Integration of an eco-design process within an SME: knowledge feedback on a recent development of a new range of hospital carts

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Abstract: Nowadays, in order to face increasing competition, businesses must differentiate through innovation, but also crucially by positioning themselves with respect to environmental concerns, in order to improve brand image. SMEs are particularly plagued with a lack in human, financial and time resources to integrate such aspects to design. In this paper, we propose a gradual approach (short-, medium- and long-term) to implement an eco-design process in SMEs. This process comprises four stages: analysis, sensitisation, eco-design strategy and sustained improvement. A first experimentation, in collaboration with a SME (MulTiroir-Controlec), allowed us to integrate this eco-design process in the development of a new product range of hospital carts. We present the results of the product development as well as an experience feedback on the project; today the company integrates this eco-design approach in its strategy.

Keywords: eco-design; new product development; environmental aspects; sustainable process; knowledge feedback; SME.

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1 Introduction

As the regulatory frameworks become more stringent, all companies are gradually expressing more and more concern with respect to eco-design. Taking into account environmental constraints within the scope of product design is an industrial truism, but one which is mastered to varying degrees (Bovea and Perez-Belis, 2012; Maxwell and van der Vorst, 2003; Maxwell et al., 2006).

However, the stakes for companies are numerous. There are strong impacts of these environmental aspects, for example, on economic gain, brand image and market differentiation (Orsato, 2006). From a more pragmatic point of view, the issue is clearly to better understand the risks and the costs related to product lifecycles, to identify nascent expectations in stakeholders and consumers who are increasingly sensitive to environmental concerns, as well as to turn the environment into a new factor of competitiveness and innovation in processes of creative product design, by stimulating designer creativity (Plouffe et al., 2011), better mastering project costs, and opening up new commercial opportunities.

Many methods, however, have proven to be too lengthy and expensive in the field. Therefore, few SMEs have really committed to using them (ISO, 2002).

Since eco-design is little known in companies, and in particular SMEs, we have elected to study how approaches to eco-design are introduced within a company, for the design of a range of products.

In this paper, we present a short state of the art regarding the concept of eco-design as well as its various related approaches, methods, and existing tools. We then propose a pragmatic approach which we were able to evaluate from an appropriate point of view, within an SME named MulTiroir-Controlec, specialising in the manufacture of hospital carts.

2 Product design and environment

This part of the paper aims to describe the current state of literature in the field of eco-design (Brezet, 1997; Brezet and van Hemel, 1997).

2.1 Eco-design

Following the French ISO/TR 14062 standard (ISO, 2002) and the international ISO 14006 (ISO, 2011), eco-design is an activity which integrates environmental aspects to the design and development of products. Integrated activities aim to continuously improve the environmental performance of products through technological innovation (Karlsson and Luttropp, 2006; Pierini and Schiavone, 2008). One might further add to this definition by specifying that it is a preventive, holistic approach which takes into account the whole of the product's lifecycle (from extraction of raw materials to product disposal at the end of its life) as well as all possible environmental criteria (consumption of raw materials, water and energy; water- and airborne emissions, production of waste material, etc).

By acting at the level of product design, environmental performance will very likely be optimal. Thus, up to 80% of a product's environmental nuisances, throughout its lifecycle, are determined in the design stage (Butel-Bellini and Janin, 1999). It therefore appears crucial to reflect on integrating ecological concerns from this very stage, e.g., environ how the product might be processed, dismantled, reused, how its value might be further enhanced, etc (Butel-Bellini and Janin, 1999; ISO, 2002).

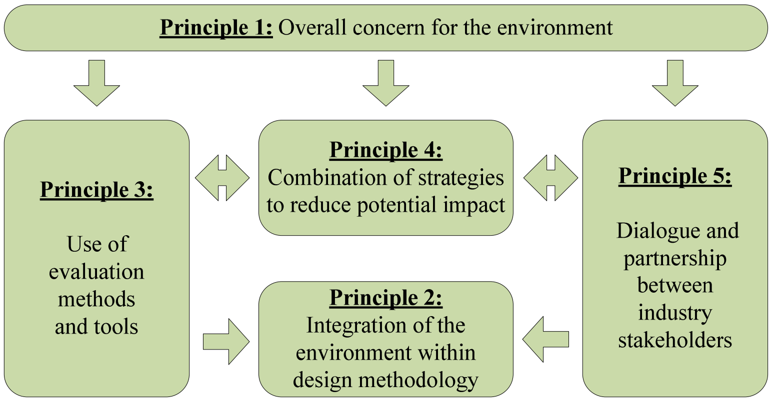
Since eco-design is still a relatively new topic (Talaba and Roche, 2005; Vezzoli and Manzini, 2008), the main difficulty therefore is how to switch from theory to practice, i.e., how to allow designers to easily integrate the environment within the design of products and services?

