Transportation Research Part E 78 (2015) 40–56

Contents lists available at ScienceDirect

Transportation Research Part E

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

UK supply chain carbon mitigation strategies using alternative ports and multimodal freight transport operations

V. Sanchez Rodrigues [a,*], S. Pettit [a], I. Harris [a], A. Beresford [a], M. Piecyk [b], Z. Yang [c], A. Ng [d]

[a] Cardiff University Logistics and Operations Management Section, United Kingdom
[b] Heriot-Watt University Logistics Section, United Kingdom
[c] Liverpool John Moores University, United Kingdom
[d] University of Manitoba, Canada

ARTICLE INFO

Article history:
Received 31 March 2014
Received in revised form 19 December 2014
Accepted 22 December 2014
Available online 27 February 2015

Keywords:
International freight transport
Port choice
CO_2e reduction and supply chain decision-making

ABSTRACT

In the last few decades, the building evidence that CO_2e emissions lead to climate change has pointed to a need to reduce CO_2e emissions. This research uses five scenarios in the context of UK import trade to assess total CO_2e emissions and costs of import re-routing containers. The overall objective is to assess possible carbon mitigation strategies for UK supply chains by using a combination of alternative ports and revised multimodal strategies. The model adopted includes three elements: port expansion, container handling and freight transport. The alternative scenarios explore different settings modal shift and short sea shipping.

1. Introduction

Examination of international freight transport chains and supply chains has recently been highlighted by, for example, Sanchez Rodrigues et al. (2014) who investigated possible options for the use of alternative ports as a way of contributing to supply chain carbon mitigation strategies. This was in contrast to the greater proportion of research into supply chain structures which largely relate to the coordination of the chains and the distribution of economic value among supply chain partners (see, for example, Leslie and Riemer, 1999; Oro and Pritchard, 2011; Alvarez-SanJaime et al., 2013). Further, Alvarez-SanJaime et al. (2013) suggest that vertical integration is crucially important to bring about high level of performance in the maritime segment of freight transport chains. However, the literature tends to exclude port selection as a key component of performance improvement in maritime supply chains, since research into how commodity chains and networks work has concentrated mainly on the management of relationships within supply chains.

Ports are important nodes in global distribution networks and as such they can significantly influence the performance of global supply chains. Even though, in the literature, there is a considerable degree of emphasis on the topic of port selection, the large majority of the research focuses on economic aspects of port choice, such as market forces and port efficiency (Suykens and Van de Voorde, 1998; Tongzon, 2001, 2009; Malchow and Kanafani, 2004; Gonzalez and Trujillo, 2008; Steven and Corsi, 2012). Steven and Corsi (2012) analysed port selection in the context of the United States while Leachman (2008) and Tongzon (2009) focus on the management of inland distribution as a port choice factor. The remit of these studies did not extend to CO_2e reduction or to how future changes in the carbon intensity of road freight transport could influence port selection decisions. Further, global supply chain and shipping line decision-making has not incorporated

* Corresponding author.
E-mail address: sanchezrodriguesva1@cardiff.ac.uk (V. Sanchez Rodrigues).

http://dx.doi.org/10.1016/j.tre.2014.12.013
1366-5545/

CO_2e emissions as a factor in the port choice process, although Emission Control Areas (ECA) have led to some organisational and tactical modifications by shipping lines to their operations in order to be aligned with the current legislation (Fathom Shipping, 2013).

A key aspect of improving the environmental performance of global maritime-based supply chains is the reduction of their overall carbon intensity. This can be achieved in several ways: reducing the fuel consumption of vehicles *per se*, which occurs as a consequence of port selection and which alters if an alternative port is selected, shrinking the carbon content of the fuels themselves, or by transferring freight from road to less carbon-intensive freight transport modes such as waterborne transport and rail. Related to this, in the context of international freight movements, is the 'sea-maximising-land minimising' principle whereby ports which are located close to the market regions to which the cargo is destined are selected, thereby minimising road miles. Recently, research into the mitigation of the carbon footprint of freight transport has concentrated on the reduction of carbon emissions in separate modes of transport. For example, Qi and Song (2012), Cheng et al. (2013) and Chen et al. (2014) have focused on a number of initiatives which can be adopted to reduce the carbon footprint of the maritime leg of freight transport chains. However, the literature on port selection in maritime supply chains does not incorporate CO_2e emissions as a factor in port choice. Furthermore, when evaluating the alternative solutions for shifting cargo from road to less carbon intensive modes, it is important to include opportunities for CO_2e reduction within road transport operations. Therefore, there is a need for more disaggregated analysis to be undertaken in order to estimate the impact of port selection under a range of scenarios which include the carbon intensity of road freight transport as a key variable.

