Assessment of Sustainable Practices in New Product Development

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Abstract. Decisions during NPD process have impact on 80-90% of a product's life cycle sustainability performance. The objective of this study is to investigate the integration of sustainability into product design, mainly focusing on the environmental aspects. The investigation has been carried out by means of a questionnaire developed based on a 3-pillar framework outlining the essential elements for successful integration of sustainability and Life Cycle thinking in NPD process. 10 manufacturing companies with high innovation cycles, operating in Italy in mechanical, electrical and automotive sectors was assessed, supporting the questionnaire with 2 complementary case studies. The results revealed that companies fail to implement sustainability in product development process and gap exists in all the enablers since companies just try to tackle the legislations, considering sustainability as a constraint rather than exploiting the opportunities for eco-innovation.

Keywords: Sustainability, Eco-efficiency, New Product Development (NPD), Eco-design tools

1   Introduction

In the last couple of decades, significant research work has been carried out in order to investigate different ways of supporting engineers in the development of more sustainable products. However, most of the efforts and studies are mainly directed towards the environmental aspect of sustainability as the industrial world has changed its approach to the environment. The importance of the environmental sustainability of industrial products and processes derives not only from the ever stricter-becoming environmental legislations issued in most of the developed countries, but also from the higher awareness of customers concerning environmental problems. In particular, the competitiveness of putting on the market more sustainable products is becoming a key factor in recent years [1].

Product development is one of the most critical aspects for companies in reaching their sustainability objectives as almost all the products are outputs of the product development process. In particular, early design decisions can have a very significant

impact on sustainability. These decisions not only concern choices of material and manufacturing but also have a strong impact on the product's entire lifecycle [2].

Based on the estimation from the EU report, 80-90% of all product-related environmental impacts are determined during the design phase of a product. Hence, eco-design is a way to improve products' life-cycle environmental performances by systematically integrating environmental aspects at a very early stage in product design [4]. As a matter of fact, key challenges have to be overcome to enable eco-design methods to be applicable in early design stages.

With this study, we aim to understand the main motivations, limitations, and effectiveness of integrating sustainability in new product design and to understand how and what companies are doing currently to integrate sustainability in their products and product development processes. In doing this, the focus is mainly on company characteristics, sustainable strategies and applications of the company, ecodesign tools and relevant product development processes. In this context, we identify the main research objectives as below:

- Understand how and what companies are doing currently to integrate sustainability into their products and product design processes
- Determine the priorities of companies during product design and stimuli for sustainable product design
- Understand the level of consideration given to integration of sustainability into product design on the industry side
- Develop insight into the use of eco-design tools in companies' product design practices
- Identify the gap between the literature and the practice

This paper is structured as following: State of the art for relevant concepts and the framework used for designing the survey is provided in part 2. The methodology followed is explained in detail in part 3. Next, the results of the analysis is shown and discussed in part 4. The main insights from the paper and conclusions are presented in part 5 and finally part 6 mentions the limitations of the study together with some ideas for future research.

2   State of the art

2.1   Framework of Enablers for Integrating Sustainability in NPD

The study and the survey are constructed based on a framework from a previous study of the authors. The framework has 3 main components: Drivers/barriers, the enablers which foster efficient and effective integration of sustainability in NPD (i.e. strategic paradigms, supporting tools and manufacturing process paradigms) and impact of integrating sustainability in NPD on NPD performance measures, as shown in Figure 1 below [5]:
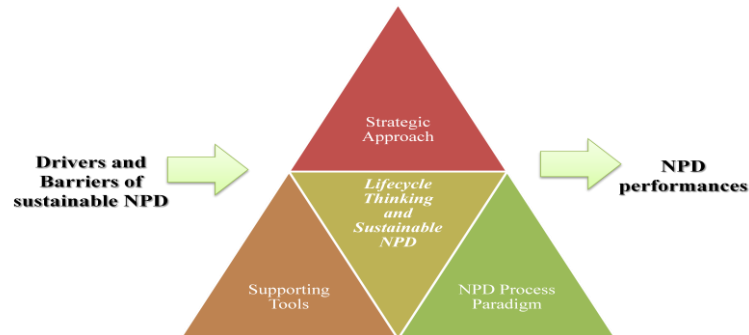
Fig. 1. Framework of enablers for successful integration of sustainability in NPD [5]

2.2   NPD Process Paradigms

Analyzing NPD process paradigms concerns assessing how companies organize their NPD processes in such a way that sustainability is effectively integrated into product design. To design any product, some set of processes should be followed and types of processes depend on the type of products as well as companies' considerations of different aspects and related decisions in product development. Hence, the structure of a design and development process affects the sustainability performance of a product to be designed [3, 7].

