LCA/LCC Tools for Environmental Compliance

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ABSTRACT

SMEs are increasingly aware of the importance of the environmental impact of their business especially because of customer and legislation demands to support organisations complying with environmental directives. The authors propose two decision-support tools to be used by designers in the early phases of product development: 1. a Life Cycle Assessment tool and 2. a Life Cycle Cost estimation tool. These tools can assist organisations in measuring the environmental performance of a product whilst also assessing the product's life cycle cost.

1 INTRODUCTION

The DeFESS (DFE Skills for Suppliers) project is a pan European project involving 10 partners with the aim of developing a training toolkit to help employees of SMEs in technological sectors comply with emerging environmental legislation. As part of this project, SME partners across 7 countries were surveyed to determine the environmental design challenges facing them, their readiness to comply with these challenges and the deficit in environmental skills across these organisations. Focus group meetings (with representatives from OEMs, suppliers and sub-suppliers, industry associations and trade bodies, academics, government and state agencies, consultants and other intermediary and support bodies) were also held in 3 countries (Ireland, the United Kingdom and Turkey) to elicit more qualitative information regarding their views on emerging legislation and their requirements for tools and training modules to assist them in complying with such legislation.

Some of the conclusions arising from these meetings include:

- SMEs already recognise the importance of emerging environmental issues alongside increasing customer demands, competition and more demanding legislation.
- Requirements for environmental compliance are cascading from the primary companies (OEMs) down the supply chain.
- Most of the SMEs surveyed set environmental targets exceeding those required by legislation (46%) or they think that compliance is compulsory for them to continue in business (38%).
- Organisations currently face problems in compliance with some of the emerging legislation. Whilst they have a reasonable understanding of emerging legislation, they have difficulty in implementing legislative requirements in their products and processes and measuring the environmental compliance of their companies.
- Organisations mostly use conventional methods such as guidelines (66%) or checklists (65%) in measuring environmental compliance.
- The use of DFE (Design for Environment) and LCA (Life Cycle Assessment) in measuring environmental compliance is low (27% for DFE, and 19% for LCA).

In response to the needs expressed by the interviewed parties, the authors developed a set of tools to be used by SMEs in order to develop environmentally superior products: the LCA tool (see section 3) and the LCC tool (see section 4). These tools can be used early in the design phase to assess the environmental impact as well as the life cycle cost of the products, thereby supporting the designers in the decision-making process. An introduction to LCA and LCC will be presented further in section 2.

2 BACKGROUND TO LCA AND LCC

Design offers an excellent opportunity to reduce environmental burdens associated with products and processes. Design for environment (DFE) is a practice by which 'environmental considerations are integrated into product and process engineering design' [Curran 1996].

The importance of including environmental criteria in the product design has amplified the need for companies to consider the entire product life cycle from an environmental perspective [Reyes 2006, Emblemsvag 2003, Behrendt 1997, Curran 1996] – see figure 1 [Roche 1999].

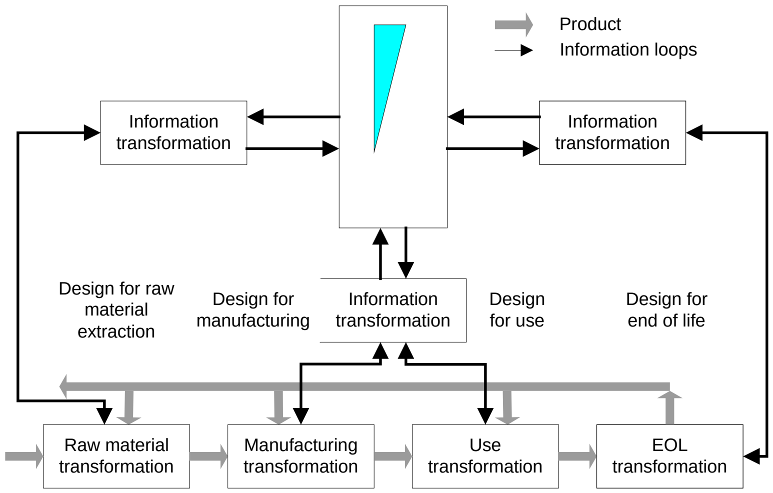

Fig. 1 Life cycle thinking in DFE [Roche 1999]

By applying a life cycle approach in product design and development, the aim is to answer one or both of the following questions [Behrendt 1997]:

- What are the most important environmental problems of a product?
- What is the best solution?

