RESEARCH AND APPLICATIONS ON THE SUSTAINABLE DEVELOPMENT OF PRODUCTS AND INDUSTRIAL ORGANIZATIONS

MAREȘ Adrian-Daniel[1], MANEA Elena-Mădălina[1], Marian GHEORGHE[2], Manuela-Roxana DIJMĂRESCU[2] and Dragoș ILIESCU[2, 3]

[1] Faculty of Industrial Engineering and Robotics, Specialization: Industrial Economic Engineering, 4th study year, e-mail: adymares24@gmail.com
[2] University POLITEHNICA of Bucharest, IIR Faculty, Manufacturing Engineering Department (TCM)
[3] S.C. Nuclear NDT Research & Services S.R.L.

ABSTRACT: The industrial organisations, as well as the industrial products, which are sustainably developing, meet a series of specific requirements. Sustainable development requires knowledge of influencing factors. There is evidenced a series of design and eco-design tools necessary for a sustainable product or industrial company. Also, the information and results of experimental research on the sustainability of the product or organization are presented within various methods and strategies.

KEYWORDS: product, sustainability, development, design, industrial organization

1. Introduction

Sustainability refers to the ability of a product to function in the long term, the same time minimizing the impact on the environment and providing social and economic benefits. Sustainable design solutions ensure an efficient management of the functional attributes of the product and balance the three dimensions of sustainability. It is important that all three aspects of sustainability are taken into consideration into the sustainable design process, although the environment has often been the only concern in product design.

2. General considerations

2.1. Sustainable and ecological design

The concept of sustainable design could be easily understood, taking into consideration the term 'design', which is a creative activity of choosing between different possibilities. It represents a broad concept that includes the generation and development of a product. There are four stages of a typical design process, as presented in Fig. 1.

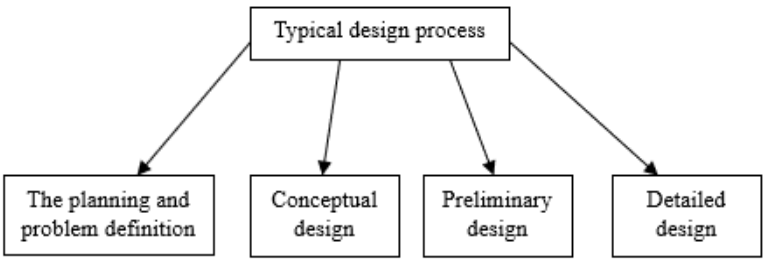

Fig. 1. The stages of the design process [1]

The sustainable design of a product considers the entire life cycle of the product, from the selection of raw materials and materials, conceptual modelling and detailed design, manufacturing and usage until the end of the product's life, reuse and recycling.

Ecological design is a concept that aims to minimize the impact on the environment by selecting materials and resources used, as well as addressing end-of-life scenarios [1].

2.2. Eco-design tools

Eco-design is an innovative approach in the design of products and systems, which primarily aims to minimize the impact on the environment and the increase of durability. To implement this type of design, various tools and methods allowing designers to consider the entire life cycle of the product, from production to use and disposal, are used [2].

Some of the most commonly used tools of eco-design are presented in Fig. 4.

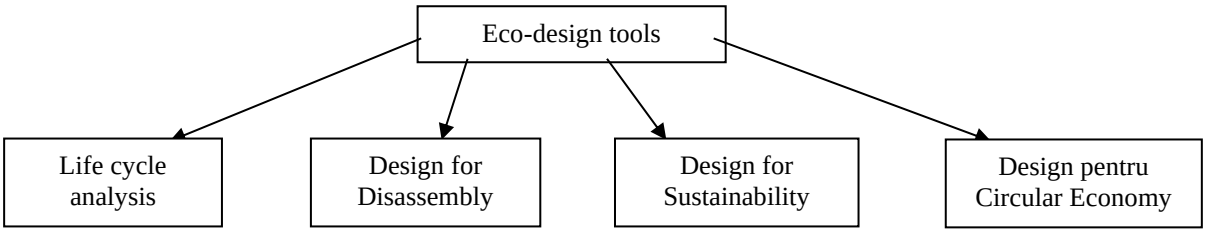

Fig. 4. Eco-design tools [2]

3. Partial sustainable product design (P-SPD) tools

Partial sustainable product design (P-SPD) tools cover one dimension of sustainability (economic or social) together with environmental aspects.

These tools do not take into account all three aspects of sustainability, nor are they limited only to the impact on the environment [3].

