INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'09
24 - 27 AUGUST 2009, STANFORD UNIVERSITY, STANFORD, CA, USA

THE TROJAN HORSE METHOD AS A VECTOR OF ECODESIGN INTEGRATION: A CASE STUDY AT A FRENCH SME

Tatiana Reyes[1], Serge Rohmer[1]
(1) University of technology of Troyes

ABSTRACT

Integrating environmental issues into process design is a complex task. On the one hand, many ecodesign methods and tools have been developed, but little practical use has been made of these tools in industrial spheres. On the other hand, companies are under considerable external pressure to become more environment-friendly and are therefore tending to adopt rather fragmentary and intuitive ecodesign strategies. The resulting problems have given rise to the need to develop a readily accessible method of implementing sustainable process design in the long term.
The research presented in this paper focuses on integrating environmental awareness into the design processes at SMEs. The results of a pilot survey carried out on some pioneer French companies in the field of ecodesign show that integrating ecodesign principles requires appropriate methods to base this approach on. It also requires an overall picture based on a process of gradual improvement, which enables a company to work on increasingly innovative projects. The mechanism proposed for this purpose was based on an ecodesign tool that was co-produced by all the main participants in the design process. This mechanism makes it possible to gradually improve environmental performances within an organization. We have called this approach the "methodological Trojan horse" approach ("mTh") because the underlying strategy consists in introducing an appropriate pretext (the Trojan tool) promoting teamwork (the ecodesign tool has to be co-designed) and supplying the organization with the necessary skills to develop the tool in a later stage. The "mTh" approach based on the use of the ecodesign tool facilitates the propagation of sustainable design knowledge at all levels within the company and thus induces the company to progress towards complete integration (from a partially sustainable design approach to a complete eco-innovation approach integrating the requirements of sustainable development). The whole mTh concept was tested during a period of two years at a French SME. The results obtained show the benefits we can get by using this integrated approach based on the "mTh" mechanism.

Keyword: Ecodesign, appropriation, methods and tools, the methodological Trojan horse, trajectory models

1 INTRODUCTION

The aim of ecodesign practices is to improve companies' environmental performances by promoting a proactive approach among industrialists seeking means of gaining a competitive advantage. Companies using an approach of this kind can develop products showing a good balance between the economic and ecological constraints, while continuing to pursue the objectives of competitiveness, quality and fast marketing.
First it is proposed to discuss the main problem involved in integrating ecodesign at SMEs, explaining that it is necessary for this process to be driven within the organization itself, using appropriate procedures. Secondly, the steps involved in the ecodesign integration process will be described. Lastly, the tools and methods on which this approach is based will be presented and a pilot study in which it was applied at an SME will be described.

2 LIMITS INVOLVED IN ECODESIGN INTEGRATION

To integrate environmental considerations into process design, a number of difficult problems have to be solved. In the first place, product development is generally perceived as involving severe constraints because it is an iterative process in which many compromises have to be made between various aspects of the designers' activity. The environmental aspects are thought by most designers to be rather fuzzy because they are based on multiple criteria, stages and players. Because of this great complexity, it is not possible to handle environmental constraints in the same way as more traditional design parameters, especially in the context of innovative strategies.

2.1 Are there any "ready to use" methods or tools?

There already exist many ecodesign tools [1] and others are currently being developed by various research groups, companies and institutions. These tools can be classified depending on their characteristics and their functions. In our previous studies, we identified the following four main types of instruments for implementing ecodesign projects: environmental impact assessment tools (life cycle cost analysis, life cycle assessment, social life cycle assessment, etc), tools for improving environmental performances (standards, advocacy tools such as check lists, organizational tools such as concurrent engineering tools, etc.) , tools eliciting creativity and innovation, and strategy implementation tools (awareness tools, communication tools, labeling tools, objective definition tools, etc.).

Many useful papers have been published on methods and tools developed for ecodesign purposes. Baumann et al., who published a review of 650 papers on ecodesign methods and tools, noted, however, that there were relatively few empirical studies available on the topic (they amounted to only 10% of the 650 papers reviewed) and that most of the studies published so far deal with conceptual and normative developments. There were many limitations, such as their lack of practical value, the development of too many tools, the lack of links between the content of these tools and companies' strategic practices, the fact that the tools were unsuitable for use in many industrial contexts, and the fact that the system point of view was often not taken into account [1]. Ecodesign tools and methods tend to lack an overall awareness of the life cycle of products and the data required in the various stages of the design process [2]. As Dewulf has pointed out, most of the ecodesign tools currently available on the market require a large number of data (such as LCA and DfE data, in particular). In any case, these expert tools are not suitable for use at SMEs [3]. The purportedly "universal" tools and methods designed so far are often far too time- and resource- consuming to meet the needs of firms and users. Tukker et al. have suggested four reasons why little use is being made of these tools: the research workers involved play the most active part in the development and implementation of these ecodesign procedures, whereas the industrialists themselves usually play only a minor role; the designers and users of these tools cooperate very little and exchange little information; the various users targeted are poorly defined; and very few of these tools are easy to use [4].

