A Survey of “Design for Environment” methodologies and Tools

Yogesh Kulkarni

Abstract

Incorporating environmental compliance into product development has not remained ’good-to-have’ but become ’must-to-have’ due to increasing regulations to check environmental degradation. Adhering to those regulations is not very prevalent as there is wide unawareness and also lack of easy to use design tools. Research efforts have been going on in the area of “Design for Environment” (DfE) for past few decades. Demand to create products and services catering to Environmental Sustainability is growing in the industrial world. It is necessary to develop environmental methodologies, corresponding CAD/PLM tools based on EcoDesign guidelines as major decisions that affect environment happen at design time. This paper reports broad range of devised-adopted DfE methodologies-tools with focus on mechanical-manufacturing industry and critically comments about state of the art DfE techniques.

Index Terms

Design for Environment, CAD, PLM, Product Life Cycle, Ecodesign

I. Introduction

CRITICALLY depleting natural resources and increasing market consciousness for the health of the environment has made the environmental superiority of products a critical competitive factor for manufacturers in the future [1]. The consumption and production of products throughout its life cycle is at the origin of the most pollution and resources depletion that our society causes [2].

Design for Environment (DfE) has become an increasingly important issue for enterprises[3]. DfE refers to the systematic incorporation of environmental aspects into a products design and development [4], [5], [6]. The reasons behind the use of DfE are e.g. increased environmental concern within society, more stringent legislation, increased customer demands and an awareness of the gains that an analysis of a product from an environmental perspective could give, such as the life cycle perspective approach. Lindahl has pointed that the environment would reap positive rewards if more environmental aspects could be considered as far back as during product design, as described, for example, in ISO 14 062[7]. Keoleian et. al. mention that it has also been estimated that up to 90% of the life cycle cost of a product is determined during the design process[6].

This paper reports broad range of devised and adopted methodologies of DfE by research community worldwide and critically comments state of the art of this issue.

II. Methodologies

During the past years, there has been a trend towards the rapid development of DfE methods and tools to employ in the area of product development. [7] .

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A. Life Cycle Assessment

Life Cycle Assessment (LCA) [8] is a method for assessing the environmental aspects and potential impacts throughout a products life (i.e. cradle-to-grave) from raw material acquisition through production, use and disposal. This is accomplished by compiling an inventory of relevant inputs and outputs of a product system; evaluating the potential environmental impacts associated with those inputs and outputs; and interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study (Wikipedia : `http://en.wikipedia.org/wiki/Life_cycle_assessment`).

Author feels Life Cycle Assessment is very complex to quantify as it involves lot of variables large number of domains. Typically variables dominant for particular domain are picked as they have greater impact. Abridged Life Cycles are also devised for easy incorporation into programs.

B. Quality Function Deployment for Environment

Quality Function Deployment for Environment (QFDE)[9] is a methodology to support DfE developed by incorporating environmental aspects into Quality Function Deployment (QFD) in order to handle environmental and traditional product quality requirements simultaneously. Design engineers can determine which parts are the most important in order to enhance the environmental consciousness as well as the quality of their products.[7]

Quality of decision of determining which parts are most important needs subject matter expertise and can be prone to errors. Ready formulation - quantification of impact assessment would help in prioritizing design portions to analyze.

C. DfE checklists and guidelines

DfE checklists and guidelines are widely used as a means to adapt products to environmental demands. DfE checklists and guidelines are distilled from DfE knowledge, and their structure varies. However, they tend to focus on a specific issue, e.g. material reduction or on a specific phase of a products life cycle . The range of different types is from general to company or product-specific, and requires different levels of knowledge and education. According to Graedel et. al. DfE checklists and guidelines can be valuable yet simple tools to enhance the design process and ensure that some of the more important environmental issues and impacts are addressed [4].

DfE checklists and guidelines are more of suggestive in nature. Their usability depends on how well they are incorporated in Design via tools.

III. Tools

Here is a list of tools-programs based on methodologies mentioned above.

A. D4N

D4N is a design tool that not only analyzes products life cycle by including all end-of-life issues in the analysis and evaluates designs ecologically and economically, but also provides guidelines to redesign. Some of these guidelines are incorporated into the method in a way to make redesign process semi-automatic. [10]

B. Environmental Design Support Tool (EDST)

EDST evaluates products design on terms of its environmental sustainability, i.e. material selection, recyclability and disassembly analysis. According to Yu et. al. [11], disassembly is the first step in evaluating a product's environmental performance by this tool, and it provides the time needed on disassembly, number of distinct components and other information.

C. Green Design Advisor

This method evaluates products through eight metrics: number of materials, mass, amount of recycled material, toxicity, energy use, disassembly time and end-of-life disassembly cost. The evaluation is made in two steps: definition of an appropriate data model that includes all relevant data in determining products environmental impact, and environmental point's calculus. Thus, Sun et.al. point that the method can identify the weaknesses of the product and indicates the direction for improvement [12].

