assess the economic feature, there was a need for software such as EIOLCA. This method depends on the government data and the best feature of this LCA is that it is available to all consumers via Internet. This method was invented and modified further by Wassily Leontief for which he was awarded the Nobel Prize [10].

5. INCENTIVES FOR LCA

Usage of any tool or application in a business has to produce satisfactory results at both ends of the deal. Some incentives and advantages which can be provided so as to ensure world wide application of LCA methods are as follows:

1. Operation Reinforcement – Improvement of process in which adverse effects are observed can enhance in the protection of environment. In some cases, alternative processes can be suggested so as to increase savings.

2. Financial incentives such as tax exemption should be provided to users who employ LCA and follow its suggestions. But, such incentives are to be provided if and only if there is decrease in emissions, if they exceed threshold levels as set by environmental committees.
3. Not only the producers, but also consumers should also be subjected to financial benefits such as reduced rates for buying such environment friendly products.
4. Incorporation of LCA method into Green Building rating system at a large scale. Some rating systems such as Green Globes allot 50 points out of their 100 points if LCA is put into action.
5. Passing of legislative bills by the government every year reducing the emission levels according to the carbon footprint released. This will increase the number of users employing LCA methods to evaluate their emissions as well as reduce their emissions.

6. DISCUSSION

In this paper, we have discussed the basic process of Life Cycle Assessment, the different stages involved in its “cradle to grave” life cycle and the major steps involved in the usage of LCA. We have established a basic understanding regarding the need of LCA in building projects. Every method or software tool used in LCA has its own limitations. But with the development in the field of research has ensured that these limitations will be resolved. The distinguishable incentive which is available is to demonstrate the payback period for a green building. And if the discussed monetary incentives along with non-monetary incentives were implemented, there would be increase in adoption of LCA in various fields of construction ranging from pavements design to skyscraper construction. In the above EIOLCA example performed, we can clearly distinguish between asphalt mixture and bio asphalt mixture and choose the better among them.

7. CONCLUSION

This suggested EIOLCA method has however got some limitations which have to be considered such as the nature of input-output analysis. Approximation in technical coefficients and the static analysis and omission of capital services are some of the limitations which may prove cynical. Another advantage is the expression of environmental impact coefficients in terms of environmental effect and money value in output instead of physical units makes the software more straightforward and avoids the trouble of adding conversion factors. However, tax related conversions and variations need to be taken care of. We can conclude that EIO-LCA is an adaptable tool for LCA consumers. There is still scope for betterment of the EIOLCA software[11] by deciphering its regulations and validating it as different stages to check if boundary conditions aren’t violated. When all these issues are elucidated, EIOLCA can be made available as a regular LCA tool for use all over the world.

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