Partial sustainable product design tools are as follows [3]:

- Method for sustainable product development (MSPD – Fig. 5)
- Multi-objective material selection method
- Quality function deployment and LCA based method (Fig. 6)
- Normative decision analysis method for the sustainability-based design of products
- Design framework for a customized service system.

Fig. 5. Sustainable development [3]

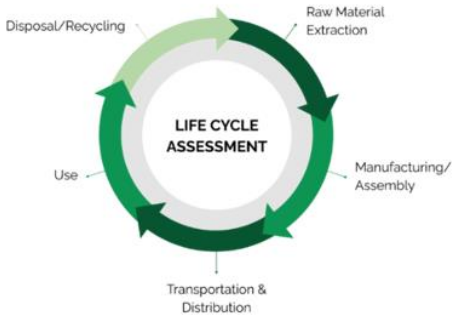

Fig. 6. LCA method [3]

3.1. Life Cycle Assessment method

Life Cycle Assessment (LCA) is the most frequently used method for the ecological design [7]. LCA provides quantitative data about a product's impact on the environment throughout its life cycle, from material extraction and production to the end of the product's life, considering multiple environmental indicators [8, 9]. Simplified LCA is a way to conduct evaluations in a shorter amount of time and with fewer resources, but which provides uncertain results.

MSPD Method

This qualitative method, for sustainable product development, extends the existing eco-design tools (manuals and matrices) by using the back-casting system (a modular system for guided questioning), to cover the fundamental principles of sustainability throughout all stages of the life cycle, including the environmental and social ones (Fig. 7). This tool provides valuable perspective and assistance in the early stages of product design, before conducting more detailed analyses [11].

Fig. 7. MSPD Method [11]

3.2. Sustainable product design (SPD) tools

Sustainability considers that social, economic and environmental concerns should be addressed simultaneously in the product development process [4]. This characteristic implies that the term ‘sustainable’ should only be used for those tools that take into consideration all three aspects of sustainability. In retrospect, it has been observed that the majority of the analysed P-SPD tools have only taken into account a limited economic analysis. Similarly, the SPD tools, the structures of the majority of the reviewed sustainable product design (SPD) tools were based on the integration of different tools from various fields.

Examples of SPD tools

- Decision support system for the sustainability index of machine tools
- Product sustainability index method
- Integrated product life cycle management

Decision Support System

A decision support system (DSS) is a computer application used to improve decision-making capabilities (Fig. 8). It analyses large amounts of data and presents the best possible options to organisations [5].

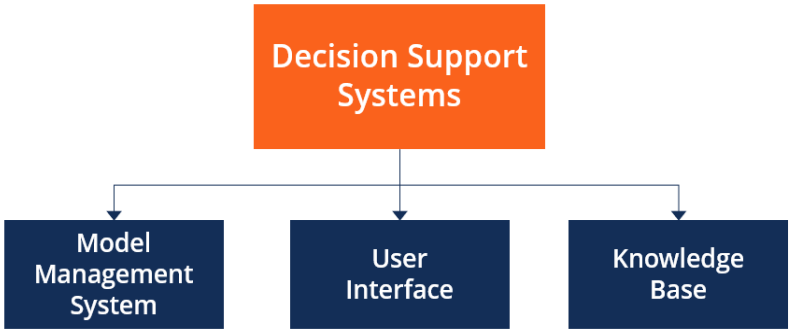

Fig. 8. Decision Support System [5]

Product's sustainability index

This quantitative method generates a sustainability index based on a set of product sustainability indicators.

Product sustainability index evaluation implies a series of stages: data scaling and normalization, score weighting and aggregation, as shown in Fig. 9.

Data scaling and normalization is used to convert measured data in dimensionless scores, whose basis is specified for each considered criterion. There are commonly used two normalization methods: objective normalization and subjective normalization. The weights are assigned based on the relative importance of certain specific indicators, using one of the three weighting methods: (i) equal value, (ii) subjective weighting, and (iii) analytical weighting approaches. Based on the assigned weights, normalized data are ultimately aggregated into a conclusive and corresponding product sustainability index [6].

