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CRADLE TO THE GRAVE - LCA TOOLS FOR SUSTAINABLE DEVELOPMENT

Roman Jaques

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Roman Jaques
Building Research Association of New Zealand
Building Technologist (Environmental)

SUMMARY

The paper begins with the inception of the cradle-to-the-grave assessment procedure for products and processes, from its humble beginnings in the USA in the late 1960's. It then traces the assessment procedures' development and progress through the decades, to its current application for buildings and building materials. The paper concludes with predictions on what direction and form building-related life cycle assessment tools are likely to take, and how this may aid progress in the development of sustainable design. In essence, assessment tools will raise the general public's awareness of building-related environmental issues and provide basic guidance on how to design lower eco-impacting structures.

THE EARLY YEARS

Life Cycle Assessment (LCA) is the method of formally analysing a system - whether it be a material, component or multitude of components - based on cradle-to-the-grave principles. Thus, a product is examined from when and how its raw materials were acquired, through to its production, use, and finally destruction. Depending on the depth and breadth of this examination, LCA can be very complex and time consuming.

The objective of LCA is to (Hobbs, 1996):

- compare alternative processes
- improve the resource efficiency of individual processes
- provide information to interested parties on resource use and releases
- assess the impact of the environment, and
- identify ways to reduce this impact.

LCA is generally recognised as being composed of a four step procedure called *life cycle analysis*, on a specific product. [It should be noted that the terms "life cycle assessment" and "life cycle analysis" are often used interchangeably]. The four steps in the life cycle analysis are generally known as:

1. **Goal Definition:** which establishes goals and boundaries.
2. **Inventory:** which quantifies inputs and outputs that occur over the life cycle of a product.

3. **Classification/Impact Analysis:** which assesses the effects of the environmental burdens identified in the previous stage.

4. **Evaluation:** where environmental burdens associated with the inputs and outputs are investigated.

What we now know as Life Cycle Assessment had its humble beginnings in the late 1960's, in the USA (Hunt, 1993). Back then, LCA was known under the more convoluted title of "Resource and Environmental Profile Analysis" (REPA), with the term "LCA" only coming into wide use in the USA much later.

The comprehensive analytical version of LCA was first conceived by the Coca Cola Company in 1969. The tool was proposed as providing a means of analysis of various packaging issues confronting the company. Its goal was to include and quantify energy, material and environmental impacts for the life cycle of packaging material. Realising the complexity of designing such a tool, the Coca Cola Company contracted in the technical expertise of the Midwest Research Institute (MRI) who were to complete several similar studies over the years (Hunt, 1993).

The 1970's brought on a number of similar studies, performed by MRI for various manufacturers. Although the impetus for undertaking the studies stemmed from waste management issues, LCA tools were also used for research and development purposes. Because of the nature of the studies, the results were almost always confidential.

It was during the first half of the 1970's that the LCA framework started to resemble its modern-day equivalent.

It was quickly realised (at least in the research fraternity) that the life cycle approach had application to the building industry. The focus for building materials was on safeguarding limited, non-renewable resources (Bekker, 1982), as opposed to previous studies which concentrated on material flow analysis.

DEVELOPMENT

Research papers on the application of LCA to both buildings as a whole and building materials were already present in the late 1970s (Bekker, 1979). It was recognised that building-related products were different from most other consumable items, in terms of LCA. Two examples of their unique properties were:

1. They had much longer expected lifetimes (eg buildings usually are built to last 50 or more years, while packaging is only required to last a few weeks).
2. A building product's use was often ill-defined, due to its many possible applications (eg timber for use in permanent walls or partitions).

The uncertainties stemming from these two properties were problematic, leading to complexities which were difficult to resolve and made accurate building-related environmental assessment difficult. For example, a material's maintenance requirements (and therefore its expected lifetime) and the anticipated recycling opportunities at the end of its life, are dependent on a whole range of factors. Some of these factors are difficult to predict. To some extent, these building-specific life cycle problems have still to be resolved even today (Chevalier, 1996).

The early 1990s saw generic LCA become more developed. Two organisations (with the assistance of international support) were largely responsible for this - the US "Environmental Protection Agency" (EPA, 1993) and Belgium's "The Society for Environmental Toxicology and Chemistry" (SETAC, 1993). Both organisations refined methodological aspects of LCA, covering everything from terms and definitions, through to its practical implementation.

As part of the development of building-related life cycle tools, ground rules on what a credible procedure should contain were informally decided upon. Credible life cycle-based environmental

assessment procedures, for whatever product, should aim to be:

- as accurate as possible
- verifiable
- based on scientific methodology
- based on consensus opinion
- transparent - ie having all product information available to the user, and
- result in more informed choices, with some degree of certainty.