All these weaknesses explain why it is so difficult for process designers to appropriate them. It is difficult to establish whether any ecodesign tools are actually being used at present and whether they really play an important part in the development process [5].

Designers have to cope with constraints such as selecting the most appropriate tools for the context in which they are working, linking up these tools with those habitually used in the design process, and making sure that the skills required to be able to use them properly at the right moment are acquired. The idea that designers might spontaneously use the most suitable tools and methods therefore does not seem to be very realistic [6]. As Lofthouse has mentioned, many designers feel they do not have suitable tools for carrying out ecodesign projects [7]. The results of a survey performed on 67 designers in the railway sector confirmed that a need was felt for appropriate tools for handling the upstream phases of the design process and for more clearly ecodesign procedures [3]. Jeswiet and Hauschild have suggested that the environmental effects of industrial production could be reduced by performing life cycle analysis during the development phase [8]. The results of a survey carried out by Stolley at 16 firms showed that environmental assessments sometimes take place at the level of individual designers, but that there was no evidence that decision-making mechanisms of this kind were being used at whole design departments [9]. Coté has suggested that a combination of environmental impact assessment tools and more classical design tools (computer-assisted design

programs, functional analysis, etc.) would improve designers' access to environmental assessment tools such as LCA [10].
Lofthouse has stated that there is a need to develop new tools for designers which are more in line with their present approach to their work [7]. However, developing new tools and improving the existing ones will not solve the problems involved in integrating environmental considerations into industrial design, because a broader view of the situation is required which takes other factors, such as economic, ethical and environmental factors, into account. [9]. Baumman et al. have also pointed out that research workers developing ecodesign processes should adopt a more systemic point of view in order to trigger synergies with the other aspects, such as the market competition, which companies have to take into account and promoting cooperation between all the players involved in the production chain [1].

2.2 Ecodesign approaches are often based on classical decision-making models

Integrating ecodesign at firms is bound to result in considerable organisational changes at these firms [11]. In order to integrate environmental factors into the design process, it is necessary to devise new tools, to change the design process and to create new knowledge [12]. As Bassetti has observed, individuals contribute importantly to whether or not changes will be successful [13]. Kemp et. al have established that decision-making, co-management and other governance processes involving multiple partners contribute to the effective integration of environmental factors and sustainable development criteria [14]. The ecodesign approach therefore cannot be placed in the hands of a single actor. This approach requires collective action involving a variety of internal and external actors. Several authors have examined how people with various functions can be integrated into the drawing up of environmental policies. Pujari et al. have pointed out that the amount of interfacing and coordination which occurs between specialists determines how successfully the design team will function when integrating environmental considerations into the development of new products [15]. Lakemond and Berggren have stressed that strongly multi-departmental integration enhances the final quality of products. These authors have stated that it is necessary to stimulate both formal and informal intra-organisational interactions around projects, including the process of development of new products [16]. Fryxell and Vryza have established that the mechanisms integrating the environment into companies most successfully are those involving multifunctional coordination. Environmental management could work if seven internal functions (production and operations, marketing and sales, accounting and finance, public relations, legal, R&D and purchasing) are integrated into the decision-making stage [17]. Ideally, all the departments in a company should integrate the environmental aspects into their daily activities. However, there are often some weaknesses, such as the way in which environmental responsibilities are distributed within the company and the lack of multifunctional coordination.
The ecodesign concept includes the life cycle thinking principle: ecodesign cannot be the prerogative of a single stakeholder, but must be a collective activity involving several stakeholders from within the firm, as well as other people involved in the life cycle chain.

2.3 Ecodesign approaches are fragmentary

Measuring the environmental performances of an organization requires the use of a complex interdependent set of indicators ranging from the short to the long term environmental impact and from the local to the global scale. Therefore, defining the environmental stakes is always a delicate and even paralyzing problem for companies. Faced with this complexity and the failures and weaknesses of the methods available, companies on which strong environmental pressures are exerted tend to adapt their policies on an ad hoc basis, without adopting any real environmental integration strategies, although ecodesign integration is a long-term process [4]. Protecting the environment is often regarded as a rather "fuzzy" constraint at the departments involved in product design [11] and the approaches to integration tend to be rather "fragmented" [18]. Also, in spite of the efforts realized by a range of organizations (institutions, occupational networks, etc.), there is little feedback from companies (especially from SMEs) that have integrated ecodesign principles. Nevertheless, some ecodesign approaches can be defined as processes of either the imitative or the benchmarking type. As Curl has pointed out, the methods used to set up this approach and to improve the results obtained have often been based on the example of competitors or companies marketing comparable products

[C2].

