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Modelling green and lean supply chains: An eco-efficiency perspective

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ABSTRACT

This manuscript proposes a model to support decision making and to help managers identify the best set of green and lean supply chain management practices to improve their eco-efficiency. To attain this objective, a mathematical model based on eco-efficiency concepts is suggested to overcome the trade-offs between lean and green practices. To illustrate the model application, a case study from an automotive supply chain is presented. Some management practices that are instituted for green or lean benefits have opposite effects on the environmental and economic performance of companies. One of the main findings of our study is that not all companies belonging to the same supply chain can be absolutely lean or green. There should be compromises in the individual companies' behaviour so the environmental and economic constraints of the supply chain are both satisfied. The proposed model represents a strategic framework to support the design of eco-efficient supply chains.

1. Introduction

Eco-efficiency is recognized as an important tool to evaluate simultaneously the environmental and the economic challenges of a company (Guenster et al., 2011; Tseng et al., 2014). Eco-efficiency is called into question when a company excessively consumes resources in order to reap economic benefits. The model encourages a balance between a company's environmental and economic impacts and promotes the idea of creating more with less (Moreira et al., 2010). The successful deployment of eco-efficiency strategies enables a business to reach an appropriate level of sustainability and it presents a method by which that company may gain a competitive foothold in the international marketplace (Cagno et al., 2012).

Innovations that improve the environment – called green innovations – help a company to conserve their resources. Companies who are among the first to establish green innovations will reap several advantages, including the ability to obtain a higher price for their environmentally-sensitive products, an improvement in their corporate image, the development of new markets, and a competitive edge.

Vachon and Klassen (2008) argue that the environmental management must go beyond the individual company and focus on the supply chain perspective. That is, the development of a green supply chain extends the environmental concerns from individual companies to the whole network of companies involved along the product life cycle. However, considering the eco-efficiency perspective, reducing the environmental externalities of the supply chain is not enough; it is necessary to promote value creation and produce economic value. The goal of efficiency is reached by the elimination of wastes, the reduction of costs, and the improvement of efficiency through lean supply chain strategies (Qi et al., 2009). Lean supply chain strategies focus on improving manufacturing efficiencies, profitability, and flexibility (Azevedo et al., 2012a).

The influence of lean and green supply chain management practices on business performance has been explored in various research studies. (Azevedo et al., 2012a; Carvalho et al., 2010, 2011). Carvalho et al. (2010) suggest a theoretical model to illustrate and explore the influence of lean and green practices on the performance of supply chains; they determine that most supply chain managers are not concerned with lean and green practices beyond the operational, economic, and environmental gains potentially reached. Dües et al. (2013) and Martínez-Jurado and Moyano-Fuente (2013) provide a comprehensive literature review exploring the synergies among lean and green supply chain management. Those reviews highlight that lean supply chain practices

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can promote sustainable green practices through waste reduction. However, some trade-offs arise when lean and green practices are deployed simultaneously.

Most of the studies that focus simultaneously on lean and green practices choose to analyze their impact on environmental performance (King and Lenox, 2009; Simpson and Power, 2005; Mollenkopf et al., 2010). The eco-efficiency approach primarily includes environmental concerns and the green paradigm (Tseng et al., 2014; Hansen and Klewitz, 2012; Solvang, 2008). The green paradigm is concerned with the reduction of environmental risk and negative impacts (Carvalho et al., 2010). The relationships between lean and eco-efficiency can be found in a few works (Moreira et al., 2010). The relationship between green and lean practices and eco-efficiency has not been explored. Moreover, Govindan et al. (2014a) stress that there is still a need to integrate eco-efficiency in supply chains to highlight simultaneously the economic and environmental aspects along the value chain. There is a gap in the literature relating lean and green supply chain management practices and eco-efficiency. Hence, an attempt has been made in this paper to fill this gap. This paper aims to model lean and green supply chain practices and considers an eco-efficiency perspective with the objective of minimizing the negative environmental and economic externalities that result from the normal operations of companies and supply chains. To attain this objective, green and lean practices and respective implementation levels are selected and a mathematical model is proposed.

The present study initially reviews the relevant literature on lean and green supply chain management, existing trade-offs, (that is, although it has been stated that lean and green complement each other, there are various situations where they are contrary), and eco-efficiency in Section 2. In Section 3 the mathematical model is developed from behaviours exhibited by both the company and the supply chain. Section 4 provides an illustrative case study from an automotive supply chain. Five scenarios are developed and the model results discussed in Section 5, and we present our conclusions and offer some future research opportunities.

