CIRP Annals - Manufacturing Technology 63 (2014) 169–172

Contents lists available at ScienceDirect

CIRP Annals - Manufacturing Technology

journal homepage: http://ees.elsevier.com/cirp/default.asp

A protocol to perform usage oriented ecodesign

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ARTICLE INFO

Keyword:
Design
Environment
Usage

ABSTRACT

Ecodesin strategies only based on technology efficiency have reached a steady state in improving product environmental impacts in use. New solutions should be investigated in order to consider the contribution of the users themselves to the actual environmental impacts of the product during the use phase. This paper presents a protocol to perform usage oriented eco-design. Combining in depth analysis of tasks realization with a more holistic model of the entire use phase, this protocol can support the design activities. An application to an espresso coffee maker illustrates the protocol implementation and show how this protocol contributes to help designers to perform usage oriented ecodesign.

1. Introduction

Consumer products, their design and their environmental impacts, have been studied widely in the last period. Mass customization was proposed to increase customers' satisfaction with acceptable production costs [1]. The environmental burden was studied through their manufacturing and end-of-life phases and solutions were proposed for smart manufacturing energy consumption [2–4], greener processes [5,6] and reuse and remanufacturing strategies [7]. Many improvements have already been done but the environmental impact of most consumer products is dominated by their use phase [8].

What do industry and academy to improve the environmental performance throughout the use phase of products? Eco-design strategies were developed based on product technology performance: substitution of technologies, process efficiency and architecture transformation [9]. The decrease of in-use energy consumption is strongly focused [10,11]. Manufacturing processes are also studied to improve the in-use technology performance. A part of the product environmental impacts tend to be driven by the manufacture of the product components since components fabricated with higher precision typically allow the product to operate at higher efficiencies [12]. Helu and Dornfeld [8] investigated the relationship between manufacturing process precision, functional product performance and life cycle environmental impacts.

Those strategies based only on technology have reached a steady state in improving product environmental impacts in the use phase. New solutions should be investigated in order to consider the contribution of the users themselves in the actual environmental impacts of the product during the use phase. Interest on product innovation and usage oriented innovation has grown [13] alongside with questioning users in the design process [14]. Design for sustainable behavior [15] has led to several solutions for adapting usage oriented innovation on the product for environmental improvements (Fig. 1). This area of research seeks a technology based solution where technology is the core element in bringing a higher environmental performance, influencing users' behavior toward more sustainable routines and compensating usage drifts when necessary.

Leaning on those research results, we propose to go further in the direction of addressing user experience as part of the eco-design process. We postulate that the dramatical decrease of environmental impacts of products during the use phase will only be effective by the simultaneous design of the product and its user experience. This paper aims at giving a protocol to perform usage oriented eco-design. The protocol is described in Section 2. Section 3 illustrates the core steps of the protocol on a coffee maker eco-design process. Section 4 concludes the paper in discussing results and perspectives.

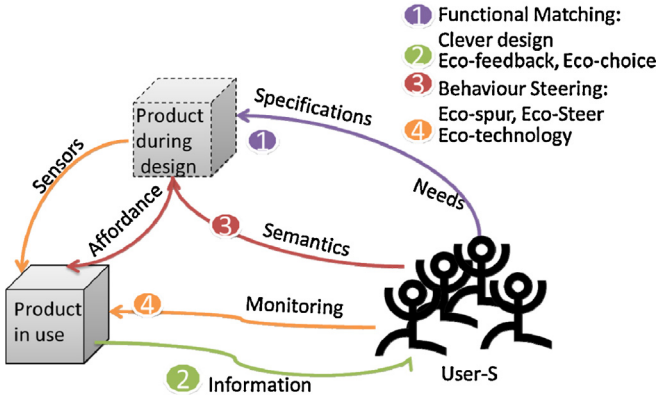

Fig. 1. DfSB strategies.
Adapted from [15].

2. The protocol for usage oriented ecodesign

Improving product usage and user experience can be a new source for enhancing product environmental performance. First of all, the evaluation of what is impacting over the use phase is fundamental and we propose a task-oriented model of the use

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http://dx.doi.org/10.1016/j.cirp.2014.03.096
0007-8506/

phase to identify product and users parameters that significantly contribute to environmental impact at a macro level. Then, task contents (micro level) are deepened to define design interventions that mix product, user behavior and experience with the product. The proposed protocol is a 6-steps method split into two main phases that address the macro and the micro levels respectively.