2.4 Integrating ecodesign principles: defining the problem

Based on our review of previous studies, the following conclusions can be drawn:

- There exist many ecodesign tools and methods, but little appropriation of these tools and methods has been made by firms,
- Firms lack internal coordination and are unable to drive any move to integrate environmental criteria taking the requirements of all the departments in the firm into account,
- Firms are subjected to external pressures and tend to apply ecodesign procedures very sparingly.

To facilitate the integration of environmental considerations into the design process, it is necessary to implement strategies involving organizational changes and to give product developers the appropriate tools. In particular, as all the above arguments show, it is necessary to make suitable ecodesign integration mechanisms available to SMEs.

3 MECHANISM OF ECODESIGN INTEGRATION BASED ON TRAJECTORY MODELS

The present research was based on feedback from experts and companies that are pioneers in the field of ecodesign in France. The main objective was to give the many companies wishing to integrate ecodesign principles access to this information The results of an analysis of two surveys carried out between 2006 and 2007 have made it possible to distinguish, to understand and to describe the ecodesign approaches adopted at 69 pioneer companies [21, 22, 23]. The present research project focused on developing a range of trajectory models which could be used to help companies achieve long-lasting integration.

The results of the second survey showed that ecodesign integration requires a proper mechanism for activating this approach. Ecodesign integration also requires drawing up an overall long term picture based on gradual improvement, which enables companies to work on increasingly innovative projects.

A given company has to set up the trajectory which is the most appropriate for its own industrial context, its own resources and its own objectives. Each company needs to have an overall picture of existing ecodesign practices and must mobilize three key components to implement the strategies adopted: ecodesign methods and tools, the stakeholders and the management.

- An ecodesign approach must be based on the gradual introduction of a suitable set of ecodesign methods and tools (qualitative tools, environmental assessment tools, socio-economical assessment tools, etc.). The integration approach must promote the appropriation of the right tools with a view to harmonizing collective design practices.
- Ecodesign integration should not involve reappraising the coherence of the organization. It is therefore crucial to identify the stakeholders involved in the ecodesign process. Therefore, the company must build or enhance the dynamics of multifunctional coordination within the organization (especially with the main departments involved in the design process: the R&D, quality, purchasing, and production, marketing and sales departments). The company also has to develop partnerships with external actors (suppliers, customers, institutional actors, etc.).
- For ecodesign integration purposes, it is also desirable to incite the whole company to acquire the appropriate skills, attitudes and behaviour. This strategy should generate reliable and useful feedback which can be used in the development of novel eco-friendly products. The circulation of relevant information among all the stakeholders (the ecodesign project leaders, the members of the design team, the main departments involved, the organization as a whole and the external actors) facilitates the appropriation of environmental knowledge (This information can be mediated by papers, labels, internal meetings, lectures, etc. The participative decision-making activities inherent to this approach will facilitate the commitment of the actors to their new responsibilities. This participative aspect will contribute importantly to the progress of the approach.

The successful launching of the ecodesign approach depends on three main essentials: the introduction of appropriate tools, the stakeholders' involvement and the implementation of an information and decision-making system. Once the approach has been launched, it has to be perpetuated by introducing a more general process. The process, which is illustrated in figure 1 in terms of trajectories, is based on the gradually increasing integration of the following three principles: the use of ecodesign tools, dynamic organizational learning and multifunctional coordination, and the implementation of a

strategy based on ethical values.

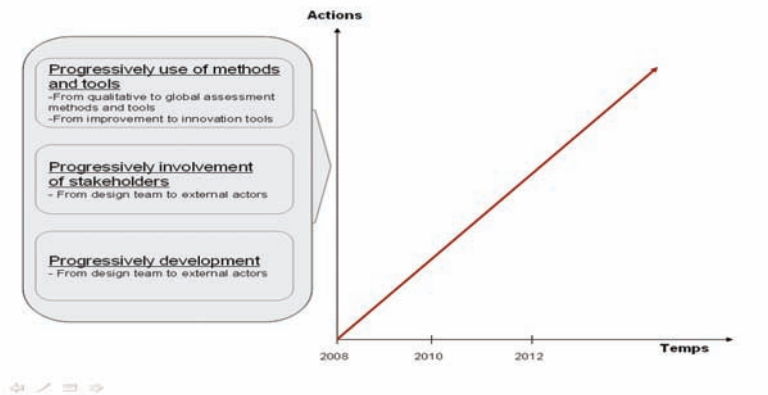

Figure 1. Construction of ecodesign trajectories

The pilot tool must help a company to identify the most suitable integration strategy, depending on its particular context. The aim is to progress step by step, and every step in the process is more complete than the previous one. This strategy ranges from introducing environmental constraints into the design process to the implementation of an innovative system based on new sustainable development principles. Since there it exist many possible trajectories for integrating ecodesign principles, each company will have to determine that which suits its own circumstances best.