Much research, carried out in companies, research centres, environmental agencies, have led to more and more varied methods, which may be accessed in the form of manuals, software, and training programmes (Boeglin et al., 1999). Based on this plethora of approaches, it would seem difficult to describe and formalise them all (Goepp et al., 2013a). However, it is possible to extract from all the existing approaches to eco-design, a number of common principles which would provide a suitable basis for company management strategies of integrating environmental concerns to the design of products.

2.2 The five principles of eco-design

Analysing the work of the French Association for Standardization (AFNOR), outlined in document FD X30-310 (AFNOR, 1998) and essentially reused in ISO TR 14062 (ISO, 2002), as well as Zwolinski et al. (2007), eco-design emerges as a process comprising five inseparable principles which must be jointly applied (Figure 1).

Figure 1 Relationships between the five principles of eco-design (see online version for colours)



1 The first principle relates to an *overall concern for the environment*. Indeed, it is crucial to have an overall view of the product's lifecycle, as well as a multi-criterion approach to identify the causes underlying the main impacts of the product on the environment, and to avoid pollution transfers (AFNOR, 1998). This allows identification of which factors are truly important, as well as tailoring efforts towards effective action in favour of the environment, with the best possible use of the company's technical and financial resources. Combining these two sources of efficiency – environmental and economic – is termed eco-efficiency (Zwolinski et al., 2007).

2 The second principle relates to *integrating the environment to design methodology*. Eco-design should not be viewed as just another constraint to add to design, but must instead blend in with existing design methods. Integrating environmental concerns to a design project should cause little or no alterations to existing design methodology. This seems self-evident, since these are already in accordance with environmental prerequisites (Zwolinski et al., 2007). The key is to integrate environmental parameters as one would integrate technical parameters, financial parameters, etc. Eco-design must therefore be viewed as an overarching methodological complement to the design process.

A large number of approaches to eco-design have accumulated beginning in the seventies. In order to make sense of this corpus, several authors have proposed various categorisation schemes. We will only quote here the scheme put forth by Zwolinski et al. (2007), which draws inspiration from the scheme described in the ISO/TR 14062 standard (ISO, 2002) since this scheme seems to us, to be of the most relevance. It comprises three levels: one level contains a 'partial' eco-design approach which implies partial alterations to the product (e.g., alterations in materials or in some components). A second level is termed 'classic' where alterations are made to the matter and form of product components, as well as the product architecture, technological and use concepts behind the product. Finally, in the last level, termed 'innovative', the design team no longer thinks in terms of product components but in terms of service (sets of functions which the product must provide to the user).

Janin (2000) has proposed a comprehensive synthesis of how businesses should go about initiating an approach to eco-design. He suggests starting with identification of hazards and opportunities, then ensuring the involvement of company leaders, before planning the process. The goal here is to identify key company capabilities and to foresee the costs and benefits of the process.

1 *Using methods and tools for evaluation.* This third stage is essential in determining which of the identified environmental impacts are significant, and to ensure the validity of the results obtained (Goepp et al., 2013b). The choice of methods and tools, in fact, depends on the specific characteristics of the product and the company. The best-known tools may be categorised into two types:

   - *Quantitative methods:* lifecycle analysis (LCA) is the most comprehensive and best-known method, but it is also the most cumbersome to apply (Hanson and Hitchcock, 2009; Ny et al., 2006). Indeed, this method relies on prior collection of a large amount of reliable data and a heavy dose of calculation (Butel-Bellini and Janin, 1999; Le Pochat et al., 2007). Therefore, many simplified methods have emerged based on this, such as simplified LCA (Butel-Bellini and Janin, 1999; Le Pochat et al., 2007), so-called integrative approaches such as evaluation of impact on the environment or EIME method (Janin, 2000) or financial-based approaches (Butel-Bellini and Janin, 1999; Janin 2000).
   - *Qualitative methods:* these are matrix-type approaches, such as simplified qualitative lifecycle evaluation, lists of materials or standard-based inspections (Butel-Bellini and Janin, 1999).

