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LIFE CYCLE ASSESSMENT METHODOLOGY AND INSTRUMENTS

BY

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Abstract. The need to integrate the assessment methodology of environmental impact in the field of constructions too, represents an extremely debatable subject, whose importance is highlighted by the more and more fast increase of the complexity of environmental issues at global level. LCA (life cycle assessment) represents an assessment process of pollution loads on the environment, associated with a product, process or activity. The present paper treats this subject from the perspective of the construction industry, discussing the LCA methodology and highlighting some problems that occur at the level of collecting the data necessary to the analysis. LCA integration within the design process shall allow the optimization of the consumption of energy and materials, necessary both in the building process and in the operational one. Therefore, we also considered purposeful the review of the most important data bases and software instruments that are now present on the market, intended to achieve the LCA.

Key words: life cycle assessment; building evaluation tool; environment.

1. Introduction

Practicing the assessment during the entire life cycle as a management instrument in respect of environmental protection started in the 1960s, under

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different forms and denominations (Selmes, 2005). In order to create some ecologic standards to be fully accepted at global level, the Society of Environmental Toxicology and Chemistry (SETAC), with the headquarters in Brussels, established the methodology of Life Cycle Assessment (LCA).

SETAC defines this type of analysis as the process of assessment of pollution loads on the environment, associated with a product, process or activity, by quantifying the quantities of energy and materials used, as well as waste abandoned in the environment.

The necessity to achieve LCA relates to the assessment of the impact on the environment, correlated with the energy and materials used to achieve a product, in the end resulting in the optimization of their consumption.

The assessment includes the entire life cycle of the product, process or activity, containing the extraction and processing of raw materials, preparation, transport and distribution, the use, reuse, maintenance, recycling and storage on the ground (burial) or incineration of residues and waste (Ryding, 2012).

The principle of an LCA analysis is relatively simple: for each stage of the life cycle, the quantities of materials and energy used and emissions associated with these processes are investigated. Emissions are then multiplied with characterization factors proportionate to their power to cause different impacts on the environment. Many times one of the emissions is chosen as reference, and the result is presented in equivalent values related to the impact of the reference substance.

The specialty literature presents the importance of the role of LCA as being given by (SETAC, 2012) namely:

a) Identifying processes and systems that have a major contribution to the environmental impact.

b) Comparing different options inside a process in order to reduce the environmental impact.

c) Establishing long-term strategies related to the increase of the level of designing products and materials, taking into consideration environmental protection.

d) Assessing the effects of using different types of resources for new products.

e) Comparing functionally equivalent products.

f) Determining producers to use only ecologically labelled materials and subassemblies in the achievement of new products.

An LCA instrument may include a generic data base, with information concerning the emissions for a certain number of construction materials and types of energy. It is likely that this information will be extracted from the EDP (Environmental Product Declarations), which are declarations of the 3rd type, according to ISO 14025.

Sophisticated LCA instruments need access to international data bases.

The complete assessment of the impact of constructions on the environment is achieved through its two components:

a) technical – ecological, called *Life Cycle Assessment* (LCA);

b) economical - ecological, called *Life Cycle Cost Assessment* (LCC).

There were many initiatives to standardize the methodology of life-cycle assessment; but the most recognized standards were the ones published by the International Standards Organization ISO (2012):

a) ISO 14040 Environmental management, LCA, Principles and framework (1997).

b) ISO 14041 Environmental management, LCA, Goal definition and inventory analysis (1998).

c) ISO 14042 Environmental management, LCA, Life-cycle impact assessment (2000).

d) ISO 14043 Environmental management, LCA, Life-cycle interpretation (2000).

2. Assessment During the Entire Life Cycle of a Product

In respect of the frame context of a LCA analysis, ISO 14040 defines the four main phases of the analysis, also highlighting the influence on each of them on the others (Fig. 1).

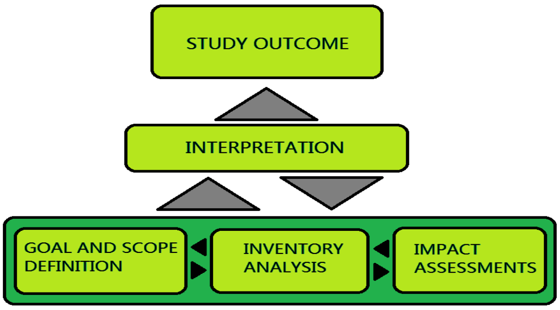

Fig. 1 – Frame structure for Life Cycle Assessment
(adaptation according to ISO 14040), (2006).

