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DESIGN FOR ENVIRONMENT AS A PART OF THE IPS-DFX METHODOLOGY FOR INTEGRATED PRODUCT DEVELOPMENT

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ABSTRACT:
The paper will present a Design for Environment (DFE) tool as a systematical way of incorporating environmental attributes into the integrated product development. The developed tool is a part of the integrated platform which already includes Design for Assembly, Manufacturing and Costs, and it is functioning in internet surroundings. The paper will provide an insight into the application of DFE tool in several case studies, using the matrix concerning period of premanufacture, product manufacture, distribution and packaging, product use and maintenance and end of life with respect to materials, used energy, solid, liquid and gaseous residues.

KEYWORDS:
Design for Environment, Design for eXcellence,
Integrated Product Development, Web Software

1. INTRODUCTION

Global initiatives are requiring greater product responsibility from producers. In Europe, new regulations have been enacted that require producers, to take more responsibility for their products by providing the disposal or recycling of products at the end of their useful life. Labeling products with environmental performance data can help to differentiate products as well [5].

Design for Environment (DFE) is a systematic way of incorporating environmental attributes into the design of a product.

Three unique characteristic of DFE are [5]:

- The entire life-cycle of a product is considered;
- Point of application early in the product realization process;
- Decisions are made using a set of values consistent with industrial ecology, integrative systems thinking or another framework.

Companies are now expected by regulators, consumers, environmental advocate groups, and industry associations to develop environmentally conscious products and processes. DFE provides a method for meeting these demands. Potential benefits to the manufacturer include [5]:

- Improved designs;
- Reduced costs and time-to-market;
- Improved marked position;
- Reduced regulatory concerns;
- Reduced future liability;
- Improved environmental performance.

DFE considers the potential environmental impacts of a product through its life-cycle. A product's potential environmental impacts range from the release of toxic chemicals into the environment to consumption of nonrenewable resources and excessive energy use. Life stages of a product include the time from the extraction of resources needed to make the product to its disposal. In effect, designers design a product life-cycle not just the product. An awareness of a product's life – cycle will help the company avoid environmental surprises and liabilities. Ideally, the design team will seek to reduce these environment impacts to the lowest level possible.

The life-cycle of a product has been considered into the five stages shown in Fig. 1. The life stages in this abridged life-cycle are incorporated into the matrix system presented in this paper.

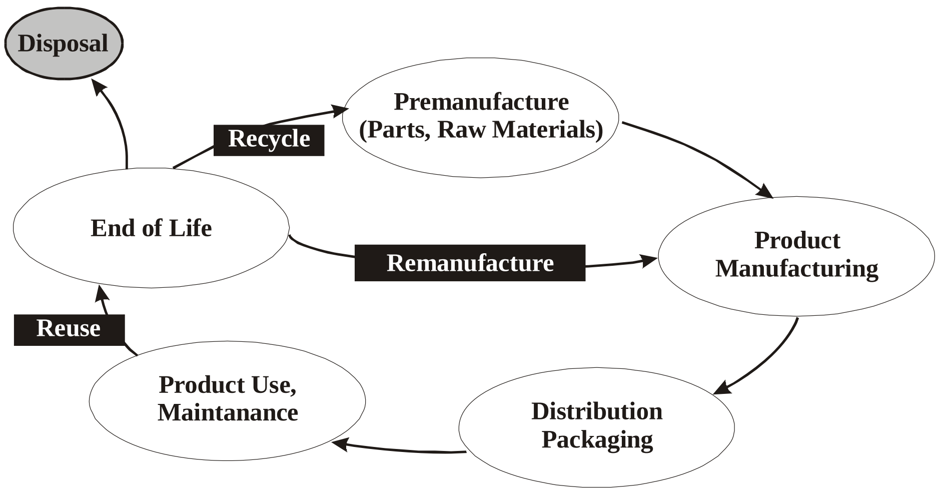


Fig. 1. The Abridged Product Life Cycle

These five stages are:

- Premanufacture – during this stage, parts and raw materials are procured for use in manufacturing products;
- Manufacture – All stages production within the company, from the raw materials enter the facility until the product is ready for packaging. Includes chemical or thermal processing, assembly and finishing;
- Packaging and Distribution – the material is packaged both for transport and purchase, and delivered to the customer;
- Use and Maintenance – the time from when the customer receives the product, until the customer is ready to dispose of the product.

