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A framework for measuring carbon emissions for inbound transportation and distribution networks

Ioannis N. Lagoudis [a,b,*], Aamil Raza Shakri [a]

[a] MIT Global SCALE Network, Malaysia Institute for Supply Chain Innovation, Malaysia
[b] University of Aegean, Department of Shipping Trade and Transport, Greece

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ABSTRACT

The paper aims at developing a robust model that can capture, calculate and manage emissions activity across a transportation and distribution network to enable corporate social responsibility practices via identifying the carbon intensive activities within the transport and extended enterprise. This is a multi-attribute problem where a number of variables need to be taken into account across the different echelons of the supply chain. A case company "X" from the apparel industry is used for the purposes of the study.
The supply chain carbon assessment study requires defining the system boundaries, process mapping of the activities involved, identifying key data requirements, collecting and sampling primary and secondary data and calculating emissions based on fuel or distance factors.
The research culminates in creating a scenario-planning tool with cost, effective lead time and carbon emissions as model attributes. As part of the research, literature is reviewed on best practices and methodologies and interviews conducted with functional heads, 3PL managers and experts from the apparel industry. In the end, the created tool enables companies to gauge their emissions, optimize them within their respective supply chains and identify key indicators for carbon reduction in inbound networks.

1. Introduction

The apparel industry faces vast challenges as well as opportunities in the reduction of its environmental impact globally. Multinational companies are in need to promote efficient transport utilization and reflect regional demands that often do not align with global perspectives. The concept of "sustainability" and "sustainable development" has become increasingly influential in policy considerations in recent years (Anderson, Allen, & Browne, 2005; Yang, Bell, & Meng, 2000). The most widely accepted definition of sustainable development is "development that meets the needs of the present without compromising the needs of future generations to meet their own needs" (World Commission on Environment and Development, 1987).

There are several factors both external and internal, which demand the development of a robust Carbon Footprint model. The growing environmental regulations and awareness have urged companies to look into carbon emissions and optimization policies. Besides, carbon auditing and reporting has become a key aspect of corporate social responsibility. Industries are thus keen in improving their carbon credentials. However, for a company, its internal motives are no less significant. Initiatives aimed at sustainable development will not only identify opportunities to reduce carbon emissions but also improve operational efficiencies. The company will be able to measure changes through time.

'Carbon Footprint' has become a widely used terminology in the public debate on abatement action against the threat of global climate change. It has gained momentum of late public appearance and is now a buzzword widely used across the media, the government and in the business world. Carbon Trust defines Carbon Footprint as a methodology to estimate the total emission of greenhouse gases in carbon equivalents from a product across its life cycle from the production of raw materials used during manufacturing, to the final disposal excluding in-use emissions. Energetics (2007) explains it as the full extent of direct and indirect CO_2 emissions caused by business activities.

For effective and innovative greenhouse gas management, setting operational boundaries that are comprehensive with respect to direct and indirect emissions will help a company better manage the full spectrum of greenhouse gas risks and opportunities that exist along its value chain. Direct greenhouse gas emissions are emissions from sources that are owned or controlled by the company. Indirect greenhouse gas emissions are emissions that are a consequence of the activities of the company but occur at sources owned or controlled by another company.

As the research work focuses on the transportation and logistics aspects of the supply chain, literature review focuses on calculating CO_2

* Corresponding author at: Malaysia Institute for Supply Chain Innovation, No. 2A, Persiaran Tebar Layar, Seksyen U8, Bukit Jelutong, Shah Alam, 40150, Selangor, Malaysia.
E-mail addresses: ilagoudis@misi.edu.my, lagoudis@mit.edu, ilagoudis@aegean.gr (I.N. Lagoudis), arshakri@misi.edu.my (A.R. Shakri).

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emissions from mobile sources. For all mobile sources, one may apply either a fuel-based or distance-based methodology to calculate these emissions. In the fuel-based approach, fuel consumption is multiplied by the CO_2 emission factor for each fuel type. This emission factor is developed based on the fuel's heat content, the fraction of carbon in the fuel that is oxidized (generally approximately 99% but assumed to be 100% in this tool), and the carbon content coefficient. Since this approach uses previously aggregated fuel consumption data, it is considered "fuel-based." Fuel based approach can be used also when vehicle activity data and fuel economy factors are available enabling the calculation of fuel consumption. In the distance-based method, emissions can be calculated by using distance based emission factors to calculate emissions (Greenhouse gas Protocol — Mobile Guide (03/21/05) v1.3).

