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Proposal of a toolset for the improvement of industrial systems' lifecycle sustainability through the utilization of ICT technologies

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ABSTRACT

The context where European manufacturers of industrial systems operate has dramatically changed over recent years, forcing them to revise their business models and including new leverages like sustainability. One way to pursue sustainability is to implement a product lifecycle approach, considering the costs and the environmental impacts generated along the whole lifecycle of the industrial systems. Life Cycle Costing and Life Cycle Assessment methodologies enable to pursue sustainability issues, however they present some gaps. Therefore, the aim is to propose a toolset for the improvement of industrial systems' lifecycle sustainability, through the utilization of ICT technologies, covering the gaps identified and hitting the industrial needs. The toolset is then applied to an industrial case and evaluated in a qualitative way via questionnaire.

1. Introduction

During the last years, the context where European manufacturers of industrial systems operate has dramatically changed. Low-cost pressure of emerging countries, more strict environmental regulations and new customers' needs have completely changed the market and the leverages that before regulated it.

In order to compete and survive in the global market, companies need to revise their business models, changing their paradigms and including new leverages like sustainability [3]. Indeed, sustainability is now considered a strategic must-have, because it enables a profitability in the long run and a competitive differentiation, hitting the customers' expectations [2].

One way to pursue sustainability is to implement a product lifecycle approach, enabling a more efficient and effective use of limited financial and natural resources [1,4].

In this context, European manufacturers of industrial systems have to identify the best lifecycle oriented solution, in order to satisfy the customers' needs and gain a competitive advantage in the years ahead on competitors.

Companies can be supported by methodologies already well known in the literature, such as Life Cycle Costing (LCC) and Life Cycle Assessment (LCA), performing cost and environmental analyses along the whole lifecycle for developing more sustainable products.

However, the above proposed methodologies have two main lacks: the first one is that LCC and LCA methodologies are very good in comparison and estimation, but when the number of alternatives increases, they are not able to support the decision in a good way. The second lack is about the accuracy of the estimation: to be more precise and accurate, LCC and LCA methodologies need to have real data from the field.

The aim is, therefore, to overcome the gaps identified, proposing the utilization of ICT Technologies, in order to improve the lifecycle sustainability (the industrial systems' costs and environmental impacts).

Section 2 shows the methodology applied for this paper, in order to achieve the proposed aim. Section 3 introduces the theoretical background about LCC and LCA methodologies, highlighting the identified gaps. Furthermore, Section 4 introduces the toolset based on ICT technologies, while Section 5 presents the industrial case where the toolset is applied. Finally, Section 6 presents the evaluation of the toolset via qualitative questionnaire, while Section 7 concludes the paper.

2. Methodology

Fig. 1 shows the methodology used, in order to conduct the research and to reach the aim of the paper. The first step was the

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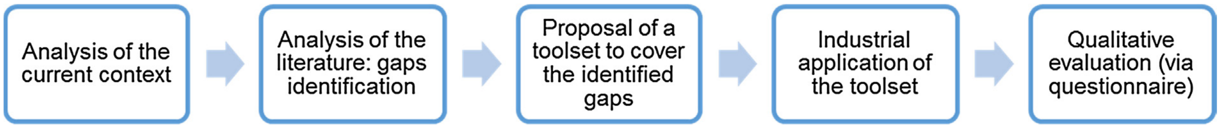

Fig. 1. Research methodology steps.

analysis of the current context where industrial systems' manufacturers operate, highlighting how sustainability could be a competitive leverage to be pursued and not only a need imposed by institutions. The second step was the literature analysis, focusing on Life Cycle Costing and Life Cycle Assessment, which are methodologies to hit sustainability issues. From this analysis some gaps have been identified. The third steps aimed to cover the gaps identified, proposing a toolset for improving the lifecycle sustainability, applying ICT technologies. Finally, the proposed toolset was implemented in an industrial environment and evaluated in a qualitative way via questionnaire, in order to collect feedback on it.

3. Theoretical background

Analyzing the literature, Life Cycle Costing (LCC) and Life Cycle Assessment (LCA) have been identified to support designers and estimate, respectively, costs and environmental impacts generated along the whole lifecycle.