This include maintenance, as well as the time after partial replacement or overhauls – as long as the customer is in possession of the product;
- End of Life – The product is recycled, remanufactured or removed from the life-cycle entirely by land filling or incineration.

Focusing only on complying with environmental regulations compliance can be costly. Hazardous waste management generates unnecessary costs if it can be shown that the hazardous materials creating the wastes could be eliminated from the manufacturing process. DFE takes a proactive approach to environmental considerations. Asking pertinent questions during the design phase regarding the potential environmental impact of a proposed product often reveals environmental liabilities that need to be addressed.

Design for Environment does not imply that a product is designed solely for the environment or the environment is the only consideration. DFE is an integral part the product development process along with other design considerations, such as product economics, customers' requirements, manufacturability, assimilability and required product functions. These parameters could be considered as part of a general design function "Design for X" (DFX) where X represents relevant design issues such as does mentioned [3, 4]. It has to be based on three principles IPS - Integration, Parallelization and Standardization, generating the acronym of the full name IPS-DFX methodology

2. IPS-DFX METHODOLOGY

IPS-DFX methodology has been developed on the clearly defined principles stated in the introduction, which denote comprehensiveness of the methodology, connecting it with other IPS-DFX methodologies in context of the wider concept of the IPS-DFX platform. The basic characteristic of the platform is the common information database in which process of integrated product development starts and flows.

It contains information about [1, 2]:
- Defined functional tasks;
- Production system and environment;
- Unique geometric model of the product;

as well as other necessary information which will be used during the developing phase.

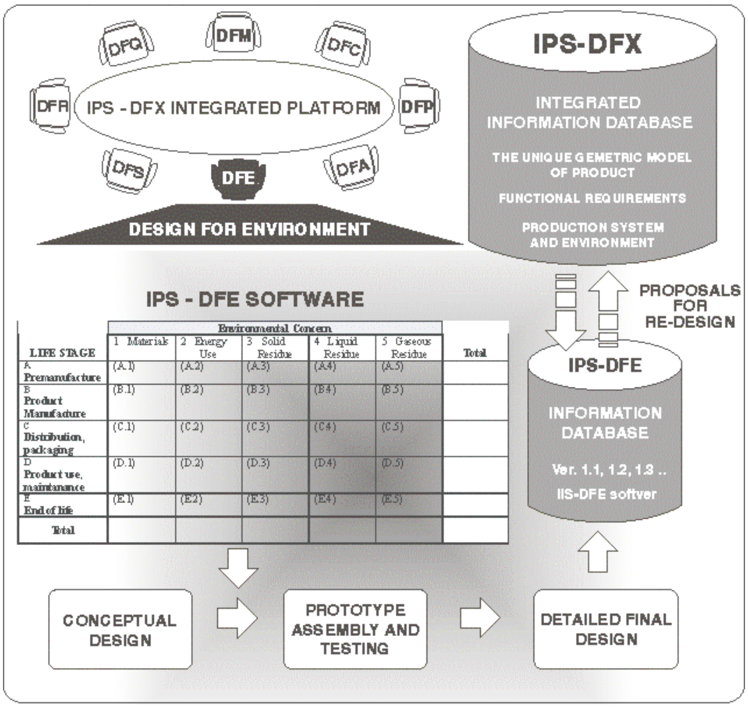


Fig. 2 IPS-DFX Integrated Platform

Fig. 2 illustrates the concept of comprehensive IPS-DFE methodology based on the principles within the frame of IPS-DFX platform, enabling simultaneous application of all available IPS-DFX methodologies.