2 The fourth principle relates to *combining strategies to reduce potential environmental impacts.* The complexity of attempting to reduce the product's environmental impact generally calls for the use of a combination of several strategies in order to attain significant results. It is when these strategies are chosen and applied that one must make compromises, striving to retain an approach based on multiple criteria and spanning the whole of the product's lifecycle. Some of the more famous strategies rely on minimising the number of materials present in the product (Le Pochat et al., 2007); on forecasting the later separation between various materials, on simplifying design to the least possible number and amount of materials; on optimising logistics; and on designing more energy-efficient products (Boeglin et al., 1999).

3 Finally, the fifth principle involves *dialogue and partnership between project actors.* Since eco-design is an approach based on multiple criteria, which must take into account the whole of the product's lifecycle, it is imperative that all actors of the process (from the provider to the customer) be involved and efficiently share their capability for analysis and action toward greater efficiency.

2.3 Standards and regulations

As Zwolinski et al. (2007) has pointed out, *environmental law in France today is rather like a jungle of standards*. One must add to this the complexity of European regulations. Indeed, these currently number 70 basic directives regarding water, air, and waste; and more than 400 international treaties. Since compliance with international regulations is compulsory, it seems necessary for companies not just to comply with them, but also to anticipate them. To achieve this, persons in charge of environmental aspects must have some legal skills, in addition to scientific skills, knowledge in terms of design and lifecycle management, and must also master the methods and tools of eco-design.

2.4 The context of French SMEs

The context of SMEs in France is rather unfavourable to the integration of eco-design, notably because of the low volume of commercial goods which it covers, as well as because of the difficulties SMEs encounter while integrating any new constraint which is not viewed as having any strategic importance. Several obstacles can be identified.

First, SMEs concentrate on short-term management, and encounter difficulties when attempting to optimise their products. This is incompatible with the strategic vision and the capability for anticipation which are necessary to integrate environmental aspects, which generally relies on a principle of medium-to-long-term improvement (Le Pochat et al., 2007; Deutz et al., 2013; Bocken et al., 2014). Furthermore, since eco-design is by definition complex through its transverse and multidisciplinary nature, applying an eco-design approach should rely on a sufficiently formalised management system. This key factor to the success of eco-design is frequently found lacking in SMEs (Le Pochat et al., 2007; Deutz et al., 2013; Bocken et al., 2014). Lastly, because of their limited means, SMEs do not have access to key internal resources for the practice of eco-design. They can call upon external resources. For a topic which does not seem of crucial importance, this is also beyond the scope of their abilities. Integrating environmental aspects is more often viewed as a source of financial, human and technological constraints rather than a source of opportunities to launch innovative products (Behrendt et al., 1997).

Thus, the two key factors contributing to the failure of standards application (and more broadly, the failure of eco-design) are, on the one hand, a structural incompatibility of SMEs with the means required for ‘traditional’ eco-design tools (e.g., LCA); and on the other hand, the issues surrounding the use of eco-design tools in companies which have not considered altering the organisational framework to allow for the production of eco-designed goods.

Gradually, methods to integrate eco-design in SMEs are being put into place. But it is essential to adapt these methods to the specific characteristics of each business.

3 A proposal for a pragmatic approach to integrating environmental aspects to the product design process, in the field of SMEs

Having presented a brief state of the art on eco-design, the task remains to make eco-design practically applicable. The first issue is how to make eco-design theories accessible to designers in order to help them take into account environmental aspects on par with financial and technical aspects (Graedel and Allenby, 1998; Borchardta et al., 2011).

3.1 The proposed approach

According to our state of the art, one should proceed using a step-by-step basis (in a continuous improvement way) when attempting to implement an eco-design approach within a company. This relies on setting short-, medium-, and long-term goals.

Which eco-design should be chosen essentially depends on two elements: the degree of product complexity, and the company's level of maturity with respect to environmental aspects (Jacqueson et al., 2003; Zwolinski et al., 2007). This choice should be carefully thought out to remain in accordance with the company's past environmental actions and current policy. As we were defining our approach, we were involved in a project aiming to design a range of hospital carts. Although the company was well informed of the stakes of eco-design, it was only just beginning to take an interest in this field. Indeed, for the specific category of hospital carts, no specific regulations exist at the time of writing. Only regulations concerning all manufactured products apply, such as regarding the use of toxic products, packaging, product disposal, etc. However, it may prove worthwhile for the product and/or company to obtain an eco-label. Indeed, as noted above, environmental aspects may be instrumental in selecting offers in public contracting.

