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# OVERVIEW ON PLANNING AND CONSTRUCTION OF A COMMERCIAL BUILDING

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**ABSTRACT:** Modern societies have demonstrated a great deal of concern with the improvement of social, economic and environmental indicators targeted to the top of the premises of sustainability. Civil engineering construction is constantly cited as one of the largest promoters of strong environmental impacts, ranging from the great use of natural resources (water, energy and materials) at the stages of construction, use and maintenance, and encompassing the problems related to the issue of disposal of materials during the demolition or disassembly at the end of the useful life of buildings. This work deals with the sustainable environmental management related to the construction industry, using a methodology known as life cycle assessment (LCA) and its respective tools, which aim to optimize various aspects, from the extraction of raw materials to the final disposal of waste generated on construction. The methodology presented here is complex and this paper aims to provide an initial contact back to the civil construction segment, demonstrating that its application becomes instrumental in the direction of more sustainable buildings.

**Index Term:** Building materials, construction industry, environmental, life cycle assessment, sustainability.

## I. INTRODUCTION

IN 1983 the Commission on Environment and Development was created by the United Nations, chaired by Gro Harlem Brundtlandt and Mansour Khalid, with the objective of discussing the issues related to the environment and development. After a series of public hearings, held both in developed and in developing regions, with government leaders and with the general public, the document Our Common Future, better known as the Brundtland report, was published in the year of 1987 [1]. This document presented a new vision about development, defining it as a process which 'satisfies present needs without compromising the ability of future generations to meet their own needs', becoming thus a definition of the concept of sustainable development. The report points to the incompatibility between sustainable development and the current patterns of production and consumption, suggesting human conciliation between environmental issues and social issues. The report emphasizes that the environmental problems such as global warming and the destruction of the ozone layer, thus expressing a concern with the high speed of these changes and the inability to evaluate

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and propose global solutions. At the same time, the report features a list of measures to be taken by the Member States, with multilateral international goals, such as reducing energy consumption, the development of renewable energy sources and industrial production based on clean technologies and being more environmentally friendly. With regard to the civil construction industry, from this new awareness, modern societies began to realise that the industry is one of the most impactful on the environment, being responsible for high energy consumption, a huge generation of solid wastes and for large volumes of global emissions of greenhouse gases [2, 3, 4].

## II. LIFE CYCLE ASSESSMENT INSERTED IN THE CONCEPT OF TRIPLE BOTTOM LINE

Currently, the results obtained by any organisation or business sector are measured and evaluated on their economic, environmental and social aspects, in an integrated manner. In the decade of 1990, the concept of the triple sustainability, also known as the Triple Bottom Line, was created by John Elkington, co-founder of the International Non-Governmental Organisation Sustainability [5, 6]. This concept represents the expansion of a traditional business model into a new model, which goes on to consider the financial, environmental and social performance of any economic sector in an integrated way, as it becomes increasingly apparent the requirement on the part of the current society to know what are the actual dimensions of these three types of impacts here considered. The idea is to insert the concept of life cycle assessment (LCA) on the concept of Triple Bottom Line as shown in Figure 1, which can be an efficient mechanism in the quest for a higher level of sustainability within the construction industry, with the goal to reduce or mitigate its highly impactful effects, at all stages of the life of a building.

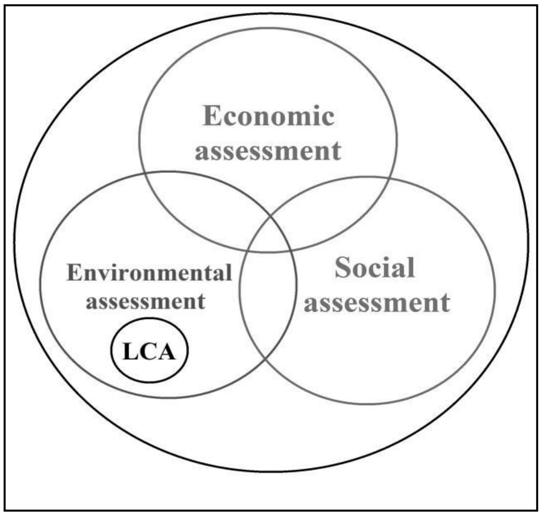


Fig. 1. LCA in Triple Bottom Line. Source: adapted from SILVA, 2003 [7]

## III. THE INTERNATIONAL STANDARDIZATION FOR THE LIFE CYCLE ASSESSMENT (LCA)

The LCA methodology is based on a series of international standards and procedures, standards of environmental management called ISO 14040 [8], that existing regulatory concepts to serve as a basis for understanding and implementing of LCA.

