

Toward a Decision Tool for Eco-Design Strategy Selection of Aircraft Manufacturers Considering Stakeholders Value Network

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ABSTRACT

This paper introduces a novel approach in order to compare different eco design practices considering the value network of stakeholders. The proposed decision tool framework in this study helps manufactures in early stage of design to select a portfolio of eco design techniques to maximize the value perceived by all stakeholders in a dual life cycle approach including the business product life cycle as well as physical life cycle. A portfolio selection approach has been used to maximize the network value of stakeholders considering the life cycle cost and risk of techniques while satisfying the diversity of allocation resources on eco design practices based on strategic objectives of manufacturers. The dynamic characteristic of stakeholder's network as the result of implementing the different eco design techniques has also been considered in order to evaluate the synergy in stakeholder's network. Therefore the developed framework in this study is an effective way to assist the decision makers in prioritizing eco-design techniques and managing an optimal portfolio of them. As an application of developed model, we proposed a guideline for Aircraft manufacturers in order to select the best set of design for end of life techniques considering all stakeholder's needs and expectations. This guideline can help aircraft manufacturer to compare the variety of eco practices in three categories including material usage, providing information and manual and design for 3R (reducing, re-using and recycling) considering pertinent impacts to all stakeholders in addition to business priority in life cycle perspective.

KEYWORDS: Eco-design techniques, synergistic effect, stakeholder's network, value creation

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INTRODUCTION

Recently, considerably extensive attention to sustainable development has started becoming a key aspect in aviation industry. Aircraft manufacturers have reacted to this situation and recognized the importance of focusing their efforts to integrate sustainable development policies into their core business strategies. However, the effectiveness and the efficiency of such efforts have been in question because systematic approaches to support such activities are limited [1]. Design for environment (DfE) or eco design strategy is one of these efforts in order to integrate the environmental

considerations into product and process design. There are different techniques and practices which can be used by manufacturers in DfE context. Material substitution, design for disassembly, design for recyclability, design for reusability are some of these practices. Each practice may have impacts on one or more stages of product life cycle as well as different effects on stakeholders and value creation framework. In addition to life cycle effects of these techniques and multitude impacts that may affect the stakeholders, covering broad range of outcomes, uncertainty, complexity and feasibility should also be considered in decisions made by manufacturers in eco design techniques

selection process. Based on the literature review conducted by [2], DfE tools and methodologies are required to be more developed. Furthermore the stakeholders, life cycle approach and multi-criteria decision analysis are needed to be considered in an integrated eco design approach [3]. According to [4], a manufacturer with sustainable organization culture, require to identify not only the stakeholders and their expectations but also interdependencies and synergies in stakeholder's network to maximize the value considering environmental, economic and social requirements. Thus, for sustainable eco design strategy, in addition to considering the value outcomes of implementation an ecodesign technique, its impact on stakeholders network is also needed to be taken into account.

This paper introduces a novel approach in order to evaluate eco design practices considering the value network of stakeholders. We considered the diversity among eco design practices, the needs and expectation of stakeholders and their influences on manufacturer and different features of each ecodesign practices including technical, environmental, economic and social features. The structure of the paper is as follows: In section 2, we provide the literature review. Section 3 illustrates the decision tool. In section 4, we provide a guideline in order to compare the different design for end of life alternatives applicable for aircraft manufacturers. We conclude with a discussion in Section 5.

LITERATURE REVIEW

Today environmental performance is given the same position as the older product values such as profit, functionality, aesthetics, ergonomics, image and quality [5]. A complete definition for eco design is provided by [5]: "An integral component of the Design for X paradigm, covers all life cycle stages including material extraction, manufacturing, transportation, usage and end-of-life phases. Design for Environment seeks to understand the life cycle of the product and its impact on the environment at each of its life stages and to make better decisions during product design so that environmental attributes of the product are kept at a desired level ". This definition can reflect different aspects of DfE defined by other literature, such as considering the environmental aspects in each stage of the product development process [6] or systematic consideration of design performance with respect to environmental, health and safety objectives over the full product and process life cycle [7]. The key elements of DfE according to [8] have been illustrated in [Figure 1](#). This figure illustrates that for DfE we need to address the relevant efficiency metrics, identifying the different alternatives and an evaluation approach in order to compare these alternatives. Reference [9] conducted a literature in order to find the gap between theory and practice in DfE context. The authors believe that the related research can be classified in three categories. The first category of research is success stories of companies known for DfE by the press. The second category of research provides engineers

and managers guidelines for integrating environmental concerns into the product design process. The third stream of research introduces specific tools to be utilized for DfE process. The authors conclude that DfE tools and methodologies are at a very early stage of development. Reference [3] provided taxonomy of eco-design tools for integrating environmental requirements into the product design process. Among the literature reviewed in this study, three studies have considered stakeholders expectations in their models. The authors in [10] developed an Environmental Objective Deployment model in order to investigate the relationship between environmental considerations and the product design. The life cycle screening matrices in this study conducted for three perspectives (environmental burdens, stakeholder preferences and liabilities). This model is applied to improve the product using the indicators obtained in the initial review, but with a strong emphasis on customer requirements. Reference [11] used an eco design methodology for product development that combines screening LCA (Life Cycle Assessment) with QFD (Quality Function Deployment). In this methodology, the author utilized a detailed process to obtain stakeholder expectations throughout the product life cycle, which will be introduced in the HoQ (House of Quality) of the QFD method in order to obtain different conceptual design proposals. Reference [12] also introduced a methodology with considering stakeholder requirements. They used a modified version of HoQ in this study. Reference [3] at the end of the study concluded that most of Eco design tools are not applied in a systematic way in companies due to their complexity, the time required to apply them and the lack of environmental knowledge.

