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Integration of environmental assessment in a PLM context: a case study in luxury industry

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Abstract. Nowadays, the environment becomes a major issue in our society. It gives rise to regulations, market demand and stakeholder's pressure which are concerning companies. These latter have to reduce the negative impact of their new product by eco-design and adopting a continuous improvement for their existing product portfolio. To do so, environmental assessment system is needed. Life Cycle Assessment (LCA) is the most known and recognized. However, this method is complex, requires significant resources and a large amount of accurate data. We propose a methodology to connect a simplified LCA tool with PLM system and ERP to evaluate an entire product portfolio at any time. This will allow design teams to consider the environmental issues in early design phase and gives the companies a global vision of their product portfolio. This methodology is experimented with packaging products of luxury brand, using the Teamcenter PLM system and a Simplified LCA Tool.

Keywords: Simplified LCA, Product portfolio assessment, Eco-design, PLM.

1. Introduction

Nowadays, the environment becomes a major issue in our society [1-3]. Governments are key drivers for environmental and sustainable management practices. They may coerce actions trough regulations, and use fines and trade barriers. Companies have also to deal with Non-Governmental Organizations requirements, or risk a loss in their brand value and a negative impact on global marketing and production strategies [4]. But the central objective of a company to remain competitive is fulfilling customer needs, which are increasingly directed toward the social and environmental performance of a product [4]. These different stakeholders ask companies for environmental certificates such as ISO 14001 [5], FSC[1]

[1] *Forest Stewardship Council*: sustainable label for wood-based products, www.fsc.org

while products have to be developed quicker since the market requests new ones frequently [4].

In this context companies have to develop not only competitive products but to make them also more respectful to the environment [6]. They have to reduce the negative impact of their new product by eco-design and adopting a continuous improvement for their existing product portfolio. To do so, environmental assessment system is needed and Life Cycle Assessment (LCA) is the most known and recognized. However, this method is complex, requires significant resources and large amount of accurate data. Numerous researches propose Simplified Life Cycle Assessment (SLCA) tools which streamline the data collection. This make it more usable at the early stages of design with reliable results [7-9]. When companies need to establish carbon footprint report, eco-labels on their products or engaging continuous improvement actions, they first need a reliable environmental assessment of the whole product portfolio. However, it still requires important resources and data for big companies' portfolio, even by using SLCA.

In this paper, we propose a methodology to connect a SLCA tool with PLM and ERP systems. This will help to evaluate the entire product portfolio (existing and developing product) of luxury industry at any time.

After this introduction, the second section presents a brief review on eco-design tools and environmental PLM Systems. Section 3 proposes a methodology to connect SLCA tool to PLM/ERP system. This proposal is experimented in section 4, and further works and perspectives will be presented in section 5.

2. From eco-design tool to environmental PLM system

2.1. Eco-design tools

Eco-design is a methodology for designing products and services, which considers in particular the reduction of their environmental impact throughout their complete lifecycle, "from cradle to grave", without compromising other criteria like function, quality, cost and appearance. Several eco-design approaches have been studied and many tools and methods exist [10-11]. However their industrial use is still limited [12]. Some classifications exist but we took Janin's one which identifies two main categories of eco-design tools: Environmental assessment ones, and improvement ones that help designers to find eco-design solutions [13]. In this paper, we will focus our study on the assessment tool that we will connect to PLM system. They enable the comparison of the existing products, or a product against a norm, a recommendation, or even legislation. They also allow the identification of the weakest points of the product to find a path towards improvement [10]. Two main categories may be distinguished: qualitative and quantitative assessment tool.

Qualitative assessment tools. These qualitative tools, such as checklist and guidelines/rules, are the easiest to use and are among the most prevalent tools in

the industry, especially in SME. Checklist is a set of items used for quick assessing a product from the environmental perspective over its entire life cycle [10, 19, 20] as "are toxic materials used in the product?". Guidelines/rules can enhance the design process and ensure that the most important environmental issues and impacts are addressed. The most famous are the ten golden rules which are a highly generic guidelines adapted for product development process [16]. The enterprises can also develop more concrete and specific guidelines in relation to their own specific product development context [15]. These tools are developed particularly for the early stages of the product design. They can also be considered as "improvement tool" as they propose a way to reduce the environmental impact by focusing on one item [14]. However, challenge remains when trade-offs exists between different life cycle stages or different environment impact categories [14]. The proper use of these tools requires extensive experience and knowledge. Compared with quantitative tools, qualitative ones are more subjective.

