Green Design Framework for New Product Development

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***Abstract*—This research paper reports Green Design Framework for incorporating green concepts into new product development. It starts at define section and ends at management review section. Developing a process in Green Engineering is very important. Poor process would results in ineffectiveness for contributing green design into the society. The result of this paper is any organization can implement this framework without affecting their regular process.**

***Index Terms*—Engineering design, Green Design Framework, Recycling, Eco-QFD, New Product Design**

I. Introduction

Environmental issues are becoming increasingly important to product designers and manufacturers. Public awareness of the value and fragility of an intact ecology constantly increases and the traditional assumption that the cost of ecological burdens is to be shared by the society as a whole is no longer acceptable.

This trend is most apparent when considering the environmental impacts of worn-out products. The shortage of landfill and waste burning facilities constantly reminds us that our products do not simply disappear after disposal. It is currently widely acknowledged that the most ecologically sound way to treat a worn out product is recycling. Since it is rarely possible or beneficial to recycle a product completely, the aim is to maximize the recycled resources while minimzizing the effort that has to be invested [1].

When the environment and potentials hazard are discussed, global warming might be the most pressing issue currently, but there are many more aspects, e.g., the depletion of raw materials and amount of water consumption. Water consumption is not a major problem in many European locations, but is a key issue in many regions where electronics component manufacturing is located. Water pollution through toxic constituents and eutrophication makes the problem.

Exhaust emissions causing photochemical smog, acid rain and transmission of toxic substances is also issues in some regions. Further aspects include noise, odor, and radiation.

All these impacts occur during a product's life cycle, maybe even several times. A company might only be involved in a specific single step within the general product's life cycle of raw materials acquisition, component production, product assembly, distribution and retail, product use, (optional) refurbishment and reuse, and final disposal (or materials recycling) at the end-of-life. However, the relationship between upstream suppliers and downstream customers, consumers, and potential recyclers means that individual companies have an (indirect) influence on and a responsibility for the environmental impacts throughout the entire life cycle [2].

The objective of this research work is introducing environmental aspects into engineering design stage itself by using Green Design Framework. It is an approach, in which planning, conception, detail design, research / prototype, production and introduction on the market in order to observe all relevant environmental aspects.

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II. Review of Related Works

A number of research works are already available at different organizations / institutions in various countries with regard to the development of Green Engineering. This research work offer different approach with framework which includes all the phases of engineering design.

A. Green Design

Green design is intended to develop more environmentally products and processes. The application of green design involves a particular framework for considering environmental issues, the application of relevant analysis and synthesis methods and a challenge to traditional procedures for design and manufacturing [3].

Product design is a process of synthesis in which product attributes such as cost, performance, manufacturability, safety, and consumer appeal are considered together. In general, products today are designed without regard for their overall impact on the environment. Nevertheless, many health and environmental laws passed by Congress do influence the environmental attributes of products. Some, such as the Clean Air Act, Clean Water Act and Resource Conservation and Recovery Act, do so indirectly, by raising industry's costs of releasing wastes to the air, water, and land. Others, such as the Toxic Substances Control Act and the Federal Insecticide, Fungicide, and Rodenticide Act, control the use of hazardous chemicals and pesticides directly [4].

Product Design is one of the most important non-price factors which determine the success of a product. The role of product design changes throughout the life-cycle of a product. In the initial product development stage, the role of design is to create a marketable product from an innovation. The product may create a need where none existed before, (for example when the Sony Walkman was introduced) or quite different products may be competing with others in the same market (for example trams, cars and buses compete for urban transport). As the product life cycle matures, more

competitors enter the market and the chief role of design is in product differentiation; through quality, appearance, performance, ease of use, reliability, reparability and so on [5].

B. Recycling Initiatives

Recycling initiatives is gaining momentum. It is becoming increasingly clear that it makes both economic and ecological sense to integrate end-of-life aspects into the design of products. Engineers are in a position to impact the recyclability of products because they directly control many of the key attributes (Material types, density, fastening**,** architecture)

They have been incorporating recyclable materials in many new product designs for years. More recently a connection has been made between designing for disassembly and designing for recyclability. In both cases, the goal is to ensure that products are designed in a way that is as attractive as possible to recyclers. Making products quick and easy to disassemble helps [6].

