Eco-Design의 표준화

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Eco-Design Standardization

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ABSTRACT

Design for Environment (DfE) is a design activity that integrates environmental aspects of a product in its entire life cycle into the product development process. It leads to a product optimized with respect to environmental performance, while satisfying inherent attributes of a product including performance, functionality, cost and safety. Possible DfE approaches in product design and development would include: improved materials and energy efficiency, designed for cleaner production, extended life, reuse and recycling, waste minimization, and minimized hazards to human health and ecosystem.

ISO/TC207/WG3 is responsible for the development of a technical report (TR) on DfE. This TR is intended for use by those who are involved in the design and development of products. A special emphasis will be given to the DfE needs of small and medium enterprises in the development of the TR.

Keywords: Life cycle Assessment, DfE

요 약 문

21세기가 환경의 세기인 만큼, 소비자들의 환경에 대한 인식이 높아지면서 기업에서는 기존의 제품 개발 프로세스에 환경적인 측면을 고려하는 친 환경 설계를 지향하고 있다. 이는 세계적인 추세로서 ISO/TC207/WG3(DfE: Design for Environment)에서 친환경설계의 표준화 작업이 진행중이다. 환경친화적 제품이란 상대적인 개념으로서 다른 조건이 동일한 상태에서 기존의 제품보다 환경성이 개선된 제품을 말한다. 제품 개발 프로세스는 제품 스펙 도출 단계(Product Specification), 개념 설계 (Conceptual design) 단계, 상세 설계(Detailed design)단계, 시험 및 원형제작(Testing/ Prototype) 단계, 시장 출하(Market launch)단계, 및 검토(Review) 단계로 나뉜다. 각 단계마다 제품 전과정(Life Cycle)에서 유입물 및 배출물의 환경적 측면을 고려하여 설계하게 된다. LCA및 QfD와 같은 분석 도구는 제품 스펙 도출 단계에서 사용될 수 있으며, 분해를 고려한 설계(DfD)방법 및 재활용을 고려한 설계(DfR)방법 등이 시험단계에서 사용될 수 있다.

I. Introduction

Environmental problems we have faced today have expanded from local and regional ones to global ones. Resource consumption as well as environmental emissions originating from the industrial activities poses serious threat to human health and to the stability of ecosystem.

It is a well-known fact that the global environmental carrying capacity has its limit. Natural resources including mineral ores and fossil fuels, agricultural productivity, and self-purification capacity of the natural environ-

ment have their own limits. Irrational resource consumption together with irresponsible environmental pollution resulting from the entire product life cycle raw material acquisition, manufacturing, use and disposal are the main cause of exceeding the global environmental carrying capacity. This is because our industrial structure and consumption pattern are not environmentally friendly. Thus, there is a growing concern that sustainable society may not be achievable.

Industry or Individual Corporation is the single most important source of all these environmental problems. This is because human society depends heavily on industrial products to sustain its living standard. Corporations consume resources and emit environmental emissions because of the products they manufacture. These are, however, not significant quantities compared to what a product generates during its entire life cycle. In general, environmental loads throughout the entire life cycle of a product are much greater than that from the manufacturing stage alone. Typical example would include durable goods such as home appliances and automobiles where environmental loads from the use and disposal stages are much greater than that from the manufacturing stage. For goods like paper towel and aluminum foil, environmental loads from the manufacturing stage are relatively high; however, the total loads are still greater than those from the manufacturing stage. From the discussion, it can be concluded that environmental loads occurring throughout a product life cycle is the main cause of today's environmental problem.

Traditionally environmental laws and regulations have aimed at commanding and controlling the environmental loads occurring during the manufacturing stage of a product. In other

words the command and control were centered on the end-of-pipe. Sincere efforts have been exerted in implementing the command and control practices in most of the developed nations. However, the global environment problems have not been mitigated: rather, they tend to be aggravated.

Since 1990, environmental policy makers in the Netherlands and Germany recognized that packaging wastes may be reduced in quantity by imposing financial burden to the producer, not to the consumer. This is the basis of a concept of the extended producer responsibility (EPR)(OECD 1996). It was a norm that manufacturers were responsible for the product only during its manufacturing stage (e.g. product function, production cost and environmental pollution control, etc). They were not responsible for the environmental problems caused by the waste product discarded after use. Collection, treatment and disposal of the waste products were the responsibility of the government and local authorities. However, under the EPR, costs associated with the waste product's collection, treatment and disposal should be borne by the manufacturer. Typical regulations based on the EPR concept included the packaging waste order in Germany, the packaging covenant in the Netherlands, and voluntary agreement on the cost bearing of the waste automobile treatment among German automakers.