Our proposed process comprises four stages (Figure 2):

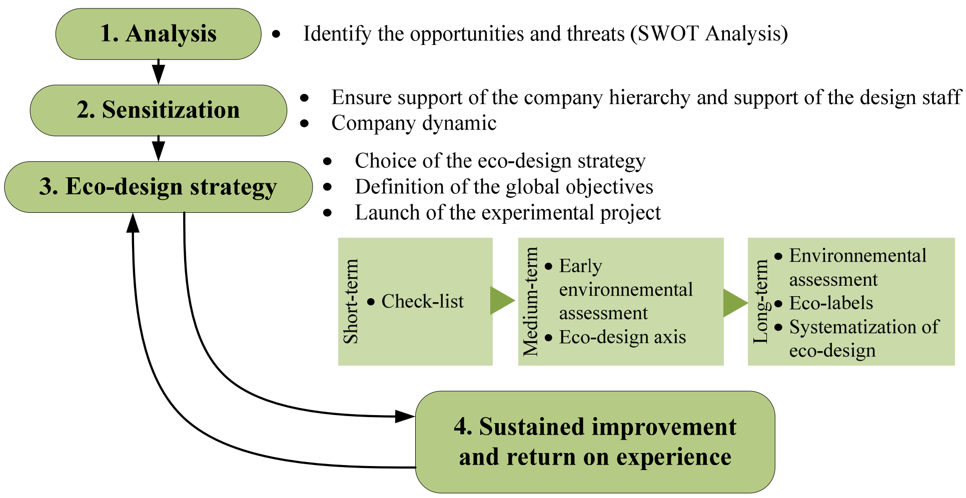
1 analysis

2 sensitisation

3 eco-design strategy

4 sustained improvement and return on experience.

Figure 2 A proposal for an eco-design process (see online version for colours)



3.1.1 Analysis

Before committing to an eco-design process, it is essential to identify the opportunities and hazards befalling the company. These criteria are divided into two groups: internal criteria (e.g., personnel motivation, leadership, company image) and external criteria (anticipated regulations, customer requirements) (Reyes et al., 2007). This helps us position the project, e.g., through the use of a SWOT diagram.

The list obtained in this way is by no means set in stone. It continues to evolve depending on the context of the industry and of the company. It is therefore necessary to regularly ensure that the list is up-to-date.

3.1.2 Sensitisation

This stage involves broadcasting the company's environmental policy in order to sensitise personnel (notably administrative and design staff). Indeed it is crucial to ensure support of the company hierarchy to facilitate decision-making, and support of the design staff to ensure that it takes into account environmental factors just as they might do with technical or economical factors.

3.1.3 Eco-design strategy

In this stage the eco-design strategy is chosen and its overall goals are set. Just as in the case of a total quality management process, appropriation of an eco-design process is done on a step-by-step basis over a period of several months or even years. First, as pointed out above, one must ensure that the hierarchy fully supports this approach. Secondly, it is necessary to launch an experimental project to define which process and tools are best suited to the company. Thirdly, the process must be continuously improved and generalised to all design projects within the company.

Once support from both the hierarchy and designers are ensured, the goals of the experimental project must be set. Unfortunately, the company's limited means, as well as the lack of time and expertise, do not allow for an evaluation protocol to be implemented. Furthermore, although environmental aspects are accounted for in decision making, technical and economic criteria remain at the highest priority. Therefore, one must adapt to the context of SMEs by setting short-, medium- and long-term goals.

- In the short-term, the goal of this first experimental project is to establish as comprehensively as possible, a list of possible strategies to reduce the product's impact on the environment. This checklist allows designers to take into account environmental aspects in all decision-making tasks. One must ensure that the product fulfils a number of criteria, while making compromises between which materials and assembly types to use, limiting the environmental impact of production and use, minimising packaging and optimising logistics, facilitating reuse and recyclability, notwithstanding technical and economic criteria. Unfortunately, even when designers are experienced in this, it is not possible to assess the benefits of this action. Therefore, our longer-term goal is to implement a method for environmental assessment.

- In the medium-term, carrying out an environmental assessment of the product's reference model at the start of the project allows us to highlight the main environmental impacts of the product, which the eco-design process will subsequently attempt to minimise. The reference model is a product, whether real or fictitious, which fulfils the same functions as the product which is being eco-designed, and which serves as a reference for the future product. Environmental evaluation of the reference model does not provide designers with straightforward solutions. In any eco-design process, evaluation methods must first be translated into pathways for design, making sure that these provide an adequate response to requirements: those of customers (functional specifications), those in terms of technical feasibility and costs (investment and ROI), and those of lowered environmental impact. For this first experimental evaluation, expert advice should suffice to assess the potential for the reduction of environmental impact provided by each design path. Quantitative assessment tools are of limited relevance since project data are imprecise (e.g., regarding materials, processes, etc.) at this stage of the project. They are better suited later on, when choosing technical solutions.

