A Manufacturing Value Modeling Methodology (MVMM): A Value Mapping and Assessment Framework for Sustainable Manufacturing

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Abstract. Sustainable manufacturing is becoming increasingly important. This requires sustainable industrial system different to today's global industry with different business models, creating different products and services requiring new strategies, frameworks, and tools. The evolution towards a 'sustainable' industrial production systems requires a holistic approach, with a fundamental reassessment of the value creation. In order to achieve this target a system design approach is required. In this paper an existing and specific Manufacturing Value Modeling Methodology (MVMM) is used as a value mapping framework to help firms in creating value propositions better suited for sustainability considering economic, environmental and social perspectives. Concerning sustainability, implementing it into the MVMM requires the setting of a catalogue that presents an overview of sustainable external and internal impact factors and a mapping between them in order to translate business goals into manufacturing strategy, and allows to improve operational performance by adopting a set of sustainable industrial practices.

Keywords: Industrial sustainability · Value modeling · Value mapping

1 Introduction

Industrial sustainability is a capability that allows to achieve competitive advantage through the increase of material efficiency, energy saving, closed-loop control at industrial system level, and through the increasing competitiveness by improving economic, environmental and social performance (Demartini et al. 2016). Some companies are making progress toward the next frontier of sustainability, data from the past five years shows that many organizations are struggling to move forward (MIT Sloan Management Review). In fact, addressing significant sustainability issues has become a core strategic imperative that these companies view as a way to mitigate threats and identify powerful new opportunities. Like any business issue, addressing important sustainability issues requires specific, hard-wired organizational support, capabilities, and measurement.

G. Campana et al. (eds.), *Sustainable Design and Manufacturing 2017*, Smart Innovation, Systems and Technologies 68, DOI 10.1007/978-3-319-57078-5_10

As highlighted by Smith and Ball (2012), achieving sustainability in manufacturing requires a holistic view spanning product design, manufacturing processes, manufacturing systems, and the entire supply chain. Such an approach must be taken to ensure the economic, environmental and societal goals of sustainability are achieved. Hence Authors decide to focus their attention on sustainability both as a competitive and strategic dimension in the manufacturing environment with respect to value modeling and mapping. Thus, the purpose of this paper is to present an overview regarding sustainability trends, implications and possibilities that affect the manufacturing company and supply chains, and leading a review in order to analyze the existing body of literature on value mapping tool for industrial sustainability, with the aim of creating a catalog that allow to mapping different dimension of industrial sustainability (economic, environmental and social).

Related works in the context of this paper consist of two research domains. On the one hand, there is the research regarding Industrial Sustainability and on the other hand the one on value modeling and mapping already addressed in (Taticchi et al. 2013; Taticchi et al. 2015; Tonelli et al. 2016; Taticchi et al. 2012) within the Manufacturing Value Modeling Methodology. Both domains are crucial for implementing a proper sustainability catalog; the research on industrial sustainability is important for the creation of the underlying sustainability model, while the research on manufacturing value modeling is seen as a key influencer towards constructing the framework for identifying the correct sustainability demand. Authors, report a qualitative literature review on value mapping framework for Industrial Sustainability in Sect. 2, then present the Sustainability Framework itself, with an overview on external and internal impact factors of Industrial Sustainability in Sect. 3. In Sect. 4 the mapping between the external and internal factors of the Sustainability Framework is presented. Finally, Sect. 5 shows the consequences and issues of the Authors' work and conclusions are discussed.

2 Qualitative Literature Review on Value Mapping Framework for Sustainable Manufacturing

The qualitative literature review has been performed using classic bibliometric techniques. The methodology used is a literature review based on an electronic search in "Scopus", the Authors interrogated the database searching for ("Value Mapping") AND ("Industrial Sustainability") AND ("Manufacturing"), in the titles, abstracts and keywords of papers published between 2000 and 2015. The interrogation resulted in 74 papers that constitute the base of further analysis. The earliest paper included in the dataset was published in 2002 and the most recent in 2015.

The distribution of publication per journal is made up of six journals where research has been published. Journal of Cleaner Production, IFIP Advances in Information and Communication Technology, International Journal of Operations and Production Management, International Journal of Advanced Manufacturing Technology, International Journal of Lean Six Sigma and TQM Journal lead the ranking with 5, 5, 3, 2, 2 and 2 publications, respectively. The most prolific scholars are Rana P., Badurdeen F., Bocken N., Chiarini A., Evans S., Short S. with 4, 3, 3, 2, 2, 2 publications, respectively. Instead, about the geographic diversity of scholars is relevant to note the leadership of