2. Literature review

2.1. Green supply chain

There are many reasons why companies have begun to adopt environmental concerns. Rigorous environmental regulations (Dahlmann et al., 2008), demands from customers, the opportunity to increase their profits, maintaining pace with competitors, and simply due to taking an ethical stand are among the most commonly cited reasons (Dahlmann et al., 2008). Beyond these common motivations, Paulraj (2009) and Chang (2011) highlight the increase of competitiveness and ethical reasons; Thoumy and Vachon (2012) present the economic benefits, and Azevedo et al. (2012a) emphasize the environmental and social benefits. Researchers agree that companies can achieve a greater competitive advantage by making their businesses more environmentally friendly. Green supply chain management practices may improve the ecological efficiency and competitiveness of a company by reducing its environmental risks and impacts (Zhu et al., 2007). When sound environmental management practices are integrated into the companies that form the supply chain, the green supply chain may contribute to the company's competitive advantage (Ortas et al., 2014). If innovative green practices are employed throughout the entire supply chain, including both the product and the delivery, the company's environmental impact will be enhanced (Azevedo et al., 2011; Diab et al., 2015). Azevedo et al. (2011) provide an extensive review of green supply chain practices and group them into four categories: supply practices, advanced practices, product-based practices, and delivery practices.

The deployment of green practices contributes to a set of advantages such as cost reduction through a more efficient use of resources (Walker et al., 2010), business sustainability, saving the environment, and better firm reputation (Lee et al., 2013). These advantages mean that the implementation of green practices can positively influence the company's performance. It means that a company has engaged in some proactive environmental behaviour, actions that are designed to reduce pollution and to improve the economic performance of the business (Zhu et al., 2012). Moreover, Srivastava's (2007) point of view considers the supply chain management; he states that the deployment of green practices may decrease the negative environmental impacts of industrial operations and may help that industry maintain their desired levels of quality, costs, reliability and energy efficiency.

2.2. Lean supply chain

Lean thinking is considered a dominant paradigm in manufacturing companies (Jasti and Kodali, 2014; Marodin and Saurin, 2013) and in supply chains (Jasti and Kodali, 2015; Manzouri and Ab Rahman, 2013). The lean thinking is a wholly new way of thinking about the roles of firms, functions, and careers to channel the flow of value from concept to launch, order to delivery, and raw material into the arms of the customer in order to achieve a further "leap." It represents a new concept which moves the whole 'value stream' for products dramatically in the direction of perfection (Carvalho et al., 2011).

Lean management strategies seek to increase the company's actual value through waste reduction and improved customer satisfaction and profitability (Womack et al., 1991). Many organizations have implemented lean principles and methods such as time compression to eliminate inefficiencies along the supply chain. The activity of time compression is designed to reveal problems in quality that are not immediately visible, and it will contribute to improved efficiency in the company's processes (Simons and Mason, 2003). Anand and Kodali (2008) argue that a lean supply chain uses resources more effectively than in traditional systems; lean methods are integrated into both upstream and downstream activities and may reduce demand variation by simplifying, optimizing, streamlining, and creating capabilities. The demand variation is a measurement of how much variability can occur in the demands from customers. As lean production focuses on the reduction of inventory and lead times, the demand must be more stable. Moreover, lean production is driven by real customer orders, rather than forecasts that anticipate market demand. This means that demand "pulls" a product through production, rather than management forecasts "pushing" it onto the shop floor. To accomplish this, lean thinking changes the focus of management from optimizing separate technologies, assets, and vertical departments to optimizing the flow of products and services through entire value streams that flow horizontally across technologies, assets, and departments to customers.

Manzouri and Rahman (2013) categorized and adopted lean manufacturing principles for the supply chain management context. Researchers agree that there are benefits for the supply chain when it adopts lean techniques; such techniques can result in greater manufacturing efficiency, reduced costs, and improved profitability and flexibility (Vonderembse et al., 2006). However, a cursory look at the advantages of lean techniques fails to disclose a deeper understanding of its environmental impacts (Dües et al., 2013). Lean techniques do assist in the minimization of waste and pollution, and promote the use of environmental management tools (EPA, 2003). One important question associated with lean techniques is its impact on the environment since it intends to