According to the EPR policy, a corporation manufacturing a product is responsible for the costs associated with the waste product's treatment and disposal. To reduce these costs, the corporation will try to design a product easy to disassemble and easy to reuse its components. The cost will further be reduced if the material for the components is recyclable.

To this end, the corporation will incorporate a new product design concept that reduces the number of components and uses environmentally friendly materials, and will develop common components applicable to similar products. When recycling is not possible, the corporation will design a product that minimizes the quantity and toxicity of materials for incineration and/or landfilling. In short, a corporation will design a product that considers environmental attributes of the product throughout its entire life cycle. This design approach is called design for environment (DfE). DfE is thus a design practice that integrates environmental aspects into product development.

In late 1999, International Organization for Standardization (ISO)/ Technical Committee (TC) 207 created a working group (WG), WG3. This WG is responsible for producing a technical report on DfE. The official title of the technical report is "Guidelines to integrating environmental aspects into product development". In its second meeting at Stockholm WG3 produced its first working draft (WD).

There are two questions arising from the DfE practice: one is that what is the outcome of a DfE and the other is that how to identify environmental aspects of a product for the DfE. The outcome of a DfE is an environmentally friendly product and performing life cycle assessment (LCA) can identify the environmental aspects of a product for the DfE.

Ⅱ. Environmentally Friendly product

An environmentally friendly product is a product that integrates environmental aspects into product development. This implies that the product's environmental attributes have been improved compared to its previous model or competitor's model by integrating specific recommendations regarding the improvement of the environmental aspects into a product from the start of the design phase.

Strictly speaking, however, there is no product that is truly environmentally friendly. Any product, however small it may be, consumes resources and emits environmental pollutants. Environmental friendliness is a relative term. In order words, an environmentally friendly product is a product that causes less stress on the environment compared to the other products belonging to the same product category. Here a product category is defined as a group of products that performs the same or similar product function and possesses the same or similar product characteristics. (ISO 14024 1999)

The manufacturer often communicates environmental attributes of a product to a market. This is called environmental labels and declaration of a product. Manufacturer hopes to increase the market share of his product by communicating product's environmental attributes to the market. If consumers feel strongly about the need for environmental preservation, the market shares of the environmentally friendly products may increase.

Manufacturing of an environmentally friendly product also reduces costs associated with the product. Consumption of lesser amount of energy and resources for the manufacturing of a product results not only in reduction in materials and energy costs but also reduction in environmental emissions, which triggers reduction in environmental pollution control costs. Increased reuse and recycling of a waste product reduces waste disposal cost and often reduces material costs. Reduced energy and

resource consumption during the use phase of a product reduces operating cost. All these also result in savings in the amount of the raw material required and the raw material acquisition cost. These indicate that an environmentally friendly product not only reduces stress on the environment but also reduces cost throughout the entire life cycle of a product.

However, caution must be exercised that a product must meet the basic requirements of a market. The requirements include(ISO/TC 207 AHG DfE N7 1999); i) delivering the required functionality in terms of function, performance, durability, safety, etc, ii) complying with all standards and regulations, and iii) corresponding to the targeted market segments such as identifying current and emerging customer expectation (e.g. Overall cost). If a product does not meet these requirements, although it causes less stress on the environment, the product will be expelled from the market. Thus, an environmentally friendly product may be defined as a product that meets all the requirements of a market and causes less stress on the environment.

Ⅲ. Identification of Environmental Aspects of a Product

LCA is a systematic analytical tool that evaluates the environmental impact associated with a product system. An LCA can be used to compare present product system with the alternatives, or improve product design by recognizing and reducing current environmental impact caused by a product system. Therefore, the identification of major contributors to the environmental impact category within a product

system is a must for the improvement of the environmental aspects of a product. This procedure of identifying major contributors is defined as key issue identification. If key issues are identified, design engineers and strategic product policy makers can devise alternatives, which lead to the improvement of environmental aspects of a product system.

