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Design to Environment: Information Model Characteristics

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Abstract

Design to Environmental (DtE) proposes an environmental parameter optimisation among the other design parameters to support the emergence of ecodesigned products that bring environmental value to the society. Numerous information systems have been developed to support the integration of domain-specific parameters. However, it is still unclear how well they perform together in supporting the emergence of ecodesigned products. This research focusses on identifying the information model characteristics needed to change a conventional design process into a DtE process. A framework for industry to find out the proper information models that will support their DtE practice is proposed through a model-view-controller structure, accessed from an operational level. Supporting frequent environmental information sharing, encouraging environmental and product designers operational initiatives, as well as measuring the environmental performance of the DtE process through local operational indicators are fondamental characteristics required for supporting product designers and environmental expertise successful collaboration in DtE. The novelty of this research is to provide a clear method to industries to find out in their information system a environmental optimisation support.

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Keywords: Product design, Design to Environment (DtE), Design models, Ecodesign, Process modeling, Environmental indicators

1. Introduction

1.1. Introduction to Design To Environment

Design is an interactive and evolving process, complex by the requirements and constraints coming from several contextual aspects (*e.g.* society, legislation, industrial sectors), as well as materials, technologies and organisations. Among those, the environmental aspect related to all the lifecycle stages of the product/system under development requires a specific environmental expertise to be integrated. *Design[ing] to Environment* (DtE) supports an environmental parameter optimisation among the other design parameters through a systemic approach. In addition DtE envisages value creations as an opportunity to make DfX (X standing for environment [1], remanufacturing, upgrading, etc. [2]) focus(es) converge along the design process to improve the global product and service lifecycle environmental value. In this view this research considers the environmental parameter integration in the company across its strategic-tactic-operational layers [3]. This ensures a DtE coherency through performance indicators' alignment between: the medium to long term environmental strategy; the project managers medium term tactics; and the operational and short term design activities of product designers [4].

1.2. Paper's objective

Information models define in this paper any information system that would bring support to DtE practices (product lifecycle management and data models, ontologies, *etc.*). Envisaging this practice in the company's system this research focuses on finding the characteristics of the information models adapted to support the DtE operational practices, *i.e* involving product designers from various expertises including the environmental one (Section 2). Considering how numerous and diverse such models are a framework is proposed to structure such DtE supports across current information systems used in industry (Section 3). Based on the possibilities offered by existing information models Section 4 presents further work that will be conducted through a case study to illustrate DtE combining PLM and SE as an attempt to clarify the concepts and terms used in computer engineering semantics for product designers and the environmental expertise.

2. Research issue: which information models to support Design To Environment practices?

2.1. Design Process models structuring multidisciplinary collaboration

Several design process models have been proposed by the *engineering design* community, including mechanical design engineering and product designers, since the seventies of the

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last century. Generic design process models given by Pahl and Beitz (1984), Hubka and Eder (1984) provide a framework to integrate the multiplicity of expertises required to design a complex product lifecycle. In a DtE process the environmental considerations starts from the need specification in the earliest stage, followed by the definition of the required task and the related experts to be included (embodiment and detailed design stages from [5], *cf.* [6,7] detailing the DtE task integration in the process stages). Since then the emergence of a new process models have brought complementary focuses adapted for DtE which practice encourages business innovation [8]: from the first design stage Wilson (1980) considers societal needs integration, Urban and Hauser (1980) the identification of opportunities, Cooper (1986) the "ideation", Andreasen and Hein (1987) the need recognition, the problem recognition (Ray, 1985), the idea, the need, the proposal and the brief definition all together for Hales (1993), the market considerations are added with Pugh (1991), and Baxer (1995) introduces the innovation opportunity assessment [9].

Many other process models are indeed developed in other disciplines than mechanical engineering: PPS, Service engineering, building design, industrial design, system engineering, software design etc. They confer various characteristics that may be necessary to combine when supporting DtE practices. However considering this plethora of process models [14] shows that supporting interdisciplinary design (including DtE practice) cannot be eased through a consensus model of the existing discipline-specific models. Otherwise the very high degree of abstraction required will make those model loose their substance.

Numerous compatible models with product designers practices in industry have been developed to find a pathway toward interdisciplinary design (here ecodesign in particular). A set of 52 integrated models developed between 1994 and 2013 has been analyzed by [10]. An operational lecture of this analysis describes the currently used models in industry integrated:

- at a meso level dealing with the formal incorporation of environmental requirements in the product development process and portfolio management;
- at a micro level dealing with the implementation of customized ecodesign tools and integration of environmental aspects into project management: for *e.g.* in 2012 concerning problem solving [11], and choosing the environmental evaluation and integration tools within other design requirements [12], including the integration of 61 maturity assessment indicators in product development process practices, with a focus on operational practices [13].

This paper hypothesis is therefore that the characteristics found in ecodesign models required to perform DtE could be expressed by various information models from different disciplines, such as system engineering or software design. A clarification of categories of information models existing in industry supporting multidiscipline collaboration is welcome to propose in a second stage the suitable supports for DtE in a given context.

The envisaged method to that purpose would support product designers in combining the required characteristics of information models within existing ones in a given company to enable them practicing DtE.

2.2. PLM, PDM, SE, MBSE, ontologies, LCA, etc. for DtE?

To find out which information models characteristics are required it is first necessary to explore the most common ones used in companies.

Product Lifecycle Management. The PLM is an integrated approach supporting the collaborative management of the product's numerical lifecycle database on Information Technologies (IT). From an operational point of view the adoption of a PLM system by a company implies a multiplicity of IT solutions and tools to enable product designers from different expertise to share their distributed competencies along the design process. PLM are supported by Product lifecycle Data Management tools (PDM): to edit data (authoring), and to automate treatments or processes using workflows, *etc.*

System Engineering. The SE aims at providing a cooperative and interdisciplinary process of problem solving seeking to bring solutions to an operational need identified by measurable efficiency criterion. Solutions are meant to satisfy stakeholders' constraints, while optimising the environmental and economical cost within the whole system lifecycle. For instance if the company uses *Model Based Systems Engineering* (MBSE) [15] a complex system will be discretised into sub-components easier to interact with. Systems architects will therefore enable a certain type of collaboration between product designers by considering their different point of views related to subcomponents.

Ontologies. Ontologies have multiple purposes. They can be developed to generate a product model along its lifecycle: in specific lifecycle stages (*e.g.* oriented toward manufacturing [16]), with the focus to integrate several expertises together using knowledge based integration (*e.g.* product design and manufacturing interface [17]). Ontologies can be also combined with engineering tools to support DtE (*e.g.* sustainable product development [18]).

DtE and Life Cycle Assessment (LCA). The product functionality is central for product designers when specifying the product lifecycle requirements. The environmental impact indicators footprint (*e.g.* carbone dioxyde equivalent emission during lifecycle stages, the recyclability rate, *etc.*) are meaningful product performances if they are compared to a product reference (*e.g.* same product versions) delivering the same function. The International Organisation for Standardisation defining Life Cycle Assessment (LCA) method (ISO 14040-44 [19]) specifies the Functional Unit (FU) as a metric to compare product versions of equal functionality. The question of standardising functional units for product design is still under debate in the community of ecodesign experts [20]. For industries designing products concerned by the Environmental Product Declaration(ISO 14025 standard compliance) some *product category rules* are defined to practice DtE, in which the function delivered is central because a quantified input resource, and energy demand for its delivery can be assessed. The integration of such standardisations and its effect on DtE practices deserve to be deeply studied in ontology-based models for product configuration and product family developed at the moment in the community of SE (*e.g.* [21,22]).