- In the long run, the company's goal is to implement a methodology for quantitative assessment which is well suited to its products (e.g., simplified LCA) in order to proceed with comparing the environmental impact e.g., of the designed product vs. existing products. This comparison must be carried out using internal and external resources, and rely on possible product variants, as well as on competing products. Such products may also comply with standards such as ISO 9001 or 14001 or specific goals, such as those set by eco-labels.

One should point out, therefore, that it is crucial to have access to a basis for comparison (or 'reference model') to use the results obtained with the chosen method of assessment. The choice of a method for quantitative assessment should assist the discovery of adequate solutions, to manage the compromises related to most design decisions. It then becomes possible to make these decisions based on objective criteria rather than subjective evaluation. Finally, this quantitative assessment allows us to lower environmental impact in order to obtain an eco-label and provides customers with the guarantee that the product has a lowered impact on the environment. This constitutes a noteworthy commercial advantage.

3.1.4 Sustained improvement and return on experience

According to Vezzoli and Manzini (2008), manufactured goods are almost always evolutions of existing products. It therefore becomes possible to identify potential areas of improvement for future products, by implementing a relatively simple and concrete process of sustained improvement which involves, when product lifespan is not too long, in relying on maintenance, reuse and value enhancement data, focusing on products of the same type. Often it is not compulsory to modify everything right away, provided the product is due to undergo evolutions towards reduced environmental impact.

One should note that the sharing of information between the various actors of the product's lifecycle is a crucial element of improving the product's environmental aspects, as well as the product itself.

4 A case study: the design of a new range of hospital carts

The industrial application of this research project is a collaborative project with MulTiroir-Controlec an SME located in the Paris area, which designs and sells storage products in various fields, including the medical field which is the company's prime area of business and also the focus of this particular project. In an increasingly competitive environment, MulTiroir-Controlec wishes to differentiate itself from its competition and to widen its catalogue by designing a range of modular carts which would be specific to this company.

Figure 3 Some examples of hospital carts developed by MulTiroir-Controlec (see online version for colours)

The industrial goal is to design a new range of modular carts addressing the needs of hospital personnel (e.g., circulation of medical files and health equipment) while taking into account the various constraints (e.g., hygiene) specific to the fields of health and medicine, ergonomics of cart use, optimisation of costs, and environmental impact. Indeed, MulTiroir-Controlec is sensitised to the issues of eco-design and sustainable development, and wishes to integrate environmental aspects to this new project. This would allow the company, in particular, to anticipate evolutions of future environmental regulations enforced in the field of public contracting, which constitutes a large part of the company's sales, and also to satisfy customers' latent requirements for environment friendliness. As we will point out, this is also a true opportunity for differentiation and innovation.

Due to the duration of the project and the limited means available to us, our approach strived to remain realistic. We endeavoured to integrate environmental aspects into the design project through the construction and implementation of a checklist to guide decision making.

4.1 Project planning

This stage allowed us to set a number of overarching goals to the project, which resources (both financial and human) were necessary, and which actions should be undertaken. At this point, the main stakeholders involved are the company hierarchy, who must carry out an analysis of business and customer needs as well as a market study, in order to identify opportunities and set its position in the market.

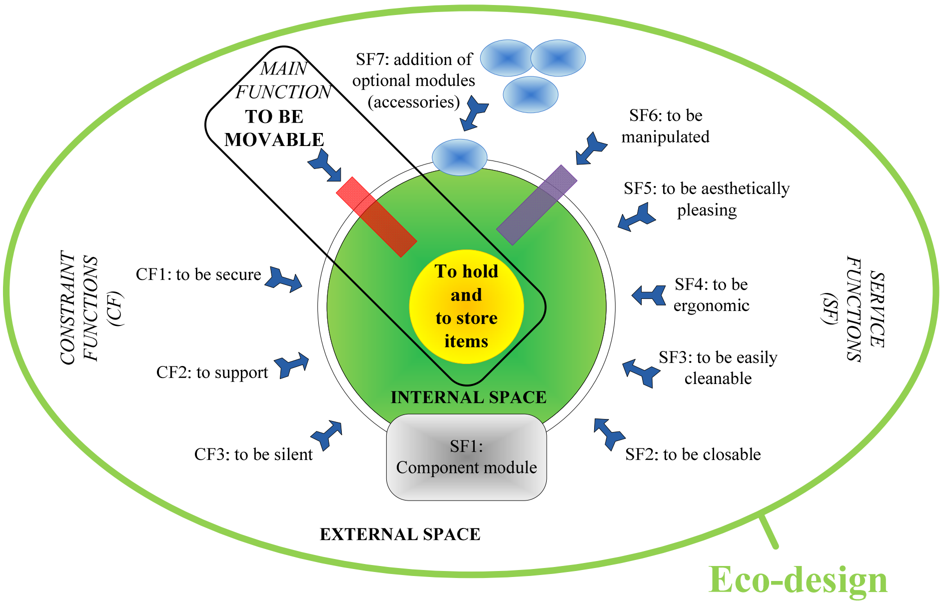
Once the needs to design a new range of products and to integrate the eco-design concept are ratified, the project team is gathered. Since the company was unable to call upon the services of an eco-design expert, this role was taken on by an engineer in addition to his duties as product designer. This person in charge of environmental aspects had to sensitise company personnel to integrating environmental criteria in decision-making.

