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Integrating sustainability indicators and Lean Manufacturing to assess manufacturing processes: Application case studies in Brazilian industry

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ABSTRACT

Operation management models have been developed according to changes in society's demands, such as better working conditions, clean production, recyclable and reusable products, and improving social conditions. Thus, new challenges in developing sustainable management models, particularly for manufacturing processes, have emerged. Lean Manufacturing and Value Stream Mapping (VSM) have been widely used to develop manufacturing processes without wastes in the production flow. However, current indicators of the VSM tool have not identified the economic, social and environmental factors. This work aims to propose a conceptual method to integrate a new group of sustainability indicators into the VSM tool to assess manufacturing processes. The development of sustainability indicators was performed through analysis of the assessment models of sustainability and sustainability indicators in the period of 2009–2014. The method was applied in three case studies, and the results demonstrated that the proposed method identified different levels of sustainability of manufacturing processes and thus enabled the development of improved scenarios. In this sense, the results contributed to the literature with the proposition of new sustainability indicators related to the manufacturing process. The case studies enabled evaluation of the interaction of a new group of sustainability indicators in different manufacturing processes.

1. Introduction

The characteristics of operation management models have evolved over a period to adapt to the new challenges of society. In the beginning of the twentieth century, the expansion of industries resulted in management models based on standard operations and the analysis of time and methods (Cheng et al., 2011). In the post-World War II period, the growth of consumer demand resulted in the improvement of quality and best practices in operation management (Voss et al., 2002). At the end of the twentieth century, the growth of competition and diversity of consumer demand due to globalization resulted in manufacturing processes managed according to quality, cost, delivery, flexibility, speed and reliability indicators (Chowdary and George, 2012; Kim et al., 2015).

According to Moyano-Fuentes and Sacristán-Díaz (2012), Lean Manufacturing (LM) has been widely applied in the management of manufacturing processes. To Ohno (1988), LM aimed for the elimination of activities and procedures that do not add value to the final product. Therefore, Chowdary and George (2012) enhanced the operational improvement in a company due to the implementation of LM practices. Reductions of waiting time, cycle time and inventory were among the improvements to manufacturing processes. Chen et al. (2010) presented a case study of the LM implementation in a factory in the USA. The use of the VSM tool resulted in reduced inventory and rework levels. In addition to the benefits of the production flow, Dues et al. (2013) commented that the use of LM tools also maximizes the gains in environmental and social areas of the manufacturing process.

Because of this, many authors seek the integration of sustainability indicators into VSM. Paju et al. (2010) integrated Life Cycle Assessment (LCA) and Discrete Event Simulation (DES) into VSM. Faulkner and Badurdeen (2014) utilized a group of sustainability indicators integrated into VSM to assess the sustainability level in companies with different characteristics in relation to the

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production volumes and product varieties. The model used consumption indicators (water, energy and raw materials), noise level and ergonomic analysis of the workplace as sustainability indicators. Kuhlang et al. (2011) used area and transportation (time and distance) indicators via VSM to evaluate and develop improvement scenarios for manufacturing processes. Lee et al. (2012) and Kumaraguru et al. (2014) analysed changes in production systems and services towards sustainable solutions, and they highlighted the need to develop methods to measure the levels of sustainability of manufacturing processes.

Thus, it can be noted that, despite the evolution of manufacturing systems towards sustainability, there are no standardized methods for assessing sustainability in manufacturing processes and no consensus on which indicators should be used. Ghadimi et al. (2012) stated that sustainable production has become an important issue among manufacturing organizations, and several methods have been developed to assess the corporative sustainability company level (ISO 14000 series, Social Accountability 8000 standard and GRI Sustainability guidelines). However, there is an opportunity to develop methods for assessing sustainability in manufacturing processes that consider the three dimensions of sustainability (economic, social and environmental).

This article aims to develop and apply a method that integrates a new group of sustainability indicators into VSM to assess manufacturing processes in Brazilian industry. The sustainability context of application in manufacturing processes in Brazilian industry is relevant to the literature due to its position as a global production centre composed of numerous multinational companies (Abele et al., 2008). Brazil is also part of a group of developing nations (BRICS) and the most economically active in Latin America (Jabbour et al., 2015; Echegaray, 2016).