DFE methodology transfers necessary data from the common information database, process them through developed procedure and returns the report with suggestions for corrections on the design. The integrated platform collates all returned suggestions for reconstruction from other methodologies, confirms them and equalizes existing differences, primarily on economic criteria but also on other general design evaluation criteria which could not be explicitly expressed through expenses.

The proposals have to be clearly presented in the document "PROPOSAL FOR RE-DESIGN", where the expected savings in assembly times and costs are particularly highlighted. Further, the proposals have to be critically analyzed if they cause negative consequences in some other aspects of the design, and if so, the proposal has to be rejected avoiding the additional efforts of other experts in the DFX team.

If the DFE expert, according to his professional knowledge and experience does not see any obstacles for implementation of the suggestion, the proposal has to be transferred to be verified by the DFX team, where two different cases may occur:

- The proposal for re-design is not delayed in any aspect, and can be directly implemented in product design;
- The proposal for re-design is delayed by the expert team, sent for a detailed cost- benefit analysis, and followed by a renewed discussion about verification.

The DFX expert's team has to have as much iteration as necessary until none of participants has any objections to the proposal, so a consensus about the design reconstruction is achieved.

3. IPS-DFE MATRIX

The IPS-DFE Matrix, shown in Table 1, uses 100 specifically defined questions that address a wide range of design and environmental topics, highlighting areas of environmental concern and providing ideas and options for resolving those concerns.

The questions have been written in a manner general enough to apply to numerous types of products; however, the design team can adopt or modify the questions to their own use, noting the specific product attributes.

Table 1. DFE Matrix

LIFE STAGE	Environmental Concern					Total
	1 Materials	2 Energy Use	3 Solid Residue	4 Liquid Residue	5 Gaseous Residue	
A Pre-manufacture	(A.1)	(A.2)	(A.3)	(A.4)	(A.5)	
B Product Manufacture	(B.1)	(B.2)	(B.3)	(B.4)	(B.5)	
C Distribution, packaging	(C.1)	(C.2)	(C.3)	(C.4)	(C.5)	
D Product use, maintanance	(D.1)	(D.2)	(D.3)	(D.4)	(D.5)	
E End of life	(E.1)	(E.2)	(E.3)	(E.4)	(E.5)	
Total						

The matrix scoring system allows the design team to:

- Score a product design as part of an overall product evaluation;
- Compare alternative product designs;
- Recognize areas where design changes are the most imperative from an environmental standpoint.

The matrix score is a relative measure of the attributes of the product. It complements the economics, customer-value, manufacturability and other parameters that may be evaluated. The matrix score should be used as an input in deciding which product design will be pursued.

Another perspective in the analysis is product recyclability. Recyclability focuses on one dimension of environmental compatibility, but is an issue that engineers can most easily impact. Further, rapidly depleting solid waste landfills are driving many governments to institute regulations mandating manufacturers extended responsibility at the product's end of life. To enhance component reuse and material recycle, engineers must embed strategic modularity into the product and reduce the cost to the recycling organizations. The key issue is the up front consideration of recycle modularity at the early stages of product design that addresses product families and its generations.