Conventional NPD process is generally structured in a sequential manner called serial engineering [8]. Sequential design process models are characterized by freezing design specifications early in a design process so that designers have a single design option to discern till it reaches a control gate. At design gates, the design concept will be tested if it meets design requirements, and at that point if the design doesn't meet the requirements either design iterations or sub-optimal product will be the result [7, 8, 9]. Thus, companies first decide the fate of the product early in the process and problem will be revealed later at the design gates in such process models. If sustainable products need to be designed following such process paradigm, two problems will happen [6]; the first one is that, if the designers found that the product does not meet some environmental requirements at latter design gates they need to redesign again, which in turn affect time to market and incur additional cost for the company. Second, since environmental considerations are taken secondary in industries, once environmental problems have been found at the gates, designers overlook the problem and prefer to launch sub-optimal products from sustainability perspectives.

Concurrent engineering (CE) was born to improve the problem of serial engineering approach of NPD process [10]. In CE, manufacturing engineers intervene in a design process to consider and improve the manufacturability of the design. Such NPD paradigm is more effective in addressing sustainability issue than sequential paradigm [3]. Therefore, successful integration of sustainability in NPD depends on how NPD process is structured in a company. This phenomenon has been a focus of investigation for the companies surveyed in this paper.

2.3   Ecodesign Concept and Tools

Ecodesign is a practice by which environmental considerations are integrated into product and process engineering design procedures. Ecodesign practices are meant to develop environmentally compatible products and processes while maintaining product, price, performance and quality standards [11].

Many efforts have been made to develop tools that support integration of sustainability in NPD. The most powerful and prevalent tools used in sustainable product design are those which consider environmental aspect of sustainability, so called "eco-design tools". Many the so called eco-design tools and methods exist [12]: some are extremely simple and qualitative (such as checklists), while some are complex and quantitative (Such as LCA), and others based on QFD (such as Green QFD). The selection of the best tool for a given application depends on the individual situation of the context of the design and development process [13].

The simplest classification of tools is into those which perform data analysis, and those, which are aimed at improvement. Analysis tools provide a measurement of the potential environmental impact of a product. They are mostly used before design starts, by analyzing a previous product or that of a competitor. Alternatively, they may be used at the end of a design project to verify the result. Improvement tools, on the other hand, are used during the design process to direct activity and provide information on the process.

Mistakes in selecting the most suitable tool depending on the specific situation may limit the effectiveness, usability and applicability of the tools. Criteria that should be taken into account during the selection of the adequate tools could be: the aim of conducting the study, the type of business or product considered, level of information available, the time available, the nature of data input, the quality of the expected results, the intended user and the design stage a tool is intended to be used (i.e. concept stages, system design level, embodiment design, and detail design) [14].

In this study we have considered around 30 eco-design tools that have been found in the literature. In the survey, we investigated companies if they adopt these kind of tools in their practices and how efficient and effective they are in applying such tools.

3   Research Methodology

In this study, literature published in the last 15 years (1995-2010) have been studied, including academic journals, books and conference proceedings, to understand what have been written and practices in literature and industries till now to integrate sustainability in new product design. This literature review formed the basis to identify the research objectives and the structure of the survey questions. The investigation has been carried out by means of a questionnaire developed in alignment with the research objectives based on a framework to assess manufacturing companies operating in Italy in mechanical, electrical and automotive sectors. The analysis was carried out on 10 companies with high innovation cycles, which are subject to many product based EU legislations (i.e. WEEE, ELV, EuP, REACH, RoHS, and others). The questionnaire was supported by 2 complementary case studies including face to

face interviews and analyzing the internal documents, to increase the relevance of the work.