Quantitative assessment tools. Many tools exist to evaluate the environmental impacts associated to product lifecycle but Life Cycle Assessment (LCA) is the most popular and recognized [2, 9]. It provides quantitative data on product environmental impact along its complete lifecycle: from the extraction and production of material to the end-of-life. Known as the most mature tool for eco-design [15], it has been formalized in the ISO series 14040 and implemented in various software tool [15]. LCA is divided into four phases: first, the goal and scope of the product assessment are defined as well as, the context, the boundaries and the environmental indicators. Then, Life Cycle Inventory (LCI) comprises the compilation and quantification of the input (energy, material) and output flows (emissions, wastes), for all the processes related to the lifecycle of the product under investigation. In the impact assessment phase, these flows are converted into ecological effects such as global warming potential, abiotic depletion, human toxicity and finally compared with the objective.

LCA represents an assessment and comparison tool for existing products [9, 13]. It assists decision-makers in industry by identifying opportunities for improving the environmental performance of a product and can also help governments and non-government organizations by the implementation of eco-labeling [6]. However, it is complex and requires expertise and it's also both time and resource consuming due the large amount of accurate data needed to perform it [7, 9]. We identified three LCA limits and some propositions to overcome them:

- **LCA is not applicable in the early stages of design**

Many existing tools based on LCA fail because they do not focus on design, but instead, they are set to a strategic management or a retrospective analysis of existing products [17]. A complete LCA can only be correctly used for a completely defined product where data about lifecycle are available and accurate. This data collection is also time-consuming. So LCA cannot be properly used in the early stages of design phases where many alternatives are studied and product lifecycle

data are incomplete. To enable early application as well as to improve overall use of LCA within design, less complex and data demanding, Simplified Life Cycle Assessment (SLCA) have been developed [9, 13, 23]. The simplification is related to data reduction either by excluding a lifecycle stage (use or end of life) and/or by reducing the complexity of the Life Cycle Inventory [7]. Then, it could be a source of error if it is not well parameterized or used by non-experts. So SLCA lowers the level of consensus among the scientific community because reducing the data inputs increases the level of uncertainty [6]. However, some method exist to manage the data quality of the inventory such as Pedigree Matrices [25, 26] which allow an easy identification of the inventory weaknesses. It is then possible to improve its quality by directly working on these data. SLCA estimates the environmental impacts of design alternatives according to product characteristics such as the type of material or the weight. Thus, SLCA method reduces the time necessary to run the LCA [9, 24] and makes it usable in design process to evaluate different alternatives.

- **LCA do not lead to eco-designed solutions**

LCA needs expertise especially to define the scope of the study or the relevant environmental indicators, and review their reliability. Designers have some difficulties to interpret the environmental results and to identify the product improvement areas [22]. This can be due to the lack of correlation between the environmental impacts and the product designer parameters such as material or manufacturing process [23]. If designers cannot use the method or interpret its results, the product cannot be eco-designed. Thus, it's important to create tools for non-expert users. That will to provide indicators which help designer to identify what product characteristics are the source of an impact in order to lead to eco-designed solutions. Then, human oriented interface is recommended [6]. The result indicators should be structured and flexible in a way to obtain easily selective, relative, absolute and environmental information linked to product characteristics.

- **LCA is not adapted for a global corporate vision**

When companies need to establish carbon footprint report that includes its product, eco-labels on their products or engaging continuous improvement actions [24], they first need a reliable environmental assessment of the whole product portfolio. But, LCA is both time and resources consuming and thus not usable for global portfolio assessment. The central problem for sustainable business alignment is to analyze, to optimize and to communicate on product portfolio with the least effort [6]. It is then necessary to find a way to perform global environmental assessments with limited resources at an acceptable quality level [24]. The intelligent use of existing digital databases as PLM, ERP systems, design tools and a good supplier relationship may streamline the data collection to obtain explicit and tacit environmental knowledge [5, 13]. The table 1 compares LCA and SLCA on selected criteria.