C. System Thinking

A central concept in green design is the notion that the systems effects of design decisions should be considered. In designing a new product, the environmental burdens associated with material supply, manufacture, use and disposal may all be relevant [3].

D. Business Responses to Environmental Problems

Until quite recently the usual technical response of business to environmental problems involved measures to reduce pollution and wastes after they have been produced; For example, by installing factory waste water treatment plant or equipping cars with catalytic converters. However, from the late 1980s onwards some companies began to shift their attention from these so called ‘end of pipe’ or ‘cleanup’ approaches up the production chain in an attempt to reduce or prevent environmental impacts at source. Initially the focus was mainly on developing ‘cleaner’ manufacturing processes, which generate less pollution and waste or make more efficient use of energy and materials. Then, with the growing understanding that many environmental impacts arise from the choice of materials in and the use and disposal, of a product attention began to turn to the design of greener products [7].

E. Engineering Design

Most engineering designs can be classified as inventions-devices or systems that are created by human effort and did not exist before or are improvements over existing devices or systems. Inventions, or designs, do not suddenly appear from nowhere. They are the result of bringing together technologies to meet human needs or to solve problems. Sometimes a design is the result of someone trying to do a task more quickly or efficiently. Design activity occurs over a period of time and requires a step-by-step methodology. Design problems are open ended in nature, which means they have more than one correct solution. The result or solution to a design problem is a system that possesses specified properties [8].

The five steps used for solving design problems are:

1) Define the problem
2) Gather pertinent information
3) Generate multiple solutions
4) Analyze and select a solution
5) Test and implement the solution

F. Ecological Factors during Engineering Design

On every stage of work we should take varied factors into consideration: functional, marketing, sociological, economic, qualitative, ecological, etc. Larger requirements about the environment protection caused that on the stage of designing the special attention is put on the environmental aspects. This initial phase of life cycle of product plays the decisive part in quality assurance of its functioning in the next stages of usage (production, exploitation and liquidation) with reference to relation with the environment, also. Knowing problems relating to designing it is easier understand ecodesign concept. It was created in the aim of emphasis of environmental and economic problems in the present designing.

The ecological design depends on implementation of ecological aspects in the area of traditional products designing in the aim of improvement of their environmental aspects, without principal change of the product conception.

Despite of individual features of every organization, designing processes are similarly realized. Each of them begins from the qualification of needs and the product functions. Next, one defines requirements, conception of design, detailed design and on the end productive assumptions. On every stage of design, designer analyses alternative solutions. Implementation of ecodesign principles requires of good organization and connection requirements relating to the environment protection with designing process. It requires of suitable tools usage which are the source of actual information from the range of the environment protection, also [9].