3.1   Survey Design and Procedures

Based on the research objectives and framework described in section 2.1 that identifies essential elements to successfully integrate sustainability and life-cycle thinking in NPD process, a questionnaire of 25 questions has been developed to assess the companies. This survey was composed of questions about company characteristics, sustainable strategies and applications of the company, ecodesign tools and relevant product development processes. The questionnaire has been approved after some revision phases in which some of the questions have been modified in order to simplify their understanding, and other questions have been added, in order to gain all the possible information aligned with our objectives. The expected recipients of the questionnaire were product development department responsible.

On-line version of the questionnaire has been created using Survey Monkey and was sent to companies via the following link: http://www.surveymonkey.com/s/ZD5ZLPR The on-line questionnaire has been proposed to over 200 contacts, of which 10 companies replied directly via the link provided by e-mail.

3.2   Survey Questions

Questionnaire was based on the framework to implement sustainability in new product development (NPD): So, questions have been identified considering the main components of the framework as listed below:

1. Drivers/Barriers:

- The stimuli factors considering sustainability in NPD
- Barriers of incorporating sustainability in NPD
- Causes of Eco-design projects failures and successes, etc.

2. Enablers
A. Strategic approach

- Mandatory and voluntary sustainability policies and legislations company adopts
- Commitment of top management
- Environmental parameters used in product design
- Sustainable product strategy
- Expected benefits of applying ecodesign
- Trade-off between traditional design performances (e.g. cost, quality, time to market) and environmental and social issues, etc.

B. Supporting tools

- Types of sustainability design tools used
- Criteria to choose specific tools
- The impact of using sustainability design tools on the NPD performances, etc.

C. NPD Process Paradigms

- Systematic integration of sustainability issues throughout a design process
- Coordination between product's lifecycle partners
- Product's lifecycle consideration
- Exploration and utilization of past project's knowledge
- Level of innovation adopted (e.g. product improvement, product redesign, new product concept, new product system, etc.)

3. NPD Performances

- Financial and non-financial benefits gained
- Impact of integrating sustainability on the traditional NPD performances such as time to market and project costs
- Internal changes due to sustainability consideration in NPD

3.3   Sample Firms and Response Collection

Questionnaire was sent to a combination of large companies and SMEs that might have already been integrating sustainability into their product design processes for several years. Sample firms were selected from manufacturing companies operating in Italy in mechanical, electric and automotive sectors. Although the questionnaire was proposed to over 200 companies, we got the responds from and analyzed 10 companies with high innovation cycles, which are subject to many product based EU legislations (i.e. REACH, RoHS, WEEE, EuP, ELV and others). The respondents were all relatively large companies. Some of the SMEs responded to mails to inform whether they don't consider this kind of approaches during product design or they are not interested in such activities. Thus, this information might be considered as a clue for a low-level adoption of sustainable practices and especially ecodesign tools among SMEs.

3.4 Complementary Case Studies

We carried out two complementary case studies to support the results achieved by the survey analysis. The aim was to collect relevant information about sustainability practices and sustainable product design processes of the companies via face to face interviews, analysis of their internal documents and going deeper in their responds to survey, as complementary to survey analysis. The two companies selected for case studies were globally known large enterprises; one automotive manufacturer and one tire manufacturer. Face to face interviews have been made with technical responsible in both cases. The other dimension of the analysis was to analyze the documents such as annual sustainability reports, sustainable strategy reports, etc. for supporting the results gained by the prior survey study.

4   Research Results and Discussion

First of all, almost 90% of the companies responded that they consider sustainability in NPD. However, the definitions of sustainability differ from company to company and most of them take sustainability and environmental consciousness as same without a comprehensive approach of sustainability as the balance between Economic-Environment-Social dimensions.

However, the results demonstrate that companies still consider sustainability as a constraint rather than opportunity for eco-innovation. Furthermore, companies are trying to meet only the minimum requirements asked by legislations despite the efforts from academia side to drive strategic push, effective tools, and suitable NPD process paradigms to foster sustainable product innovations. In fact, companies won't be spending time and money in implementing sustainability unless government legislations forced them. Indeed, quality and cost seem to be the most important factors considered during product design. Environmental aspects and legal requirements are not the priority ones for the companies. Indeed, companies showed mostly used environmental parameters in product design as raw material consumption, energy consumption and energy efficiency, all of which can be directly related to costs.