4 TRAJECTORY BASED ON APPROPRIATION OF ECODESIGN TOOLS: THE METHODOLOGICAL TROJAN HORSE MECHANISM (MTH)

4.1 The mTh mechanism: the theory

One of the trajectories that we identified for facilitating ecodesign integration is based on the use of tools. This trajectory based on an activation approach makes use of a tool developed by the design team and introduced into the design process, resulting in a gradual change in the whole organization. The mechanisms described above for initiating and integrating ecodesign principles help to understand the strategies adopted by firms using ecodesign tools to initiate this move. In this study, we present the "methodological Trojan horse" approach as an organizational mechanism promoting the integration of environmental considerations into the design process. This mechanism, which involves the use of a tool developed by the design team, which is introduced into the design process and results in a gradual change in the whole organization, consists of three elements: an ecodesign tool appropriate to the company's field of activity, a method of co-designing this tool, and a course of environmental learning to be followed by all the members of the organization. The term refers to the classical story about the Trojan War, in which the Greeks gave their enemies the Trojans a giant wooden horse, purportedly as a symbol of peace. But once the horse had entered the city walls, the Greek soldiers it contained sneaked out and opened the city gates, allowing their army to invade Troy. The term "Trojan horse" is also used in the context of computer software to denote a program used to carry viruses (where the program is not a virus itself). The propagation of viruses by the Trojan horse is triggered by the actions of the intended victims. In the case of the present mTh approach, the Trojan horse tool (or Trojan tool) is a method of introducing an environmental dimension into core design and disseminating it inside the organization viaan approach based on the co-development of the tool. However, in this case, the mTh is not a mechanism injecting harmful elements into the organization.

The mTh approach depends on the contrary on multi-functional cooperation as a means of facilitating the emergence of new values within the company.
The mTh mechanism is based on three components: an ecodesign tool appropriate to the company's needs (the Trojan tool), a method of co-designing this tool (the Trojan approach) and a course of environmental learning to be followed by the organization. The tool developed continuously generates environmental knowledge. In the long term, the integration process must be based on the gradual development of a whole set of appropriate tools. As the design process evolves, the set of tools must be tested, updated, improved and adapted to meet other constraints such as innovation. The aim is not to create a new universal tool, but quite the opposite: the tool has to fulfil the fundamental requirements of the company in order to make the product design more environmentally friendly. The tool can be used by all the actors involved in the design process and can be used systematically for any project.
The development of a tool which is both compatible with existing design tools and appropriate for multifunctional team practices requires all the stakeholders in the ecodesign process to be involved. To coordinate the actions in ecodesign integration and to capitalize knowledge, a workgroup has to be created, involving representatives of the main company functions (R&D, environment-quality, purchasing, production, marketing and sales), suppliers, the waste disposal branch and at the beginning, an ecodesign expert (a research worker or consultant).
The main steps in activating the trajectory based on the use of these specific tools include:

- life cycle assessment (LCA) of a range of products with an expert tool,
- co-designing an interactive environmental tool appropriate to the company's needs in order to set up an approach to developing tools,
- Experiments on the tool in real design projects,
- propagation of environmental considerations at all the levels of the organization to facilitate the harmonization of collective design practices,
- recommendations for tool modifications,
- evolution of the organization according to an initial ecodesign project.

4.2 Applying the methodological Trojan horse mechanism at a French SME

The Trojan horse mechanism described above was tested at a French SME. In this section, it is proposed to present the various stages in which the environment has been integrated into the design process at this SME since June 2005.

4.2.1 Using an LCA tool to facilitate ecodesign learning

To facilitate learning and the emergence of new knowledge, we began this study on a French SME using an LCA tool. The results were satisfactory as regards:

- Making the committee aware of environmental issues,
- Developing different points of view (environment, design constraints, market),
- Introducing a life cycle thinking approach into the design process,
- Highlighting the key points and the weak points of the systems studied.

The monthly meetings which took place during this initial stage led to making environmental assessments of several products.
Based on this experiment, the authors concluded that the use of an expert tool provided a solid basis on which the ecodesign integration process could be built. However, in spite of the relevance of the LCA tool, the designers felt the method was rather complex and that it required too much expertise. This tends to consolidate the authors' feeling that ecodesign tools tend to be too complex and that experts are therefore required to use them. This constitutes a barrier to spreading ecodesign principles into the design process and among the other designers. The ecodesign experts therefore set up a multifunctional team to develop a tool which was appropriate and accessible to all the participants involved in the design process: the Trojan tool.

