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Lean versus green: The impact of lean logistics on greenhouse gas emissions in consumer goods supply chains

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ABSTRACT

Consumer goods supply chains have gradually incorporated lean manufacturing principles to identify and reduce non-value-added activities. Companies implementing lean practices have experienced improvements in cost, quality, and demand responsiveness. Nonetheless certain transportation and distribution practices may have detrimental impact on the environment. This study asks: What impact do current best practices in lean logistics have on the environment?

The research hypotheses propose that since just-in-time inventory management significantly increases the frequency of transport it will also increase greenhouse gas emissions in a supply chain. Conversely, product postponement and vendor-managed inventory practices decrease supply chain emissions because they improve the flexibility of the system to manage uncertainty in supply and demand and thus reduce transportation-related emissions while only increasing facility-related emissions, which are relatively smaller. The hypotheses are tested using a simulation model of a manufacturing-retailer supply chain. The research hypotheses are empirically supported, suggesting that business process improvements need to consider when operational changes can have the unintended consequence of significantly increasing emission-intensive transactions.

1. Introduction

The emergence of global supply chains and increased reliance on suppliers by brand manufacturers has increased the amount of transportation and logistics occurring within the consumer economy. With this increased activity also comes an increase in the total environmental footprint associated with these activities. In some consumer product supply chains the greenhouse gas emissions due to transportation are between 5% and 15% of total emissions over the product life cycle (World Economic Forum, 2009). Because transportation is a part of every consumer product supply chain, though, its aggregate environmental impacts are even more significant when considered as a whole. A study by the World Economic Forum (2009) estimated that 2800 mega-tonnes of the world's CO2 emissions could be attributed to transportation and logistics, representing 5.5% of the world total. Of this about half is attributable to road transport, one-third to rail, air, and sea transport, and one-sixth to logistics buildings. This macro-level data highlights the overall opportunity that industry has to reduce global greenhouse gas emissions through green logistics, as well as the relative emissions-intensive nature of operating transportation vehicles versus logistics facilities.

Contemporary supply chain practices have been shaped by the introduction of total quality management principles in the 1980s (Flynn et al., 1995; Corbett and Kirsch, 2001; Heizer and Render, 2004) and lean management principles in the 1990s (Womack et al., 1990; Womack and Jones, 1996; Simpson and Power, 2005). In particular, lean manufacturing techniques that aimed to reduce inventory and waste, such as just-in-time inventory management, were ported from manufacturing settings to warehousing and retailing, thus impacting logistics. Approximately 85% to 95% of total inventory from global leading retailers is managed through lean logistics practices (Simchi-Levi et al., 2003, Sheu et al., 2006).

The introduction of lean manufacturing strategies into logistic operations has brought benefits such as reduced costs and product waste while improving productivity (Porter and Van der Linde, 1995; O'Brien, 1999; Woensel et al., 2001; Childerhouse et al., 2002; Hesse, 2002; Marlow and Paixao, 2003; Kleindorfer et al., 2005; Busch, 2010; Fliedner and Majeske, 2010). It may be natural to assume that since lean practices in general are aimed at reducing waste of every form in a supply chain that they would also be

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associated with a more sustainable organization. The assumption that "lean is green" has not been formally studied however in previous research, and it may be that certain lean practices have produced environmental benefits while others do not. Thus our research question is: what are the environmental impacts of lean logistics practices in modern supply chains?

Logistics activities create a number of environmental impacts including increases in emissions related to climate change, ecosystem quality, and human health (Porter and Van der Linde, 1995; Kleindorfer et al., 2005; Busch, 2010). Because of the relative importance of climate change and the legislative, cost, and supply chain governance factors driving attention to it, this study shall focus on the greenhouse gas emissions, specifically carbon dioxide (CO_2), associated with logistics. While we include transportation activities, we focus on impacts due to lean practices rather than other improvements that have been made to make vehicles more fuel-efficient. Additionally, we shall focus on the supply chain link between a manufacturer and a retailer, although the hypotheses and findings can be generalized to any portion of the supply chain. We will use a discrete event simulation, modeled after a prototypical supply chain in North America, to test our hypotheses.

This study contributes to a body of knowledge concerning the environmental impacts of supply chain practices (Wu and Dunn, 1995; Beamon, 1999; Hall, 2000; Simpson and Power, 2005; Linton et al., 2007; Seuring and Muller, 2008; McKinnon, 2000; Giunipero et al., 2012). As more of an organization's or product's environmental footprint becomes influenced by the footprint of transportation and logistics, it is important to know which practices lead to positive synergy between operational and environmental performance, and which have unintended consequences of improving operational performance while increasing environmental impacts.