4. APPLICATION OF THE DFE METHODOLOGY

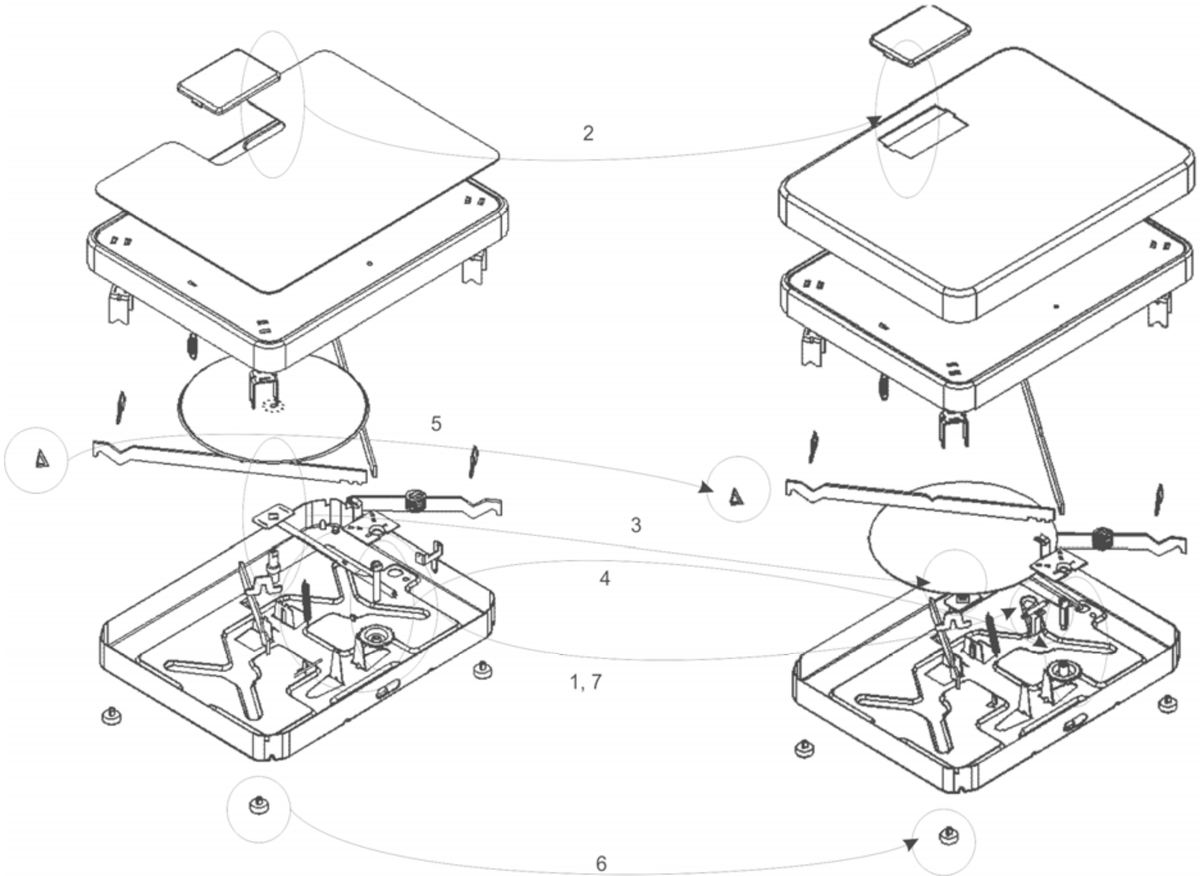
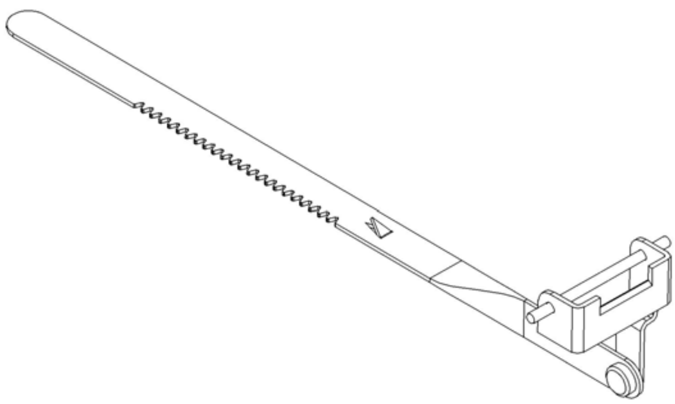


Fig. 4. Exploded view of the product before and after improvements.

