Journal of Cleaner Production 99 (2015) 177–191

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Greenhouse gas reduction in transport: analyzing the carbon dioxide performance of different freight forwarder networks

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ARTICLE INFO

Article history:
Received 26 May 2014
Received in revised form
7 December 2014
Accepted 7 March 2015
Available online 14 March 2015

Keywords:
Greenhouse gas (GHG) / CO_2 network analysis
Network carbon footprint
Fast Moving Consumer Goods (FMCG)
Distribution network analysis
Logistics service provider (LSP)
Distribution logistics

ABSTRACT

There are growing concerns in the food industry about how supply chains can be managed in a more sustainable way. When distribution activities are outsourced to a logistics service provider (LSP), shippers need to evaluate the LSPs they may (potentially) engage in order to ensure that supply chain sustainability goals are met. In this paper, we present a methodology for LSP evaluation and focus on the ecological dimension of sustainability. We examine how the network carbon footprint of a real-world distribution system is affected by the LSP network that is chosen to forward goods from production facilities to customers. To do this, we analyze the shipment data of an existing Fast Moving Consumer Goods (FMCG) manufacturer. A quantitative distribution network model is set up to study the network carbon footprint of 125 scenarios. Real-world shipments are forwarded via five generic, idealized types of LSP networks. In total, 625 network carbon footprints, specified by three distribution logistics variables and the structure of the LSP network, have been calculated. The results show that LSP structures practicing a geographically decentralized consolidation of shipments are most efficient in reducing of greenhouse gas (GHG) emissions. Furthermore, the effects of changing the manufacturer's and the LSP's strategies for deciding on the tonnage to be forwarded via the LSP network or moved by direct transports are quantified. Finally, we estimate the GHG effect of improving the capacity utilization of the vehicles that move the products.

1. Introduction

During the 1990s, distribution network design received increased attention in academic literature as improved designs promise great cost saving opportunities (Arntzen et al., 1995; Camm et al., 1997; Vidal and Goetschalckx, 1997). The primary aim of companies is, undoubtedly, the maximization of profits, but recently distribution network designs have also been analyzed with respect to sustainability aspects (Fleischmann et al., 2001; Jayaraman et al., 2003). Halldórsson et al. (2009), for instance, identified several drivers for companies to improve sustainability. Network modeling and network design-related issues and practices have, however, been neglected, despite the growing importance of sustainability within supply chains (Srivastava, 2007).

In this context, green logistics activities are crucial for providing greener products and services to the consumer (Wu and Dunn, 1995). To quantify “ecological performance” in the Fast Moving Consumer Goods (FMCG)[1] market, the concept of the carbon footprint has been introduced, whereby the greenhouse gas (GHG) emissions caused by an organization, event, product, or person are determined. A number of methods for calculating the environmental impact can be found: Kohn (2005) estimates carbon dioxide emissions per ton-km, Hugo and Pistikopoulos (2005) work with a life cycle assessment model, and Frota Neto et al. (2008) designed a logistic network using a life cycle analysis to balance profit and environment. In Germany, the Platform for Climate Compatible Consumption analyzed the product carbon footprint for some FMCG such as strawberries, coffee, eggs, and noodles along their supply chains. Consumers focus on the product carbon footprint as a reference object, whereas companies are additionally interested in GHG emissions that stem from its supply chain activities, e.g.,

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[1] The abbreviations used in this article are: DC (Distribution Center), DCDL (DC-direct shipment limit), FMCG (Fast Moving Consumer Goods), GHG (Greenhouse Gas), HGV (Heavy Goods Vehicle), LF (Load Factor), LSP (Logistics Service Provider), LSPDL (LSP-direct shipment limit), TSP (Transshipment Point).

http://dx.doi.org/10.1016/j.jclepro.2015.03.026

from purchasing, production, and distribution processes. National and international initiatives and protocols are trying to improve and standardize the assessment of GHG emissions related to supply chain activities; these include the Greenhouse Gas Protocol, PAS 2050, and PEF World Forum. Special focus is placed on the food industry, e.g., by PEF World Forum, as it is a high volume industry offering great potential for GHG reduction along the supply chain. In fact, food consumption accounts for a large proportion of the global GHG emissions arising from anthropogenic activities (Röös and Tjärnemo, 2011). Furthermore, customers are particularly aware of product characteristics in this industry. The way in which food is sourced, produced, and distributed has been the subject of increasing attention by consumers, environmental groups, policymakers, and food producers. Jones (2002) observes a growing recognition of significant environmental burdens associated with the food production, distribution, and marketing systems that have evolved. Apart from reducing negative ecological side-effects, companies may benefit from an efficient eco-supply chain management that distinguishes them from their competitors.