The authors believe that early integration of environmental aspects into the product design and development process; the life cycle approach, which takes into account how the product can affect the environment in its different stages; and a multi-criteria approach are needed in this context. In the other words, an integrated approach includes three essential elements, early integration of environmental aspects into the product design and development process, life cycle approach, which takes into account how the product can affect the environment in its different stages and multi-criteria approach, which simultaneously takes into account all the traditional requirements that affect the product together with the relevant environmental aspects and impacts.

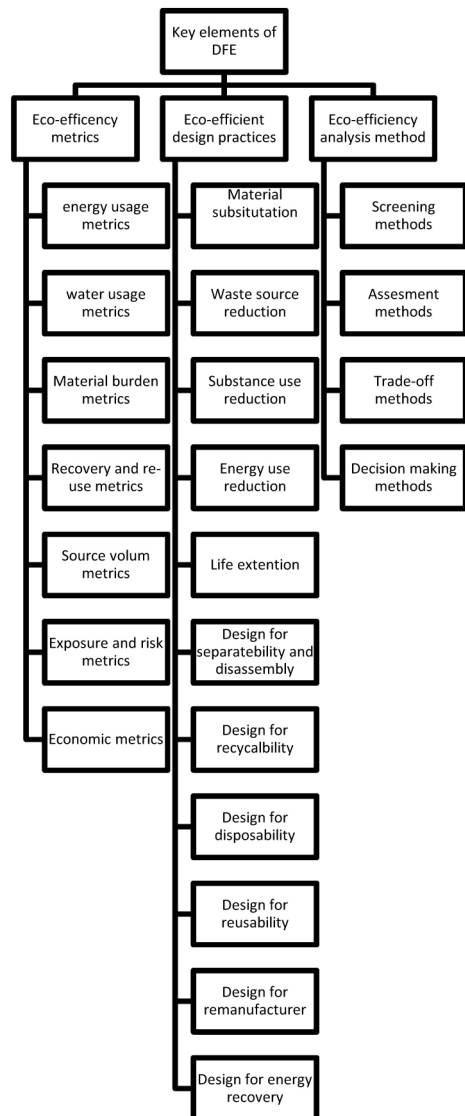


Figure 1. The key elements of DFE according to [8]

For selection of appropriate eco design techniques, we have three categories of attributes. There are some independent attributes for implementation of each practice such as the costs and benefits derived from applying this practice. The second attributes are interrelated attributes such as shared resources or shared risks and finally some synergistic attributes such as diversity in life cycles or design stages. As the portfolio selection approach includes these three types of attributes [13] hence we utilized this approach to select the optimal portfolios of eco design techniques. Furthermore, according to [14] decision-makers must consider multiple objectives and regularly have slight preference information. With this limitation they can improve their chances of achieving success by a two-phase approach that first determines the solution space of Pareto-optimal portfolios and then allows them to interactively search that space. Hence in this study we used a two phases approach for modeling. In first phase we find the optimal portfolios and

then in second phase considering the strategic objectives of manufacturers, network implication and life cycles effects, the best portfolio can be selected. There are few studies that consider stakeholders in eco design methodology such as [10] and [12]. Moreover the literature is not so rich with respect to proposed methods or approaches for analyzing the value perceived by stakeholders. The value of stakeholders in design decision or implementation a new strategy has been taken into account recently. For example [15] introduced a stakeholder value loop analysis for space based earth observation. Reference [16] developed a general methodology for value network analysis including Exchange analysis, Impact analysis and Value creation analysis. Reference [17] proposed a methodology to support the initial analysis of stakeholder needs and attributes, and the derivation of corresponding design requirements.

In comparison, there are more studies which address the value models for customers. Taxonomy in these models and methodologies shows that an integrated approach is needed to use the benefits of each model [18]. The integrated framework should include value exchange model which addresses the associated costs and benefits for customers, value build-up model which addresses four aspects including the view of relationship, the customer benefits (from tangible to intangible), customer need (utility need from psychics need) and view of customers and dynamic aspect that addresses level of satisfaction of customers as the absence or presence of an attribute. So there is a need for developing a model for analysis the stakeholder's value considering the above aspects. Social network analysis literature is full of different measures and functions which can be used in order to study the networks. However some of these measures can provide highlights with respect to functionality and efficiency of network. According to [19] there are two challenges in modeling networks from strategic point of view. Explicitly model the costs and benefits that arise from various networks and how the individual incentives translate into network outcomes. In addition since the sharing information and opinions formation are important characteristics of social networks, how the structure of network can affects learning and information diffusion are needed to be considered in social network analysis. In this study the dynamic characteristic of stakeholder's network as the result of implementing the different eco design techniques has also been considered in order to evaluate the synergy in stakeholder's network.