2.1. Defining the Goal and Objective

Generally speaking, the objectives suggested by a LCA study may be classified in two main categories, as follows:

a) The hot spot analysis or the analysis of improvements brought to the product from an ecological point of view: the system is studied in order to determine the stages in the life cycle with the highest environmental impact.

b) The comparative analysis: two or more systems are analysed in order to compare the corresponding environmental impact.

The goal and objectives of the LCA study are clearly defined in relation to the planned applicability (ISO 14040, 2006).

This first LCA phase involves:

a) time limitation (the life time of the product, the time horizon for processes and their impact);

b) geographical limitation of possible effects of pollution (local, national, regional, continental, global);

c) identification of relevant impact types and feasible options of improvement;

d) establishing requirements concerning data quality;

e) defining the functional unit;

f) formulation of the set of important hypotheses, questions requiring an answer, in order to make a critical analysis.

2.2. Life Cycle Inventory (LCI)

This stage represents the analysis of constructive solutions by means of constituent materials, involving documentation and collection of data which is present in the flows of processes (the material flow and the used energy) during each stage of the life cycle. In the case of constructions, the life cycle consists of the following stages:

a) extraction (exploration) of primary resources;
b) processing of raw materials;
c) transport;
d) distribution;
e) use;
f) recycling, etc.

The final result is represented by a table-inventory, with quantifications of entries and exits related to the functional unit chosen in the analysis. For example, entries are resources and exits are air, water and soil emissions (ISO 14044, 2006). Scarcity of data can affect the goals of the study, so that data quality is important. Therefore ISO defines a series of steps in this phase, beginning with the collection of data, deriving from quality sources, then validation of those data, relating data to processes taken into account in the analysis and then relating calculated data to functional unit chosen.

The accuracy of LCA results is given by the introduction in the system of some data as real as possible, preferably measured at the site. Nevertheless, this exact data may be absent, and in this case the international data bases may be used. However, a thorough analysis regarding this data bases is necessary.

2.3. Environmental Impact Assessment (LCIA)

ISO 14042, the international standard for life-cycle impact assessment (LCIA), defines the impact assessment like this: “*Examine the product system from an environmental point of view using impact categories and category indicators connected with the LCI results. The LCIA also provides information for the life-cycle interpretation phase*” (ISO 14042, 2006).

The environmental interventions taken into consideration in the analysis are “transformed” in this phase in environmental impacts. This environmental impact load of the system complies with the goal of the study and is presented to users in a comprehensible form.

The goal of this phase is to understand and weigh the magnitude and importance of the possible impact on the environment, of a system-product, based on the results of the inventory and on the selected list of impact categories, which are relevant for the analysed system (for example: climatic changes, ozone depletion) (ISO 14044, 2006).

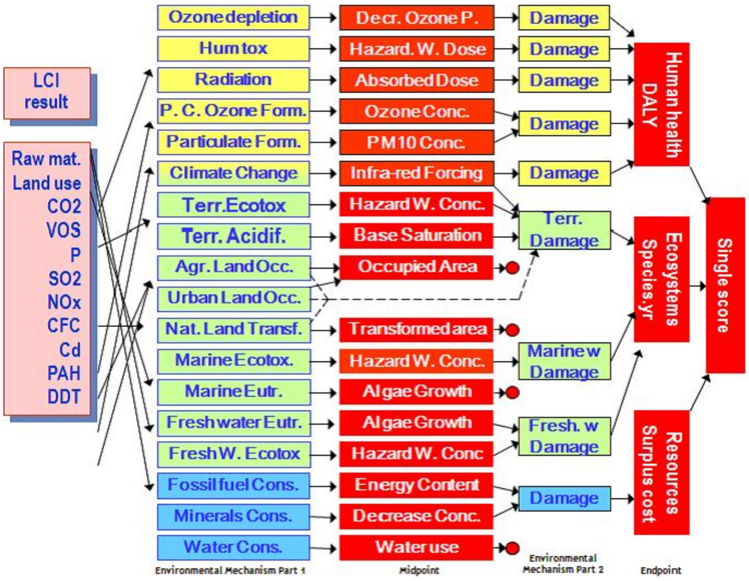

Fig. 2 – Representation of relations between inventory, midpoint categories (environmental mechanisms) and endpoint categories, including the single score (damage-oriented model) (PRé, 2014).

