From Life Cycle Assessment to Systematic Integration of Eco-Design Criteria Inside Product Development Process: Experience at a First Tier Automotive Supplier

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Abstract

The systematic integration of environmental consideration in product design is object of research activities all over the world, since companies are showing an increasing interest in products and processes that are environmentally sound. This paper shows a research activity performed at Università di Firenze for Rieter Automotive. First of all an introduction to Design for Environment is showed; then, starting from application of Life Cycle Assessment (LCA), a methodological approach is presented that integrates all elements playing a role in eco-design implementation, analysing and organising them in a logical framework. The results of the project are showing promising opportunities for improvement of the methods for optimised and eco-efficient design and technical choices. This will support designers and technologists both in innovation tasks and during product definition, in order to find eco-efficient solutions by means of user-friendly methods.

Keywords

life cycle assessment (LCA), design for environment (DfE), eco-design, product development process, design methodologies

1 INTRODUCTION

Like most industries, the automotive industry is confronted with environmental issues related to vehicles emissions, consumption of non-renewable material and generation of waste during production and at end of life to name some of them. There is increasing stakeholder awareness, which finds its expression in new legislation and customer requirements [1]. At the same time environmental friendly innovation offering solutions for example for recycling or end-of-life alternatives represents a great business opportunity, which has not been yet fully tapped in. Environmental management in operation has become “state of the art” but upstream implications in product design and development still demands further development for adequate methods and applicable tools [2].

For this reason Rieter launched a research project in collaboration with the Università di Firenze on the implementation of eco-design inside the company. The project has focused on the optimisation of the environmental features of car components, aiming at developing innovative and effective methods and tools to be easily implemented into the typical design procedures of the company.

2 THE STEPS OF THE PROJECT

To achieve the aim of integrating environmental aspects into product development, three steps were followed in the project:

1. Analysis of the environmental background: Identification and collection of all relevant information from research activities, cultural background, industrial inputs and analysis of all involved elements, like legal compliance, customer demands and expectations.
2. Environmental analysis of products: Definition of company requirements for such kind of tools and expected results from final application. Collection, trial-test and evaluation of tools available on the market, analysis of their applicability for the company in case studies.
3. Systematic implementation of results in development of new products: creation of customised tools for the necessities of the company, as a result of the case-study application.

3 ANALYSIS OF THE ENVIRONMENTAL BACKGROUND

In order to get a clear vision of the background of eco-design and to identify the relevant environmental drivers for the company, many different aspects shall be taken into account: e.g. the requirements of the customer, expectations of the company and image, the legal compliance, the state-of-the-art in the research, the availability of tools, the interest of all stakeholders and people perception and sensibility towards environmental issues. A clear vision on these points of view is required, and the results of this background study can be summarised in next sub-sections.

3.1 A snapshot of the eco-design landscape

If a company approaches eco-design for the first time, it will immediately face the conflict between the two spotlights of the landscape on eco-design: the top-down inputs and the bottom-up ones. The top-down input is the wide set of cultural considerations like academic research, activities of environmental experts and tool developers. The bottom-up inputs are all other cultural considerations coming from productive-industrial realities and from managers and companies organisations. These two actors have different requirements for eco-design: the academic and research world is aiming at increasingly detailed and consistent tools laying the basis for their environmental considerations. This often results in complicate tools difficult to apply in industrial day-by-day processes: Life Cycle Assessment is a typical example.

From the other side, companies, managers and designers look for simple approaches and consistent, user-friendly tools in order to allow effective decision-making. The reconciliation of these two visions into widely accepted and standardized procedures requires some further work [3].

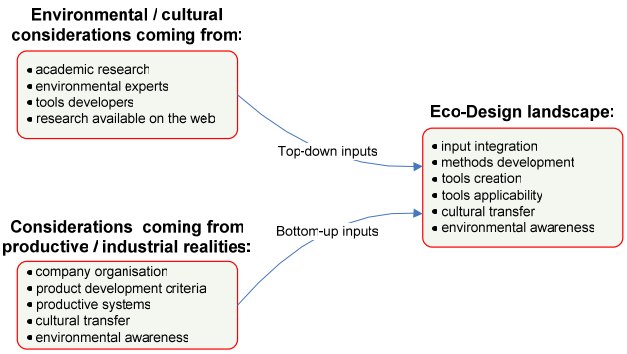

Figure 1: Snapshot on eco-design landscape

3.2 Preliminary considerations regarding eco-design inside companies

Some considerations collected by means of interviews with people from industrial world [4, 5] can help to understand how eco-design is perceived from designers and managers. Some interview findings are listed below:

- generally, the customer is the leading actor and cost consideration have the major role in decision-making
- a high level of mistrust (or lack of knowledge) exists towards eco-design methodologies
- people have different sensibility and experience on environmental matters and usefulness of eco-design
- inside product development process, each work-area requires a dedicated approach for implementing environmental considerations
- some managers and designers environmentally better skilled sometime develop own methods and criteria for quick environmental analysis, which might result in a lack in inter-departmental communication and in standardisation issues
- the diversity in tasks that eco-design should fulfil at different development stages implies that more than one single specific tool shall be developed; consequently a great effort
- eco-design is directly involved in innovation: a well-defined innovation process helps in integration of eco-design.

3.3 Identifications of internal and external drivers

There are several entities playing a driving role in eco-design implementation. The following collection has been created starting from the reality of Rieter, but can easily be extended to a generic company.

- specific customer requirements and expectations
- legal compliance
- market demand
- corporate image communication and marketing
- customer environmental criteria and assessment methods (e.g. recycling indexes developed by customers)
- internal environmental strategy (e.g. internal strategic recycling indexes, focus on recyclability or on renewable materials, …)
- internal environmental criteria and assessment methods (e.g. technical recycling indexes, production waste economical/environmental analysis, …)
- environmental benchmarking analysis

These drivers are relevant in the definition of environmental consideration for products/processes as they represent a motivation for certain environmental criteria to be implemented inside the product/process. An environmental criterion can be considered like a principle for eco-efficiency that can influence the technical choices for the design stages: for this reason an environmental criteria is both a constraint and an objective in the meantime.

4 ENVIRONMENTAL ANALYSIS OF PRODUCTS

Eco-design tends to be integrated into company processes via a pilot project selecting an existing product [6], starting from the bottom of the development process, and then enlarging to more advanced design stages. In this sense, it is a bottom-up approach.

According to Brezet [7], "One of the main conclusions was that the best approach to creating eco-design awareness and initiatives in a company is to establish a link with the company's specific type of products and development process. A good way to guarantee this strong relation was to select one of the company's products and assist the company in applying the step-by-step approach to this specific product."

4.1 Starting with LCA on pilot project

Several pilot studies on environment had been performed at Rieter before starting this eco-design project. LCA is a tool, recognised by regulators, legislators, scientists, consumer groups and environmental groups, and it represents a common base for the environmental quality assessment of products and processes. The general aim of an LCA is to:

- investigate the environmental impact of technologies for the different phases of the life cycle
- identify all relevant processes from an environmental point of view, such supplying detailed information about energy consumption and raw material quantities
- create an environmental profile for each technology/product/process
- compare technologies in order to identify a priority level according to eco-efficiency criteria
- supply useful information for the development of a customized environmental tool.

The LCA provides a wide set of results, by which very useful information about the environmental properties of the product can be collected. However, this is not enough for an exhaustive analysis: the information developed in the LCA study should be used as one component of a more comprehensive decision process assessing the trade-offs with properties, cost and performance. For this reason, the main findings of this LCA application is not the numerical environmental impact, but is the critical interpretation of the product environmental profile: this includes both numerical inputs from LCA and other environmental criteria, like availability of recycling technologies, the possibility for product dismounting and disassembly, the opportunity for using recyclable or recycled materials.

4.2 From LCA to Eco-Design

It is easy to understand that a LCA provides very useful results, but, on the other side, performing an LCA is resource and time intensive. LCA requires a significant amount of information and gathering specific data can be problematic. Therefore, it is important to balance the availability of data, the time necessary to conduct the study and related costs against the expected benefits of the LCA. Moreover, LCA does not determine which

product or process is the most cost effective or works the best. For this reason this method cannot be applied for every single development.