Key issue is defined as a unit process and inventory item of which potential impact to the environment is relatively significant within a given product system. Performing contribution analysis identifies Key issues. In contribution analysis any process and inventory item contributing more than a certain percentage of the total environmental impact of a product system is defined as a key issue. (Lee, K.M 1998)

Contribution analysis requires the generation of a characterization matrix for each impact category. The ratio of the impact of a process/activity to the total characterized impact in a given impact category is determined. This ratio is defined as the relative contribution of a process/activity, and is expressed as in equation (1).

$$\% \, relative \, contribution = \frac{CI_{i,j,k}}{CI_i} \times 100 \quad (1)$$

Where,

CI = characterized impact, g-eqv/f.u.,

$i = i^{th}$ impact category,

$j = j^{th}$ inventory item,

$k = k^{th}$ activity,

$CI_{i,j,k}$ = Load$_{j,k}$ eqv$_{i,j}$,

$Load$ = load of an inventory item, g/f.u.,

$f.u.$ = functional unit,

eqv = equivalency factor, g-eqv/g,

$$CI_i = \sum_j CI_{i,j} = \sum_j Load_j \cdot eqv_{i,j}$$

$$Load_j = \sum_k Load_{j,k}.$$

If it is assumed that X % is the cut-off criteria in the contribution analysis, processes contributing more than X % of the total characterized impact in a given impact category are identified as key issues in that impact category. As a result, the relative importance of an activity (and inventory) item for each impact category is identified.

IV. Integration of Environmental Aspects into Product Development

A typical product development involves several development stages as shown in Fig. 1. The product development may be divided into three stages, i.e., the product strategy/planning stage, the design stage and the test stage. Each stage consists of several activities.

The product strategy/planning stage involves quality function deployment (QFD). QFD analyzes consumer requirements, characteristics and functions of the competitor's products, among others. Activities such as product system requirement analysis and feasibility analysis are dealt in the QFD analysis. Then system requirement review (SRR) is performed and the product development plan is established.

The design stage involves product system's basic (architecture) design, preliminary design review (PDR), system design including hard-ware, software, and mechanics. Then critical design review (CDR) follows.

The test stage involves verification and validation of the product design. The hardware integration, the software integration, and the mechanics verification are performed, and manufacturing design review (MDR) follows.

Then the entire system test is carried out followed by system test results review (STR) and product test and evaluation. Completing the test stage, a mass production and sale of the product begins.

At each stage choices are made with respect to technical principles, materials, component production methods and assembly methods. At the same time the choices are made within the constraints of legal and regulatory requirements and economics. In other words factors including quality, costs and safety of a product are considered in the product development. In addition, the product development must consider the entire life cycle of a product. Thus the choices to be made for the product development must encompass all the requirements and constraints occurring in the entire life cycle of a product, not just manufacturing and/or use phase.

The goal of integrating environmental aspects into product development is to reduce stress on the environment occurring during the entire life cycle of a product. This goal can only be achieved by combining three basic strategies, e.g. optimization of the function or service rendered by a product, reduction of resources use for the product system, and minimization of environmental emissions from the product system. (AFNOR 1998) These strategies are in line with the common sense for the design of an environmentally friendly product, e.g., less is better, considering entire life cycle, and minimizing environmental impacts. (ISO/TC207 AHG DfE N7 1999)