It is no coincidence that this "checklist" is similar to that described in the ISO draft standard ISO/DIS 14020 "*Environmental labels and declarations - General principles*". This details nine specific environmental principles which have to be met. The ISO 14000 series of standards is developing standards dealing with environmental management systems. A subcommittee (SC5) is dedicated specifically to address the area of LCA, and is currently finalising the methodology which will define its principals and framework (refer web page: www.ansi.org/documents/iso14000).

There are other more building-specific approaches which are progressing the LCA field also. The International Energy Agency's *Annex 31* "Energy related environmental impacts of buildings", is developing guidelines to determine energy-related environmental impacts of buildings. These guidelines will be able to be used by anyone trying to create new methods, tools or benchmarks for rating the environmental impact of buildings, based on the life cycle principle (refer web page: annex31.edu.rmit.edu.au/iea/home.htm).

The aim of Annex 31 is to influence the energy-based impact of buildings and the building stock on the environment. It plans to achieve this by developing, testing and refining tools which will assist in the evaluation of buildings using suitable and agreed upon environmental-based methods. These tools are all based upon LCA principles, and will be available to teaching institutions, policy makers, funding organisations and researchers.

Generic (ie non-building related) LCA problems have also hampered its use and application in the construction industry. The impact assessment stage is the most difficult and (as yet) unresolved of the four life cycle analysis stages (Beetstra, 1996 and Baumann, 1994). At present, there is no consensus on how to compare differing environmental impacts. For example, how does one compare habitat loss to acid rain or green house gases?

In response to this difficulty, some LCA techniques have tried to assign single dimensionless values to environmental impacts, in order to calculate the total burden of a product. Thus, a fast comparison of products can be performed. Early examples of this include: the *ecological scarcity method* (Ahbe, 1990), where ecological scarcity is defined for an area by the relationship between the critical load of a pollutant and the human-induced emissions of that pollutant; the *environmental theme method* (Annema, 1992), where the total impact is calculated based on an involved calculation method; and the *environmental priority strategies in product design method* (Ryding, 1991), based on resource and emission indices.

A more recent example of this is the *Eco-Indicator 95* program, which involved a multi-disciplinary team (involving scientists, industry and government representatives), which had its beginnings in the Netherlands (Ecocycle, 1997). Their goal was to factor a single number which represents the environmental impact of a material/process, based on life cycle principles. The short-list of environmental issues was limited to: the green house effect, ozone, acidification, eutrophication, smog, and toxic substances.

All these methods for impact analysis and evaluation have the potential to produce differing results according to:

- the depth of analysis performed
- the quality and accuracy of the data
- the effects considered, and
- how the algorithms are constructed (Baumann, 1994 and Jonnson, 1997).

Because of this, the potential arises to recommend a product which is actually less environmentally benign than its competitor. LCA does, however, provide an extra dimension for those involved in the building sector to consider, along with the more commonly used parameters of cost, durability and utility. The development of life cycle based tools has added weight and credibility to the environmental debate. This type of holistic analysis also brought some scientific rigour and further meaning when associated with the catchword - "sustainability".

MATERIAL ASSESSMENT

In the building materials arena, a variety of labelling, certification and other environmental assessment programmes have been implemented since the start of the 1990's. These have ranged from focused inventory studies which feed into

eco-labelling programmes (Ceuterick, 1993; Ecobilan, 1993; and the Swedish Standards Institute, 1993), through to comprehensive, voluntary certification programmes, such as Canada's "Environmental Choice" eco-labelling scheme (Environment Canada, 1993). Although labelling schemes are principally directed at consumables, they do cover some building materials as well.

Non-certification schemes, which rank building materials based on core environmental principles, are also available. A very popular European method is the "*Environmental Preference Method*" (EPM), initially developed in 1991 in the Netherlands (Anink, 1996). The EPM is a practical tool for comparative assessment of building materials, based on simplified LCA. In the EPM, comparisons are made using "functional units".

Functional units (also called "functional equivalence") are a method of comparing a range of materials equitably, based on their ability to perform a particular service (rather than basing it on a unit of production - say mass or volume). Using paint as an example, the functional unit may be "*the amount of paint necessary to cover 10m² with an opacity of 95%*".

In the EPM, materials are categorised into four preferences, by building element, according to their relative environmental impact. The EPM has seen wide application in seven EU countries as an evaluation tool (Anink, 1996).

Other simplified LCA-based tools, even if less than comprehensive, are an alternative avenue with which the environmentally-concerned can become pro-active in a very immediate way. These tools can range from a simple list which prioritises material-related environmental issues (Environmental Building News, 1997); through to extensive environmental-based building material data sheets (NZIA, 1996).

All of these environmental assessment tools are founded on (consensus-based) expert opinion. The effectiveness of these systems in influencing purchasing decisions, varies with the tool used. Also, to a large extent, they require the user to have a good understanding of the materials being compared. Like any consumer-driven system, its future application and success depends to a great extent on the demand from the public.