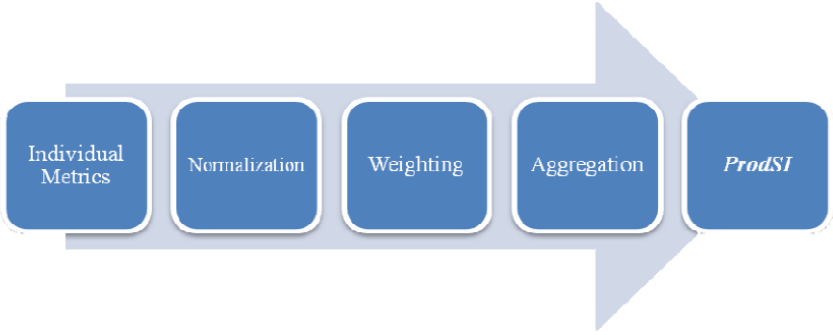

Fig. 9. Product sustainability index [6]

4. Case study

This case study focuses on identifying the sustainable strategies necessary for Madelman SA company to assure a sustainable development in the future.

Certain examples of products that Madelman SA company manufactures are presented in Fig. 10 and Fig. 11.

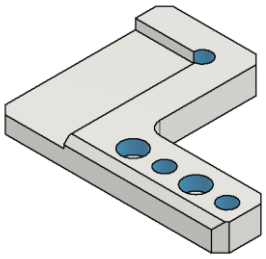

Fig. 10. DK21 DS01.04 Panel

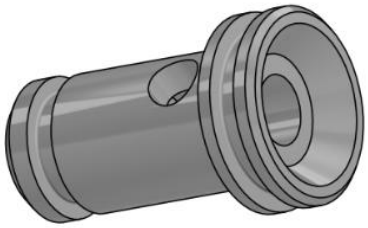

Fig. 11. Adjustable chair HR01 SSB02.12

The main sustainability action directions are analysed, and, by consequence, different ways in which the company can become sustainable. In the final part, four strategies that the company can adopt to increase its level of sustainability are proposed.

Objective: sustainable development means meeting the needs without compromising the ability of future generations to meet their own needs.

Method: the company must adopt life cycle evaluation method and method of sustainable development of products.

Material selection: it is proposed the usage of recycled materials for its products.

Also, the investments into a series of energy efficiency initiatives, such as solar systems, would reduce costs and carbon emissions.

Another method for helping the company to make good decisions regarding its development is represented by design and implementation of the decisional support system, as well as the four strategies of sustainability: sustainability management, sustainable innovation, ecoefficiency, sustainable competitive advantage [10].

All of the life cycle analysis, design for sustainability and circular economic design can be taken into account for the evolution of the company.

The case study develops a system that provides a product sustainability index. Sustainability index is limited in the case study to the impact created by the selection of raw materials and materials.

Within this case study, the evaluation of the sustainability development level is proposed as presented in Table 1. For each criterion, C_i, the objective is maximization or minimization, as the case.

Table 1. Sustainability evaluation (example)

Criterion, C_i	Objective	Significance
The carbon footprint from the extraction and use of biomass, fossil fuels, ferrous and non-ferrous ores	↓	↑ - the criterion is aimed to be maximized, ↓ - the criterion is aimed to be minimised
The consumption rate of domestic materials (that are not sourced through a supply chain or imports)	↑	
The involvement of hazardous/toxic substances or waste	↓	
Raw materials/materials sourced from recycling	↑	
The utilization degree of the energy from renewable sources	↑	

Through analogy with an evaluation method applied for audit team assessment [12], the contribution of certain criterion C_i to the objective achievement is evaluated by a factor $E(C_i)$ that could have the value of 1, 3 or 9, i.e., 1 - if the criterion has no contribution, 3 - if the criterion has a moderate contribution, and 9 - if the criterion has a strong contribution. Further, if $E(C_i)$ is the evaluation factor associated to the criterion C_i, the calculus of correspondent sustainability index, SI, is proposed for each considered type of product, P, and each design version, v, as:

$$SI_{P-v} = \prod_i E(C_i) \quad (1)$$

and the sustainability index of the design stage is considered of value SI_P^*,

$$SI_P^* = (SI_{P-v}) \quad (2)$$

5. Conclusions

Sustainable development is important for ensuring a prosperous and balanced future for both our planet and the following generations. This implies a balance between economic development, social development and environmental protection.

It is important to take immediate action to reduce the negative impact on the environment by adopting sustainable and innovative business practices. It is essential to promote changes in individual and community behaviour to reduce the carbon footprint to which humanity is subjected and to support a sustainable lifestyle.

In order to achieve sustainable development for a company or its products, it is necessary to analyse various directions, methods or strategies in relation to a series of product characteristics: the nature of the material, the environment in which the piece is manufactured, etc.

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