An answer to these questions can be given by applying the Life Cycle Assessment (LCA) methodology, a comprehensive analysis tool for design evaluation against environmental requirements. LCA provides a quantitative and scientific basis for the sustainability aspects of the companies' operations [Goedkoop 2006].

2.1 Life Cycle Assessment (LCA)

The LCA approach developed originally by SETAC [SETAC 1993] has been set down in the ISO 14000 series. As the ISO14040 standard defines it, the LCA is "*a technique for assessing the environmental aspects and potential impacts associated with a product by compiling an inventory of relevant inputs and outputs of a system, evaluating the potential environmental impacts associated with those inputs and outputs, interpreting the results of the inventory and impact phases in relation to the objectives of the study*" [ISO14040].

Through its four phases – Goal and Scope Definition, Inventory Analysis, Impact Assessment and Interpretation [ISO 14040] (see figure 2) – LCA is an extensive methodology which uses techniques for identifying and evaluating the adverse environmental effects associated with a product system over its entire life cycle (from 'cradle to grave'). It must be mentioned that LCA doesn't offer solutions, instead it is a support for decision-making.

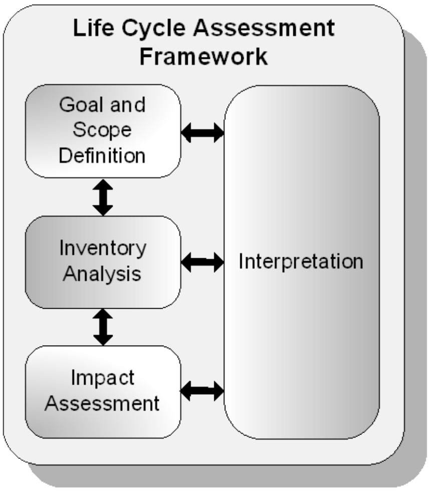

Fig. 2 Stages in LCA Methodology [Graedel 2003]

LCA is a powerful tool that can be used in the design process to [Guinee 2001]:

- improve products: analyse the origins of problems related to a particular product and redesign the product or process in order to reduce the impact on the environment; design new, more environmentally friendly products (DFE)
- make decisions: choose between comparable products; choose between different design alternatives; prove that one product is environmentally preferable to another
- benchmark a product against competitive products.

2.2 Life Cycle Costing (LCC)

If LCA is a tool that can be used in DFE in order to evaluate design alternatives from the environmental impact perspective, Life Cycle Costing (LCC) can be used to evaluate design alternatives and perform trade-off studies in order to optimise the life cycle cost.

From the very beginning LCC has been closely related to design and development because it was realised that it is better to eliminate costs when they are committed instead of trying to cut costs after they are incurred. This represents a 'paradigm shift from cost cutting to cost control during design' [Emblemsvag 2003]. This is important, as it is estimated that 70-80% of the production cost is committed at the early design phase – see figure 3.

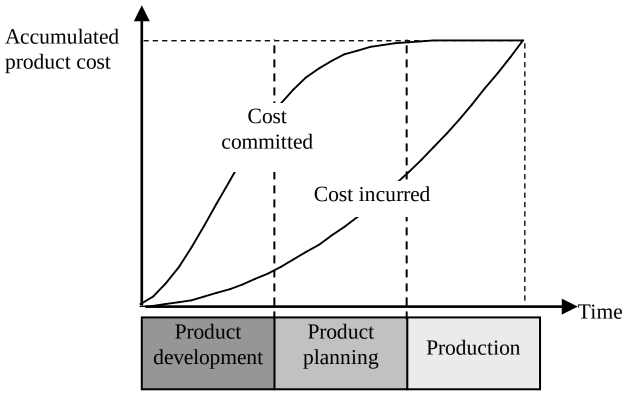

Fig. 3 Product development and cost [Layer 2002]

LCC is the process of economic analysis to assess the total cost of a product/project, including the environmental costs [Ravemark 2004]. This analysis provides important inputs in the decision-making process in the product design, development and use and can be effectively applied to evaluate costs associated with a specific process/activity, to cover a specific part of a product or to cover only selected phases of a product's life cycle as well as the total life cycle of the system/product.

LCC allows comparisons of design alternatives by estimating the costs and timing associated with each alternative over a selected period and converting these costs to economically comparable values considering the time-value of money [Ravemark 2003]. Product suppliers can optimise their designs by evaluating alternatives and by performing trade-off studies. They can also assess various operating and maintenance strategies to optimise life cycle cost.