THE DECISION TOOL

The framework of proposed decision tool is shown in Figure 2. The first part of the decision tool is data module. The data from the other design models, economic models and LCA models or other complex system models are far too complex to be linked directly to decision tool. Therefore an interface between the complex system models and the design tools are needed. We used the fuzzy logic concept in order to

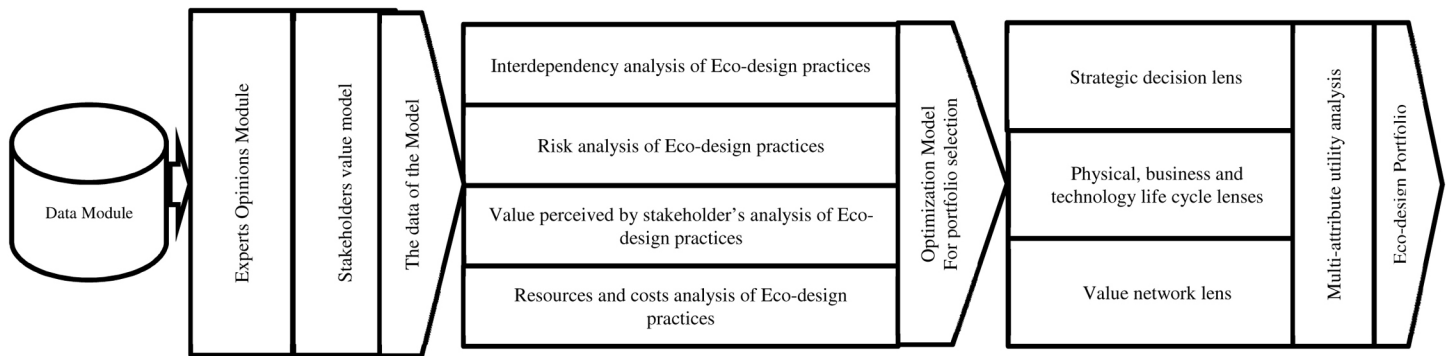


Figure 2. The framework of decision model

provide the required data for the decision tool. We named this module expert opinion module. We also developed a separate model in order to calculate the value perceived by each stakeholder as the result of implanting each eco design practice. The next part of decision tool is portfolio selection module. We developed an optimization model in this part. The optimization model includes the required resources and cost of each practice, the value perceived by stakeholders, the associated risk and the interdependency among practices. After this phase, we considered the synergistic attributes of portfolios via value network analysis, life cycle analysis and strategic decision analysis. We also utilized multi-attribute utility analysis in order to rank the portfolios in last step and finally we achieve the best eco-design portfolio. The detailed elements of this decision tool will be described in next section.

Data Module

For each Eco design practice we need to address the technical, environmental, economic and social features. Moreover we need the stakeholders need and expectations. The source of this data can be the models or in some cases expert opinions. The source of data for these four groups is shown in [Table 1](#).

Table 1. The source of data

Data	Source
Technical features	Design models /Experts opinions
Environmental features	LCA results /Experts opinions
Economic features	Economic models /Experts opinions
Social features	Experts opinions
Stakeholders need	Annual survey, Interviews with stakeholders and Experts opinions

Stakeholders Value Model

As we explained in literature review, an integrated approach for customer's value model is needed to cover the exchange, build-up and the dynamic aspects of value. In order to reflect the value exchange concept in the model, we need to address the associated risk, benefits and cost of implementing each Eco design practice for stakeholders.

For considering the value build-up model, we need to address four aspects including the relationship between stakeholders and manufacturer, the types of perceived value (from tangible to intangible), the types of stakeholders need (utility need from psychics need) and finally view of stakeholders. With respect to dynamic aspect, we need to address level of satisfaction of stakeholders as the absence or presence of an attribute. Reference [17] proposed a methodology to support the initial analysis of stakeholder needs and attributes, and the derivation of corresponding design requirements. They applied the introduced method for a power solution case study. They used Maslow's hierarchy of needs concept [20] to address the level of stakeholders needs and relevant stakeholder's requirements which can be demonstrated by prospective solutions (hereafter Stakeholders attributes). This model supports two aspects of value build up models including (the types of stakeholders need and the type of perceived value). With applying the concept of fuzzy logic, we are also being able to address the level of satisfaction of customers as the result of absence or presence of attributes. The relationship between the needs of stakeholders and attributes can be obtained by applying this model. But we need to address the relationship of these attributes and eco design features. For achieving this objective, we applied the concept of conjoint analysis and Lens model [21]. Lens model illustrates key concept of customer response to a new product and its marketing mix. Conjoint analysis also link features to perception and preference (for more details please see [21]). The concepts of Lens model and conjoint analysis have been illustrated in [Figure 3](#).