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Possible roles for environmental Life Cycle Assessment in building specifications

Abstract

Life Cycle Assessment (LCA) is a systematic methodology for evaluating the environmental impacts of different product systems. It is a useful tool for comparing different alternative products or systems (including buildings. However, complexities of the built environment and limitations in current LCA data and methodology make implementation of LCA into decision making for building design and specification, very difficult. Streamlined LCA techniques and life cycle thinking are currently the easiest ways to introduce LCA to the building sector. However, in the future, with new developments in LCA, more rigorous tools should become available.

Keywords: Life cycle assessment, environmental impact.

DIE MOONTLIKE ROL VAN LEWENSSIKLUS-ONTLEDINGS (-ASSESSERING) VAN DIE OMGEWING IN BOUSPESIFIKASIES

Lewenssiklus-ontleding (LSO) is 'n sistematiese metodologie vir die evaluering van die omgewingsimpak van verskillende produksisteme. Dit is 'n bruikbare hulpmiddel om die onderskeie alternatiewe produkte of sisteme (ingeslote geboue), te verge-lyk, maar die kompleksiteit van die beboude omgewing en die beperkinge in die bestaande LSO-data en metodologie, maak die implementering van die LSO vir besluitneming vir geboue-ontwerp en -spesifikasies, baie moeilik. Vaartbelynde LSO-tegnieke en -lewenssiklus-ontleding is tans die maklikste manier om LSO in die boubedryf te inkorporeer. Nuwe ontwikkelings op die terrein van LSO kan moontlik daartoe lei dat meer effektiewe metodes in die nabye toekoms beskikbaar gestel word.

Sleutelwoorde: Lewenssiklus-ontleding, omgewingsimpak.

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Introduction

In a world where purchase price is the only criterion, all useful information about products is found at the point of sale. If the full financial consequences of decisions are taken into account, it is necessary to look beyond initial up-front cost, to the running costs and eventual disposal incomes or costs at a product's end of life. If environmental considerations are going to be taken into account it is necessary to look both forwards towards the use and disposal of the product, and backwards to the production processes and inputs which go into the manufacture of these products. This is referred to as the 'life cycle' view and forms the basis of an environmental assessment method called Life Cycle Assessment (LCA).

LCA has a particular complexity that relates to the incomparability of the environmental flows it measures. Unlike cost, which is generally limited to comparable dollar values, environmental impact is measured in terms of damage or potential damage to the environment. This could include global warming, increasing nutrient loads in waterways, urban air quality and so on. The procedure for accounting for these significantly different impacts is called life cycle impact assessment. The challenge for decision makers, be they builders, clients, specifiers or architects, is to make some sense of the complex environmental information and integrate it with other decision criteria. This article intends to provide an overview of what LCA entails with regard to the current status of methodology and practice in Australia, and to indicate what forms of LCA may be introduced into the building, design and construction process.

Life Cycle Assessment (LCA)

LCA can be understood on a number of levels. Firstly, as a way of thinking, LCA broadens our understanding of the environmental impacts of products, to include upstream and downstream effects of decisions. In trying to implement this new thought process, questions inevitably arise about what exactly are the impacts of these decisions. This is where the more literal view of LCA becomes important, that is, as a systematic methodology for evaluating the impacts of different product systems ('product' in this context includes materials, services and so on). LCA takes a systemic view of the interaction between human activity and the environment. *Figure 1* indicates the supply chain of human activity with in the 'system boundary', which defines the elements of human activity considered in the assessment (note that this can be truncated in some LCAs depending on the scope). There are flows from the environment that are required by the human activity, which are generally resources and energy, and there are flows from the human activity back

SYSTEM BOUNDARY

INPUT

| | OUTPUT |

Raw materials acquisition → Waterborne wastes

Manufacturing, processing and formulation

Energy → Distribution and transportation → Airborne wastes

→ Solid wastes

Raw materials → Use/re-use/maintenance → Other environmental releases

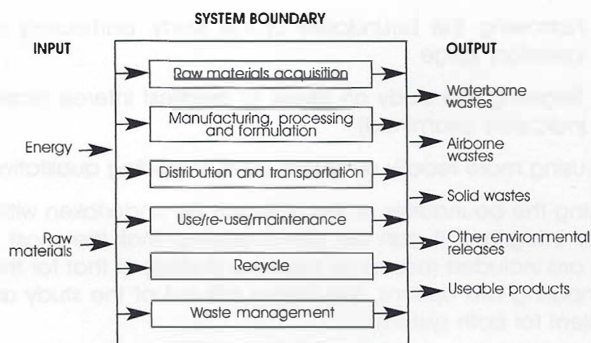Recycle → Useable products

Waste management

Figure 1: Product system from life cycle perspective

to the environment, namely releases to air, water and soil. The system also produces some usable products or functions, which are the main reason for the system activity in the first place.