European academic institutions that contribute for 50% to the research field development. Moreover, there is an emerging contribution of scholars from India and Brazil. This suggests the relevance of this topic also for emerging countries. Further, the frequency of publications over time highlighting a research field that is growing very fast. The top three keywords are "Sustainability", "Value Stream mapping" and "Lean". It is apparent from the literature that most approaches for progressing towards sustainable development are generic and high level, this has been confirmed by Smith et al., that highlight a lack of guidance and tools for manufacturers to identify improvement opportunities within their own factories. Bocken et al., propose a value mapping tool that takes a multi-stakeholder perspective and considers different forms of value, such as value captured, value missed, value destroyed, and new value opportunities. Paju et al. introduced a new methodology termed sustainable manufacturing mapping (SMM) which incorporates discrete event simulation (DES) and life-cycle analysis (LCA). For Fearne and Martinez Value Chain Analysis tools need to adopt more holistic sustainable perspectives. These include addressing external factors, such as health, environmental damage and poverty, which can offer opportunities for a chain to create shared value (Porter and Kramer 2011).

For Schaltegger and Burritt, opportunities mostly originate from management decisions of the focal company. This requires both knowledge about sustainability problems, ranking of possible solutions and the assessment of consumer expectations and market strategies to make sure that the most sustainable product offering becomes a market and business success.

Other works have utilized tools such as Value Stream Mapping, discrete event simulation, and value network mapping to model the current state as well as future state maps in complex environments (McDonald et al. 2002; Lian and Van Landeghem 2002; Irani and Zhou 2003; Braglia et al. 2006). To summarize, existing tools generally tend to focus on just one dimension of sustainability, and fail to engender a holistic perspective that incorporates all three dimensions of sustainability within the business planning process (Bocken 2013). Futhermore, the literature review highlights the necessity of a tool that includes both an assessment of the sustainable external factors, and the company strategy. To identify these perspectives, we propose one approach in order to highlighting the relationships between various principles, strategies, issues, through what Authors named hierarchical Manufacturing Value Modeling Methodology (MVMM) (Tonelli 2016), it allows to assist firms in better understanding sustainable value creation within their business activities, and assist them in developing new strategies with sustainability at their core.

3 Sustainability Framework

The scope of the Authors' work is to provide a guide for manufacturing companies, in order to understand what sustainability trends and drivers are fundamental to the manufacturing environment and a set of KPIs that allows firms to control and monitor the reaching of these goals. The sustainability catalog combines these two approaches by using the MVMM, in order to include internal and external influence factors analyzing them with respect to the triple bottom line approach. The sustainability catalogue starts

from the core concept of the MVMM, using the structure of external influence factors (Manufacturing Challenges), internal influence factors (Manufacturing Objectives and Sustainable Industrial Practices) and also applies the value map by using the aforementioned contents, and the concept of relationships between the value map items (Fig. 1).

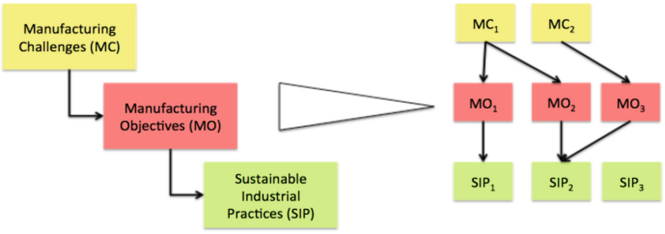

Fig. 1. Example of relationships between the value map items according to the MVMM

3.1 External Factors

The external view represents Manufacturing Challenges (MC) as shown by Table 1, where sustainable challenges that have an impact on the manufacturing environment are reported. This section gives a background on the challenges associated with embedding sustainability

Table 1. Manufacturing Challenges

External factors: MC	Sustainable dimension
Higher production flexibility and re-configurability	Economic
Highly variable and difficult to forecast market conditions	Economic
Increase in productivity	Economic
Need to enhance specific competences and skills	Economic
Need to manage dynamic and complex business networks	Economic
New models of collaboration reshoring-offshoring-nearshoring	Economic
Products to satisfy the demand for comfort, health and wellbeing of specific target groups	Economic
Pervasiveness of internet	Economic
Reduce energy consumption	Eco-Environmental
Exploitation of energy from waste and scrap	Environmental
Increase in urbanization - integration of industry in urban context	Environmental
Increase the resilience of industry to global warming and climate change (on production, procurement and markets)	Environmental
Manage environmental changes due to exploitation of farmland, deconstruction of infrastructure and urbanization	Environmental
Need to recycle components and products	Environmental
Reduce pollution in air, ground and water through improved environmental sustainability	Environmental
Use of alternative energy sources in manufacturing	Environmental
Change in the interaction with the individual (customer, worker, citizen)	Social
Growth of a new middle class at global level	Social
Increase the worker well-being in terms of high satisfaction, safety and inclusivity	Social
New forms of employment	Social
New services tailored on the people	Social
Growth of emerging countries (production and consumption)	Socio-Economic

into corporate performance management, these contents are derived from various roadmap: Factories of the Future (EFFRA), Vision 2020, Pathfinder, Cluster Fabbrica Intelligente (CFI). Examples of MC could be for instance Manage environmental changes and/or Reduce energy consumption. Due to the different markets in which companies operate, the MC might vary from scenario to scenario and related industrial context. There might be MC, which are globally valid, while there are also MC which are only true for a certain branch or industry, then it is important to study the environment of the company and the domain in which it operates in order to identify a valid set of MC. The external view is followed by the analysis of the internal process and strategies.