Companies implementing sustainability in NPD could have many reasons or drivers to do so. Among them; long-term benefits (i.e. image improvement, new market opportunities) and innovation potential, genuine environmental impact reduction, improved resource and process efficiency, customer demand due to increasing environmental consciousness, reduction of costs and risk are the reasons given by companies interviewed. In reality, most of the decisions and interest depend on either costs or long term plans as image improvement and entering to new markets. On the other hand, there are many barriers on the way of companies for implementing sustainability. Companies mentioned that the lack of time and budget to discern sustainability (in terms of investment in new or modified technologies, materials, etc.) in NPD are the most important barriers.

Most of the companies interviewed have high level sustainability initiatives such as CSR (corporate social responsibility) strategic scheme, ISO14001 EMS (Environmental management system), and EH & S (Environment, health and safety) polices. This shows that top managements are also committed for overall sustainability of the industries. However, when it comes to the ground level, as of NPD, there is no evidence that sustainability is properly integrated in top-down approach. Almost all interviewed companies adopt only mandatory EPR (extended product responsibility) EU policies (i.e. REACH, RoHS, ELV, WEEE and EuP, etc.) which ask only minimum requirements to be fulfilled. Hence, the main focus is on the current legislation with little effort to impact future EU policies that might give further competitive advantage.

Investigating how tradeoffs are handled between Economic considerations (cost, performance, and functionality), environmental and social considerations gave us the possibility to check strategic alliances of sustainability in NPD. Therefore, companies seem to consider sustainability in a balanced way although high priority is given for economic considerations (about 50-60% importance comparing to environmental (30%) and social ones (20%)).

The level of investment for sustainable innovations shows that only 5-10% of total R&D budget is invested in average. This figure cannot be taken as absolute measure since 5-10 % might be huge for one industry and small for another. However, sustainable innovation level is limited to product upgrading or modification instead of investing in new and more sustainable materials and technologies.

The reason why companies mostly talk about or direct to environmental commitment appears to be mostly a matter of marketing and advertisement. Even though top managements seem to focus on green marketing on strategic level, there is no evidence that sustainability is properly integrated in top-down approach when it comes to ground level, as of NPD.

Companies interviewed emphasized the fact that fully integrating sustainability in NPD projects cost them more than the gain they could have achieved. Moreover, time to market could be extended if sustainability issues are addressed effectively. As mentioned above, the reasons are mainly internal problems (lack of designers' knowledge, eco-design tools are time consuming, new innovations in terms of material and technology take time and huge investments). On the other hand, they also stress that non-financial gains have been achieved such as; new skill and competencies, company image, customer acceptances, and overall sensitivity towards environmental impacts have been raised inside the company. However, the performance benefits come with penalty in development cost and time to market. Therefore, the main issue here is how to structure NPD strategy, tools, and process in such a way those traditional NPD performances are either unaffected or even improved.

Although the selected companies have claimed that they adopted sustainability for so long (5-10 years), only six out of the ten companies adopted 'proper' eco design tools ranging from simple checklists (e.g. Banned material and chemical lists, disassembly lists and so on) to full or simplified LCA tools. LCA based, QFD based and checklist based tools are the most prevalent tools used in companies' practices. Most of the other tools present in the literature are not used and even sometimes not recognized by companies. This is probably due to the fact that current ecodesign tools are too much expert tools that are little adapted to designers' current needs, tools and practices. Indeed, the methods available in the literature are not good enough to support designers and there are few to help designers find solutions in Design for Environment (DFE) for variety of processes. That is to say, most of the current methodologies and tools serve in a fragmented way which limits designers in finding effective solutions to sustainability problems in product design. There is a huge gap here between literature and the applications of companies. In all likelihood, ecodesign has not been routinely practiced in design teams.