The strategy for optimization of service provided by a product indicates that the product functions and product performances and other aspects, such as extended product life must be optimized while minimizing the potential
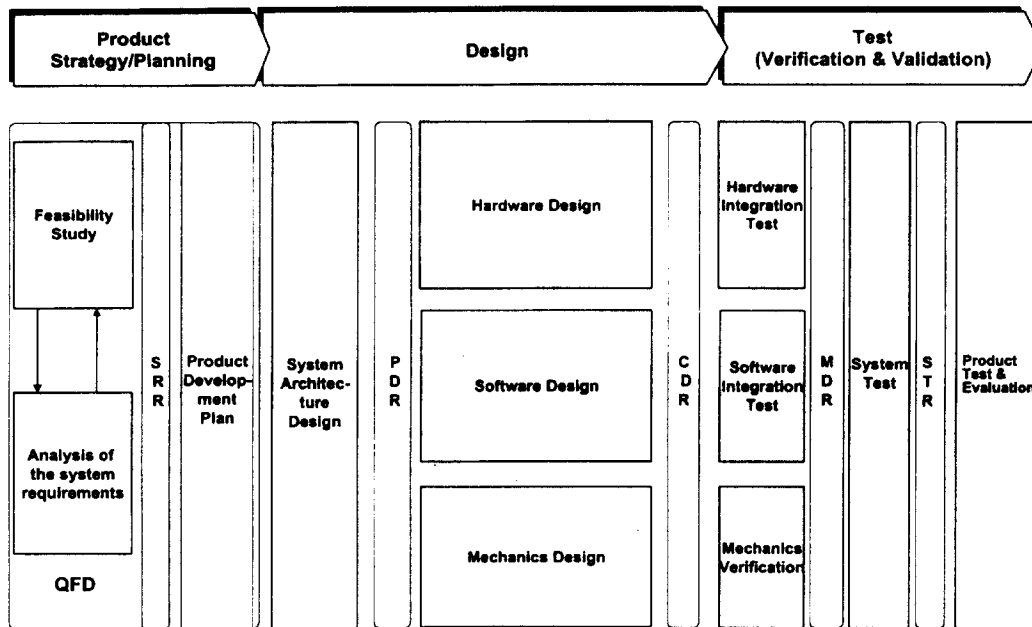
Fig. 1. Product Development stage and accompanying activities

environmental impacts caused by a product system. The strategy for reducing

resource use in a product system is to minimize the use of virgin as well as recycled resources as much as possible. This leads not only to the reduction of the potential environmental impacts but also to the reduction in materials and energy costs, and waste disposal costs. The strategy for preventing environmental emissions of a product system is to devise and implement measures to prevent pollution from the source, not to treat environmental emissions from the end-of-the-pipe.

It is obvious that the three strategies are not independent with each other. Rather, they are all interrelated. Thus, the three strategies shall be combined or integrated into one for the design of a product. Integrating environmental aspects into product development, therefore, is to integrate the three basic strategies into the typical product development stage. In other

words environmental aspects are now added into a list of a typical product development.

There are tools available for the identification of the environmental aspects of a product such as LCA. There also exist tools such as design for disassembly, design for recycling and reuse, etc. However, there is no comprehensive tools or even methods that integrate environmental aspects of a product into the product development stages as shown. Clearly this is the research area that deserves most attention.

V. DfE standardization by ISO/TC 207

Interest in DfE by ISO/TC207 surfaced in 1998. ISO/TC207 created an ad hoc group on DfE to investigate the needs and feasibility of DfE standardization in 1998. After one year of work the ad hoc group submitted a report to TC 207. The group had not come to a recommen-

dation for ISO/TC207 to start or not to start work on DfE standardization.

A new work item proposal to TC 207 was made by France and Korea to launch a work on DfE. The proposal had passed in December 1999, which led to the creation of WG3 under ISO/TC207. The first meeting was held in Paris in late January and the second in early June in Stockholm. The outcome of the second meeting was the first WD.

Highlight of the WD lies in chapter 5 entitled "Consideration of environmental aspects in product development process". This chapter describes key elements in integrating environmental aspects into product developments process including product specification, conceptual design, detailed design, testing/ prototype, market launch and review.

Fig. 2 is conducive to understanding the relationship between product development and environmental aspects of a product in its entire life cycle stages. Specific issues to be considered in each product development process described in the WD (ISO/TC207/WG3 WD1 2000) are summarized below.

1. Product Specification

This process encompasses project planning and formulating product specifications. Product development starts with analyzing the factors, internal as well as external, influencing the planned product. Tools for the analysis include LCA, QFD, and decision-making matrix, etc. This process is the same as the product strategy/plan development shown in Fig. 1.

Possible environmental approaches in overall design strategies include: improving materials and energy efficiency, design for cleaner production and use, design for disassembly, design for extended function, design for reuse and recycling, and using land sparingly.

2. Conceptual Design

A feasibility study is a starting point of this process and leads to precise engineering and procurement requirements. The defined design criteria and requirements as laid down in design specifications give clear hints to environmental goals for the product. The key task of the conceptual design stage is the iterative evaluation of the developed ideas against each other and in comparison with the existing solutions on the market. This process is the same as the design in Fig. 1.