3 THE LCA TOOL [Roche et al 2001, Man et al 2002]

The authors developed the DFE Workbench [Roche 1999, Roche et al 2001, Man et al 2002] which is focused on the analysis, synthesis, evaluation and improvement of the life cycle design of the product. The DFE Workbench is a design for environment software tool integrated into a CAD environment (the application has been ported to Pro Engineer 2001, Solid Works 2000 and Catia V5 R16). It has been developed to assist and advise the designer in the development of environmentally superior products in order to meet the requirements of the latest legislation related to environment and the customers' needs.

The DFE module consists of: the Impact Assessment System (IAS), the Structure Assessment Method (SAM), the Advisor Agent, the Knowledge Agent and the Report Generator.

The *Impact Assessment System (IAS)* is an abridged quantitative approach to LCA, performing synthesis, evaluation, prioritisation and improvement of environmental data – see figure 4. It automatically extracts the appropriate data from the CAD drawing. Based on this information and the processes associated with each component, the environmental impact may be calculated for each component or for the entire assembly.

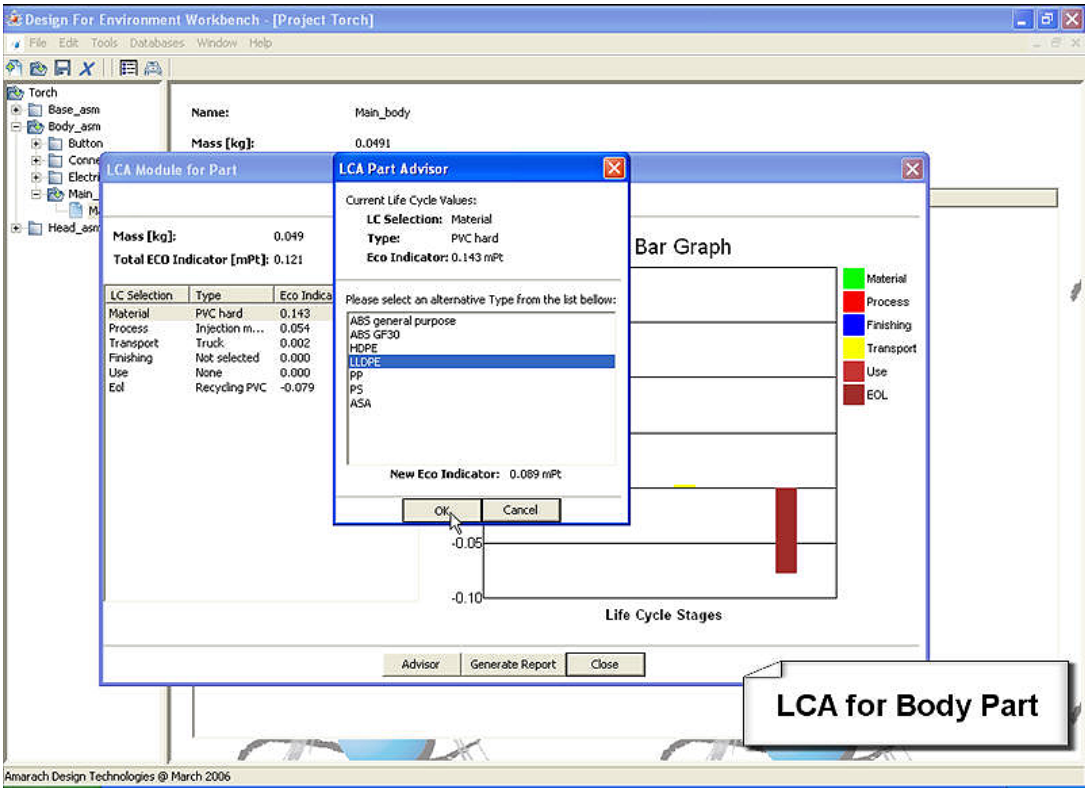

Fig. 4 DFE Workbench – LCA module

The *Structure Assessment Method (SAM)* is a complex methodology, which quantitatively measures and records data such as material compatibility/substitution (taking into account fasteners), components' serviceability, number and types of fasteners, number and types of tools required for disassembly and total standard disassembly times and component removal times.