However, before the emergence appearance of this series of standards, at the beginning of the year 1990, the Society of Environmental Toxicology and Chemistry (SETAC) [9] had already published his first works along this line of research. His first publications, packed with

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diagrams, brought as a central theme the entrances and exits of life cycle inventory, covering many inventory components, as for example: origin of raw materials (location, quality, contamination etc.), energy spending, manufacturing processes, distribution, transportation, maintenance, reuse, recycling and waste management. Such considerations were very important for the advancement of life cycle assessment. Shortly thereafter, the United Nations Environment Programme-UNEP [10] has published several reports, atlases and newsletters.

As a good example, the fifth Global Environment Outlook assessment GEO5 was published [11], which is a detailed report on the environment, development and human well-being, providing analysis and information for the public and political powers in general.

One of the many points the document makes is a warning (questioning) that the world population is living far beyond the possibilities developed.

The document notes that the human population is now so large that the amount of natural resources needed to sustain it is beyond what our planet is able to provide.

Finally, as a consequence of these first initiatives, the environmental management standards 14040 series, used nowadays and governing the life cycle assessment (LCA) as mentioned below:

ISO 14041:1998 Environmental management -- Life cycle assessment -- Goal and scope definition and inventory analysis;

- ISO 14042:2000 Environmental management -- Life cycle assessment -- Life cycle impact assessment;
- ISO 14043:2000 Environmental management -- Life cycle assessment -- Life cycle interpretation;
- ISO 14044:2006 Environmental management -- Life cycle assessment -- Requirements and guidelines;
- ISO 14045:2012 Environmental management -- Eco- efficiency assessment of product systems -- Principles, requirements and guidelines;
- ISO 14046:2014 Environmental management -- Water footprint -- Principles, requirements and guidelines;
- ISO/TR 14047:2012 Environmental management -- Life cycle assessment -- Illustrative examples on how to apply ISO 14044 to impact assessment situations.

ISO series standards 14040, 14041, 14042 numbers and 14043 ended up being condensed to only two documents, ISO 14040 and ISO 14044, aiming to facilitate their application.

## IV. ASPECTS CONNECTED TO THE USE OF LCA

According to ISO 14040, the LCA is a technique that aims to enable a correct assessment of the environmental aspects and potential impacts associated with a product, consisting of four distinct analysis steps, as listed below, and can also be observed in Figure 2.

1) Definition of the goal and scope;
2) Establishment of life cycle inventory (LCI);
3) Valuation of the impact of the life cycle (VILC);
4) Interpretation of results

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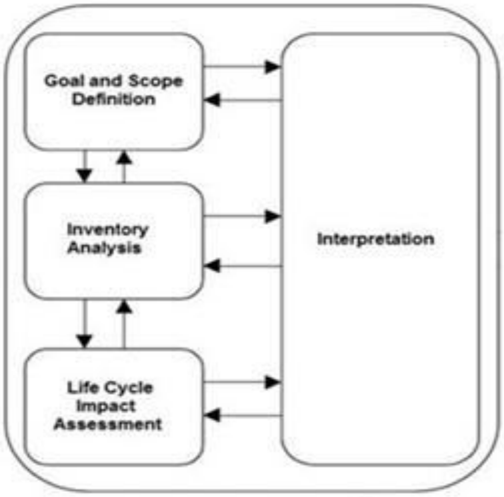


Fig. 2. LCA framework based on ISO 14040 [8]

The definition of the objective and the scope involves the identification of the purpose and limits of the system, while the life cycle inventory (LCI) involves the collection of data for each unit or process in respect to all of its inputs and outputs. Already at the stage of valuation of impact of the life cycle (VILC) are identified potential environmental impacts and estimates of resources used in the modelled system, consisting of this step of three mandatory elements:

- The impact categories selection;
- Attribution of results of LCI (classifications);
- Modelling category indicators (characterisation).