This stage of the life cycle assessment includes three compulsory elements: *selection of impact categories*, *classification* and *characterization* (ISO 14040, 2006). Impact categories may be classified in two levels: *midpoint* and *endpoint*. The midpoint consists of categories based on environmental mechanisms, which may be relatively easy to measure in the laboratory. The categories of the endpoint, fewer as a number, are not that easily measurable as the previous ones.

Midpoint impact categories are *problem*-oriented and have scientific grounds, often being difficult to interpret, while the endpoint categories are *damage*-oriented and are easier to interpret, still presenting a certain degree of incertitude (RTVM..., 2014). The relations between the parameters of the inventory, the 18 midpoint categories, the 3 endpoint categories and the single score are synthetized in Fig. 2.

2.4. Interpretation

In this phase are contoured the conclusions and recommendations for those who need to make decisions, from the analysis of inventorying and from impact assessment (ISO 14044, 2006). It involves the assessment of the solution in order to improve the product.

The final stage of a LCA analysis is the interpretation stage. In this stage, results from the inventorying analysis and/or impact assessment are reviewed and discussed. The opportunity of reducing the environmental impact associated with the functional unit is identified and assessed.

The goal is:

a) to analyse results;

b) to reach conclusions;

c) to explain limitations;

d) to offer recommendations based on results from previous stages of LCA or LCI;

e) to report the results of life cycle interpretation in a transparent manner.

The interpretation of the life cycle is also intended to offer an easily understandable, complete and coherent presentation of the results of a LCA study, in compliance with the definition, goal and field of application of the study (ISO 14040, 2006). ISO 14044 establishes the fact that this phase should include the communication of the study results “in a form which is both comprehensible and useful to those making decisions” (ISO 14044, 2006).

3. Types of Instruments and Models for Sustainable Construction

In this section are discussed a series of design instruments and models underlying a sustainable construction.

As the complete nomination of all models already existent or in course of issue is impossible, the list presented below is limited to the well-known examples from Europe and America, available on the market at present.

Instruments and models are classified in the following typologies:

a) *Decision Support Models*

Decision support models – or decision models – do not effectively calculate the environmental impact, being calculation programs connecting sustainable measures presented in different lists with the scores of performance extracted from the calculation instruments, offering an approximate indication of the environmental performance of the project.

b) *Simple Instruments of LCA*

This term refers to instruments personally allowing the user the execution of a life cycle analysis ("Do your own LCA"). The exact knowledge of entry data (resources, products, processes and means of transport) is necessary. Among the existent examples are the software programs SimaPro and IDEMAT.

c) *Assessment Models*

These models are additional to the standard methodology of LCA. Generally, these offer a weighting method, necessary to obtain a final score. Sometimes these models include some environmental aspects that the standard LCA does not take into consideration. Examples are the models TWIN2002 and Eco-Indicator 99.

d) *Design Support Instruments*

These represent the most extended group of instruments, conceived as support for the design phase. Most of these instruments are based on the standard of the LCA methodology.

Such examples are: BREEAM and Envest (Great Britain), Eco-Quantum and GreenCalc (the Netherlands) and LEED and BEES (the United States of America).

As the software instruments and data bases that these software instruments use are extremely important in the design, a selection of the most important of those which are presented on the market at present is achieved in Table 1. Data bases and instruments mentioned in this table present differences mainly due to (Ortiz *et al*., 2009):

a) objectives of the study;
b) users;
c) field of application;
d) used data;
e) geographical location.

Regarding the geographical locations, variations in respect to the environmental impact assessment which may be significant, are due to several factors, among which: energy sources, supply hypotheses, product specifications, differences in the production processes and economical aspects (Menzies *et al*., 2007). In order to argue this statement, one could take as example the energy source and two different countries, France and Great

Table 1

Selection of Data Bases and Software Instruments for LCA Studies, for the Entire Construction Process, Materials and Subassemblies.

