Chapter 1
Modeling Carbon Emissions of Alternative Distribution Network Designs for Seaport to Demand Center Just in Time Delivery

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ABSTRACT

This chapter presents a decision support tool that can be used to evaluate the level of carbon emission and duration of delivery time for alternative distribution systems charged with just-in-time product delivery. An Excel-based transportation model is solved using linear programming to model transport truck carbon emissions and delivery time for a product landed at seaports in the United States and transported to meet customer demand at inland locations under stochastic demand conditions. The alternative network designs examined provide insights as to the viability of the optimal network design as determined by the transportation model. The model is illustrated using simulated demand scenarios and the robustness of the solution methodology is examined using a sensitivity analysis.

INTRODUCTION

In today's highly competitive marketplace, the success of many companies is highly dependent on the ability to implement a viable business strategy across a global supply chain. Managing a global supply chain is characterized by decisions involving offshoring and onshoring of manufacturing and sourcing, intermodal transportation, and intra and intercompany operations across different business cultures. A

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global supply chain can lead to lower production and procurement costs, access to technological innovation and entry into new markets. Challenges that face supply chains such as risk, quality, and delivery timeliness are typically intensified for global supply chains (Inman & Bhaskaran, 2019; Golini, Caniato, & Kalchschmidt, 2016; Manuj & Mentzer, 2008). As a result of this enhanced risk it is essential that companies follow best practices in the management of their global supply chains.

Over the past few decades, the adoption and implementation of green and sustainable practices have become a key concern and initiative for many businesses. A major component of this concern has focused on the carbon footprint associated with acquiring raw materials, production processes which transform raw materials into finished products, and the logistics system which delivers the products to customers. In response to environmental issues and market pressures to operate green and sustainable enterprises, many businesses have embraced a triple bottom line strategic orientation whereby economic performance is interlinked with environmental stewardship and social performance (Elkington,1998). By integrating economic, environmental and social performance in overall business strategy, modern day supply chains have transitioned into green supply chains (Srivastava, 2007). Performance measurement, which is integral to the management and control of global supply chain operations, has been expanded in scope for green supply chains. Guidelines for establishing performance measurement frameworks and metrics in green supply chains are addressed by Ahi & Searcy (2015), Beske & Seuring (2014) and Hassini, Surti, & Searcy (2012).

The logistics and last mile product delivery function has been identified as being one of the most polluting segments of the overall supply chain (Ülkü, 2012; Gevaers, Van de Voorde, & Vanelslander, 2011) and is highly dependent on the effective management of fuel costs and carbon emissions (Gurtu, 2019; Bouchard, 2015; Gurtu, Jaber, & Searcy, 2015, Gourdin, 2006). The dominant mode of freight movement in the U.S. is by road and transport truck emissions, which contribute significantly to the nation's carbon footprint, are projected to increase. As a result of economic growth, transport truck vehicle miles traveled in the U.S. are predicted to increase by 52% from 397 billion miles in 2018 to 601 billion miles in 2050 (Annual Energy Outlook 2019, p. 120).

Improving logistics activities to reduce carbon emissions has become an important aspect of managing green supply chains (see for example, Ellram & Murfield, 2017; Abbasi & Nilsson, 2016; Adenso-Díaz, Lozano, & Moreno 2016). Ren, Hu, Dong, Sun, Chen, & Chen, (2020) present a comprehensive review of sustainable logistics. Transport mode specific reviews of sustainable logistics include: (i) roadways (Demir, Bektaş, & Laporte, 2014), (ii) railways (Aditjandra, Zunder, Islam, & Palacin, 2016), (iii) maritime (Davarzani, Fahimnia, Bell, & Sarkis, 2015), (iv) air (Teoh & Khoo, 2016), and (v) intermodal (Roso, 2013). Opportunities for improving the environmental impact from a given mode of transport exist and can be achieved by investigating alternative design structures of the logistic function (Kelle, Song, Jin, Schneider, & Claypool, 2019; Aronsson & Brodin, 2006).

BACKGROUND

With the value of global digital commerce sales worldwide predicted to be over $6 trillion by 2022 (McKee, 2018), the scope of product movement in global supply chains is staggering. Managing the movement of products from their point of manufacture or interim storage location to the final customer is fundamental in the operation of a global supply chain. Beginning with the pioneering work of Hitchcock (1941) who mathematically modeled the movement of goods from "origins" to "destinations", a

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