WHOLE BUILDING ASSESSMENT

The early 1990's saw the advent of voluntary, practical, whole building environmental analysis, based on simplified LCA. Two of the most popular are the UK's *BREEAM* (Crisp et al, 1991), and the

Austin, Texas *Green Builder* programme (Seiter, 1992). These schemes focus on environmental assessment applied at the design stage of domestic buildings. They cover a range of issues, and award a certificate for designs fulfilling minimum environmental criteria.

These formative schemes were seen as an initial step in the shift towards more “sustainable” architecture. Essentially practical design assistance tools, they were able to raise the general public’s awareness of building-related environmental issues, and the long term significance of choices made at the design stage.

Whole building voluntary-based analysis schemes have since branched out. The BREEAM scheme, for example, has expanded to include a whole host of building types (such as new offices, existing offices, superstores, and supermarkets, as well as first revision of the original scheme called the “Environmental Standard”) and having global derivatives (including Canada’s *BEPAC* (Cole, 1991). Also, they are becoming more sophisticated (eg *Office Toolkit* (Bishop et al, 1995), *Scottsdale Green Building Program* (City of Scottsdale-Arizona, 1998)) in the range of issues being addressed and the introduction of environmental weighting systems based on perceived environmental importance. Some of these environmental diagnostic tools comprise complex system models, which generate composite energy and emission profiles for part, or all of a design.

Two examples of these complete system models are ATHENA (Cole et al, 1996) and The Office Toolkit (Bishop, 1995). The ATHENA model is able to generate an “environmental profile” based on environmental issues, such as: resource usage, energy used, global warming potential, solid waste, and air and water pollution. The profiles are based on a series of investigations and product life cycle studies carried out over several years, which formed an extensive data base. ATHENA covers most building types, and has the ability to quickly and easily investigate the implications of design alternatives. Another example is the UK’s Office Toolkit, which only focuses on one type of building. It includes both direct and indirect environmental impacts, as well as health and safety aspects. To gauge the relative importance of the different types of environmental impact, the Office Toolkit uses the Swiss-originated “ecopoint” which was developed in Holland (refer web page: www.Pre.nl). The dimensionless ecopoint is a measure of the severity of the environmental damage, based on society’s desire to reduce that damage.

NZ INITIATIVES

Environmental issues have stimulated a lot of interest in building related fields in NZ, with diagnostic tools based on LCA methodology gaining recognition. Life cycle based applications have formed the basis of several building-related assessment tools. Two examples of those tools are a series of material comparison charts (NZIA, 1995) and a whole building assessment procedure (BRANZ, 1997).

The most widely disseminated LCA-based documents in NZ have been the NZIA’s *Environmental Impact Comparison Charts* for building elements (NZIA, 1995). Twenty charts divide the elements into eight categories which relate to the life cycle stages. Categories include “Materials Acquisition”, “Manufacturing”, “Construction” and “Operation”. Although descriptively based, they do contain some quantitative data. Readers can quickly make material comparisons, based on their own environmental priorities. It is unknown just what the uptake of this scheme has been, or the resultant effects on the building industry.

A whole building environmental assessment scheme, the “Green Home Scheme” (BRANZ, 1997) examines new homes at the design stage. The scheme is mainly concerned with environmental issues, but some health and safety issues are also addressed. Although based on the UK’s BREEAM scheme, it is greatly modified, being more descriptively based and covering a wider variety of issues. Fourteen environmental, health and safety issues are considered, based on life cycle principles. So far, although there has been interest in the scheme, the application has been minimal. The scheme will be continually developed (incorporating attributes such as environmental indicators), with an office version also being produced.

INTO THE FUTURE

So what is likely to happen over the next 10-15 years, in building-related LCA tools? To a large degree, this depends on the demand by interested parties (eg designers, material suppliers and specifiers, and general public), but it is most likely that:

- the range of specialised LCA tools will increase in both sophistication and variety, with a few of the most sophisticated becoming linked to computer aided drafting and design-type packages. A rudimentary example of this is the

Australian embodied energy¹ impact modelling software, which estimates embodied energy values in buildings directly from three dimensional drawing programmes (Tucker, 1996).

- there will be more of a consensus within (if not between) countries, on standard methods for addressing building-specific issues such as durability and recycling. This will greatly assist in LCA's development and credibility.
- as environmental reporting for the manufacturing industry becomes more common, the amount and accuracy of product information collected will increase, also aiding its acceptance and application.
- There will be further exploration of possible non- and pseudo-LCA based alternatives, for addressing building-related environmental diagnostics (Beetstra, 1996). These will mostly take the form of truncated LCA methods.

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¹ Embodied energy is the "*the total primary energy that has to be sequestered from a stock within the earth in order to produce a specific product*" (from Hobbs et al, 1996).

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