D. Environmental Design Industrial Template (EDIT)

The concept of the method is the generation of a product disassembly sequence that optimizes profit generation in a way that end-of-life treatments can be evaluated. This method allows the designer to define how and with which material the product will be made, choose parts and processes considering some environmental and economic information, access and modify the available data base, and simulate end-of-life results [13].

E. MET matrix

The MET Matrix is an abridged LCA tool which can be useful at the beginning of the design process. The MET Matrix is made up of five rows and three columns that help the design team to obtain a global view of the inputs and outputs in each stage of the product life cycle. The rows correspond to the five different product life-cycle stages, while the columns denote three important environmental issues: the material used; the energy used; and waste, including toxic emissions. Hence, the name of the method 'MET' (materials, energy, toxicity).

Bhamra[14] cites following example of MET Matrix:

		Materials Cycle Input/output	**Energy Use** Input/output	**Toxic Emissions**
Production and supply of materials & components				
In-house production				
Distribution				
Utilisation	**operation**			
	servicing			
End of life system	**recovery**			
	disposal			

According to Brezet, it is a tool that enables the rapid formulation of a list of a products main environmental aspects, and is a simple input-output model combined with the products life cycle. It also provides the first indication of environmental aspects for which additional information can be required [15].

F. EMAS Toolkit for small organizations

`http://www.inem.org/new_toolkit/` An environmental management system (EMS) is built upon a set of environmental actions and management tools. Those actions depend on each other to achieve a clearly defined goal: environmental protection. An EMS is a continual cycle of planning, implementing, reviewing and improving the environmental performance of an organization. It helps to initiate environmental management in all areas. Focus on implementing an environmental management system (eco-design to be seen as a sub-aspect). EMAS website indicates following cycle of ISO14001:

G. Eco mapping

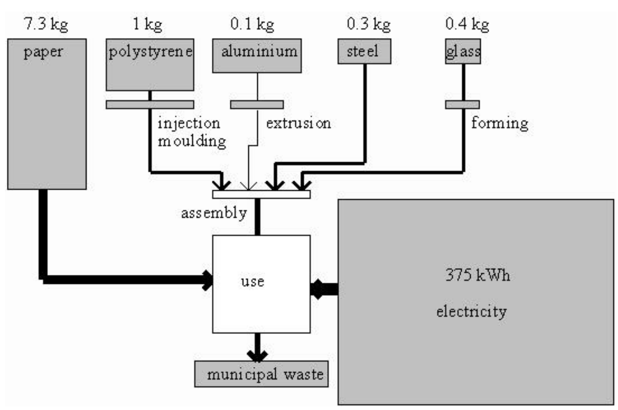
`http://www.proveandimprove.org/new/tools/ecomapping.php`

The purpose of Eco-mapping is to provide small companies and organizations with a free, visual, simple and practical tool to analyze and manage their environmental behavior. It involves making a map of an organization's site, for example, a shop floor, a workshop, an office, a community center to create an understanding of an organization's current environmental situation. Author understands that focus is on implementing an environmental management system (eco-design to be seen as a sub-aspect).

H. Eco-Indicator 99

`http://www.pre.nl/ecoindicator99/default.htm`

The Eco-indicator 99 is both a science based impact assessment method for LCA and a pragmatic Eco design method. It offers a way to measure various environmental impacts, and shows a final result in a single score. Author feels this is one of the State-of-the-art in one-indicator LCAs. Their website has following example showing a quick Eco-indicator analysis of a coffee machine. It shows the ecodesign priorities: minimizing use of electricity and paper filters. This analysis is made by simple multiplication of the material and energy amounts with the available indicator values.



I. EcoInvent

`http://www.ecoinvent.ch/` The ecoinvent data v2.1 contains international industrial life cycle inventory data on energy supply, resource extraction, material supply, chemicals, metals, agriculture, waste management services, and transport services.

J. ELCD

`http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm`

The ELCD core database comprises Life Cycle Inventory (LCI) data from front-running EU-level business associations and other sources for key materials, energy carriers, transport, and waste management. Focus is laid on data quality, consistency, and applicability.

K. GaBi DfX

http://www.gabi-software.com LCA tool industrial (automotive and electronic) and commercial application. If you would like to include during product design different regulations such as the EU directives of end of life vehicles, of waste electrical and electronic equipment, or of restriction of hazardous substances, then GaBi DfX is claimed to be a useful software tool for the compliance and sustainability in product design.

L. SimaPro

http://www.pre.nl/simapro/
SimaPro 7.1 provides you with a professional tool to collect, analyze and monitor the environmental performance of products and services. You can easily model and analyze complex life cycles in a systematic and transparent way, following the ISO 14040 series recommendations.

IV. Conclusion

This paper gives an overview of DFE methodologies. Clearly, a wide variety of approaches for reducing the environmental impact exists , as well as supporting tools. According to Thomas Roche it is imperative that a company recognizes its current state and capabilities, as well as its motivation and target level for integrating environmental issues in product design and realization. Furthermore, a unilateral decision may have deep consequences in todays highly integrated product realization practices[1].

Due to inherent complexity and broadness of environmental issues there is ample scope for development of more methodologies and tools. Effectiveness of these will depend on how well they are integrated and automated for easy usage.

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