3.2 Internal Factors

The internal influence factors are used to represent the sustainable goals and strategies of the manufacturing company. Different internal influence factors could be identified as:

- Manufacturing Objectives (MO): describe the company strategy in terms of sustainable opportunities and issues (Table 2).

Table 2. Manufacturing Objectives

Internal factors: MO	Sustainable dimension
Client satisfaction (21)	Economic
Decarbonisation of the global energy system (22)	Environmental
Energy efficiency (23)	Economic & Environmental
Increase recycling rates (4)	Economic & Environmental
Increase usage of renewable resources (24)	Economic & Environmental
Material Efficiency (22)	Economic & Environmental
Minimize emissions to land (25)	Environmental
Minimize impact on species (21)	Environmental
Minimize water usage (28)	Economic & Environmental
Reduce usage of raw material (21)	Economic & Environmental
Reduction of air emission (27)	Environmental
Safety (21)	Social
Waste Reduction (17)	Economic & Environmental
Client satisfaction (21)	Economic
Decarbonisation of the global energy system (22)	Environmental
Energy efficiency (23)	Economic & Environmental
Increase recycling rates (4)	Economic & Environmental
Increase usage of renewable resources (24)	Economic & Environmental
Material Efficiency (22)	Economic & Environmental
Minimize emissions to land (25)	Environmental
Minimize impact on species (21)	Environmental
Minimize water usage (28)	Economic & Environmental

- Sustainable Industrial Practices (SIP): as a set of planning practices, production, purchasing and logistics aimed to incorporate a sustainable perspective in operations (Table 3).

Table 3. Sustainable Industrial Practices

Internal factors: SIP	Description
Ecodesign (17)	It is treated as the designing phase of product life cycle. It is based on Life Cycle Assessment that is a technique that summarizes the quantification of the environmental consequences of products and services
Green Supply Chain (GSC) (18)	GSC is viewed within the planning and sourcing phase of the product life cycle. GSC can be understood as sustainable operations practices together with suppliers and/or customers covering project design, selection of raw materials, selection of suppliers, green purchasing, packaging and logistics
Cleaner Production (CP) (19)	It refers to the production phase. It represents the application of an economic, environmental and technological strategy integrated with the processes and products in order to make them more efficient
Reverse Logistics (RL) (20)	RL refers to the management of waste related to the consumption of manufacturing products. Reverse logistics can be understood as the return process of moving goods in order to capture value or give the appropriate destination

3.2.1 Manufacturing Objectives

After the market related view, the MVMM suggests reviewing the MO. The goal thereby is to identify the strategy of the company and the goals that are used to achieve this strategy. Hence the aim of the sustainability catalog is to analyze the sustainability in the production process. Nonetheless when analyzing the strategy, it is also mandatory to understand the overall business strategy, since the production strategy should fit to the overall strategy of the company. The goal of this step is to set up a goal system that should identify the important areas, which have to be addressed.

Especially these two first steps of identifying the external influences, through the MC and the internal influences trough MO and SIP are mandatory for the sustainability catalog because assessing the market view as well as the internal manufacturing process related view are crucial for identifying the causes behind a certain sustainability demand. After identifying the Manufacturing Challenges and Objectives, it is important to further specify the context in which the sustainability demand occurs with the analysis of the Sustainable Industrial Practices.

3.2.2 Sustainable Industrial Practice

The identification of the context consists of selecting the correct functional areas or practices, which need a detailed analysis. Due to the focus on production, these practices are the functional areas in the manufacturing operation management domain. In this section Authors starting from this point analyze the manufacturing strategy, focusing on sustainable industrial practices in order to bring out the alignment of manufacturing strategy with business strategies. Table 3 shows the definition for each practice:

4 Contents Mapping of the Sustainability Framework

From a value modeling point-of-view, capturing the environment of the given scenario by identifying the external and internal influence factors and mapping them is necessary to find which domain specific market trends fit to which domain specific project targets. Besides the general description of the sustainability framework, it is mandatory to explain the application of the catalog itself. Since the general approach is derived from the MVMM approach it is also possible to create relationships between the different components. Generally speaking there is the possibility to create a relationship between external influence factors (Manufacturing Challenges) and the business strategy (Internal factor) that is used to tackle them. This means there is a certain set of internal influence factors that fit to a certain external factor (Table 4).

