Improving Environmental Performance of Products by Integrating Ecodesign Methods and Tools into a Reference Model for New Product Development

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Abstract. New product development (NPD) is a critical process to improve a company's competitiveness. As environmental impacts generated throughout the product lifecycle are significantly determined during the early phase of its development, NPD plays a crucial role in enhancing the environmental performance of new products. Ecodesign may be defined as the systematic introduction of environmental concerns during product development. Despite the fact that several opportunities for competitive advantage have been associated to ecodesign the implementation of this concept has not reached companies worldwide mainly due to the gap between eco-oriented and product-oriented research. Thus both points of view must come together in order to achieve ecodesign benefits. This paper aims at proposing a systematic approach to do it by introducing some selected ecodesign methods and tools into the early phases of a reference model for NPD. The expected result is a set of structured activities that can successfully combine ecological and business perspectives. This paper presents some preliminary results on the field of sustainable product development (SPD) conducted by the authors.

Keywords. New product development, reference model, ecodesign.

1 Introduction

The increasing consumption of products is at the origin of most pollution and depletion of resources caused by our society [10]. Environmental impacts observed throughout a product lifecycle are, to a large extent, determined during its development phase [9]. Hence, taking environmental aspects into consideration during the new product development (NPD) phase can play an essential role in the reduction of environmental impacts related to product lifecycle. Ecodesign can be

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defined as the systematic introduction of environmental concerns into NPD through the application of specific methods and tools. Despite the fact that the number of available methods and tools has increased in the last decade, ecodesign has not been implemented by companies worldwide mainly due to the gap between eco-oriented and product-oriented researchers [2, 12]. Eco-oriented researchers fail to see NPD as a business process crucial to competitiveness, which leads to partial or poor integration of ecodesign methods and tools into NPD, failing to generate the expected ecodesign competitive advantages [1, 11]. On the other hand, product-oriented researchers pay too little attention to environmental aspects, focusing on legal compliance and 'end-of-pipe' solutions due to little knowledge of ecodesign methods. This gap generates a lack of systematic use of ecodesign methods and tools in NPD, contributing to low levels of environmental performance. The goal of this paper is to propose a systematic approach to bridge the aforementioned gap, through the introduction of ecodesign methods and tools into the early phases of a reference model for NPD, as a way to structure activities in a business process. The ecodesign methods to be integrated have been selected through literature review using a structured classification method. The reference model, used as the integration baseline, resulted from experiences accumulated since 1990. The expected result is a set of structured NPD-oriented activities that can successfully combine environmental and business perspectives to help companies worldwide to achieve sustainability by making new and "green" products that are also successful in the market. This paper presents some preliminary results conducted by the authors.

2 Literature Review

2.1 New Product Development and Ecodesign

According to [21] new product development (NPD) is "The overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialization of a new product". It is also frequently referred to as just "product development." Clark and Fujimoto [7] state that "Product development process is the resulting process when market information is transformed into information and necessary sources to manufacture a product with the aim of commercializing it." For Pugh [23], "Product development process is the necessary systematic activity from the identification of the market/customer needs until the product sale, an activity that includes product, processes, people and organization". It is not a new notion that product development has become one of the key processes for competitiveness in manufacturing. One of the well-known factors of product development is that the degree of uncertainty in the beginning of the process is very high, decreasing over time. The decisions in the beginning of the development cycle are responsible for 70% of the cost of the final product [3]. As regards environmental impacts related to products, if environmental requirements are taken into account at the beginning of the development phase environment impacts may be reduced by an estimated 70% [9]. Hence, taking

environmental aspects into consideration during the new product development (NPD) phase plays an essential role in reducing environmental impacts related to the product lifecycle.

Ecodesign (Europe) or Design for Environment (US) implies a new way of developing products where environmental aspects are given the same status as functionality, durability, costs, time-to-market, aesthetics, ergonomics and quality. Ecodesign aims at improving the product's environmental performance and may be seen as a way of developing products in accordance with the sustainable development concept [4,6,13,16,28].

Baumann et al [1] identify more than 150 existing ecodesign methods and tools to implement what they call Environmental Product Development (EPD). In the ecodesign research field the terms "tool" and "methods" are often interchangeable. In this paper we selected four methods/tools: Life Cycle Assessment (LCA), Quality Function Deployment for Environment (QFDE), The Ten Golden Rules and Environment Effect Analysis (EEA). Those methods and tools were selected because there is more available information about them, addressing definitions and usage, as compared to other methods. LCA assesses environmental aspects and potential impacts associated with a product by compiling, evaluating and interpreting an inventory of relevant inputs and outputs. In reality, LCA constitutes a class of methods, since there is no single method for conducting LCAs [8,17]. QFDE analyzes functions required for a product or its structure to promote these functions, helping design engineers to select the best plan among design improvement alternatives while concurrently meeting consumers' needs [21, 26]. The Ten Golden Rules are a summary of guidelines gathered from the company's guidelines and in different handbooks [5,19]. EEA systematically identifies and evaluates potential environmental impacts in all product lifecycle phases, by assessing each activity in the product lifecycle. EEA should be carried out together with Design-FMEAs [18]. Table 1 shows the systematization of methods/tools according to input and output data.