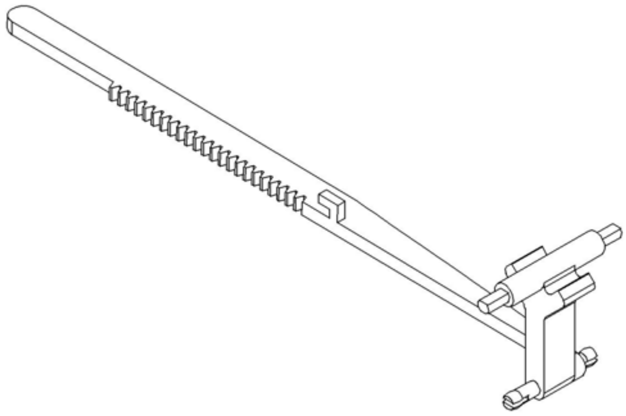
Fig. 4 (left) illustrates the basic product (mechanical bathroom scale) that was analyzed using the IPS-DFE methodology. On Fig. 4 (right) the optimized product can be seen. The evaluation of the results of the DFE analysis showed that seven changes could be made. The 7th change is illustrated on Fig. 5.

Previous solution



Estimated environmental factor 82/100

Proposed solution



Estimated environmental factor 85/100

Fig. 5. The 7th change

The estimated environmental factor change during the optimization process is shown on Fig. 6.

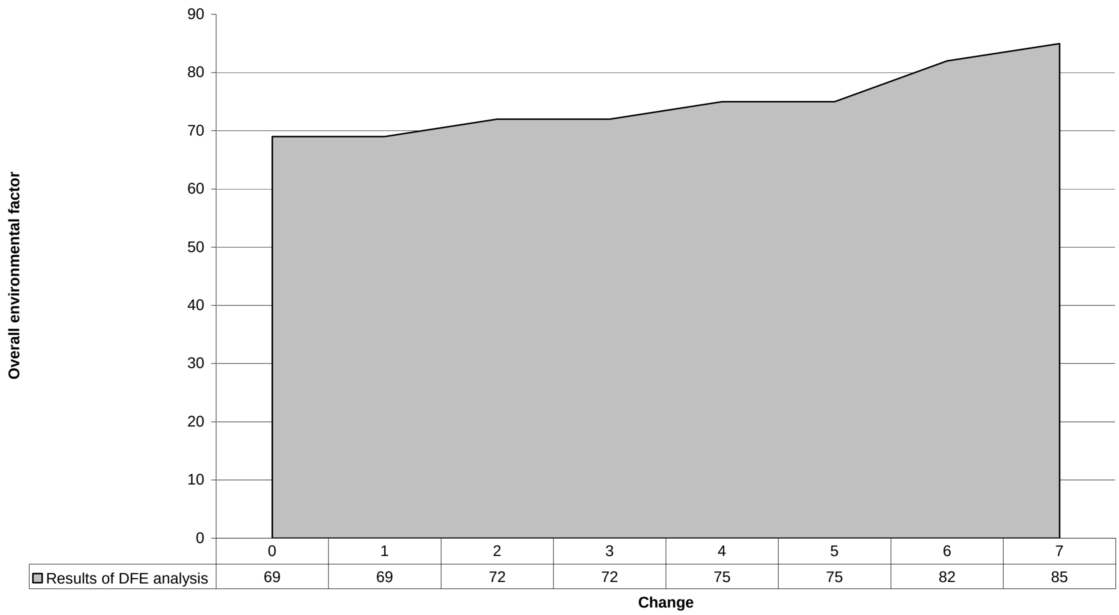


Fig. 6. Estimated environmental factor

The results showed that the number of used materials in production was reduced, and that optimizations in the design were introduced through elimination of the joining elements, and also through reduction of the number of used parts, and structural changes.

5. CONCLUSION

For the reasons of growing requirements for product responsibility from producers and new regulations that have been introduced over the past decade, DFE as a systematic way of incorporating environmental attributes into the design of a product has attracted steadily increasing attention.

This paper gave on overview of current DFE research and practice in Serbia & Montenegro, through the development of the IPS-DFE methodology in the context of the wider concept of the IPS-DFX platform, in which process of integrated product development starts and flows.

The usage of the IPS-DFE methodology in the development of the analyzed new product showed that by incorporation of environmental issues in the development process, the design team can achieve improved designs, and as a result of that, reduced costs and improved market position. Therefore, the IPS-DFE methodology became an important part of the IPS-DFX platform, as a successful systematic way of implementing environmental attributes in the design process of new products.

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