Database	Country	Function	Type	Level	Software
Athen	Canada	Database + Tool	Academic	Whole building design decision	Eco Calculator
Bath data	UK	Database	Academic	Product comparison	–
BEE	Finland	Tool	Academic	Whole building design decision	BEE 1.0
BEES	USA	Tool	Commercial	Whole building design decision	BEES
BRE 3	UK	Database + Tool	Public	Whole building design decision	–
Boustead	UK	Database + Tool	Academic	Product comparison	da
DBRI 4 Database	Danmark	Database	Public	–	–
Ecoinvent	SL	Database	Commercial	Product comparison	–
Eco-it	NL	Tool	Commercial	Whole building design decision	ECO-it
ECO methods	France	Tool	Commercial	Whole building design decision	În curs de dezvoltare
Eco-Quantum	NL	Tool	Academic	Whole building design decision	Eco-Quantum
Envest	UK	Tool	Commercial	Whole building design decision	Envest
Gabi	Germany	Database + Tool	Commercial	Product comparison	Gabi 5
IO- database	Danmark	Database	Academic	Product comparison	–
IVAM	NL	Database	Commercial	Product comparison	–
KCL-ECO	Finland	Tool	Commercial	Product comparison	KCL-ECO 4.1
LCAiT	Sweden	Tool	Commercial	Product comparison	LCAiT
LISA	Australia	Tool	Public	Whole building design decision	LISA
Optimize	Canada	Database + Tool	–	Whole building design decision	da
PEMS	UK	Tool	Public	Product comparison	Web
SEDA	Australia	Tool	Public	Whole building design decision	SEDA
SimaPro	NL	Database + Tool	Commercial	Product comparison	SimaPro 8.0.3.14
Spin	Sweden	Database	Public	Product comparison	-
TEAM	France	Database + Tool	Commercial	Product comparison	TEAM 3.0
Umberto	Germany	Database + Tool	Commercial	Product comparison	Umberto
US LCI data	USA	Database	Public	Product comparison	–

Britain: in the case of France, the nuclear energy represents the majority, while in Great Britain gas and electricity are the majority. This difference regarding the energy sources concerns first of all the production process and obviously the embedded energy of the system.

4. Conclusions

Generally, the society came to realize the need to ensure a social progress to answer people's needs, considering an efficient environmental protection, as well as the efficient use of resources. In order to reach these objectives, a correct appreciation of the present situation is necessary, and implicitly the reason which led to this situation. Finally, we need to identify the target towards which we are heading and the manner this target may be reached. We need an approach based on the measurement of the environmental performance of products, using relevant indicators specific to the area of analysis.

Although the use of LCA at large scale in the field of constructions is done since the 1990s, being an important instrument for the assessment of ecological efficiency of buildings, its application is less developed in comparison with other industries.

This instrument generally captures the complicated network of relations between the location of the building, construction, its use and their impact on the environment, a network which is similar to the complexity of ecological systems in the nature, which operate as an integer, any change having a resonance within the system.

The importance of getting the environmental information for products through LCA is generally recognized, as well as the fact that LCA is one of the instruments necessary to achieve the sustainable practices in constructions. The industry of constructions, through the field of design and research in this field is more and more influenced by the current tendency of environmental protection strategies.

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ANALIZA PE CICLUL DE VIAȚĂ

Metodologie şi instrumente

(Rezumat)

Societatea actuală realizează, la un nivel din ce în ce mai generalizat, că asigurarea progresului ca răspuns dat nevoilor actuale, trebuie să țină cont de problemele de mediu ce se leagă de acest proces. Pentru a susține o atitudine responsabilă este necesară aprecierea corectă a situației prezente şi implicit a motivului pentru care s-a ajuns în această situație. Necesitatea integrării metodologiei de evaluare a impactului de mediu şi în sectorul construcțiilor, reprezintă un subiect extrem de discutat, a cărui importanță este subliniată de creşterea tot mai rapidă a complexității problemelor de mediu la nivel global. Analiza pe Ciclul de Viață (LCA) reprezintă unul dintre cele mai eficiente procese de evaluare a încărcăturilor poluante asupra mediului, asociate unui produs, proces sau activitate. Integrarea LCA în cadrul procesului de proiectare în domeniul construcțiilor, prin intermediul programelor software disponibile pe piață, va permite optimizarea consumului energetic şi de materiale, necesar atât procesului constructiv cât şi celui operațional.