Table 1. Methods/tools input and output data

Methods/Tools	Input Data		Output Data	
	Description	**Nature**	**Description**	**Nature**
Life Cycle Assessment (LCA)	Used materials and energy Lifecycle inventory Product characterization	Qualitative and Quantitative	Analysis of contribution of lifecycle stages Exposure of up- and downstream impacts Ideas to reduce environmental impact	Qualitative and Quantitative
QFDE	Customers' voice Engineering metrics Product requirements Energy	Semi-Quantitative	Important attributes and function units Possibility of design improvements	Semi-Quantitative

	Chemicals used Energy Use Solid Residues Liquid Residues Gaseous Residues			
The Ten Golden Rules	Product concept	Qualitative	Product evaluation	Qualitative
Environment Effect Analysis (EEA)	Earlier LCA Environmental function requirements Legal and other external requirements QFD for customers demand Internal objectives and targets	Qualitative	Identification of the LCA focus of specific areas Verification of legal compliances EEA on detailed design Design requirements	Qualitative

However, in order to ensure concrete results with the selected methods and tools, it is necessary—as a preliminary measure—to introduce the topic of sustainability into the company's business core. Porter [22] indicates that the environmental aspects should be integrated with the company's strategic and operational activities, should be specific to each company and be seen as source of opportunity, innovation and competitive advantage. To put in practice this win-win principle, companies have to identify the intersection aspects between environmental impacts of the product lifecycle and stakeholders' demands; to define the environmental aspects to be dealt with and to incorporate the environmental dimension and goals into the company's strategy. In agreement with IISD [14] the following seven steps are required to manage enterprises according to sustainable development principles: (1) Perform a stakeholder analysis; (2) Set sustainable development policies and objectives; (3) Design and carry out an implementation plan; (4) Develop a supportive corporate culture; (5) Develop measures and standards of performance; (6) Prepare reports; and (7) Enhance internal monitoring processes. This may be a prerequisite task to all NPD-related activities. Baumann's organizational tools are also suitable for this propose [1].

3 Integrating ecodesign methods and tools into a reference model for NPD

When systematizing a NPD for a company, a pattern should be established to define projects for the development of products, thus contributing to the standardization of some practices, use of a common language, repeatability among

projects and quality. The NPD process used as a reference to define the scope of product development projects is normally represented by a reference model, also known as standard process [25]. The reference model presented in this work was created through a joint project of three research institutions based on a community of practice [24] on the Internet, created to promote knowledge sharing about product development among universities and companies. Standard processes have been derived from this model for some companies, which helped the researchers to improve it [25]. A general view of the reference model, divided into macro-phases, is presented in Figure 1.

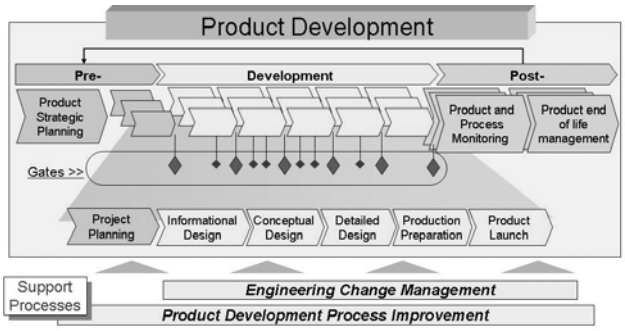

Figure 1. The reference model for product development [25]

The product strategic planning phase includes product portfolio management in accordance with the business strategic plan, taking into consideration market and technological innovations. This phase deals with the whole product portfolio whereas the following phases are related to a specific product, i.e., a sole project. During the project planning phase, the project scope, resources, people in charge, effort, duration and costs are defined. PMBOK best practices are considered during this phase. If the project plan is approved by means of a formal gate process [27], the project begins and will come to an end at the product launch phase. The product lifecycle, the stakeholders and their requirements are determined at the informational design phase. The product requirements, which must be quantified in measurable variables with target values, derive from the stakeholders' requirements. This is not the first time the requirements have been defined, since their definition begins in product strategic planning, when marketing supplies information about the market, which is now detailed in the informational design for a specific product. The product functions (physical, quality, interface, etc.) are established in the conceptual design phase so as to meet the product requirements. Technological solutions and product architecture are also determined at this point. Creativity methods may be applied in this phase. Innovations may emerge based on new technologies developed by the R&D process (complemented by NPD). Nevertheless, not all of the projects go through the conceptual design phase, as product architecture does not usually change into derivative projects. The next phase is the detailed design, which consists of three integrated cycles: detailing, acquiring and improving cycles. Calculations, simulations, product modeling, drafting, bill of materials, process plans, failure analyses, prototypes, evaluations