Life Cycle Cost (LCC) can be defined as "the total cost of ownership of machinery and equipment, including its cost of acquisition, operation, maintenance, conversion, and/or decommission" [18].

On the other hand, Life Cycle Assessment (LCA) can be defined as "a tool to assess the potential environmental impacts and resources used throughout a product's lifecycle, i.e. from raw material acquisition, via production and use phases, to waste management" [13].

LCC and LCA methodologies have some limitations. The first one is that these methodologies are good in comparison and estimation of few products or alternatives; however, when the number of alternatives increases, they are not able to support decision makers in a good way. For an industrial system, composed by hundreds of different products or components, each with some alternatives, LCC and LCA methodologies are not sufficient to identify the optimal lifecycle oriented solution. Combining these methodologies with algorithms or mathematical methods, it is possible to create and identify optimal lifecycle oriented solutions. The second limitation is about the accuracy of the estimation: to be more precise and accurate, LCC and LCA methodologies need to have real data from the field. Indeed, these methodologies usually work with estimated data, instead of real data. In order to solve this limitation, it is necessary to enable the collection and use of real data by LCC and LCA methodologies.

Furthermore, designers have been identified as the main actors involved onto LCC and LCA methodologies, due to their high influence on lifecycle costs and environmental impacts. Indeed, different empirical researches [6,10,14,17] have been conducted to evaluate which is the percentage of lifecycle cost or lifecycle environmental impact influenced during the design phase, identifying how product design represents only 5–10% of the total cost, but it is able to influence up to 80% of lifecycle cost. The same consideration, about lifecycle environmental impact, is reported by [19].

4. Proposal of a toolset for the improvement of industrial systems' lifecycle sustainability

In order to cover the gaps previously identified, this chapter proposes a toolset for the improvement of industrial systems' lifecycle sustainability, using ICT technologies.

The toolset is composed by 2 tools:

- *Life Cycle Optimization Tool*. It is a tool for the creation and identification of the optimal lifecycle oriented configuration, defining those components of an industrial system that minimize lifecycle costs and lifecycle environmental impacts, according to technical constraints. The tool enables the comparison of different technological solutions (e.g. for an assembly station there can be automatic, semi-automatic or manual stations).
- *Life Cycle Data Tool*. Its potentiality is the elaboration of data collected from the field, from the different sensor installed along the whole line, in order to return useful data for designers and system engineers. At a practical level, Life Cycle Data Tool is able to collect data importing *.csv files from PLC of the different stations/machines or using new QLM language.[1]

The toolset covers the so called Beginning of Life (the design phase), through the Life Cycle Optimization Tool, and the Middle of Life (the use phase), through the Life Cycle Data Tool. End of Life (dismissal or recycling/remanufacturing phase) has not yet been considered.

Fig. 2 shows how the toolset can be integrated into the process. The industrial system manufacturers usually receive a request for tender by the customer, which also provides technical requirements of the system (life span, cost's and environmental impact's voices to be considered, minimum performance, etc.). To send to the customer a tender, first of all the supplier has to define the bill of process, in order to satisfy the customer needs (the product/s that the customer has to manufacture). Defining the bill of process, the supplier knows which kind of stations/machines it needs to realize the industrial system, and the possible alternatives for each station. Therefore, the supplier has to prepare the costs, the environmental impacts and the performance voices, combining its data with those provided by the customer. After the "data preparation phase", Life Cycle Optimization Tool can be used. Inputs of the tool are the data previously calculated. Output is a set of optimal lifecycle oriented solutions. Supplier's designers can choose which solution to propose to the customer. If the tender is won, the system is realized and installed at the customer plant. During the use phase of the system, Life Cycle Data Tool can be used, enabling the monitoring of the system and the collection of data from the field in a structured and useful way.

Next sections present Life Cycle Optimization and Life Cycle Data tools, showing more details and highlighting their logic and implementation.

4.1. Life Cycle Optimization Tool

4.1.1. Logical model

In [7] a model for the multi-objective optimization of lifecycle costs and lifecycle environmental impacts has been proposed.

[1] http://www.opengroup.org/getinvolved/workgroups/iot.