In real, companies have multiple criteria to choose among tools, and the important ones are: easy to implement and easy to learn, delivering accurate results, less amount of required information and less resources for the assessment. This shows that sophisticated ecodesign tools have little importance to bring sustainability to the mainstream NPD practices. Hence, there is a need to modify effective but sophisticated tools such as LCA (Life Cycle Assessment) so that they could be adopted more in new product design. Disseminating and introducing such tools to industry is a viable way to foster sustainability in product design.

Certainly, most eco-design projects fail for two main reasons according to the industries interviewed. The first one is due to insufficient information available and knowledge about the impact of complex product systems on the environment and society. The other one is the existence of many uncertainties in developing sustainable products such as: Suppliers' compliance issues, integrating manufacturing capabilities, and uncertainty about the market acceptance of the product by the customer. Although these reasons are obvious, proper attention should be given to deal with supply chain and lifecycle uncertainties for the success of ecodesign projects.

Many companies reported that they have life cycle view of the product they are designing and they consider all except logistic phase of a product life cycle (material extraction, manufacturing, use, and end of life phases). In particular, manufacturing is given high priority to be considered in design. This could be from the fact that CE is almost applied in all companies nowadays, and it is easy to coordinate and evaluate the manufacturing phase compared to other parts of the life cycle phase.

Crucially, companies responded that they consider sustainability issues mostly at embodiment design phase (60% of the time) and detail or prototyping phase (30% of the time) and never at concept development stage. This gives an intriguing insight as designers have a lot of potential for sustainable innovation at concept design but they don't consider it at this phase. Moreover, design arrives at embodiment stage or prototyping stages after committing a lot of resources (time, cost). If sustainability targets are not met at these phases, designers tend to ignore them and prefer to launch inferior products, since sustainability requirements are considered as something additional comparing to time to market or cost. Even if designers want to improve the sustainability performance of the design, they need to re-iterate the process, which in fact is additional waste of time and cost.

Last, in general companies have no means of using past product's knowledge to be used for future product development. This might hinder the continuous knowledge development inside the company about products' sustainability performances.

5   Conclusion

In this study, we assessed the companies in terms of their level of sustainability practices and found out that companies fail to implement sustainability in product design due to below reasons:

- Decisions depend mostly on cost factors.
- Existent tools are not adapted to designers' needs (especially relevant tools not available for product design phase). Most of the tools present in the literature are not used and even sometimes not recognized by companies.
- Companies especially SMEs consider it as a time consuming and costly activity.
- Companies are mostly focused on improving processes instead of improving products by means of implementation in product design.
- Companies are just trying to meet the minimum requirements asked by legislations despite the efforts from academia side to foster sustainable product innovation

- Sustainability is not integrated during early design in most of the cases but in the later phases.
- There is not enough coordination and cooperation between academia and industry, which might foster the use of applicable theoretical solutions in practice.

To sum up, cases in this study revealed that the consideration of sustainability is not matured enough to attain the general sustainability goal expected by multiple stakeholders. Thus, academia should not only focus on developing sophisticated tools but also on the need to investigate new way of NPD process structures and to better align strategy objectives with sustainability goals.

6   Limitations and Further Research

First of all, as most of the companies are not interested in such activities or do not apply such practices effectively, it is hard to make a detailed analysis on companies, especially on SMEs. So, it is hard to get respond to requests from the industry side. It is not so hard to see that there is a huge difference between what is in the literature and what is applied in companies' current practices. Another limitation lies in the companies' responds to the questionnaire. For many of the questions, intentional or unintentional bias would occur in the answers as some companies would be willing to see/show themselves more sustainable than what they really are. A potential weakness of the study is the impossibility to use a number of tools and techniques to compare the data obtained by our on-line survey. For example, because of the nature of the data (mostly qualitative) it is difficult to use a correlation analysis or other BI analysis techniques.

From this research, we realize that this topic is still at its earliest stage and the extensions of this research filed are unlimited. Here we recommend the following topics by worthy of further study:

- Further researches should be done taking more cases and samples to better understand the maturity level of integrating sustainability in new product design and development.
- A modified or new method of integrating sustainability criterions into the product development processes that fill the existing gap would be developed for a better application in the industry.
- Sustainable product design in a SBCE (Set Based Concurrent Engineering) environment would be studied.

Acknowledgement

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