III. Working Framework

A. Planning

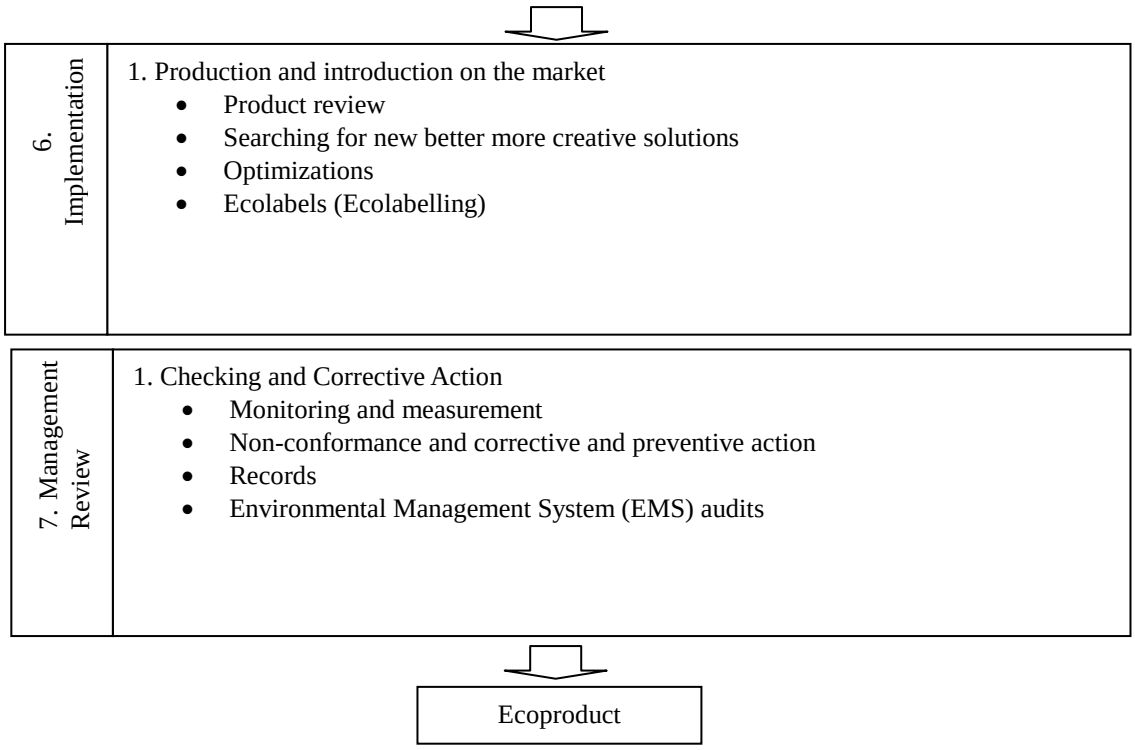
The planning phase should be started from the exact analysis of market which gives necessary information to decisions making connected with the product. The subject of research is: competitive products existing on the market demand on new products, absorptivity of the market, expectations and customer requirements. In the aim of got these information different analysis and investigations methods are used. Eco-QFD is used to understand which customer and ecosystem requirements are very important. The Eco-QFD is a useful tool to integrate not only the environmental concerns but also quality, cost, and customer needs to improve the product design process. It is essentially important to satisfy customer needs from a wide variety of considerations if the Eco-product is to be successful in the market place. Finally, various technical attributes and environmental concerns can be prioritized such that the product development team can concentrate their limited resources on critical issues to develop customer-oriented environmentally friendly products [10].

Customer

1. Define/Planning	1. Market information about product demand • Analysis of competitive products existing on the market • Customer requirements • Enterprise requirements- financial resources • Environmental and legal requirements • Standards, laws • Ecological criteria in the total life cycle of product • Market analysis ✓ Public opinions ✓ Analysis methods 2. Creation of designing team • Division of tasks and qualifications • Communication among team members • Knowledge management – financial resources • Including team of experts from the field of environmental management

3. Generate multiple solutions	1. Openness to new experiences • Healthy and positive attitude toward new experiences 2. Willingness to take risks • Not afraid to take risks and try new experiences or ideas 3. Ability to observe details and see the "whole picture" • Notice and observe details relating to the problem • But step back and see the bigger picture 4. No fear of problems • Not afraid to tackle complex problems, and even search for problems to solve • Seek solutions to problems with their own abilities and experience if possible. 5. Ability to concentrate and focus on the problem until it's solved • Set goals and stick to them until reached • Focus on a problem and do not give up until the problem is solved.

4. Analyze	1. Concept design • Brief foredesign • Analysis of available solutions • Analysis of available methods and tools • Analysis of results • Choice of improvement strategy • Analytic tools of LCA • Minimization of using materials and resources quantity • Energy saving 2. General design • Specification of available materials and technological process • Economic analysis • Proper quality assurance of the product 3. Detailed design • Design in detail • Restricting of possibilities (materials, technological process) • Optimization • Elimination of harmful and dangerous materials • Minimization of resources and material usage • Renewable resources usage • Waste reduction • Usage of materials from recycling • Usage of materials about low influence on the environment



Few of Voice of Customers (VOC) is defined below.

1) Safe emission
2) Less material usage
3) Renewable/reusable
4) Energy efficient
5) Resource efficient
6) Harmless to living environment
7) Safe disposal
8) More recyclable material usage
9) Easy to dissemble

Few of Engineering Metrics (EM) is defined below

1) Energy cost
2) Rate of recyclable material
3) Rate of standard components
4) Toxicity of materials

The designing team creation is the next stage. The person responsible for design should takes care of the commitment of suitable persons – it is the design manager. The design team should consists of: engineers, constructors, experts from the field of materials selection and production processes and experts from the field of the environment protection (especially experts from recycling methods) and the environmental management, too. The employment of experts from so many fields is necessary because of the interdisciplinary character of the work. It gives great possibilities and makes possible many mistakes avoid [2].