Starting with the results of these analyses, it is possible to highlight which thematic areas concerning the MC do not find a mapping with key strategic objectives. These themes, which need to be investigated more in depth, manly concern three aspects:

- New emerging markets (Highly variable and difficult to forecast market conditions, Need to manage dynamic and complex business networks, New models of collaboration reshoring-offshoring-nearshoring, Need to enhance specific competences and skills of each geographical area): increase the number of manufacturing companies strategically involved in innovation activities to cope with increasingly uncertain and unpredictable market conditions through the improvement of specific territorial skills;
- Demographic change (New services tailored on the people, Products to satisfy the demand for comfort, health and wellbeing of specific target groups): improve the social impact, making manufacturing jobs more attractive, in terms of greater safety, inclusion and personal achievement, and improve the integration of industry in an urban context that is constantly expanding to satisfy the specific demands of consumer comfort, health and well-being;
- Technological acceleration (Increase in productivity, Pervasiveness of internet, Change in the interaction with the individual (customer, worker, citizen)): increase R&D investments in the manufacturing sector exploiting the opportunities offered by technological acceleration linked mainly to the development of new technologies, the integration of advances technologies and the pervasiveness of the Internet and mechatronics.

Differently, the Manufacturing Challenges factors that are better reflected among the Manufacturing Objectives, are related to all the activities concerning the management of resources and environment: reduce the environmental impact by reducing the emission of greenhouse gases resulting from manufacturing activities, the reduction of energy consumption and of materials deriving from manufacturing activities, the reduction of waste produced by manufacturing activities and the creation of eco-products and eco-technologies.

5 Conclusions and Future Developments

Author's purpose was to examine evidence of Value mapping framework for industrial sustainability, it has been realized a structured Sustainability Catalogue within the Manufacturing Value Modeling Methodology allowing to translate sustainable trends and goals into manufacturing strategy, improving operational performance.

Companies should move away from using the traditional techniques that focused only on cost minimization and efficiency improvement to those that also take into account the environmental and societal implications of operations. It is growing ever clearer that it needs action at material, product, process, plant and system of production levels. As a result, sustainability decisions become an integral part of business decision making, the business planning cycle, and customer/supplier relationships. The sustainability catalogue is a hierarchical approach that seek to integrate consideration of the three dimensions of sustainability (economic, environmental and social) in a manner that align company and manufacturing strategy and create value for all stakeholders including the environment and society. There are some limitations to the sustainability catalogue, the model is largely qualitative, it does not allow for detailed quantitative analysis. Besides it needs to be validated with real case in order to verify and improve the catalogue. More tests are planned to further understand the applicability and suitability of the tool in different contexts. Finally, it is evident that this area still requires significant investigation at the operational and strategic levels, the framework provided will guide industry and supply chain sustainable progress and improvement.

Appendix

Table 4. Mapping between external/internal factors

External Factors: Manufacturing Challenges	Internal Factors: Manufacturing Objectives												
	Client satisfaction	Decarbonisation of the global energy system	Energy efficiency	Increase recycling rates	Increase usage of renewable resources	Material Efficiency	Minimize emissions to land	Minimize impact on species	Minimize water usage	Reduce usage of raw material	Reduction of air emission	Safety	Waste Reduction
Higher production flexibility and re-configurability			X	X	X	X	X		X	X	X		X
Highly variable and difficult to forecast market conditions	X												
Increase in productivity													
Need to enhance specific competences and skills													
Need to manage dynamic and complex business networks													
New models of collaboration reshoring-offshoring-nearshoring													
Products to satisfy the demand for comfort, health and wellbeing of specific target groups	X											X	X
Pervasiveness of internet													
Reduce energy consumption			X										
Exploitation of energy from waste and scrap		X	X	X	X	X							
Increase in urbanization - integration of industry in urban context	X				X		X	X			X		X
Increase the resilience of industry to global warming and climate change		X					X						X
Manage environmental changes due to exploitation of farmland, deconstruction of infrastructure and urbanization		X					X						X
Need to recycle components and products					X	X				X			X
Reduce pollution in air, ground and water through improved environmental sustainability		X		X			X	X			X	X	X
Use of alternative energy sources in manufacturing		X	X	X	X	X							
Change in the interaction with the individual (customer, worker, citizen)	X											X	
Growth of a new middle class at global level								X			X		X
Increase the worker well-being in terms of high satisfaction, safety and inclusivity					X		X	X			X	X	
New forms of employment													
New services tailored on the people	X												
Growth of emerging countries (production and consumption)									X		X		X

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