4.2.2 Implementing the Trojan approach

In this section, we will describe the main stages in the specification of the requirements for the Trojan tool.

- Assessment of the usual design practices

We started by defining the requirements and the features of the tool: this is an indispensable stage before starting to do any development work.

• Specification of the Trojan Tool

Some authors have written about the requirements that should be taken into account when developing focused ecodesign tools [2, 7, 11]. The main requirements suggested by these authors are: easy to understand; short setup time, visual presentation of results, language understandable to designers, etc.

The French SME used for the experimental part of this study uses some special tools in the design process. Among these tools the "calculation sheet" (an Excel MS tool), which helps with the main calculations, especially in the last stages of the design process (estimates, planning, and concept development) right up to the final product design stage. This calculation sheet is used daily by the designers and the marketing and R&D specialists. The calculation sheet contains all the technical product data as well as the economic data.

The following three main requirements were suggested by the ecodesign experts as regards the development of the Trojan tool:

- Since the tool must be compatible and completely integrated into the calculation sheet, the main requirements are: optimized timing, technically accessible to all the users, indicators understandable by all the stakeholders, visual and interactive presentation of the results, life cycle stages taken into account and the quality of the data.

-The tool should reduce the environmental impacts neither too early nor too late in the design process,

-The tool should serve three additional functions: environmental assessment, knowledge capitalization and marketability.

The ecodesign integration project at the French SME was supported by the company's Director. The main managers (R&D, Marketing, QEHS, designers,), who were involved from the very beginning of the process, attended the meetings regularly and directed the operations. The specifications for the environmental assessment tool were defined by this coordination team.

- Environmental assessment criteria

The ecodesign integrator induced proactive behaviour by asking the participants to choose the environmental assessment criteria. The committee decided to define environmental indicators of three main kinds: life cycle thinking, multicriteria evaluation and evolving towards sustainable development criteria. Eight indicators were eventually selected.

- Life cycle stages

The integrator suggested including the following main stages in the life cycle: the extraction of materials, the manufacturing of products, their distribution, their use and the end of the life cycle. The installation phase was not included because its environmental impacts are very slight in comparison with the other phases in the life cycle, especially the use phase. The integrator suggested improving the distribution stage by acquiring a crane truck, which could be used when the analysis of a product shows that an excavation is required to install the product.. The coordination team agreed with the five main stages defined.

The coordination team decided to use data from existing inventories in the business for the environmental assessment. The data on which the inventories of products are based are mainly expressed in Ecoinvent values. Some data not included in these inventories were completed by using information provided by suppliers. We also introduced values which could be used in the development of the new ranges of products, such as the environmental data on new materials and the possible end-of-life scenarios, in particular.

Another point defined at the meetings of the group was the capitalization of the future LCAs. The idea was to facilitate the access of the design team to a database so that the designers could assess the work performed and continuously improve the environmental aspects.

-Presentation of results

One of the most important aspects addressed by the group concerned the presentation of the results: they have to be easily understandable by both the designers and the customers. The presentation of the results in the form of a radar diagram was suggested by the integrator and approved by the coordination group.

• Testing the relevance and understanding of indicators

To check the relevance of the indicators selected, a questionnaire was handed out to the customers, that is to say all the members of the marketing department, the design core and the commercial staff. This questionnaire was designed to measure how well the environmental indicators were understood.

The responses given by the members of staff included in our survey showed that nine of the indicators presented were the most easily understood by commercial specialists. All the respondents were asked to choose the most relevant indicators, and most of them chose five. We crossed the results of this survey with the three fundamental aspects mentioned above (life cycle, multicriteria and sustainable criteria) and the following eight indicators were eventually selected: Energy consumption, Noise pollution, Visual pollution, Safety, Recyclability, Mineral depletion, Climate change and Toxicity.
The toxicity indicators, climate change and mineral depletion were calculated using the Eco-indicator 99 (Egalitarian) method of calculation. We decided to use this "endpoint" method because it is easier to interpret. The other indicators (the noise pollution, visual pollution and safety) were calculated using the Failure Mode, Effects and Critical Analysis method. The designers carried out brainstorming sessions in order to determine 10 evaluation criteria for each of these three indicators.

- First layout of the Trojan tool

Based on the indicators and preliminary specifications, the prototype tool was developed. This layout was used to test the ergonomics, the complexity, the suitability of the indicators, the time required to use it, etc. The users' main demands were taken into account in this tool: data entry in a single table, data arranged by product component, accessibility to the data on the reference product, on which users will want to base their environmental assessments, and capitalization of the assessments in a data base. The program used to systematically record the results in a data base was developed by the company's computer engineering manager.