The result of the conceptual design is one or more possible solutions that meet all requirements (including environmental) and is described precisely enough for the following detailed design stage. This will include a performance specification. Typical support tools will be checklists, manuals and guidelines.

3. Detailed Design

The solutions selected from the conceptual design are developed further to specify the product prior to production. This stage may be seen as an extension of the conceptual design stage. Developing the chosen design idea further may need detailed information and data related to: the product life cycle, risk related, material data, manufacturing, production, recycling technology, market, legal, costs, customer needs, and regulatory framework.

Relevant experts and actions could be involved including company internal actors (e.g. marketing, purchasing, manufacturing, environmental) and potential external partners (e.g. raw material suppliers, product components sup-

PRODUCT DEVELOPMENT PROCESS

Product specification

Conceptual design

Detailed design

Testing/prototype

Market launch

Review

PRODUCT LIFE CYCLE

INPUTS
- materials
-energy

Raw material acquisition

Transportation

Manufacturing

Transportation

Use/maintenance

Transportation

Re-use/recycling/disposal

OUTPUTS
- products
- air emissions
- water effluents
- waste materials
- other releases

Environmental Impacts
- resource depletion
- ozone depletion
- smog formation
- eutrophication
- climate change
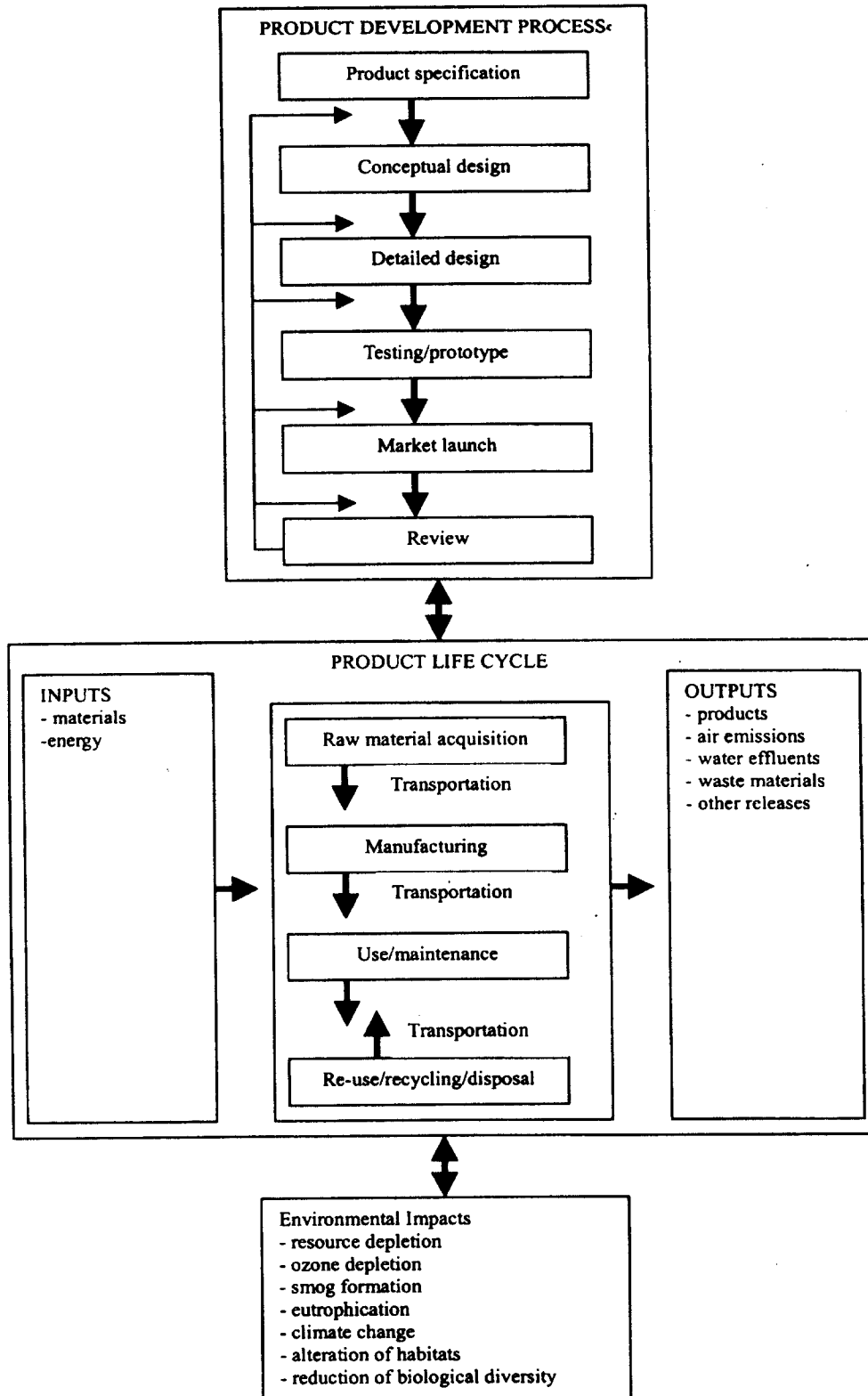- alteration of habitats
- reduction of biological diversity