2.1. Phase 1 (macro level): break the use phase down to moments that can be assessed then classified

Step 1. Identify the types of moments and the initial usage scenario

A model of the continuous usage of the product throughout the use phase is needed to have a full representation of the phase from the purchase action to when the product is of no need for the user and is brought to the end-of-life collector. The use phase is defined in smaller units of time called moments, which are similar to what ergonomics defines as tasks and other authors as sub-phases of the use phase. The granularity of the moments depends on both the accuracy expected and the data available. The set of the moments cover the entire use phase. A moment characterises activities that start when input conditions are there and stop when the expected state is achieved. Domingo et al. [16] have defined seven different types of moments for classical consumer products: installation, learning, core use, maintenance and cleaning, storage, upgrade, decommissioning. The number and type of moments are defined depending on product functions and on users' routines. Finally, the set of moments creates the scenario of the use phase when moments are coordinated together to cover the whole lifetime of the phase. Fig. 2 gives the general model of the product lifecycle for eco-design activity based on the environmental assessment of moments performed throughout the use phase.

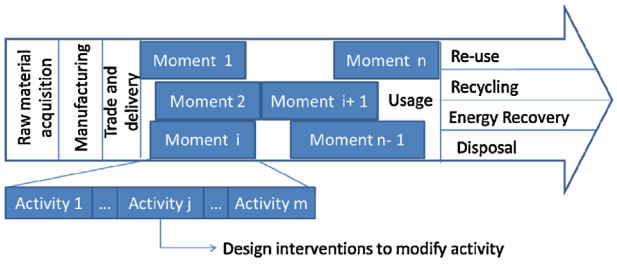

Fig. 2. Product usage modeling for eco-design.

Step 2. Use phase environmental impact assessment

A product lifecycle has been defined as the succession of the following phases: raw material acquisition, manufacturing, trade and delivery, use/maintenance and re-use, recycling, energy recovery, disposal [17]. Improvements of product environmental impact are based on an assessment of its lifecycle and modifications of product according to the most impacting aspects of it. Even when focusing on the use phase, the contribution of the other lifecycle phases should be considered additionally.

Each one of the 7 types of moments has been parameterized to give easily the in-use environmental burden from specific LCA modules pre-defined for the product category. Every task is given an in-use environmental performance. Environmental performances of moments over use are evaluated depending on the different types of consumption (energy, water, etc.) and wastes, i.e. flows, that will be needed to perform them and how those different flows will be solicited by users The solicitation of users can be identified based on different sources of information: tasks analysis, literature, online polls... [16]. Then, the environmental impact of the whole use phase is generated by the repetition of all the different moments over the product lifetime and finally the elementary environmental performance of moments are summed against the scenario studied for the whole use phase.

Step 3. Select the most impacting and improvable user moments

With the environmental assessment, the most impacting moments can be identified. The impact can be broken down into impacts related to users' solicitation and impact related to product flows. This differentiation between users' and product impacts is helpful to identify the most improvable moments. If the contribution to the environmental impact is mainly associated to product flows, technical improvements should be made (Fig. 1 – strategy 1). If there are few technical improvements identified by the design team, the moment with high product contributions is considered not improvable. Nevertheless, if the contributions are mainly associated to user behavior, strategies that directly connects product in use and users (Fig. 1 – strategies 2–4) should be considered.

2.2. Phase 2 (micro level): improve the in-use environmental performance by design interventions

Step 4. Identify possible design interventions to improve product usage

The main objective of the protocol is to decrease the environmental impacts of the most impacting users' moments by modifying user's behavior thanks to the implementation of design intervention strategies. According to studies led on design strategies for sustainable behavior, a detailed classification of the intervention strategies found in literature can be made depending on: the objective of the intervention on the user, the possible design for sustainable behavior strategies to employ for the implementation, the implementation format for the design intervention. All this information has been grouped and summarized in Table 1.

Table 1
New features implementation format related to DfSB strategies.

Interventions objective Selvefors et al. [21]	DfSB strategies Tang et al. [15]	Implementation format Selvefors et al. [15]
Increase knowledge	Eco-information	Adapted information
	Eco-information	Written information
	Eco-information	Oral information
	Eco-choice	Demonstration
Engage	Eco-feedback	Comparative feedback
	Eco-choice	Self-monitoring
	Eco-spur	Social validation
	Eco-steer	Objective to reach
	Eco-spur	Competition
Steer and spur	Eco-spur	Guilt
	Eco-steer	Constraints
	Eco-spur	Penalties
	Eco-choice	Motivation
	Eco-technology	Persuasive Technology
	Eco-steer	Behavior steering
Create attention	Eco-technology	Affordance
	Eco-feedback	Real time-feedback
	Eco-feedback	Personalized feedback

Then for each moment previously identified as a most impacting moment and depending on the design strategies retained, designers can select possible format to realize new product features to influence users' behavior. In the next step of the protocol, an experimental procedure has to be developed to observe environmental performance during the usage of those new features. So, each design intervention has then to be implemented on the product to be tested and assessed from an environmental behavior point of view.

Step 5. Connect user's experience activity to product features

Designers have to retrieve information about the use phase to determine how new features on the product influence the behavior and decrease the environmental impact. For this, an observation of the use phase has to be realized. The following schema (Fig. 3) adapted from [15,18], lists the elements chosen to be recorded during the experiment. At the end of the experiment, a statistical