- Presentation to future users and recommendations for improvement

The coordination group participated in defining the specifications of the tool in detail, assessing the prototypes and validating the 1st version of the tool. The development of the tool was based on an iterative process. Version 1 was then presented at a collective meeting to the coordination group, the production manager, the head of the purchasing department, three people in charge of projects and a designer.
The "calculation sheet" now places environmental issues at the same level as technical and economic issues in the design process. The Trojan tool version 1 has been completely integrated by the R&D, design, marketing and QSE departments (See figure 2).

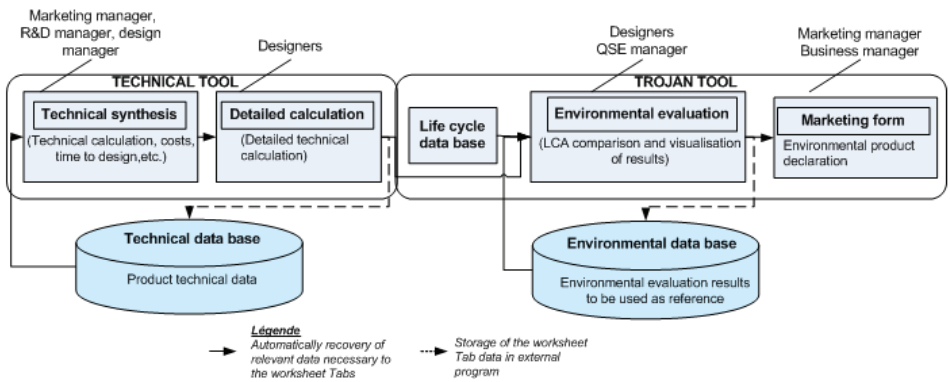

Figure 2: the new calculation sheet

4.2.3 Testing the tool on a real design project

The tool was tested on a product development project. The coordination team worked on a combination of three ecodesign strategies to develop the new product: changing the materials, reducing the energy consumption and recycling components. These three design approaches were applied to reduce the environmental impacts of a product.
For this purpose, a leading product in the same range as the new product was selected for comparative analysis. The data were mainly obtained internally and by applying to the suppliers.
As the price of some materials such as cooper, which is used in large quantities in the system studied,

are constantly on the increase, changing the material was thought to be a relevant option as this would reduce the economic problems while improving the ecological performances of the product. We substituted copper parts were therefore replaced by steel ones without changing the technical characteristics of the product.
In the case of this leading product, a less energy-consuming system was obtained, which led to savings especially during the use phase (the most environmentally harmful phase). The cost price of the new system is a little higher, but the savings in terms of the energy consumption mean that this investment pays off very quickly.
The last strategy tested consisted in remanufacturing the components of products. In this case, the recovery and dismantling of redundant products and they are carried out by suppliers, whereas the refurbishment of the components and their integration into the system are performed by the company.
Comparative evaluations were conducted using the tool developed by the company. The results obtained using this simplified LCA tool were then compared with those recognized and obtained with other available LCA software. The results of the environmental analysis were in favour of the new product.

4.2.4 Harmonization of collective practices

At the end of the project, in September, 2007, some recommendations were proposed to improve the tool in the middle term. One of the main ways in which improvements can be obtained is to find indicators to sustainable development (human health, fair production of wealth and healthy working conditions).
Only one quarter of the data necessary for the environmental evaluation are available via the calculation sheet and access to the remaining three quarters is rather delicate from the designers' point of view. We therefore propose to establish connections with internal tools in the company containing the information required. It would be possible to imagine exporting data from the management's software programs, for example.
In terms of its features, the tool will therefore have to acquire a function assisting innovation and another function for assisting decision-makers with purchasing options and the choice of suppliers.
At the strategic level, we recommended the creation of a quality and ecodesign process in the company's system of management.

4.2.5 Recommendations for the improvement of the tool based on the Trojan approach

The tool has to evolve constantly. In September 2008, the company therefore suggested means of improving the tool. The second version of the Trojan tool was developed using the Trojan approach (LCA, specifications, tests, etc.). The second version of the tool was based on CML 2001, which is a scientifically recognized method of calculation. Our first choice (Ecoindicator 99) did not seem to be appropriate for the type of application developed so far. The method selected made it possible to include two toxicity indicators (ecotoxicity and human toxicity) instead of just one (human toxicity). The new method of calculation led us to develop a new database with the newly adopted materials ans process, in particular. With a view to simplifying the interpretation of the results, it was attempted to improve the graphic presentation (radar graphs) of the results. The marketing sheet was also simplified, keeping only the most essential information.