Fig. 2. Conceptual relationship between product development and the environmental impacts associated with the product during its life cycle. (ISO/TC 207/WG3 2000)

pliers, consumers, recyclers,...) To exchange necessary information and to organize environmental supply chain management along the product's life cycle appropriate communication systems (e.g. type Ⅲ Environmental Declaration(ISO/TR 14025 1999)) are needed. This process is the same as the design in Fig. 1.

4. Testing/ Prototype

Prototype evaluation and testing are important milestones in the product development process, because testing and prototyping is the last opportunity to interact with manufacturing planning and detailed process engineering. Prior to and parallel to the prototype evaluation, testing occurs on multiple levels, including material properties, wear resistance, functionality, quality, lifetime, material, process and product. This process is the same as test in the Fig. 1.

During the testing and prototype stage, the environmental aspects of the product can be evaluated for the first time. The environmental performance of the product in use, weight, production scrap, material and energy efficiency, disassembly properties, recyclability, etc, can be assessed. In addition, testing and prototyping is often the first point in time, where major sub-assemblies, materials and production processes can be evaluated with respect to economic and environmental performance, against given criteria. The last point becomes important with the growing influence of services, parts and sub-assemblies purchased from suppliers. Improvement opportunities can be derived on multiple levels, e.g.: reconsiderations of detailed design, improvement of manufacturing processes, and reviewing the manufacturing sequence.

5. Market Launch

This involves the delivery of the product to the market place. Types of activities include presentation of environmental information to consumers (environmental claims), and information on the features and benefits of the product in a certain geographical area for market testing.

6. Review

Feedback and criticism from customers and other stakeholders are important for the integration of environmental aspects in future product development process. Therefore a review of the company's products on the market is helpful. It shows whether the planned environment related product qualities prove to be valid in practice.

VI. Summary and Conclusions

The human society has a legitimate goal to achieve: i.e., saving the earth by reducing stress on the environment and by reducing resource consumption. The sources of the stress on the environment and on the resource reserve are environmental loads associated with a product system.

An environmentally friendly product is a product that causes less stress on the environment compared to the other products belonging to the same product category. However, a product must meet the requirements of a market such as product function and performance, all regulations, and overall product costs. Therefore an environmentally friendly product may be defined as a product that meets all the requirements of a market and causes less

stress on the environment. The environmentally friendly product not only reduces stress on the environment but also reduces cost throughout the entire product life cycle.

An LCA is a systematic analytical tool that evaluates the environmental impact associated with a product system. The identification of major contributors to the environmental impact category, or key issues, within a product system is a prerequisite for the environmentally friendly product development. Performing LCA identifies the key issues. However, use of LCA requires database for materials and processes.

A typical product development process involves the product strategy development stage, the design stage and the test stage. Each stage includes several activities and review steps. The goal of integrating environmental aspects into product development is to reduce stress on the environment occurring during the entire life cycle of a product, and this goal can only be achieved by combing three basic strategies, e.g. optimization of the function rendered by a product, reduction of resources use for the product system, and minimization of environmental emissions from the product system.

ISO/TC 207/ WG3 is in the process of developing a technical report on DfE. The first working draft includes a chapter that depicts product development process considering integration of environmental aspects into product development. The product development process consists of product specification, conceptual design, detailed design, testing /prototype, market launch, and review. Analytical tools such as LCA and QFD can be used in the product specification stage, and evaluation tools such as DfD and DfR in the testing/ prototype stage.

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