The *Advisor Agent* has two functions: firstly to prioritise variables generated by the IAS and SAM tools; secondly to give advice to the designer on alternative structural characteristics in order to enhance either the environmental impact or structural characteristics of the emergent design – see figure 5.

The *Knowledge Agent* provides advice to the designer in a consultative mode (for example, help to find a material with specific mechanical and environmental properties).

The *Report Generator* automatically generates reports on the product designed by the user.

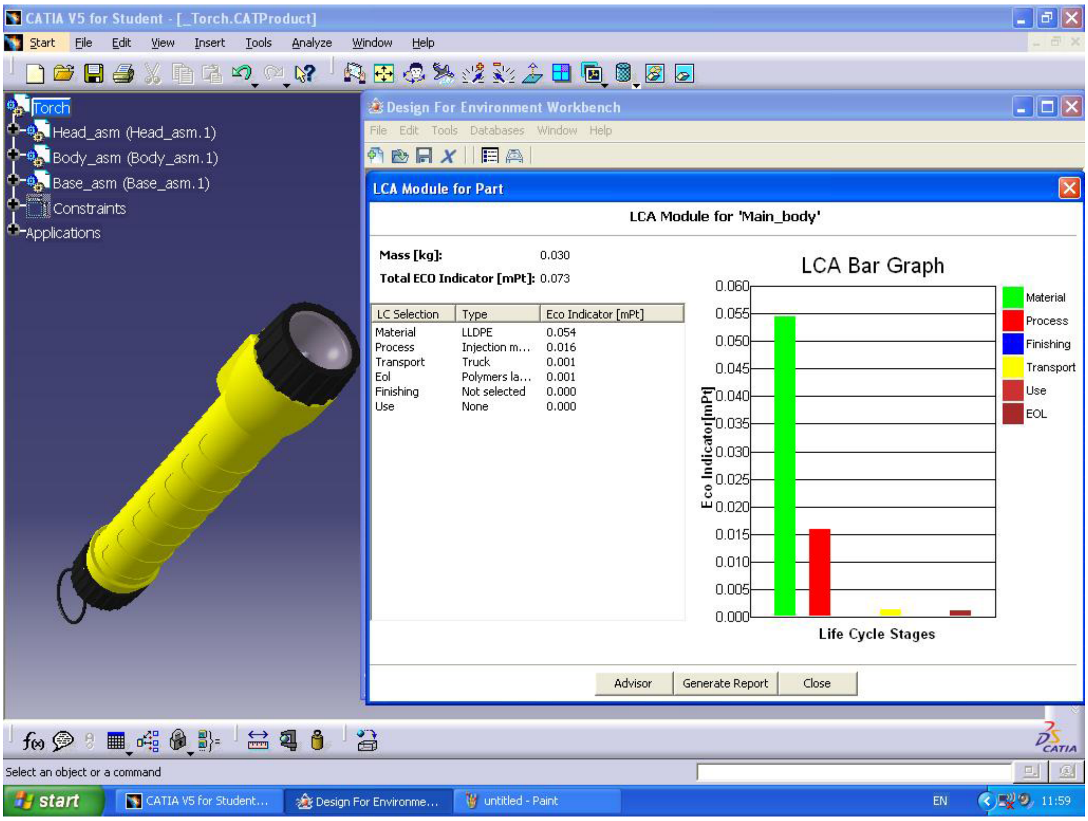

Fig. 5 DFE Workbench – LCA module: The Advisor

Using the DFE Workbench, several design alternatives can be generated according to the designer's choice or the suggestions made by the tool's advisor in order to improve the environmental characteristics of the product. IAS and SAM will calculate all indicators for each alternative. Design parameters that can be changed and that influence the product's impact on the environment as well as on costs include: type of material, mass, dimensions, no. of fasteners. Any change to these parameters can result in different processes which will result in a modification of the environmental impact and the total cost of the product.

4 THE LCC TOOL [Dimache et al 2007]

The cost estimation tool is intended to support designers in the decision-making process by giving indications of the individual life cycle stages costs (e.g. manufacturing) and the overall life cycle cost of the product so that comparisons of design alternatives at the early stages of the design process can be made.

To effectively compare alternatives, the designer must be able to accurately estimate costs for the complete system so that 'what if' scenarios can be built. The costing information is derived from the description of the product and its components and from the description of the processes the product/components are subjected to – see figure 6.