The new group of sustainability indicators allowed for analysis of the manufacturing process from the perspective of lean manufacturing associated with the three dimensions of sustainability. The integration of economic indicators resulted in the insertion of the operations and inventory costs into the assessment of the manufacturing process. The Takt Cost indicator determined the economic sustainability level of the manufacturing process and cost constraint operation. The Takt Cost can be obtained through analysis of the external factors or through analysis of the cost of the operations. The integration of social and environmental indicators allowed for assessment of the level of sustainability. For the analysis of these indicators, reference values were used considering the area where the manufacturing process was inserted. Thus, it was possible to identify the constraint operations relative to global or regional benchmarks.

2. Lean Manufacturing and sustainability indicators

Lean Manufacturing stands out as a model of manufacturing process management. Taj (2008) and Eatock et al. (2009) defined LM as a set of concepts, principles, methods, procedures and tools geared towards improvement of the production flow by reducing waste. Among the several tools of Lean Manufacturing, VSM (Value Stream Mapping) can be highlighted since it provides a holistic view of manufacturing processes and has been one of the most used in the universe of applications of lean thinking in industrial and service companies (Lasa et al., 2009). According to Rother and Shook (1999), VSM describes the information and process flow, which allows for identification of sources of waste, and thus it proposes future scenarios for improvement. Mcdonald et al. (2002) applied VSM in an engineer to order a production system to identify waste in all stages of the manufacturing process, and thus they reduced the process lead-time. Seth and Gupta (2005) utilized VSM to reduce high inventory levels and activities that do not add value to the process, and as a result, they increased the productivity of a process in the automotive industry. Lummus et al. (2006) applied VSM in a medical clinic to reduce the waiting times of patients, which demonstrated that VSM can be applied in different segments. VSM can be used to identify points of waste or opportunities for improvement in processes of all applications.

Thus, some studies have integrated new indicators into VSM to extend the scope of analysis. Kuhlang et al. (2011) proposed an extended VSM with area and transport indicators. The analysis of the extended VSM proposed by the authors allowed for development of future scenarios to improve the manufacturing process towards optimization of the production flow (Lean Manufacturing Concepts), the area used for operations and inventory (Area Indicator) and the distances and time travelled in internal logistic operations (Transport indicator).

More recently, several authors have also started considering sustainability indicators to amplify VSM comprehensiveness. Faulkner and Badurdeen (2014) developed a model of sustainable VSM (Sus-VSM) through the integration of sustainability indicators. The model uses environmental indicators related to the consumption of raw materials, water and energy. The Social indicators are related to work safety, ergonomic aspects and level of noise. The economic dimension used the same indicators as the traditional VSM, i.e., cycle time of operations that add and do not add value. Brown et al. (2014) applied the model developed by Faulkner and Badurdeen (2014) in three companies with different configurations of manufacturing processes (Flow Shop, Manufacturing Cells and Job Shop). The application confirmed the efficiency of the model in the development of future scenarios to reduce the consumption of water, raw materials, and energy and the level of noise in operations.

Brundtland et al. (1987) and Clancy et al. (2013) defined sustainability as a group of actions taken to meet the needs of the present moment without committing to future capacity. According to Faulkner and Badurdeen (2014), sustainability is the ability to maintain profits as expected by shareholders, to manufacture without damaging the environment and to improve the quality of lives of stakeholders. Elkington (1997) defined sustainability as the balance of economic, social and environmental dimensions, known as the TBL concept (Triple Bottom Line). Strezov et al. (2013) emphasized that each dimension of sustainability consists of indicators to assess the sustainable performance of the company. Therefore, economic, environmental and social indicators have been inserted into sustainability management models (Searcy and Elkhawas, 2012; Schonsleben et al., 2010).

According to Bartelmus (2010), economic sustainability and, consequently, its indicators are directly linked to the profitability of the company. However, environmental and social factors may enhance the sustainability due to the increased value of their image in society. Martínez-Jurado and Moyano-Fuentes (2014) stated that economic sustainability aims for decision-making in the present that will make the company prosper in the future. Roufechaei et al. (2014) highlighted that economic sustainability will always build on the investment ratio and its return according to the expectations of the investor. Therefore, the use of integrated economic indicators in VSM contributes to the assessment of the economic characteristics of the manufacturing process and the effectiveness of actions for sustainability. However, this integration requires detailed information regarding the cost of operations (Lee et al., 2014).

Hueting (2010) defined environmental sustainability as any action that will protect vital environmental functions for future generations. Hutchins and Sutherland (2008) discussed environmental sustainability as a result of the actions of companies in relation to product lifecycle management and the integration of supply chains. Dues et al. (2013) analysed the relationship between