4.3 Evaluation the Trojan horse mechanism

As we have described above, the use of the Trojan horse mechanism was expected to facilitate the integration of environmental principles into the design process. To check the validity of this assumption, the success of the mechanism in the context of the company in question was measured using two indicators: the relevance of the Trojan tool and the rate of uptake of the Trojan tool approach.

- Trojan tool relevance

This indicator reflects the aptness of the results obtained with the tool, as well as its coherence with its users' needs. To analyze the performances of the tool, we estimated the compatibility of the tool with the collective needs. The Trojan tool not only performs three functions (environmental assessment, knowledge capitalization and market development), but it is also completely compatible with the classical design tools used at the company under investigation. Furthermore, the results produced by

the tool correlate well with the four other LCA methods of calculation available for use with the product in question. This does not necessarily mean that the company obtains perfect results, as these are based on indicators, rules, configurations and data bases that are constantly evolving. The tool was designed so that it would evolve gradually. The co-design process makes it possible to improve the tool and add other functions.
The second version of the tool includes improvements focusing in particular on the method of calculation, the data base and the visual presentation of the results. In terms of functions, the Trojan tool version 3 will have to acquire a function facilitating innovation and another one providing assistance with purchasing decisions and the choice of suppliers.

- Level of the Trojan tool propagation

Lindahl has suggested that the success of tools can be measured using two criteria: their level of usability and the degree of appropriateness [7]. We chose the degree of usability as the first indicator to the uptake of the tool within the company. Trojan tool version 1 was being used systematically at that time by the R&D, design, marketing and QSE departments.
At the company, we have noted that a better understanding of environmental issues throughout the life cycle of products has developed since the introduction of the Trojan tool. At the technical level, environmental criteria have been integrated into the tool used to manage the development of new projects.

5 DISCUSSION

It is proposed here to provide ecodesign experts with a tool for piloting the environmental integration process and mastering the long-term creation of knowledge at their firm. Trajectory models were tested and the Trojan horse mechanism was applied at a French SME as a means of integrating environmental awareness into the company's industrial projects. The results of this pilot project confirmed:

- the relevance of developing a suitable tool meeting the specific requirements of a firm,
- the importance of multifunctional cooperation in the development and improvement of this tool, under the management of a steering group composed of members of all the company's departments,
- the need to promote continuing organisational learning processes (using an evolutive approach) to harmonise the design practices which are being continuously changed and improved.

The results of the study described in this paper show the efficiency of the methodological Trojan horse mechanism as a means of initiating the integration of environmental considerations into product design. The results obtained using methods based on our scientific findings showed that these methods provide definite responses to some of the problems arising, which were reviewed above.

The results of this research confirm the need to conduct further studies with a view to helping companies integrate ecodesign principles. In the present experiment, we noted that mechanisms such as the mTh mechanism can be used to promote the integration of environmental considerations into the design process Activatory mechanisms of two other kinds were also identified: relational mechanisms and decision-making and information mechanisms, with which it would be interesting to experiment. There certainly exist other mechanisms facilitating the dissemination of environmental knowledge within a company, which we hope to discover. In the middle term, it is proposed to conduct surveys to identify these mechanisms, make use of them and draw up ecodesign trajectory models in the context of French firms. A toolbox is envisaged as a means of achieving these results. The toolbox consisting of various modules will facilitate the choice of tools at every stage in the design process, the choice of actors at every stage, the operations required during the integration process, etc. It therefore seems to be essential to determine what factors are responsible for the choice of a trajectory model at three different levels (the methods and tools, the stakeholders and the management). In other words, it would be interesting to define a method helping companies to plan an ideal trajectory in keeping with the situation of their company (size, sector, organization, structures, usual practices, objectives). The idea would be to develop proposals for specific actions on every trajectory, which could be explained in a guide intended for companies. The scope of the governance would still be an essential point, because the efficiency of trajectory management depends strongly on

how knowledge is organized both inside and outside the company, and on the involvement of the customers and other stakeholders in the ecodesign process.

REFERENCES

[1] Baumann H., Boons F. and Bragd A., (2002) « Mapping the green product development field: engineering, policy and business perspectives », Journal of Cleaner Production, 2002, 10, 409–425.

[2] Lindahl M. Skoglund L. and al., (2003) « Use and perception of Design for Environment (DfE) in Small an Medium Sized Enterprises in Sweden », Proceedings EcoDesign 2003: third International Symposium on Environmentally Conscious design and Inverse Manufacturing, Tokyo, Japan, 8-10 December 2003.

