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Management tool design for eco-efficiency improvements in manufacturing – a case study

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Abstract

As the worldwide GDP is forecasted to double by 2035, the energy demand globally is expected to increase by 34%. The industrial sector is also expected to account for more than 30% of the primary energy demand by 2040. These projections make manufacturing operations even more complicated when combined with predicted long-term inflation of raw material prices and increasingly stringent environmental regulations. Therefore, it has become increasingly more challenging for practitioners in manufacturing to improve their eco-efficiency or to "do more with less". Traditional manufacturing management tools based on lean principles such as Value Stream Mapping have not been designed to facilitate eco-efficiency improvements. On the other hand, environmental management tools such as Life-Cycle Analysis focus more on improving environmental impacts rather than financial sustainability. This paper addresses the design gap between these tools and proposes an integrated toolkit for eco-efficiency improvements. The toolkit development process and design principles are described through a case study in the flooring industry. Results from each module are validated and the overall output is used to propose a range of applicable solutions to the manufacturer.

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1. Introduction and research objectives

As natural resources scarcity and environmental concerns become more and more urgent on the world scene, manufacturing emerges as a key area to address environmental pollution and usage of raw materials [1]–[3]. Aligned to the World Business Council for Sustainable Development (WBCSD), this study falls under the working area of eco-efficiency or as it is generically defined "doing more with less" [4]. Within this subject area, various frameworks have been proposed that intend to operationalise eco-efficiency at manufacturing level. The focus in this work is the design of tools that may facilitate and accelerate eco-efficiency improvements.

Nomenclature

LCA	Life Cycle Assessment
SVSM	Sustainable Value Stream Mapping
EVSM	Environmental Value Stream Map
ERFMI	European Resilient Flooring Manufacturers Institute

2. Literature review and research gap

The authors observe a trend in literature to combine existing tools that enhance productivity with tools that enhance environmental performance [5, 6]. Verrier, Rose and Caillaud [7] analysed the most effective "Lean and Green" tools: Value Stream Mapping (VSM), Visual Management

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and Key Performance Indicators. The attractiveness of application of the VSM tool to analyse environmental wastes is a recent research endeavour as the first attempt was undertaken in 2002 [8] by Simons and Mason who proposed a method named Sustainable Value Stream Mapping (SVSM). In that study, the authors aimed at reducing the green-house gas emissions in a supply chain but did not include other important environmental indicators such as water, material and energy usage. In 2007, the United States Environmental Protection Agency [9], aimed to standardise the use of the SVSM in a toolkit which integrates Lean and Environment practices in order to facilitate the identification and measurement of environmental wastes. The study includes material and water usage and provides several industrial cases but does not cover energy consumption. Acknowledging this gap the US EPA proposed a second toolkit aiming at integrating energy goals in the SVSM.

Fearne and Norton [10] enhanced the methodology developed by Simons and Mason to analyse the waste in the UK chilled food sector adding indicators regarding material waste, Green House Gases (GHG) emissions and water use. The same authors also used the methods indicated in the LCA procedure by Guinee to attribute values when the allocation was uncertain. The study used the energy as a mean to calculate the CO2 emissions but failed to not take into consideration the environmental impacts of the raw materials production. Moving forward, Faulkner et al. [11] applied SVSM at a satellite-dish manufacturer, for the first time separating the amount of energy used in processes from the one used in distribution. The study was then taken up and enhanced by Brown, Amundson and Badurdeen [12] as they successfully applied the framework in three different manufacturing systems in terms of volume and product range. However, the authors focused on validating the method of Faulkner et al. [11] without taking further the energy mapping. The energy mapping was improved by Müller, Stock and Schillig [13] as they aim at optimizing the value-stream on two levels:

- Machine level: include rump up, production and idle time.
- Transportation: include the inbound and outbound transportations.

Their study fails to provide a real case study for the application of the extended transportations value-stream. Instead, Bogdanski et al. [14] and Schlechtendahl et al. [15] concentrate solely on the machine levels. Lastly, Alvandi et al [16] use discrete event simulation to model multi product environment and overcome the static nature of the VSM. With regards to the use of additional tools combined with VSM, Paju et al [17] indicate the use of life-cycle analysis (LCA) and discrete even simulation that could feed the map with more data. Vinodh, Ben Ruben and Asokan [18] use LCA to complement the mapping of automotive component process with the environmental impacts of the various process steps.

Torres and Gati [19] recognised the need to combine the SVSM with additional tools to analyse alternatives and future scenarios. Following up from this study, the authors observed that the referenced VSM-based studies do do not follow a tool design approach for the tool development phase. Little attention is also paid to the way that the tool can be used by practitioners and how practitioners can generate and prioritise improvements. According to Ilevbare et al., the creation of a business tool takes place in two stages: an initial framework or sketch of the intended tool and what key outputs are expected from the tool (figure 1)[20].

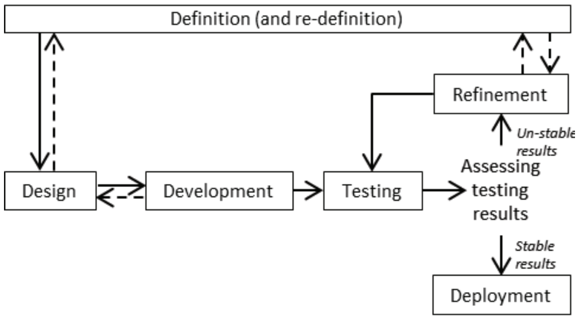

Fig 1. Management tool design process according to Ilevbare et al. [20]

Ilevbare et al. [20], suggest that the tool needs to be efficient for the user (e.g. an SME as opposed to a multinational) and satisfy two principle conditions:

1. *"On the one hand, this means that it can be successfully applied within the capabilities and resources available to the target user group.*
2. *On the other hand, the tool should be sufficiently sophisticated to align itself with the level and breadth of analysis that is seen as the norm for such a business (e.g. the use of simulation software in a multinational versus the use of simple charts and templates in a micro-sized firm)*".

In this study, the process by Ilevbare is followed to develop a type of SVSM that can map energy and material usage (more than time) applied in the case of a flooring manufacturer in the UK. The authors produce a sketch of the tool's internal functions and propose a way of using it through the case study. The novelty of this work lies in the internal functions of the tool. Ways to inform the tool with existing data are described as well as ways of prioritising improvements.

Finally, the authors argue that tools such as VSM and LCA are designed to drive economic and environmental performance respectively. By further expanding the utility of VSM, as illustrated by other authors, with environmental management capabilities, companies can reach higher eco-efficiency levels [21]. Nevertheless, the design principles that need to be obeyed are subject to review in this work.

3. Case study and tool development

The company where this study took place is a leading flooring manufacturer in the United Kingdom. It is a large size company with worldwide presence that offers a diverse portfolio of PVC-based products (floor and wall coverings). Three years prior to the case study, the company initiated lean and green improvement efforts and aims to a six-fold revenue growth in by 2035. The aim of the improvement strategy was to support the 2035 vision but also to further reduce its environmental impacts. One of the key challenges had been to understand what areas of improvement should attract their