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Linking Use Stage Life Cycle Inventories with Product Design Models of Usage

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Abstract

Usage can have a significant environmental impact on the product life cycle. A precise evaluation and understanding of this impact during design is crucial to support early and adapted feedbacks to design experts to encourage the eco-design practice. Information on usage is spread across different field of expertise, and involves explicit and tacit knowledge. This research aims at improving the link between the available usage information, and the environmental expert's explicit knowledge on usage. A five steps method is proposed and exemplified in this paper to formalize this link. The paper finally raises the question of how to deal with conflicting usage information during design in industry.

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Keywords: Product Design; Life Cycle Assessment; Model Driven Engineering; Usage integration

1. Introduction: usage in eco-design

Each expert intervening during product design has his own view on how the product will be used. The design brief gives instructions to designers about the product's functionalities. The mechanical and material engineers design the product's mechanisms for a given lifespan and under certain conditions of use. The ergonomic expert anticipates the product design to be error-free. Retailers interact with clients and advise them. After sale agents receive feedbacks from users and repair products. Waste treatment plan agents observe all kind of used products. Each view may be close or less from the real use due to the non-negligible influence of individuals. Yet, for products having major environmental impact during use phase, ecodesign seeks to minimize the environmental impacts of the use stage, and other potential environmental impacts generated during its life cycle, while optimizing the product's functional values [1]. The divergent of design views on usage should not slow down the ecodesign effort for this life cycle stage.

Industries and researchers insisted on the necessity to integrate the global lifecycle environmental expertise as early as possible during design with adapted tools to provide specific feedbacks to each expert. A combination of methods to evaluate the environmental aspects, tools to integrating the environmental aspects into the design process, and methods for integrating environmental and other traditional requirements are indeed required [2]. However, a precise correlation between the design parameters and a usage view, and how they influence the environmental impacts generated during the product's usage may be unknown by the expert in charge of defining the life cycle model for the environmental assessment.

This research therefore aims at supporting the ecodesign practice by linking available usage information, embedded in expert view, and the information needed by the environmental expert on usage. The hypothesis is that a formalized link would support adapted feedbacks to product designers as early as possible during design and encourage the ecodesign practice (section 2). A five steps method is introduced in section 3 to (a) improve information transfer of available information on usage from various expert outputs to the life cycle inventory - LCI (environmental expert inputs), and (b) support the provision of explicit environmental impact information from LCA results in the form of

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adapted feedbacks to design experts. This method is exemplified in Table 1. The last section discusses the research limitations and addresses further work.

2. Research focus: sharing explicit knowledge on usage to fuel ecodesign efforts during design

2.1. Linking expert parameters to the environmental lifecycle analysis

A number of solutions exist for the environmental expert to get access to information about the product being designed, for instance:

- The product's Bill Of Material (BOM) is generally accessible through the Product Life Cycle Management (PLM) software that gathers information about the product: material chosen, parts and components, assembly, manufacturing processes, etc.
- The associated material and components' providers, or suppliers referenced in the Enterprise Resources Planning (ERP) software of the company.

Automatic data transfer between product designers' software and LCA tools (mainly) can be supported by the information system of the company (for instance [3]). Commercial solutions exist (*e.g.* linking software from Dassault Systems©, PTC©, Granta Design©, to PE International© or CODDE©). However product models are usually centralized in a common model based on a standard model of data used to describe each component of the system. Information about the use stage are generally not included in the BOM (*e.g.* energy consumption), in particular if such information is not given by any supplier or other contract of any kind (*e.g.* leasing). Usage seems indeed hardly described by such a common product standard.

Complementary research have been published recently defining specific ontology, such as the Ontology Based Identification of Sustainable Options (OBISO) [4], or using existing ones, such as Model Driven Engineering based on Eclipse Modeling framework in FESTivE (Federate EcodeSign Tools mEthod) [5] to express and organize the information on the product spread across the experts' tools during product design. FESTivE is based on the federation approach of interoperability (*cf.* [6], and [7]addressing the different type of interoperability). Dynamic links are defined between different software based on different syntax. The information contained in those links deals with semantic interoperability between data that could have different meaning for different expertise. To generate data transfer the explicit links between the environmental impacts generated by design parameters and usage views must therefore be defined first. FESTivE, for example, supports the definition of such links through *knowledge transformation* mechanisms.

2.2. How use stage information are usually chosen today to model the product life cycle?

The information used to model use phase for life cycle purposes can be quite heterogeneous. Most of the time the model aims at representing average conditions of use and if possible it is based on a standard [8]. Analyzing the latest edition of the LCE conference, the following examples provide a good overview of current practices in research and in industry. Van Lieshout et al. used information from national surveys (US) to estimate water consumption for washing hands and dishes [9], while Bhakar et al. used recommendations from EPA mixed with manufacturers information [10]. For legislatives purposes, LCA in the preparatory studies for the European ecodesign directive implementation used various sources of information (such as phone surveys for refrigerators and washing machine), but none of them are tied to other design activities. Additionally, outsourcing data collection on usage can be resource intensive, leading to using "old data" to model current usages.

With an average scenario disconnected from current design activities, it has been difficult to propose eco-design improvements on the use stage. To overcome this, researchers have disconnected the improvement efforts from the assessment in approaches such as design for sustainable behavior [11]. They have been used in various design processes with relative success on improving use phase performance. In order to be aligned with life cycle thinking and ecodesign, Design for Sustainable Behavior (DfSB) requires to be reconnected to the other phases of product life cycle. Impact transfers can therefore be avoided.

2.3. Problem statement

Federation of design tools has been applied successfully to connect life cycle model for environmental assessment to design parameters from PLM or others design. Building on this approach, the research question is: **is there information on usage available during product design that can be transformed into explicit knowledge for the environmental expert:**

a. To construct the Life Cycle Inventory (LCI) of the product? And,

b.To fuel the eco-design effort across design experts?

3. Proposal

Considering this research problem a method is required to (a) improve information transfer between available sources on usage from various expert outputs to LCI (environmental expert inputs) – using *Knowledge transformation* [5], and (b) support the emergence of explicit environmental impact knowledge from LCA results adapted into feedbacks to design experts. A five steps process has been proposed:

Step 1 – *Describing* the coexisting usage information models from different fields into explicit knowledge.