[3] Dewulf W., (2003) « A Pro-Active Approach to Ecodesign: Methods and Tools,.Ecodesign in central America », , PhD Thesis Katholieke Universiteit Leuven, Leuven, 2003, ISBN 90-5682-419-8.

[4] Tukker A., Haag E., Eder P., (2000) « Eco-design: European state of the art : Comparative analysis and conclusions, » and « Eco-design: Part II: Strategies for dissemination to SMEs », Prepared for the European Commission, ESTO, IPTS, Espagne.
ftp://ftp.jrc.es/pub/EURdoc/eur19583en.pdf

[5] Luttropp C. and Lagerstedt J., (2006) « EcoDesign and the ten Golden Rules: generic advice for merging environmental aspects into product development », Journal of Cleaner Production, 2006, 14, 1396-1408.

[6] Jacqueson L., 2002 “Intégration de l’environnement en enterprise : proposition d’un outil de pilotage du processus de creation de connaissances environnementales”, PHD thesis, ENSAM, Paris.

[7] Lofthouse V., (2006) « Ecodesign tools for designers: defining the requirements », Journal of Cleaner Production, 2006, 14, 1386-1395.

[8] Jeswit J., Hauschild M., (2004) « EcoDesign and future environmental impacts », Journal Materials and Design, 2004.

[9] Stoyell J.L., Kane G., Norman P.W. and Ritchey I., (2001) « Analyzing design activities which affect the life-cycle environmental performance of large made-to-order products », Design Studies, Vol 22 No 1, January 2001.

[10] Coté C., (2005) « Analyse comparative de deux méthodes d’analyse de cycle de vie simplifiés utilisables pour la conception des produits », Master report, Faculté des études supérieurs, Université de Montréal, Canada 2005.

[11] Le Pochat S. Bertoluci G. and Froelich D., (2007) « Integrating ecodesign by conducting changes in SMEs », Journal of Cleaner Production, 2007, 15, 671-680.

[12] Millet D. (sous la direction), Coppens C., Jacqueson L., Le Borgne R., Tonnelier P., (2003) « Intégration de l’environnement en conception », Ed. Hermes, Paris, 2003.

[13] Bassetti A.L, (2002) « Gestion du changement, gestion de projet : convergence-divergence. Cas des risques en conception et mise en place d’une organisation de management de l’environnement», PHD thesis, ENSAM, Paris, 2002.

[14] Kemp R. Parto S. and Gisbson R.B, (2005) « Governance for sustainable development: moving from theory to practice ». International Journal sustainable development, Vol.8, Nos.1/2, 2005.

[15] Pujari D., a. (2004) « Eco-innovation and new product development: undestanding the influences on market performance », Technovation, 2004,XX,1-10.

[16] Lakemond N. Berggren C., (2005) « Co-locating NPD ? The need for combining project focus and organizatinal integration», Technovation, xx, 2005.

[17] Fryxell. G. E. and Vryza M., (1999) « Managing environmental issues across multiple functions: an empirical study of corporate environmental departments and functional co-ordination », Journal of Environmental Management, 55, 1999, pp. 39-56.

[18] Boeglin N., (2002) “L’intégration croissante de l’environnement dans la conception des produits ou le développement des démarches d’éco-conception », Revue Annuelle des Arts et métiers, 457-465.

[19] Curl M., (2003) « Ecodesign in central America », PhD Thesis, Delft University of Technology, Norvège, 2003.

[20] Butel-Bellini B., Janin M., (2004) « Eco-conception: état de l'art des outils disponibles », Techniques de l'Ingénieur, Traté Environnement, 2004, G 6 010.
[21] Reyes T., Millet D. et Brissaud D. Study of parameters of ecodesign integration process in French companies, 13th CIRP Life Cycle Engineering, may 31th – june 2th 2006, Leuven, Belgium.
[22] Reyes T., Synthèse de l'enquête 2006-2007. http://creidd.utt.fr/fr/membres/reyes.html
[23] Reyes T., Millet D. and Joan M., (2007) « Development of ecodesign integration trajectories: two surveys and LCA case of study with a power distribution product », 13th International Conference on Engineering Design ICED'07, 28 – 31 august 2007, Paris, France.

Contact: Tatiana Reyes
Institution/University : University of Technology of Troyes
Department : Institut Charles Delaunay – CREIDD - CNRS FRE 2848
Street: 12 rue Marie Curie
Postal Code, City : 10010 Troyes Cedex
Country : France
Phone : 00 33 3 25 71 84 42
Fax: 00 33 3 25 71 76 98
E-mail Address : tatiana.reyes@utt.fr

Tatiana Reyes is an associate professor at the Institute Charles Delaunay Institut, University of technology of Troyes. She received her PhD in the field of ecodesign. She is currently a researcher working on ecodesign integration in SMEs and LCA.