Table 1 Comparative between LCA and SLCA

Criteria	LCA	SLCA
Usable in early design phases	-	+
Lead to eco-design solutions	-	+
Results reliability	+	0
Global portfolio assessment	-	0

SLCA seems to be a good compromise to overcome most of LCA limits. The main challenges are to reduce complexity of product and portfolio data collection (inputs) and the indicators comprehension (outputs), while maintaining the main features and accuracy of a complete LCA. Then, it is important to study:

- Inputs: what type of information is required and how this could be collected.
- Outputs: what kind of results should be produced to help designers and how to manage their accuracy?

One way to simplify data collection is to connect SLCA with design tool as CAD or PLM system where product characteristics are included. Connection with ERP will then provide a global vision of the product portfolio.

2.2. Connecting PLM to environmental assessment tool

The results of industrial surveys identified CAD Geometric models as data reference, CAD, PLM and PDM systems as the most used tools during the design phase [9]. PLM is an approach in which processes are as important as data, or even more [25]. Thus, many authors agree that PLM is the key concept for the establishment of eco-design processes [4-6, 14, 27, 28]. The opportunity to influence a product's sustainable characteristics is prevalent in the design phase. The connection between PLM/CAD and sustainability might provide useful insights to a sustainable new product development approach [4]. This connection should be bi-directional [4, 23]. PLM supplies the necessary data for an LCA, which then ensures and evaluates the environmental character of a product. Different interoperability approaches have been studied to connect environmental with design tools. These can be defined following three distinct points of view [28]: integration, unification and federation. System structure will be easier to evolve on a federative way than on an integrative one, if one of the tools have to change [23]. This connection between environmental and design tools is one of the emerging challenges that design software companies, like Dassault Systèmes, have to face [29]. Here below are described existing software with their main functionalities and limits:

- **Module in CAD tool: Sustainability in Solidworks by Dassault Systèmes [29]**

It's an SLCA module integrated into CAD Solidworks. The user can choose the material and the main process so the tool will calculate environmental indicators.

However, it's often criticized because of its low accuracy [16, 22]. Morbidoni et al. proved its weakness comparing its results with those of a specialized tool [8].

- **Information transfer PLM (SmarTeam) – Environmental tool (EIME) [3]**

Compared to CAD, various relevant information can be extracted and imported from PLM into LCA software (mass, material, process, location…) [9]. It's also flexible since PLM data transfer can be customized according to the product context. However, only few studies explain how to customize and formalize the necessary information for accurate LCA [23] and it doesn't include global reporting.

- **PLM / CAD / ERP / environment platform: Environmental Data Workbench**

It is an integrative platform based on central standard model that connects design (PLM, CAD), ERP and environmental tools [21, 29]. It is able to create global corporate report such as material compliance or carbon footprint as well as "product environmental profiles". However, the environmental data are decontextualized since the link between environmental results and design parameters is lost.

- **Knowledge transformation between design and environmental tool**

This solution proposed by Rio et al. [23] is a federative system with flexible data exchange (knowledge transformation) between design and environmental tools used during the design process. It also keeps the link between design and environmental parameters. However, the formalization of the necessary information for reliable evaluation has not been studied.

2.3. Existing solutions limits

A synthesis of existing solutions based on the criteria defined in paragraph 2.1. is presented in Table 2.

Table 2 Comparative between different existing solutions

Criteria/System	Solidworks Sustainability	Smarteam EIME	EDW	Knowledge Transformation
Usable in early design phase	+	+	+	+
Lead to eco-designed solutions	+	+	-	+
Results reliability	-	0	+	0
Global portfolio assessment	-	-	+	+

However none of these tools or methods gives a reliable and time efficient product portfolio assessment.

Existing models prove the relevance of connecting SLCA with PLM system for eco-design and product portfolio assessment when connected with ERP system. However, few studies discussed the customization of the PLM which take into ac-

count the reliability of results, which also have to be usable by designer to lead to eco-designed solutions. In the following, we propose a methodology to customize PLM and connect it with SLCA tool and ERP system for (1) An environmental assessment in the early stages of design process. (2) Meaningful results without weighting on product design time: this will lead to trade-offs between reliability of SLCA results and the information that the design team has to provide. (3) Ensure that environmental factors remains manageable and environmental potentials for a product can be identified and influenced early. (4) A time efficient product portfolio assessment and reporting.