B. Conceptual Design

The aim of conceptual design creating is elaboration of conception connected with general specification of materials.

The designers should consider in it product requirements which were already analyzed in the planning phase. All created conceptions have to take into consideration the environmental aspects on this stage. Formulation of general brief foredesign make the designers do analyzing of all available technological solutions and materials data [9].

C. General Design

The aim of the stage of general design creation is extension of the conception. From general considerations, ideas during design works product form are presented. The constructors have to create draft documentation, determine parameters, dimensions. The designers should make specification of available materials and technological processes, from which the product can be produced (taking into consideration ecological aspects, recycling possibility, recycling technologies). They have serious task to carry out. The subject of their considerations should be these materials and technologies, which are safe and the environment friendly only. The influence of products on the environment is subject to changes in individual periods of life cycle that is why analysis carrying out in the next stages is necessary.

The necessary element of the engineering design of product is proper quality assurance. The quality has the greatest meaning in this phase of product formation, because the best technological process carried out will not assured of high quality, if it is not considered in the design [9].

D. Detailed Design

On this stage of designing the designers should limit possibilities of materials and technological processes usage to one, alternatively several. They should use databases make their precise specification. The designers should answer on the following questions:

1) Is it possible to usage of renewable materials?
2) Which from applied conventional materials could be substituted by renewable equivalents?
3) Are proposed materials usages in recycling?
4) How many various kinds of materials could be used in the product?
5) What is the cause of such diversification? Is possible simplification of design (construction) to

reduce quantity of kinds of materials?

These questions have to inform that the designers should usage materials from recycling and materials about the smallest influence on the environment first of all [9].

E. Verification of Design and Prototype Examination

After the end of designing stage the designers should make the product verification. The penetrating analysis of technical documentation makes possible finding potential mistakes and shortcomings, especially if it's carried out a person who did not participate in the design. The lack of commitment in the design makes possible the objective opinion. The compatibility of input and output data should be examined. The design should fulfill all requirements (in this ecological first of all), both these defined by customer, and defined by law. When the design is positively verified the designers make a prototype of product. Next, the investigations are carried out until its destruction. During these investigations verified: does the product fulfill constructional, qualitative requirements, does it fulfill assumed functions, etc [9].

F. Production and Introduction on the Market

This stage includes product production, its introduction on the market, and all actions connected with promotion, advertising and marketing also. The main aim of this phase is acquaintance of potential purchasers with information concerning of the product and advantages resulting from its purchase. In this phase of design the designers should prognosis of exploitation costs carried out, that is all liabilities connected with the product functioning, certainly this costs should be the smallest. The good and effective way of product promotion is ecological labeling, also called ecolabelling. After certification on the product are placed ecological sign which testifies that manufacturer adapted product or processes applied during its production to requirements connected with the environment protection [9].

IV. Expected Outcomes of the Framework

The proposed framework reduces the amount of waste through remanufacturing, reuse, and recycling. It also reduces the environmental impact of its products by placing environmental considerations at the forefront of all products and manufacturing decisions. It minimizes the impact of raw materials used in its products and reduces energy requirements.

V. Business Opportunities for Sustainable Design

Beyond managing risk or pressures from external parties, sustainable design offers a variety of opportunities to prosper. Companies can gain access to markets, increase market share, reduce or avoid compliance costs, and more easily attract investor capital. There are also positive ripple effects related to product performance, cleaner production, customer satisfaction and brand loyalty, employee morale, and community relations. These opportunities provide the business case for sustainable product design the way to strengthen a company's position and produce benefits for the bottom line [11].

VI. Conclusions

Due to the continuing disturbance to our environment, industry is expected to make greater contributions to solving the ecological problems created by their products. *In this research paper, we represented/proposed a framework which allows industry to take responsibility for the whole life cycle of a product starting at the DEFINE stage itself.* The decision making about designing of the environment friendly product is not a problem, it is important to realize the design in due time, with predetermined budget, and this requires the perfect organization of designing process. In this moment very useful framework can be carried out. It systematizes workings performed during designing process and shows the meaning of the ecological aspect in this process.

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