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A lifecycle-enhanced global manufacturing platform for enterprises

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Abstract

A growing interest toward the adoption of a lifecycle perspective in product design is characterizing current industrial trends. The cooperation of global manufacturing actors is fundamental to retrieve information from each lifecycle stage. From this background, a lifecycle based platform is proposed to efficiently set up feasible design configurations by including global manufacturing information. Starting from a set of input parameters, the idea is to collect lifecycle information in a customized XML structure in order to draw up the environmental profile. Such platform can also be adopted as an organized "knowledge repository" enhancing information sharing among the global manufacturing network.

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1. Introduction

Data sharing is worldwide considered as a crucial step forward, both in industry and research, as science is becoming more data intensive and collaborative [1]. Among the different fields of application, a particular focus is given to data sharing in the context of product design. Specifically, the level of competitiveness that characterises current market products asks for an efficient, reliable and flexible system to manage data. Such trend encourages corporates to collaborate at different levels by sharing data which try to "cover" the entire life cycle of a product [2][3]. Globally distributed manufacturing networks are characterised by the collaboration of different actors, which contribute with competences and experiences to the realisation of products. Such environment is of increasing importance for the sustainable competitiveness of companies in the global market and, moreover, the adaptation process is a growing challenge for the management [4].

The implementation of global manufacturing and data sharing frameworks within the eco-design context is the objective of the present research work. Eco-design, defined as a group of actions performed at the design stage which aim at reducing the environmental impact of a specific product, is also "taking the lead" in current European and International policies as the environmental "factor" is gaining importance due to recent climate issues. The idea of this paper is to convey the advantages of a collaborative data system with eco-design techniques and methods, with the aim to obtain a comprehensive overview of the environmental performances of a product, based on realistic information. Thus, data shared should focus not only on the manufacturing phase, but also on those that occur outside the manufacturer boundaries, namely raw material extraction, transport, distribution, use and End of life (EoL). This work would try to overcome issues coming from the advanced and complex domain previously introduced, such as lack of effective sharing instruments in order to anticipate the introduction of environmental issues. The objective is twofold: i) the definition of a structure to include life cycle data and ii) the design of a platform which enable an efficient transmission of life cycle information.

In the following section (section 2), the state of the art regarding data sharing and the implementation of eco-design techniques in product design is illustrated. In section 3, the platform framework and its relative characteristics are described. The implementation of the presented platform on a real case study is depicted in section 4, while conclusions and further steps are outlined in section 5.

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2. State of the Art

The transition to a sustainable development and the consideration of environmental issues during the design process requires the application of the Life Cycle Thinking (LCT) paradigm [5]. This can be reached by using different methodologies, but generally the most common and useful are Eco-design and Life Cycle Assessment (LCA).

Eco-Design applies at every stage in a product's life: raw material extraction, production, packaging, distribution, use, recovery, recycling, incineration, etc. [6]. It is considered as an intervention tool as it takes action during the design phase. Many tools supporting Eco-Design can be found in literature and different classifications have been proposed [7][8]. The most general one includes those tools that embrace a LCT approach, guidelines and diagrams [9], matrix based approaches [10] and checklists [11].

LCA [12], instead, is an analytical tool that serves to evaluate Eco-Design concepts. In other words, LCA examines consumption of resources materials, energy, water, land, emissions (to air, water and soil) and waste production at every stage of a product's lifecycle, and quantifies the related environmental impacts. The scientific community is largely populated with LCA applications as design supporting tool, in particular in the context of large companies [13].

The LCT approach is essential to avoid burdens shift, as it addresses the problem from a 360 degrees perspective. The major limit concerns the need of large amount of data, which come from inside and outside the company boundaries. Due to the unavailability of primary data coming from the Global Production Network (GPN), usually only internal data about materials and processes are considered. In addition, literature or referential data from standardized databases are used in order to reduce the complexity of the analyses and the required time and effort. Due to these simplifications the reliability of estimations is largely affected.

In scientific literature several research works focus on the different aspects of the GPN. Tchoffa et al. [14] presented an approach to combine model-based enterprise platform engineering, model-driven architecture and system engineering in order to address the establishment of a sustainable interoperability within dynamic manufacturing networks. Palmer et al. [15] presented a reference ontology to accelerate the development of new product-service systems considering all the information exchanged between the actors of the GPN. Schuh et al. [16] developed a software tool based on operation research optimization methods and genetic algorithms to design and evaluate production networks. Ferdows et al. [17] focused on the delayering of production networks into a set of congruent subnetworks with the aim to discover anomalies in the allocation of products, in the level of resources and in the location of productive plants.

Environmental and social sustainability of manufacturing networks is becoming an important research topic in the scientific community. Most of the literature studies focus on the correlation between operation and management of GPN and sustainability issues [18]. Borsato [19], instead, investigated how to overcome the interoperability issues between engineering and business applications and facilitate the use of lifecycle data. He proposed a reference ontology to enhance the data sharing and reuse. Despite the great number of studies about GPN, none is oriented to consider the influence of the manufacturing network during the design process, making available product lifecycle information.

Supply Chain Management (SCM) is another widely used approach to manage materials and information flows and increase the collaboration between supply chain stakeholders [20]. Over the last decade, the sustainability concept applied to SCM has received considerable attention in literature [21]. Sustainable Supply Chain Management (SSCM) is an extension of the traditional concept of SCM, where the aim is to maximize the value creation, adding environmental and ethical aspects [22]. In the context of SCM, the collaboration between stakeholders is recognized as an essential point to improve the overall sustainability performances of the entire network [23]. SCM is an operation management approach, very useful to select the most appropriate partners to involve in the GPN. However, it cannot be used during the product design to support the decision-making process.

From this literature review a lack of eco-design approaches and tools able to consider the entire GPN with the relative data emerged. The proposed global manufacturing platform aims to involve supply chain actors, together with EoL dealers in order to collect data on a lifecycle base. A high level of data sharing is considered as an important milestone to set a solid framework that contains structured data coming from different actors and describing each product lifecycle stage. The final objective is to implement a LCT approach, adding information without introducing extra effort for designers.

3. Global Manufacturing Network Platform

In this section the framework, overall structure and dataflow of the proposed platform are described in details. At last, an example of the expected workflow is given.

3.1. Platform architecture

In the most generic scenario, the company which trades a specific product is inserted into a virtual network where suppliers, distributors, EoL traders and transport facilities are included as well. The platform is design-oriented, therefore it is customised to deal with users which are familiar with design environment. However, in order to obtain more realistic results, data flows from complementary departments such as marketing, have to be included since their contribution has a strong influence at decision level. The context of use refers to a particular stage of the design process, commonly denominated "Embodiment design" [24]. At this stage, the design team has already defined the geometry of the assemblies and their components in accordance with the required functions. Technical drawings are available, however materials, manufacturing processes and further operations still need to be defined.

In addition a re-design scenario is also suitable since all the geometric and functional information are already available. In order to clarify the introduced concept, Fig. 1 illustrates the platform architecture on a detailed scale.