3. Proposed methodology and architecture

In order to connect PLM with SLCA tools and ERP system, we propose a four steps methodology (Figure 1).

- **Planning**

According to the environmental strategy of the company, the objectives of the assessment are established such as carbon footprint reduction or product labeling. This will define the scope of the assessment, the relevant environmental indicators and their level of accuracy, as well as the methodology to calculate them. A preliminary analysis of existing database and tools containing product lifecycle information (transport, sales, markets…) is recommended. Applying a complete LCA on some products could help to determine the relevant lifecycle stages. The system operators (users, administrators…) and system development team are defined. According to the objectives and the available data, the assessment scope can consider a part of the product portfolio and limit the lifecycle stages included. This planning step is an important input of the system design.

- **Definition of required elements**

For reliable results without compromising product design time, the level of information required is defined. It has to limit the amount of additional data that designers provide. The indicators depend on the objective and strategy. The results must be structured in a way to be usable by designers and decision makers. Uncertainty indicators can be used for decision-making. These results have to be duplicated and stored in the PLM as report to avoid computing time for global assessment.

- **System specifications and development**

Once inputs and outputs are outlined, this step defines the functional and technical specifications of different parts, modules and interfaces of the PLM system.

- **Deployment of the eco-design**

Creation of the tool is not sufficient. Relevant KPI, involvement of all design team and adapting the design process are also important to lead to eco-design.

A synthesis of this methodology is presented in Figure 1.

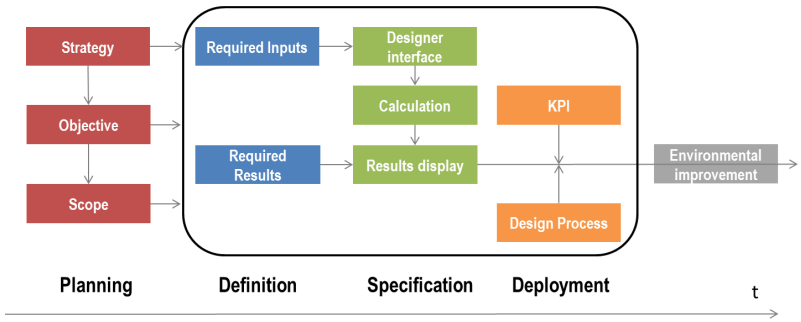

Fig. 1. Proposed methodology

The architecture resulting of the methodology deployment in an industrial luxury industry is an environmental assessment system able to deal with information already available in the PLM. We present it in the Figure 2. This architecture is based on three pillars: ERP, PLM and environmental expert tool. It can provide, thanks to SLCA module included in PLM, an environmental assessment at the early stages (filled arrow) or global assessment and reporting when connected with an ERP (empty arrow).

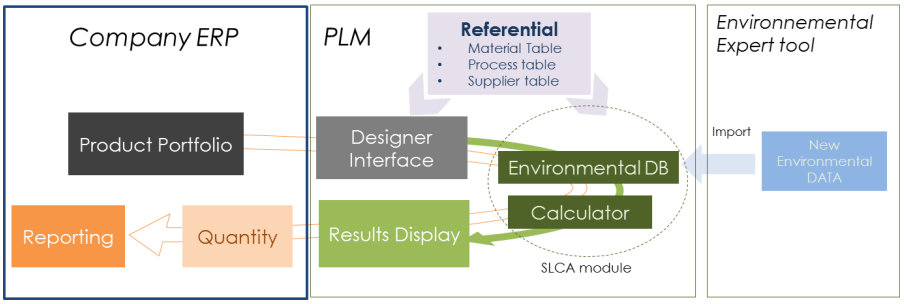

Fig. 2. Architecture to connect SLCA with PLM and ERP System

4. Case study

The methodology, previously described has been deployed in the context of packaging development in a luxury brand. This company is implementing Teamcenter PLM system of Siemens and the SLCA is a part of it. It should be underlined that Siemens integrates for the first time environmental assessment in their PLM system. This method has been conducted until the specification phase (Figure 1).