The LCA methodology has developed over the past three decades, and despite substantial diversity in approaches, an agreed methodology has been documented in the ISO 1 4040 standards. The standards (International Standards Organisation, 1997) break LCA up into 4 stages:

1)   Definition of the goal and scope of the LCA, that is, the questions under investigation

2)   Life cycle inventory analysis of materials and energy used and environmental releases from all stages in the life of a product or process

3)   Life cycle impact assessment, examining potential environmental and health effects related to the use of resources (materials and energy) and environmental releases

4)   Life cycle interpretation of the results to check significance of trends and quality of key data effecting the conclusions.

A detailed description of the methodology is not intended here but can be found in Guinee, Gorree et al (2001). Between viewing LCA as a guiding principle and undertaking detailed LCA studies according to the ISO 14040 standards, there is a spectrum of LCA activity that is often referred to as streamlined LCA. Streamlined LCA is undertaken for different reasons, but most often to reduce the costs and time that can be associated with full LCA studies. According to Weitz, Todd et al., (1996)

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LCA can be streamlined by:

√   Narrowing the boundaries of the study, particularly during the inventory stage

√   Targeting the study on issues of greatest interest (narrowing the indicators examined)

√   Using more readily available data, including qualitative data.

Narrowing the boundaries of the LCA can be undertaken without a loss in study integrity if it can be demonstrated that the most important stages are included (based on previous studies) or that for the purpose of comparing two options, the stages left out of the study are roughly equivalent for both systems.

Targeting the indicators of most interest or importance may be sensible if these were going to be the only points considered in the decision making regardless of what else was examined in the LCA. It is also less problematic if the systems being compared have similar industrial characteristics, and a reduction in one indicator could be expected to produce reductions in most indicators examined. It is dangerous, however, when substantially different systems are compared, for example when timber is compared to steel production. Some qualitative caveats need to be included if this sort of streamlining is being undertaken.

The most popular streamlining approach is to reduce data collection through the use of previous studies and generic LCA databases. Many software packages are available which include data sets for basic materials and processes, as well as standard environmental impact models. This software-based approach can quickly provide insights into the possible impacts of products. Most software allows for the examination of impact results across different stages of the life cycle. Figure 2 is an example of a process tree, generated from SimaPro LCA software for the production of concrete.

At the top of the tree is the final product (in this case concrete) and the processes are indicated in each box below (in LCA referred to as unit processes) that contributes to its production. Each unit process may have inputs and outputs to the environment (for example the electricity process will have coal inputs and carbon dioxide output). The unit process may also have other processes, which it requires (for example cement production needs the process of clinker production, gypsum production and so on as shown in Figure 2). The side bar each unit process represents is set in this example to show cumulative greenhouse impacts through the life cycle (from the bottom of the tree up to the final production at the top of the tree).
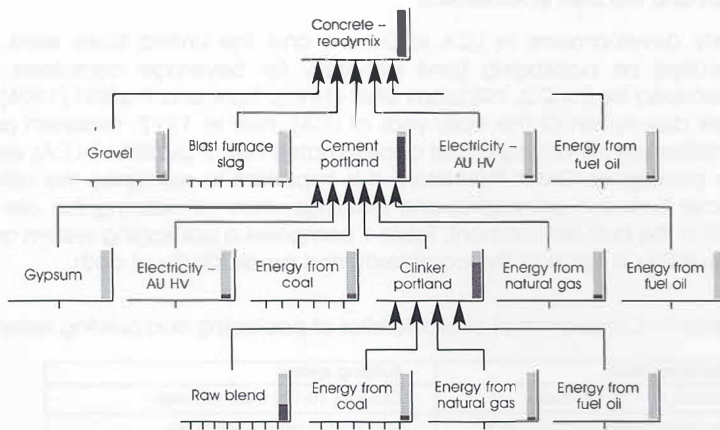
Figure 2: Example of a process tree from SimaPro 5 LCA software show-ing cumulative greenhouse impacts for different unit process-es[1] used in the manufacturing of concrete.