This paper therefore extends the work of Sanchez Rodrigues et al. (2014) in considering whether the use of alternative port gateways can contribute significantly to an overall reduction in freight transport-related CO_2e emissions in international supply chains. The approach taken in this study mirrors that of Liao et al. (2010) and Sanchez Rodrigues et al. (2014); an activity-based CO_2e emission model is used to estimate the cost and CO_2e impact of five Scenarios which are described in the paper as the "current situation" and four "proposed Scenarios". The model includes a carbon reduction parameter to account for likely future reduction in the carbon intensity of road freight transport. The paper includes several new contributions to the literature: firstly the model developed by Sanchez Rodrigues et al. (2014) has been substantially expanded here by considering different scenarios aimed at minimising overall road distance travelled (the land transport matrix is resolved using Excel Solver). We also introduce a road-based carbon reduction parameter as part of the modelling and analysis of the carbon mitigation strategies. In addition, we consider implications of modelling the London Gateway port on the network operations to reflect current ambitious plans of the British Government to expand the London Gateway port. We also include cost and CO_2e related to port expansion and we estimate the total CO_2e emissions generated from changes in the level of congestion as a consequence of transferring containers from less carbon intensive modes and/or route combinations. Finally the model developed in the current paper assesses the tradeoffs between CO_2e reduction in road freight transport and modal shift from road to water and/rail. The impact of the modelling exercise on ports' capacities is also discussed where each scenario determines a transport framework and the port capacities required to satisfy all demand.

In terms of the modelling approach adopted in this study, a range of variables which can impact on the overall cost and CO_2e emissions are considered. These factors include terminal building costs, transport operating costs, intermodal freight transfer cost, and CO_2e emissions derived from the use of alternative modes and routes. The Scenarios modelled in the paper include a baseline scenario and a series of scenarios which capture the outcomes when alternative routes are used.

The model is constructed at a strategic level rather than at an operational or tactical level, since the purpose of the modelling approach is to formulate a broad picture of the cost and CO_2e impacts of re-routing containers. Nevertheless, the model integrates some tactical aspects which are linked to changes in traffic volume generated by the shift of containers among the Scenarios.

The aim of the modelling process is to achieve an understanding of how UK import containers may potentially be re-routed such that either costs or CO_2e emissions, or both, could be reduced. The variables used in model can be broken down into several parameters which could impact on the overall cost and CO_2e emissions of re-routed containers. These parameters which are incorporated into the model are: port expansion cost, transport cost per TEU, port/intermodal terminal handling charges per TEU, and CO_2e emissions per TEU-km. In order to account for the expected changes in the CO_2e levels in the modelled scenarios, variable carbon conversion factors, which are dependent on the average speed of vehicles in all the port origin–destination routes, have been incorporated. The speeds of vehicles on all the port origin–destination routes used in the five scenarios are estimated from average number of vehicles per day statistics on all the relevant routes used in the study, gathered from the Department for Transport (DfT, 2013).

2. Road freight transport-based decarbonisation initiatives

There is a growing body of research into carbon mitigation in supply chains and freight transport operations. In this paper, we outline recent developments in the area of CO_2e mitigation in the supply chain and freight transport literature with a focus on through transport and gateway port selection. There are a range of decarbonisation initiatives for freight transport and the literature focuses on a number of CO_2e reduction elements, namely shifting to less carbon intensive transport modes, more efficient consolidation of goods, running a more carbon efficient fleet and reducing the carbon content of the fuel used. The classification of these initiatives varies from author to author. For instance, in the areas of carbon footprint reduction and Green Supply Chain Management (GSCM), Rao (2003) and Sarkis (2003) focused on how a range of initiatives can make