4.1. Planning

First, the aim of this integration is determined according to company's strategy. This will help the company to achieve different goals such as: Allowing new product eco-design by providing "usable" and reliable environmental assessment results at the early stages of the design process; answering to a potential environmental labeling program in discussion in the French and European scope, carbon footprint calculation, material compliance (REACH, RoHS…) and allowing a global vision of product portfolio to enhance improvement actions; system operators (users, administrators…) and system development team are defined to consider user's needs as well as IT and environmental constrains. Three complete LCA have been performed on three products and show that packaging is the main contributor on the selected indicators and helped to choose the relevant lifecycle stages. Regarding the scope, the products portfolio covers all the samples, tests, gifts and sales products. Only the packaging is taken into account and the formula is not yet included. This is about 1.600 references and more than 12.000 different parts. The lifecycle stages covered by the assessment are: Material extraction, manufacturing process, transports and end-of-life. The use phase and conditioning are not included since the formula is not yet considered

4.2. Definition of required elements

Some representative products are selected to run Life Cycle Assessment: typology, manufacturing technologies and suppliers. These analyses helped to define how the results should be presented to be usable. Besides, lifecycle inventories have been performed for each product to identify the environmental hotspot.

Required results. The environmental indicators should be adapted to objectives that companies have to fulfill such as carbon footprint or product labeling. As consequence, the environmental assessment needs to be connected directly (or indirectly) to the ERP in order to link individual product impact with the sales quantities (information not available in the PLM). At least three different environmental indicators need to be calculated for the product labeling a*biotic depletion*, *water consumption* and *global warming potential*. This latter indicator must be calculated in two different ways: the first for the product environmental labeling and the second for carbon footprint. These results will help designers to find areas of improvement for eco-design. So, the interface needs to give a strong detail of the origin of the environmental impact: component, lifecycle stage and the most important sources of impacts as well as total results with uncertainty indicators for decision-making. It is semi-quantitative to avoid computing time and rely on Pedigree matrices [25-26].

Required inputs for relevant LCA. In order to define the relevant level of information and data collection required, we perform different studies. The company has chosen to create a specific SLCA tool to perform their studies and use it pending the PLM development. All these assessments allow drawing some rules and defining data that need to be taken into account in order to have a relevant result.

These data, as material weight, was not already completely included in the PLM. Discussions in system development team leads to find the best way to integrate them without compromising data collection time, for example:

The part weight: The detailed weights were not capitalized by the design team while it is really important to evaluate environmental impact of manufactured parts. It has been added in the design interface for each element. This data could not be extracted automatically from other company's tools, so designer will enter it manually as CAD tools are not used internally.

Country where the part is processed: Accurate evaluations need the electricity mix: The impact of producing 1 Kwh which varies according to the country. We decided to get it indirectly from "supplier reference table" where the country will be informed. So the evaluation will be more precise without any consequence on the designer interface where only plant name will be selected.

4.3. System specifications and development

According to the input/output and the objective, the functional and technical specifications of the system are created. Modules, interfaces, referential, databases, information flow, calculation algorithm and data management are specified in order to collect all relevant data to perform SLCA at different stages of design phase. Validation is necessary on a case study before the launching for software development. The experimentation is currently in this phase. Once the software is ready it will have to be tested before the integration in real work environment.

5. Conclusion and perspectives

This article proposes a methodology and an associated architecture to connect PLM, SLCA and ERP in order to eco-design new products and get easily a product portfolio assessment. The necessary data for accurate results have been identified through several LCA studies on representative products. A qualitative indicator on reliability results has been set. The system results keep the link between the environmental impact and their sources from products characteristics in order to identify improvement areas. This methodology has been conducted as part of a project to implement Teamcenter PLM system in a luxury company for packaging products. This is a first time Siemens integrates environmental assessment in their system. It's currently in the specification phase and will be soon integrated. Other environmental tool will be considered as packaging recyclability indicators and specific guidelines-checklist. A further work could compare the results of the proposed evaluation system with complete LCA in order to find improvements. This methodology could also be enriched by including new functionalities to improve data collection by connecting CAD tools, web platform to collect data from suppliers and different design tools.

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