For an assessment of the impact of the life cycle, there are basically two methods [12]:
1) Problem-oriented (mid points), where the approach involves the environmental impacts associated with climate change, acidification, greenhouse gas, eutrophication, potential for destruction of the ozone layer and human toxicity, and may be evaluated using methods such as CML baseline (2001), EDIP 97 & EDIP 2003 [13] and IMPACT 2002 +[14,15];
2) Damage-oriented (end points), classifying the cash flows on various environmental themes, modelling the damage that each theme gives to human beings, the environment and natural resources, and for this use, for example, the methods Ecoindicator 99 and IMPACT 2002 +. In the step of interpretation, significant problems are identified and results are evaluated to reach conclusions and make recommendations, then generating a final report which is the last element to complete a LCA. This methodology enables the study of the environmental aspects and potential impacts caused throughout the life of a product, i.e. the ‘cradle’ to ‘grave’, from the procurement of raw materials, through production, to use, to reach its dismount. It can be of great help also for selecting environmental performance indicators, including measurement techniques and also to outline marketing strategies, as in the case of an environmental statement or an eco-labelling programme. To aid in the visualisation of environmental flows in the life cycle of a building for example, Figure 3 with base in Silva [7] shows the various inputs (energy, water and materials), their related life cycle stages themselves (preparation of the site, construction, use, maintenance, demolition, recycling and reuse) and their outputs (emissions of atmospheric gases, dust, noise, solid waste, garbage and sewage). According to Taborianski et al. [16] and Fava [17] the LCA has been used in the construction industry since 1990, being an important tool for the evaluation of buildings.

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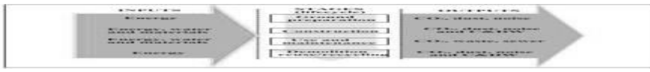

Fig. 3. Environmental flows in the life cycle of a building [7]

According to Singh et al. [18] there are four categories of applications for LCA:

- Selection of construction materials;
- System evaluation and construction processes;
- Tools and databases for the construction industry and
- Methodological Developments aimed at the construction industry.

According to Ortiz et al. [19] in industrial activities, companies must understand the application of life cycle assessment, not only to meet the demands of consumers for ecological products, but also to growth the productivity of ecology construction markets. Bilec et al. [20] conclude, for example, for aspects related to energy consumption and $CO_2$ emissions (greenhouse gas emissions), the operation and maintenance phase is the one that offers the greatest contribution to the impacts along the life cycle of a construction when compared to other phases, as can be seen in Figure 4.

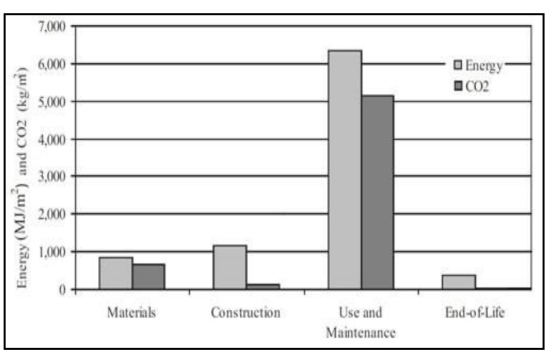


Fig. 4. Energy and $CO_2$ by life cycle stages [20]

## V. TOOLS USED IN LCA

Regarding tooling currently developed and available for the implementation of the methodology of life cycle assessment, these tools are classified according to three different levels:

- Level 1 to product comparison tools.
- Level 2 for decision support of construction project.
- Level 3 for the evaluation of total construction.

In Table I, some of the main tools used for life cycle valuation are listed, along with their respective web addresses [21].