In view of the limits of the application of LCA, a more simple and quick approach is required for integration of environmental impacts during product/process definition and for simplifying decision-making: these are the aims of Design for Environment or Eco-Design [8]. Testing different LCA approaches in practice led to the conclusion that the method is not usable for the regular use in product development and design [9, 10, 11].

What would be helpful but still missing is an LCA based, standardised database for materials, processes and recycling methods. Instead of detailed LCAs, a holistic life cycle thinking is necessary, which analyses the product life cycle but in a more quantitative and pragmatic way.

As far as the development of the methodology is concerned, the main results achieved in the case study of LCA deal with the opportunity of integrating LCA and eco-design, and can be summarised in figure 2:

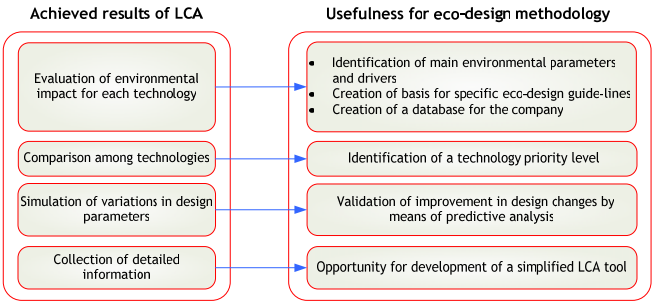

Figure 2: Linking LCA and Eco-design

These findings might help overcoming the main difficulties that companies face in performing Life Cycle Assessment, which are time and resources requirements and costs. Figure 2 shows that the creation of a simplified and customised tool for DfE is feasible, relying on company-specific LCA database. This is the subject of the next section.

5 SYSTEMATIC IMPLEMENTATION IN DEVELOPMENT OF NEW PRODUCTS

5.1 Integrate industrial inputs and academic research: tools for DfE

One of the starting points of the project was to get an overview about available and useful eco-design tools, and to categorise them according to their complexity and purpose [12]. The necessity for a tool dedicated to the specific company requirements has already been explained. Each company has its own requirements towards such a design methodology. Moreover the experience developed in environmental tools and in product development shows that a tool shall comply with the different expectation of many people in a company, often belonging to different departments and performing different tasks. For this reason, and according to the results of the case studies, a customisation is necessary. The first challenge, consequently, was to understand Rieter's expectation on eco-design. This required a deep analysis of the innovation process and of product development at Rieter one side and the compliance of available tools to these expectations on the other side. In order to understand applicability for Rieter some tools [13, 14] have been tested (e.g. ECODESIGN PILOT [15] and MET-matrix [7]). Unfortunately, most of them didn't comply with the expectations. Some showed to be too generic, some others instead were too complicate. A balanced trade-off was not available. For this reason a customisation task took place. Among the tested tools some have been selected as basis for the development of a new specific one aiming at satisfying expectations of all levels of product development [16].

5.2 Basis for the development of the eco-tool

The development of a customised tool was based on the following requirements:

Design issues:

- definition of the set of environmental guide-lines
- development of specific database of LCA results, from application to the main products of the company, inside the company product portfolio
- development of a simplified tool for LCA, interfaced with the created database
- identification and collection of environmental criteria, like recycling, disassembly, use of recycled material, use of renewable materials, use of recyclable material, end-of-life options, database of material properties
- creation of numerical indexes for each criteria, for assessment purposes
- creation of a template for a "product environmental release", that summarises the environmental properties of the product
- implementation of the tool in simple software (like MS. Excel application, or database navigation tools).

Process issues:

- identification of product environmental priorities, by analysing customer requirements and stakeholders' expectations
- identification of roles for involved figures
- clarification of innovation tasks

The analysis of these considerations led to the conclusion that the first step in developing the tool was to clarify the aims of the tool itself and the expected result: it was found that it was necessary to integrate input from designers and input from all related entities playing a role in eco-design into a "product environmental strategy", before starting the development phases, with the aim of supporting designers in reaching the expected environmental profile for the product. Then, this should turn into an application instrument.