4.2 Contextual study and product specifications

During this stage, we carried out an external functional analysis, drawing on a comprehensive user study carried out by an external design consultancy firm. This study was instrumental in defining product concepts as well as the product's functional specifications. This study was also a means for designers to gather information regarding customers' environmental expectations: do they give any stock to eco-labels? Which environmental criteria do they view as fundamental? What are their perceptions of existing products? Etc. It also allowed designers to gather information regarding current standards and regulations.

In this stage we identified a number of functional, as well as environmental requirements, which allowed us to draft some early specifications to the product (Figure 4). Environmental aspects were integrated directly to the product's functional requirements, in an attempt to give environmental aspects similar importance to technical and economical aspects.

Figure 4 Functional analysis of the hospital cart, including eco-design aspects (see online version for colours)



This approach also allowed us to highlight pathways for eco-design, i.e., to identify criteria and stages of the lifecycle on which to focus the search for technical and environmental solutions.

4.3 *Concept elaboration*

This stage consists in constructing innovative product concepts or in improving existing concepts in terms of product use and technical characteristics, while complying with functional specifications. Here, the person in charge of environmental aspects must push the project team towards more environment-friendly alternatives, while of course ensuring technical feasibility just as would be the case in 'classical' design. Concept elaboration typically relies on 'creativity sessions' (e.g., brainstorming, analogical reasoning, idea sheets, etc.) where no idea should be rejected at first (e.g., extreme ideas, such as product dematerialisation, etc.).

Following this search for solutions, designers must make a choice between the various product concepts generated in this way. This relies on the results of technical, economical, and environmental assessment. At this point, it is useful to provide an appropriate checklist of environmental factors (Table 1) for presentation to project stakeholders in order to penalise or even reject concepts which are deemed too remote from environmental goals, and to add value to those which are in accordance with these goals.

Table 1 Checklist of environmental criteria used in the project

Choice of materials and assembly	Easily recycled product	• Lower the number of materials present in the product • Choose materials compatible with available recycling outlets • Choose composite materials that can be recycled • Design to include subsequent separation of the component materials • Design with a mindfulness for end-of-life collection, disposal and value enhancement
	Products containing recycled materials	• Ensure that the product contains recycled materials
	Mastering risks related to materials and component substances	• Optimise the concentration of these substances • Master the risks related to these substances • Search for substitutes liable to fulfil the same functions
	Renewable and renewed materials	• Favour the use of renewable materials
	Product simplification	• Design with simplicity in mind, i.e., less components • Lower the number of subunits
Towards cleaner production		• Use simple manufacturing processes
Minimise packaging and optimise logistics	Reduce to the source	• Reduce the quantity of matter used and the volume of packaging
	Optimise logistics	• Lower transport requirements
Use of the product	Quality and environmental performance	• Improve the reliability and efficacy of products
	Strategy of sustainability	• Favour the upkeep and maintenance of the product • Allow for product evolution based on the progression of user needs • Establish and maintain an affective relationship between the user and the product

4.4 *Preliminary design*

In this stage, designers define the product architecture, ensuring that the project goals are reached as much as possible, whether these goals are environmental, technical or economical. Once again, the environmental aspects of the functional specifications, as well as a checklist, are essential to ensure that the environmental criteria defined at the beginning of the project are maintained.

A design review then allows the design choices to be ratified or rejected. If the choices are validated, the project proceeds to the detailed design stage. If not, the architecture needs to be improved, and the concept may need to be changed.