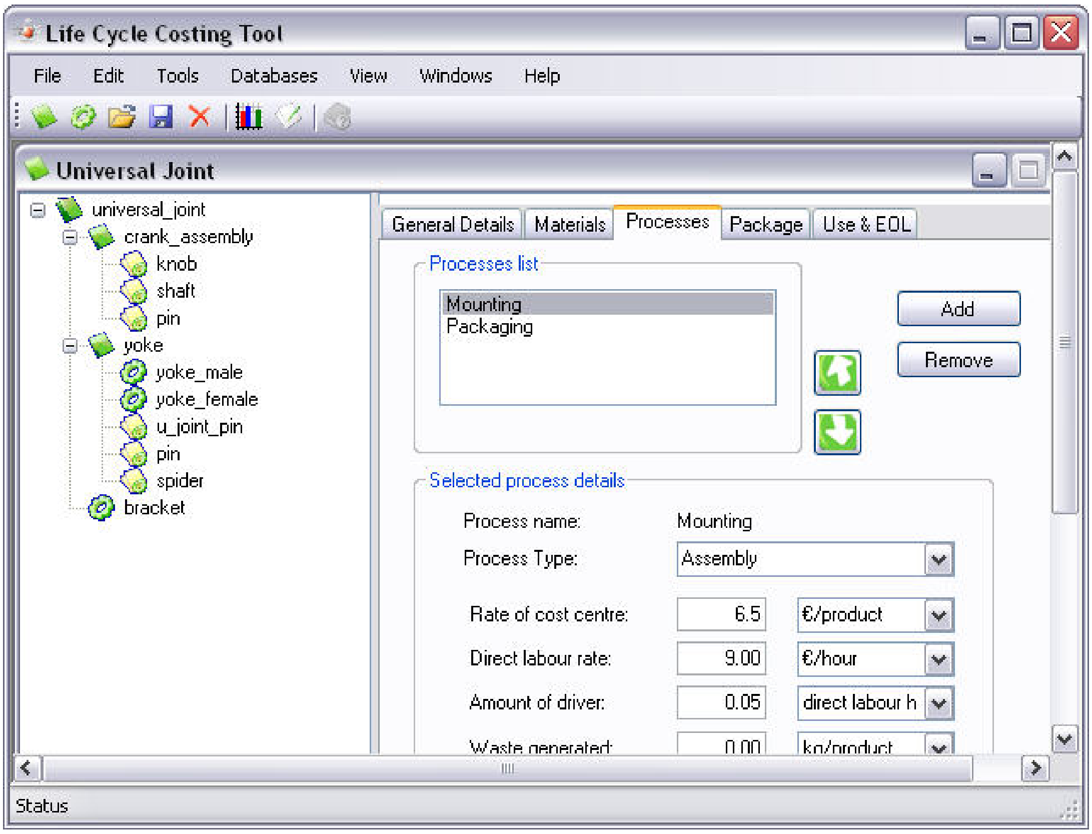

Fig. 6 LCC tool – description of product and associated processes

The cost model is a combination of life cycle costing (LCC) [Emblemsvag 2003], feature-based costing and activity-based costing (ABC) [Ben-Arieh 2003, Emblemsvag 2003]. As the majority of the costs considered in the model are future costs, their present value is calculated using an appropriate discount rate. The cost model aims to give the designer a complete picture of the product cost and to show the influence of different changes in the design on the total cost of the product as well as on different elements of the cost.

The outputs of the analysis with the LCC tool are:

- A summary of the costs necessary to produce, use and dispose the product. This information is shown per product and per component and is broken down into: total life cycle cost, manufacturing cost, labour cost, materials cost, component cost, consumables cost, recycling cost, disposal cost.
- A graphical representation of the product cost of each life cycle stage that permits the designer to see at which stage improvements should be made.

- A graphical representation of the components' costs. This will show a hierarchy of costs and the designer will be able to see which component is the most cost-effective and which needs re-design.

5 CONCLUSIONS

The authors propose two powerful decision-support tools to designers in the early phases of product development: a Life Cycle Assessment tool and a Life Cycle Cost estimation tool.

The two systems provide results like costs and environmental impact at product level or component level in the context of the full life cycle of the product, thus offering a solid base for decision-making to the product designer when it comes to producing environmentally-compliant products in a cost-effective manner.

It should be noted that the LCC tool is currently under further development. Future work is necessary for test and validation of the model, and for collection of data necessary to populate the database.

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