Then it is important to understand what kind of results are expected, that is to say how the tool should be used during the different design phases. To do this, a flow diagram has been developed that explains what kind of support the tool should provide (figure 3):

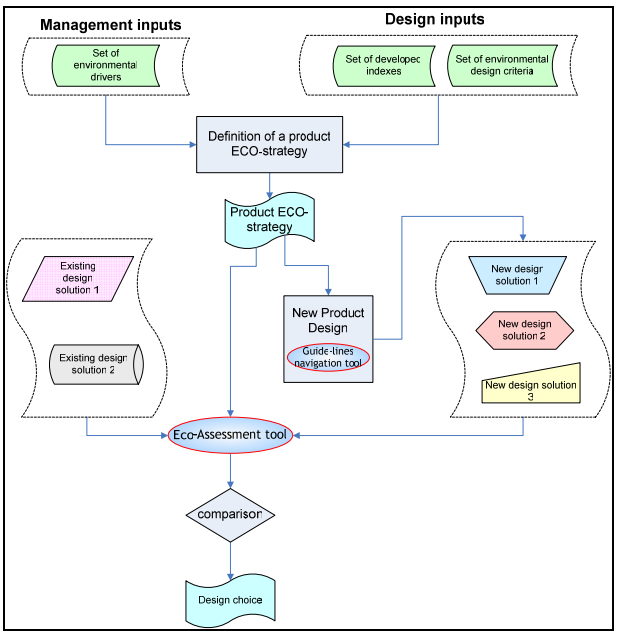

Figure 3: Integration of eco-tools in design process

The flow diagram is composed of the following steps:

- management and design inputs are integrated in the definition of the "product environmental strategy";
- the environmental strategy is the driver for the application of the eco-tool;
- the strategy and the tool help during early design phases;
- the strategy and the tool help in evaluation and comparison of the designed feasible solution, in order to find the most eco-efficient one.

A special role shall be addressed to innovation, which is extremely relevant in eco-design implementation: for this reason, before explaining the development of the tool, we first need to understand the main levels of innovation. An analysis of innovation inside of Rieter has been performed, and needs to be explained before showing the framework of the tool.

5.3 Analysis of innovation tasks

A new concept or an innovative product can arise in different ways:

- as a spontaneous initiative (e.g.: result of a personal research activity)
- as an answer to an elaborated request from managers (e.g.: specific market demand)

This two sources for innovation relate differently towards eco-design: in the first case the designer has full design (and eco-design) freedom, while in the second one the possibility for product development and design definition can be limited due to managerial choices. As a consequence managerial inputs have an equal or higher relevance as designers' input and cannot be forgotten when implementing eco-design, which leads to trade-offs. Innovation and product development can be categorised into three main levels:

1. development of a new product/process
2. improvement of existing product/process
3. customisation for a customer project starting from "shelf"-solutions.

5.4 Integration of innovation tasks and eco-design tool development

The three levels of development/innovation differentiate for the requirement towards eco-design.

As a matter of fact a new product/process (case 1) has a wider design freedom, and the designer can only rely on his own experience: there is little information for the product/process. In this case, a tool for eco-design can help the designer by providing the right design advices during concept definition. For this reason, at this level of action, an ECO-tool shall be based on consistent and reliable environmental design guidelines. A wide set of available guidelines has been collected and a method for identification of the significant ones, by means of a navigation tool, has been developed [17, 18].

While dealing with improvement of existing products/processes (case 2) and with development of customer projects (case 3), the situation is completely different. A great deal of information regarding existing design-solutions is already available. Moreover, the designer needs a different kind of advice as before, helping him in comparing design alternatives and in evaluating the improvement benefits from an environmental perspective. For this reason, in these cases the development of ECO-tool has been based on creation and utilisation of indexes and in environmental impact assessment by simplified LCA. This is a numerical approach that helps in product improvement and in identification of the best solution for a specific customer requirement, at a detail definition level.

In order to perform these different tasks two matrix-based tools have been created as shown in figures 4 and 5.

For early stages of design process the first matrix-based tool for the choice and selection of environmental guidelines has been developed. The first step is the choice and a weighting of the relevant environmental drivers, which are motivations or reasons for the implementation of selected environmental criteria. In this way, a prioritisation of the criteria can be created.