4.5 *Detailed design*

During this stage, the product is completely described: shape, size, components, materials, manufacturing processes. This relies, for example, on the elaboration of 3D models and the design of mock-ups and prototypes. Each of the design choices must take into account environmental aspects. It is therefore crucial for designers to be properly sensitised beforehand to environmental issues. The person in charge of environmental aspects plays a crucial part in this.

Figure 5 Modular description of hospital cart structure (see online version for colours)

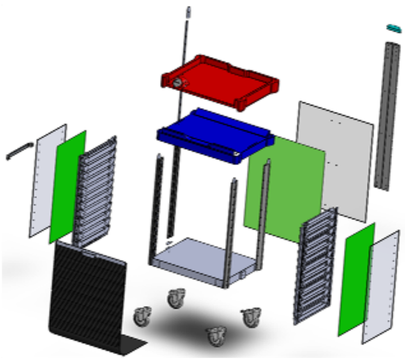


Figure 6 Hospital cart for storing patient files (see online version for colours)

Figure 7 First hospital cart prototype (see online version for colours)

4.6 Development and industrialisation

In this stage, suppliers are chosen, the necessary tools ordered, the assembly is defined, the preliminary industrial series is launched. If need be, improvements are made to the product. In terms of eco-design, the issue is to reduce the potential environmental impact of manufacturing processes, to optimise logistics, and to keep tabs on and/or improve the environmental behaviour of suppliers.

5 Results

Currently, in each instance of decision-making, various environmental criteria are taken into account. This allows us to steer our choices so as to achieve a reduction in environmental impact. Nowadays, it seems self-evident that technical and economic criteria will bear more heavily on design choices than environmental criteria. However, we were able to influence the choice of the product concept and architecture to reduce this impact – by reducing the volume of matter present in the product, by reducing the number of its subunits, and by promoting the maintenance and upkeep of products in order to improve their lifespan. The choices made in this direction include designing modular products, facilitating replacement of broken or worn-out parts, avoiding the use of wear parts, avoiding corrosion, protecting fragile parts, and including maintenance instructions with the product. Other issues include postponing product obsolescence, allowing the product to evolve along with user needs, planning optimal use of the product's functions, and helping establish an affective relationship between the user and the product through the use of timeless aesthetics.

To achieve success in product development based on compliance with these environmental criteria, it is also essential that every stakeholder in the company have a personal investment in the project. First and foremost, it is necessary to ensure support of the hierarchy. Without this support, environment protection requirements will likely be perceived as just another set of constraints. These constraints must then be managed as the design project unfolds, leading to possible delays, added costs, and commercial risks. Conversely, clearly stated support from business leaders will stimulate personnel and guide decision making towards more environmentally friendly solutions.

Businesses must also acquire new skill sets – take the time to train, motivate, and call up not just its personnel, but also its subcontractors. Consequently, the stage of appropriating the process is both long and costly.

It is also essential to take into account dialogue and partnerships, both internal and external, to achieve project success. Indeed, as we have stated above, in order to have an overall view of the product's lifecycle and to achieve efficient eco-design, it is necessary to set up communication channels with suppliers, but also throughout the industry. At this point, sharing information, and ensuring transparency, sustained cooperation and dialogue allow companies to gain an edge over the competition. This allows businesses to differentiate their products and to benefit from their assets in the long run.

Furthermore, design choices are usually the results of trade-offs that must be managed in the best possible way, to ensure optimal decision-making (Byggeth and Hochschormer, 2006). Experience, as well as well-defined goals, is a major source of assistance for decision-making, to identify:

- Trade-offs between the various environmental aspects. For example, optimising a product to reduce its weight may have an adverse effect on its ability to be recycled.

- Trade-offs between environmental and economic criteria. For example, making a product more robust may extend its lifespan. This may help the environment by reducing the use of resources and the production of waste in the long run, but can also increase initial costs.

- Trade-offs between environmental, technical, and quality-related aspects. For example, some materials may yield considerable environmental benefits, but have a negative impact on product durability and reliability. As an illustration, in the early trials of the hospital chariot prototype, the polypropylene (PP) side-plates suffered deformations because of the heat. This issue was addressed by replacing this material with a polyethylene (PE) plate coupled with two plates of painted aluminium. This has a negative impact on product recycling, but allows us to respond satisfactorily to the technical and quality-related requirements.

Finally, manufactured goods are, most of the time, evolutions of existing products. It is therefore crucial to take stock of prior experience in order to find pathways for the improvement in future products.