The difficulty with streamlined studies using the LCA data provided in software is in determining the relevance and reliability of these results to the specific real world situation being studied. The alternative, or possi-ble supplement to software-based streamlining, is the use of matrices to organize and prioritise environmental impacts. There are many approach-es to this that have been documented (Lewis; Gertsakis *et al.*, 2001; Graedel, 1996; Weidema, 1997). In this approach, a matrix is used to organise infor-mation gathered either from other studies, or from a workshop of experts and/or stakeholders. This approach relies on a broad knowledge base of participants filling in the matrix. This would normally include people famil-iar with the product or material under examination and people with more general environmental experience. The matrix can also be informed by streamlined quantitative information from an LCA software tool.

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[1]   Not all unit processes are represented in the diagram – some have been truncated due to formatting requirements, for example, gravel has processes below it such as transport and energy for extraction and crushing.

LCA and the built environment

Early developments in LCA in Europe and the United State were all focused on packaging (and generally for beverage containers as described by Bonifaz, Nikodem *et al* (1996); Hunt and Franklin (1996) in their description of the early year of LCA). Prior to 1992, Pedersen and Christiansen (1992) found that approximately half of published LCAs were on packaging. Given this history, it is important to recognise the differences between packaging and buildings when considering the use of LCA in the built environment. *Table 1* compares a packaging system and a building in terms of the complexity and predictability of both.

Table 1: Comparison of characteristics of packaging and building systems

Package system	Building system
Consists of 1-10 materials	Contains 10-100 main materials
Life cycle of weeks up to a year	Life cycle of years to centuries
Generally little interaction between impact of product contained in package and type of package	Building form generally has dramatic influence of operational impacts and local conditions
Millions of copies produced by few suppliers	Buildings are constructed by many people and many are unique

It is the last two points in *Table 1*, which make LCA of buildings so difficult. Any assessment methodology needs to be able to be easily reapplied for each building, given different locations, desired forms and available materials. This also leads to great frustration among specifiers, designers and architects, who want a clear indication of the most environmentally preferable materials, when in reality this is highly dependent on individual applications. It has also led to substantial controversy when environmental claims have been made for or against specific materials, in the absence of a reference to a specific situation.

This suggests that if simplifications are going to be made in the application of LCA to the built environment, they should not be in the selection of life cycle stages to be included. This is particularly problematic when materials are assessed in the absence of operational impacts. A safer simplification would be to reduce the indicators being used, for example, to greenhouse and energy, or energy and smog emissions. More difficult indicators such as toxic air pollutants or biodiversity may be dealt with in the decision making in a more qualitative manner.

In the Netherlands, a tool has been developed, based on Dutch LCA data and European impact methodologies, to provide a series of simple indicators for architects, designers and specifiers to use in the early design stages of buildings (IVAM Environmental Research 2001). Similar tools are under development in the United States (US EPA Office of Applied Economics, 2001), Canada (The ATHENA Sustainable Materials Institute, 2001) and Australia (LCAid – a computer tool developed by the department of pubic work, NSW not yet commercially released). Most of these tools, however, are still struggling to provide necessary data and material options to cover the multitude of design and material options, commonly considered in the design process.

Recommendations for including LCA in the specification process

Given the current situation in LCA in Australia and in many other parts of the world, it is obvious that we are still some distance from an all inclusive assessment tool. While advances are being made in the area of building modeling and LCA data, a bigger challenge still exists in the development of simple yet rigorous indicators of environment. In the meantime the authors suggest the following actions to begin the process of LCA in the built environment. In the first instance, promote the life cycle view to get specifiers, designers and clients thinking beyond the material itself to the life impact prior to and after, the material installation:

√ In undertaking streamlined LCA, limit the indicators before truncating the life cycle stages. In particular it is important to consider the impacts of material production and building operation, and depending on the volume of individual materials – at end of life

√ Keep track of qualitative information and criteria alongside quantitative data throughout the decision-making process

√ Before undertaking LCA work, prioritise the key areas for study, based on the main impact areas of the product or building being studied. Conversely avoid LCAs which are trivial, or for which the main impacts will be incomparable without a detailed environmental impact model (as we have none in Australia as yet)

√ Recognize LCA as a decision-making support tool and not a final answer.

Conclusions

LCA is a powerful decision-making tool, and is ideally suited to many of the current questions being raised in relation to the design and operation of buildings. Unfortunately the methodological infrastructure for LCA, that is, inventory data about production processes and impact models to compare and rank different environmental issues, are not well enough developed to produce simple LCA tools for ready implementation in the building industry. Streamlined LCA work can provide some information for decision-making, and the overall concept of life cycle thinking is a valuable perspective for the design of a decision-making process. New developments in LCA methodology and data can be expected over the next five years and these will increase the possibilities for integrating LCA into more general decision-making processes.

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