TABLE I

LIFE CYCLE ASSESSMENT TOOLS [21]

| Program | Web addresses |
|---|---|
| Athena | www.athenasmi.ca |
| Bees | www.bfrl.nist.gov |
| Boustead | www.bousted- |
| Deam | www.ecobilan.com |
| Ecoeffect | www.ecoeffect.se |
| Eco-it | www.pre.nl |
| Ecopro | www.sinum.com |
| Eco- | www.ecoquantum.nl |
| Ecoscan | www.ind.tno.nl |
| Eco-soft | www.ibo.at/de/ecosoft.ht |
| Envest 2.0 | www.envestv2.bre.co.uk |
| Equer | www.izuba.fr |
| Euklid | www.ivv.fhg.de |
| Gabi | www.gabi-software.com |
| Greencalc | www.greencalc.com |
| KCL Eco | www.kcl.fi./eco |
| LCAit | www.ekologik.cit.chalmer |
| Legep | www.legep.de |
| Miet | www.leidenuniv.nl/cml/ss |
| Ogip | www.ogip.ch |
| Simapro | www.pre.nl |
| Umberto | www.umberto.de |
| Wisard | www.pwcglobal.com |

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As for the main databases used for environmental assessment, some can be cited as the CML, the DEAM$^{TM}$, the Ecoinvent, the GaBi 4 Professional and SimaPro. However, the tools and the existing databases vary according to users, applications, data, geographical location and scope. These databases here cited are representative for the conditions that exist in most industrialized countries, lacking the development of specific databases for use by developing and emerging countries.

## I. POSITIVE AND NEGATIVE POINTS OF THE LCA METHODOLOGY

The life cycle assessment represents an efficient methodology, which works to provide a higher level of sustainability in the sector of the civil construction, in all its phases. As a good example of the importance of using this type of methodology applied, Runming et al. [22] note that the construction sector in China is already responsible for more than one third of its total energy consumption. Therefore, there is no doubt that the reduction of the environmental impact of the construction sector would be of utmost importance to achieve a more sustainable development. A construction can become more sustainable, for example, through the use of a smaller quantity of natural resources, in addition to the use of materials with low environmental impact and the implementation of renewable energy to reduce environmental loads, energy and water consumption, promoting greater sustainability in buildings. An example of good practice in this regard is the passive house project [23, 24, 25, 26, 27]. Based on the description of activities related to LCA methodology are valid present advantages and disadvantages significant to this methodology [20].

- Advantages
  - The detailed analysis of specific processes;
  - Comparisons between products;
  - Identifying process improvements.

- Disadvantages
  - Subjectivity in the selection of boundaries;
  - Lack, in many cases, of more complete data;
  - Great expense of time and financial resources;
  - Uncertainty generated.

## II. CONCLUSION

Increasingly the life cycle assessment (LCA) has been recognised as an innovative methodology focussed on sustainability in the civil construction industry. The promotion of sustainable principles in the industrial sector in question, both in developed countries as in developing countries, becomes extremely important for sustainable development of the planet and through the LCA techniques can better visualise and reply to questions such as: what kind of material or constructive process can make a building more sustainable? You can't forget that the greatest environmental loads generated throughout the life of a particular building focus on the operation and maintenance phase, this being the most critical period, due to significant atmospheric emissions and the high energy consumptions, hot water and lighting. Promoting improved alternatives of thermal and acoustic insulation, replacing materials to minimise environmental damage and providing support for the implementation of renewable energy technologies, for example, must be strongly desirable. Another aspect to be considered is that there are already many available software tools and also a great amount of databases, both in European countries, as in the USA, but, on the other hand, there is little literature in this field of knowledge when it comes to less industrialised countries. Therefore, there is a need, in those regions, for a further development of tools (software and databases) for the development of sustainability indicators for design, construction, operation and disassembly in order to better guide the use of material resources, water and energy. One should highlight the social and economic indicators that make up the other two bases of the so-called sustainability Triple Bottom Line (Figure 1), already mentioned at the beginning of this work, and that should also be considered, because of the important role that it represents for the developing nations around the world.

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