Based on this project, several guidelines can be issued to businesses wishing to invest in this kind of process. They must:

- take into account the whole of the product's lifecycle
- define with care targets of improvement
- take into account regulatory, technical and economic constraints
- within this framework, ensure that project stakeholders share all relevant information
- set up an information system to allow experience feedback and sustained improvement.

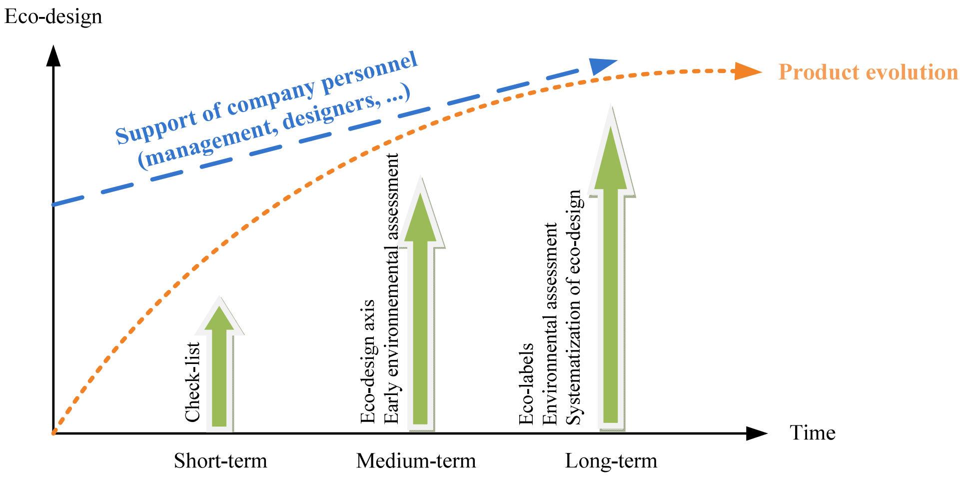
6 Conclusions and prospect

Taking into account environment-related constraints in product design is a real necessity. In the industry, this is not, even today, fully mastered. Indeed, the methods and tools used in eco-design are often cumbersome and require large amounts of resources to be invested, compared with the expected results.

In this paper, we have proposed an integrative approach to taking into account environmental aspects in the product design process. This approach can be divided into four stages, and comprises three complementary strategies, for the short-, medium-, and long-term.

In the first stage, ‘analysis’, it is important to identify the opportunities that are available, as well as the threats that face the company, before committing to an eco-design approach. In the second stage, ‘sensitisation’, the goal is to share the company’s environmental policy in order to sensitise its personnel – particularly its leaders and designers. The third stage, the ‘eco-design strategy’, focuses on the choice of relevant eco-design strategies and goals to achieve. Any eco-design approach is appropriated in several stages. Depending on the company, this may take place over a period ranging from several months to several years. Strategies include short-term (checklist-based), medium-term (early environmental evaluations, choosing axes for eco-design) long-term (environmental evaluation, labelling of eco-design projects) levels. Finally, the last stage, named ‘sustained process improvement and experience feedback’ completes and improves the three preceding stages in order to usher the company in a virtuous cycle.

Figure 8 Strategies for the implementation of eco-design (see online version for colours)



We have applied our approach to the development of a new hospital chariot within an SME. The first version of this product, a healthcare chariot, integrates environmental aspects and is currently in the commercialisation stage.

This product will come in a range of products for healthcare professionals – e.g., chariots to transport drugs, patient files, etc. – all of which will integrate environmental aspects, as in the first product. Once the range of products is commercialised, the company wishes to arrange for environmental evaluation of all three chariots, in order to define more clearly the pathways available for eco-design. In the long run, the business will require the method used for environmental evaluation to be specifically suited to this kind of product. The goal is to compare the environmental impact of the products being developed with that of competing products. Therefore, this experience feedback allows the business to set up the conditions for sustained process improvement.

Furthermore, as is the case for any new field in a business environment – notably in SMEs – new skills will have to be gradually acquired by company personnel to ensure optimal integration of the eco-design approach. To achieve this, it is necessary to transfer and to create knowledge and skills related to the environment within the company. The goal is to capitalise the experience and know-how that are required for generalising eco-design to all the products developed in the company.

By applying this approach at the product design level, companies clearly differentiate themselves from the competition. The environment becomes a clear asset to the company strategy, instead of a groundless commercial argument (i.e., greenwashing).

In order for its efforts to become more visible, this business has elected to generalise this environmental approach to the entire company. It has set up a global approach to environmental management, called 'EnVol' – voluntary engagement of the company for the environment (Letellier, 2010). This approach is compatible with the ISO 14001 environmental certification standard.

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