Environmental Criteria and Indexes	Environmental Drivers				Pondered mean value
	Legal compliance	Corporate image	Customer requirement	Cost reduction	
Light-weight solution					
Environmental quality of materials					
Recycling concept					
Technical reciclability index					
Strategic reciclability index					

Figure 4: matrix-based tool for definition of product environmental profile

A set of design guidelines is related to each criterion, which can be selected and prioritised for supporting design phases according to the relevance of the environmental drivers. The main result of this tool is that it helps in keeping in mind environmental criteria without restriction to creativity. This matrix is supporting the definition of an Eco-product-strategy as it prioritises the criteria. This is then the base for the trade-off with other design criteria (non-environmental), which apply to the product as well.

After the concept design phases took place, a second matrix-based approach has been developed, that helps in the evaluation of the environmental performance of existing design solutions. This method relies on a series of numerical indexes, on a database of simplified LCA results, on a matrix for recycling compatibility of materials, on recycling opportunities and technologies, and on quantified indexes for the environmental criteria identified.

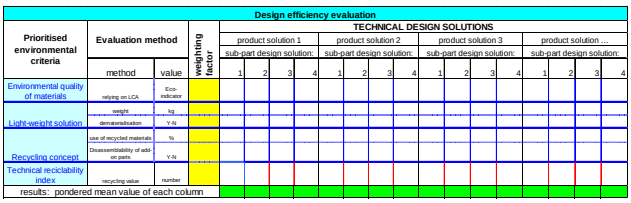

Figure 5: matrix-based tool

The prioritisation numbers of the first matrix can become the weighting factors for the analysis of the existing design solutions. They are the inputs from the product-environmental-strategy. Existing solutions can then be assessed and evaluated, and a choice can be performed, aiming at the compliance and conformity to the prioritised criteria list. This matrix and corresponding tool aim at a quick performance comparison between different solutions. It allows also assessing the sensitivity of specific parameter against product modification. The described approach helps innovation tasks as follows:

1. development of a new product/process: the method provides a selected and prioritised list of design guide-lines
2. improvement of existing product/process: relying on previously developed database and index, the method helps in assessing the improvements and in comparing different design solutions
3. development of a customer project, starting from existing product/processes: the method provides a dynamic criteria prioritisation by setting different relevance to the environmental drivers on the basis of the customer requirements. This means that specific customer and environmental priorities will drive in the choice of the design.

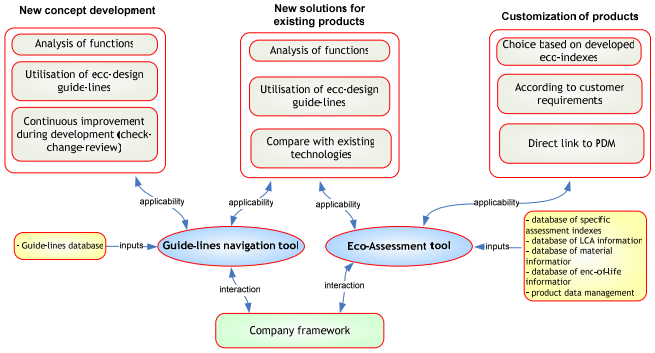

Figure 6: Overview and framework of the presented method

A direction for the application of the method has been presented. Figure 6 shows an overview of the framework of the presented method. The upper layer shows the different innovation tasks as described earlier. The middle layer shows the proposed tools and their corresponding inputs, as well as their applicability for the different design and innovation tasks. Finally, the interaction with the company framework is made understandable. The presented research lay on pilots that clearly showed the need of a consistent integration of the eco-tools in the company processes in order to ensure their application.

6 CONCLUSIONS

Based on literature research and testing of existing market solution, as well as on analysis of current design and development processes, driving-parameters for the success of a consistent implementation of Design for Environment were identified and analysed.

The described project showed the need for extended environmental analysis (type LCA) as an information source to feed tools allowing quick results (guidelines, eco-impact comparator), which can be used easily within the existing design and development processes in order to identify the best-performing design solutions.

Customised methods and tools were developed and tested in daily work of product design and development. This allowed a systematic and objective consideration of environmental aspects of the products. It guarantees an increased compliance with customer's environmental requirements and specifications, and with legal constraints.

The embedding within the existing processes, the information and training of concerned staff as well an overall company awareness are critical for a consistent application of the described methods.

Further development will be a standardisation of the methods, the complete inclusion of requirement from different customers and a continuous refinement of the methods in light of the growing experience.

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