2. Overview of lean logistics and hypotheses

2.1. Introduction

Inventory management methods exist at the core of procuring materials, products, and services across businesses and their corresponding supply chain stages. From raw materials extraction, to the gradual development and delivery of consumer goods, retailing organizations become the ultimate purchasing units before reaching customers in the global marketplace (Gelderman and Semeijn, 2006; Zheng et al., 2007).

Prior research in purchasing and supply management have extensively documented decision making processes based on cost and service levels (Rodrigue et al., 2001; Stanley and Wisner, 2001; Dong et al., 2007), leaving the potential impacts and corresponding decisions associated with the environmental dimension of logistics and retailing operations as an emerging line of scientific inquiry.

From a strategic standpoint, environmental impacts that contribute to overall company sustainability reporting, have garnered increased attention from customers and consumers focused on transparent reporting about institutional and product-level sustainability. In September of 1999, a partnership between the Dow Jones Global Indexes and the Swiss-based SAM Sustainability Group launched the first family of global indexes for tracking the performance of sustainability including several corporations worldwide (Cerin and Dobers, 2001).

Particularly, the Dow Jones Sustainability Index (DJSI) addresses the top 10% of leading sustainability companies in the Dow Jones Global Index universe encompassing 2000 organizations in 64 industry groups from 34 different countries. Consequently, the DJSI heavily relies on the environmental performance of organizations and their resulting products and services (Knoepfel, 2001; Lopez et al., 2007). The gradual adoption of these sustainability-oriented market-driven approaches, describe the emerging materiality of supply chain environmental performance.

By leveraging the continued focus on the timely identification and elimination of process-based sources of waste, environmental elements such as energy usage, materials flow, and pollutant emissions associated with core supply chain processes can be quantified. Further understanding of these cumulative operational improvements can provide a more accurate description of lean logistics practices environmental performance (Walker et al., 2008; Golden et al., 2010).

Environmental performance from retailing operations has been focused on the geographical implications of supporting supply chain infrastructure. Guided by improved customer service levels, several retail chains spread their facilities across regions fostering better market segment coverage (Hesse and Rodrigue, 2004; Brown et al., 2005; Quak and De Koster, 2007). In addition, land regulations framework, tax policy, and economic development incentives in the United States have supported the establishment of big-box retailers, conveying the idea that bigger is better and encouraging the development of large scale, space extensive facilities (Goss, 1993; Jacques et al., 2003; Brown et al., 2005; Christopherson, 2007).

By expanding the notion of waste and non-value-added activities under consideration, lean practices became applicable not only to downstream stages of the supply chain but to multiple industries and their corresponding product procurement processes servicing local and global markets. Table 1 provides an overview of prior research addressing environmental implications

Table 1
Environmental considerations from supply chain stages.

Stage	Environmental considerations	Authors
Manufacturing	Environmental performance at the facility level based on toxic emissions.	Walley and Whitehead (1994), Lamming and Hampson (1996), King and Lenox (2000).
	Pollution prevention programs as an extended outcome of quality programs adoption.	Flynn et al. (1995), Hendricks and Singhal (1997), Sakakibara et al. (1997), Klassen and Whybark (1999), Kitazawa and Sarkis (2000), Corbett and Kirsch (2001), King and Lenox (2001), Dunphy et al. (2003), Graedel and Allenby (2003), Melnyk et al. (2003), Sroufe (2004).
	Improved environmental performance through reduced: interruptions, delays, inventories, and bottlenecks.	Milgrom and Roberts (1995), Hart (1997), Hawken et al. (1999).
	Improved environmental performance from the supplier base.	Green et al. (1996), Rothenberg et al. (2001), Rothenberg (2003).
Warehousing	Land-use and impact in surrounding communities.	Wu and Dunn (1995), Rodrigue et al. (2001), Hesse and Rodrigue (2004).
	General resource utilization at the facility level.	Murphy and Poist (2000), Fulconis et al. (2007), Abukhader (2008).
Transportation	Noise and air pollution.	Cusumano (1994), Woensel et al. (2001), Trip and Bontekoning (2002).
Retailing	Land-use, general resource utilization, and impact in surrounding communities.	Christopherson (2007), Rizet et al. (2010).