For the distribution part of a supply chain, manufacturers of FMCG can either ship their products themselves or via a logistics service provider (LSP). Typically, due to profit maximization, the less expensive kind of distribution system will be chosen if performance indices such as quality, reliability, or delivery times are not endangered. However, if sustainability is an additional objective, the company may select the LSP with a less emitting freight forwarder network. The target could be a reduction of the ecological impact of distribution without major sacrifices in areas such as delivery quality, reliability and time, transportation costs, or vehicle load factor. Thus, LSP selection is a potential lever for reducing GHG emissions alongside technical solutions such as lead-free and low-sulfur petrol, three-way catalytic converters, or improvements in vehicular energy efficiency. Andress et al. (2012) present an overview of various technical possibilities. If delivery costs are quite similar for several LSPs, a manufacturer may choose the LSP with the less emitting network structure, thus reducing GHG emissions with hardly any additional costs. For the area of distribution logistics, literature provides ample research focusing on costs. There is less research on the quantification of the ecological performance of different distribution structures (Kellner and Igl, 2012). In particular, the ecological consequences of using alternative LSP freight networks to move goods from production facilities to customers have rarely been investigated, even though LSPs have been intensively measuring the carbon footprints of shipments (Verkehrsrundschau, 2011). This perception is affirmed by Colicchia et al. (2013), who state that even if logistics services operations can play a significant role in reducing the environmental burden of the supply chain, little research has been provided about the efforts of LSPs. This paper contributes to closing this gap by answering the following research question: *To what extent do different LSP networks affect the GHG performance of FMCG distribution?*

First, literature on GHG emissions in road freight transportation is reviewed. Second, key variables for a network carbon footprint of freight forwarder networks are identified. Third, five generic types of freight network structures for German LSPs are shown. To answer the research question, we use a case study approach: Dryco, an existing but disguised German branch of a multinational FMCG manufacturer, may select one of several networks to ship goods to its customers. Dryco's range of products contains mainly food products that are sold in nearly every supermarket. The brand name is well-known worldwide. A quantitative distribution network model based on real-world data for the shipping company is set up. The data cover the number and geographic locations of the distribution centers, the customer locations, and the shipment structure. The latter comprises information about the outbound shipments from Dryco's distribution centers, i.e., all shipments from the manufacturer's distribution centers to its customers (the FMCG retailers), over one calendar year. For the period observed, more than 100,000 shipments have been recorded on a daily basis as well as the corresponding shipment data for the origin-destination pair, shipment weight, volume, and number and size of pallets. The LSP networks investigated that can be used by Dryco are fictive but highly match the German landscape in terms of the geographic locations of transshipment points (TSP) and hubs, of shipment sizes, and vehicle load factors. Fourth, the sum of all GHG emissions of each network is calculated and network sensitivities to changes in certain key variables are analyzed. Simulation shows to which degree single and multiple changes in the structure influence the GHG performance of a typical LSP network. So far, the effect of the identified variables on GHG emissions has not yet been compared. This paper provides a concrete approach on how to calculate the overall network carbon footprint for different LSP structures and the amount of GHG that a single shipment emits when moved through the different network structures, and, thus, enables a more precise life cycle assessment of GHG emissions for single products where transport is part of the product system (DIN, 2006). The approach presented allows for a more precise carbon footprint approximation for distribution networks, particularly (but not only) in the FMCG industry.

2. Literature review: road freight transportation and GHG emissions

2.1. Estimating CO_2 emissions in road freight transportation

In the European Union (EU), transportation is responsible for around a quarter of GHG emissions; road transport alone contributes about 20% of the EU's total emissions of carbon dioxide (CO_2). In the USA, GHG emissions from transportation account for about 28% of total GHG emissions, making it the second largest contributor of GHG after the electricity sector. While emissions from other sectors are generally falling, those from transport have increased by 36% since 1990 in the EU and by about 18% in the USA (EC, 2014; USEPA, 2014). In Germany, road traffic generated 81% of the total CO_2 emissions in 2008 (ifeu, 2010).

CO_2 emissions occur along the complete supply chain, encompassing inbound, intra, outbound, and reverse logistics. A global standard for the reporting and the assessment of logistic-related emissions does not exist, but a convergence toward a generally accepted approach can be observed (Mason et al., 2010). Olsthoorn et al. (2001) present a broad overview of different initiatives in the area of reporting GHG emissions. In some cases, it may be environmentally beneficial to increase GHG emissions from freight transportation processes when greater CO_2 savings from other supply chain processes are simultaneously achieved (McKinnon, 2008; Rizet et al., 2010; Saunders and Barber, 2007). This contradicts the food miles concept (Smith et al., 2005), where the impact on the environment is only measured by the distance food travels. Since the focus of this paper is on transportation processes, environmental impacts of production processes are not analyzed. Our research aims to assess the GHG emissions within different LSP distribution networks.

McKinnon (2008) estimates the CO_2 intensity of freight transportation modes and presents an analytical framework for assessing the potential for cutting CO_2 emissions at the macro level in the United Kingdom (McKinnon, 2010). Decisive parameters for the overall CO_2 intensity of the freight sector are the handling factor, the average length of haul, the modal split, the average load on laden trips, the average percentage of empty running, fuel efficiency, and the CO_2 intensity of the energy source. Olsthoorn (2003)