and tests are carried out in this phase. All the manufacturing resources are specified—even a new factory when necessary. Product handbooks and instructions for technical assistance are also produced, as well as sales support information systems. The supply chain is defined at the beginning of the product development process, when arrangements are made with main strategic partners and co-developers. The last supplier contracts must be signed at the detailed design phase. Based on prototypes, the product is then certified. In the next phase—production preparation— additional equipment defined as necessary in the previous phase is installed and tested. A pilot production process is run to certify the production facilities and products being manufactured with the definitive resources, since during the detailed phase prototypes might, for instance, be built with non mass production equipment. In this phase, a new production business process (or even the whole supply chain process, including logistics) can be mapped out and established in order to define, for instance, whether production should be controlled by means of orders or Kanban. The product launch phase takes place in parallel to production preparation. Other business processes are mapped out in this phase, such as technical assistance and customer service, when, for instance, a new help desk script for the new product must be created. In short, production preparation aims at defining the supply chain from an internal standpoint and the product launch phase from an external standpoint (market and customers). After the product is launched, production and sales business processes become the responsibility of other areas of the company. Then the project phase (development macro-phase—see the Figure 1) is concluded, the team is disbanded, and its members are assigned to other projects or return to their original functional areas. Nevertheless, product life cycle management continues, since efforts must now focus on monitoring the product and its manufacturing process. Ongoing customer support and engineering change management (ECM) must be provided to eliminate failures or improve product performance. At this time, configuration management ensures product information integrity throughout the product lifecycle. ECM manages product changes, whereas other supporting processes carry out improvements in NPD. At the end of its lifecycle, the product is discontinued and could be reused, remanufactured, recycled, disposed of according to the end-of-life (EOL) plan, which is usually developed during the development macro-phase.

This brief description of the process provides only a functional overview of NPD, since only chief activities have been mentioned. Other complementary views have not been addressed here.

The proposed integration focuses on the Strategic Product Planning, Informational Design, Conceptual Design and Detailed Design phases. This is due to the fact that the entire product life cycle environmental impacts are, to a large extend determined during these phases. Table 2 shows the tools/methods selected by the NPD reference model phases in which their use is suggested.

Table 2. Integration of ecodesign methods and tools into NPD reference model

Phases	Methods/Tools
Strategic Product Planning	Porter's guidelines, the seven steps for managing an enterprise according to sustainable development principles

	and Baumann's organizing tools
Informational Design	The Ten Golden Rules, QFDE (Phase I), LCA
Conceptual Design	QFDE (Phase II and III), EEA, LCA
Detailed Design	QFDE (Phase IV), LCA

Each phase of the model presented in this paper comprises several activities. Thus, one has should explore the influences of the suggested ecodesign methods and tools on these activities in order to make ecodesign come about. This can be done by developing templates in which the usage of one method or tool is described. The process of selecting ecodesign methods and tools and deciding at which NPD phase they should be used has to be carried out by the design team members, who in turn should take into account the dynamics of their activities and their ecodesign maturity level. This selection may be assisted by a specialist.

The use of selected methods and tool depends mainly on the stage of the product development process, i.e., how detailed the available information is. Time and cost may be reduced and a more environment-friendly product may be produced if ecodesign methods and tools are used early in the design process. Since ecodesign factors of success are, to a large extend, similar to NPD factors of success [15], the task of integrating the ecodesign concept as a whole will be easier to those companies that have high NPD maturity levels.

4 Conclusion

NPD plays an important role in reducing the environment impacts of a product lifecycle. The use of a reference model for NPD may contribute to the standardization of some practices, the use of a common language, the repeatability of projects and to its quality, thus increasing the probability of making successful products by means of structuring this business process. Despite the existence of many ecodesign methods and tools, a systematic way to use them in NPD is lacking. Introducing ecodesign methods and tools into designers' daily activities through a reference model for NPD may bridge this gap. The task of selecting ecodesign methods and tools and deciding at which NPD phase they should be used is something companies have to perform internally. However, in order to ensure concrete results with the implementation of ecodesign methods and tools, it is also necessary to introduce the topic of sustainability into the company's business core as a preliminary measure. The proposed integration is a set of NPD-oriented structured activities that can successfully combine environmental and business perspectives.

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