The present work approaches the problem of effective reduction in carbon emission, via focused analysis of scenarios and trade-offs between model parameters. The research has been performed in three phases. The first phase deals with the mapping of carbon emissions for inbound transportation. The second and third phases deal with scenario modeling and optimization to obtain minimal emissions with given constraints in the supply chain.

2. Literature review

Firms that stride towards sustainable development, are seen as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission Report, 1987), intend to plan their business operations respecting the environment and all its resources. Their strategies envisage the preservation of the environment (Berns et al., 2009). This leads to business behaviors that minimize reliance on natural resources (Pullman, Meloni, & Carter, 2009) and reduce waste and pollutants in productive processes (Gordon, 2007).

In the era of Globalization the search for lower cost production has led to a dramatic relocation of production sites towards the Far East (Bonacich, Cheng, Chinchilla, Hamilton, & Ong, 1994). As a result, the impact of global transportation on the environmental concerns have taken a bigger pie. De Brito et al. (2008) state in their work that with trends in the fashion Supply Chain, such as price competition and the importance of responsiveness, the adoption of sustainable initiatives might be at risk.

Relocation strategies make the control of working conditions in the offshore production sites more difficult; deliveries of smaller size deriving from shorter delivery times may increase the amount of transport, thus raising its environmental impact. Coping with the fashion risk has become a central issue, and, as it will be seen, Supply Chain integration, is a valuable starting point to tackle it (De Brito et al., 2008). The complexity of inbound and outbound supply chain transportation activities has given a new dimension to the economic and environmental concerns.

In depth study, on the current guidelines and protocols has been made before formulating the model in this research. The greenhouse gas protocol offers customized calculation tools (WRI/WBCSD, 2006) and has worldwide acceptance as guidance for providing the tools for calculating greenhouse gas flux so as to suit the respective sector or entity. There are two available standards for measuring greenhouse gas (i) A Product Life Cycle Accounting and Reporting Standard, and (ii) Corporate Accounting and Reporting Standard. Guidelines for Value Chain Accounting and Reporting, have been defined by greenhouse gas protocol of World Resource Institute/World Business Council on Sustainable Development (WBCSD). It provides sector specific and general calculation tools and deals with quantification of greenhouse gas reductions resulting due to adoption of mitigation methods in its Project protocol. Emission data can be collected through direct on – site real – time measurements, or through estimations based on emission factors and models. Emission factors and models are the most preferred and used techniques. The time dimension must be mentioned so as to indicate clearly the time period over which the emissions have been estimated, or if it is a one-time emission (Lindstad, Asbjørnslett, & Strømman, 2011; Pandey, Agrawal, & Pandey, 2011).

Hoen, Tan, Fransoo, and Houtum (2012) formulate a model to serve the transportation mode selection problem, in which the transportation mode minimizes the expected total cost, including emissions cost. However, the assumptions are over reaching, since quotation requests are sent to a third-party logistics service providers (3PL) where, based on the offers they obtain, one mode is selected only, which is used for the entire transportation process. Their work uses order – up – to policy and the solution of the single-period newsvendor problem is used to solve the transportation mode selection problem, which yields the optimal expected total cost. The paper tackles the effect of self-imposed emission regulations in terms of cost and emissions. As a result numerical analysis clearly shows that the impact of emission related charges is small but it does not incorporate the variability of lead time and urgency to meet the service level and frequency of movement. In an earlier study Piecyk and McKinnon (2010), examined the CO_2 emissions footprint for road transportation using Delphi method, where fuel and distance have been used in their calculations. Based on their results CO_2 emissions will increase by 10% by 2020 assuming current business condition applies, whereas the optimistic scenario is to decrease by 47% compared to their base year.

In a numerical study (Kiesmüller, de Kok, & Fransoo, 2005) the influence of various model parameters is investigated and it is shown that the use of a slow mode can be economically beneficial, especially for low value items. Cost savings are less for high value items. The model enables to quantify the value of the postponement in the transportation decision and the value of using an additional slow mode instead of using a fast mode only. The study assumes base stock control and determines the optimal policy parameters for determining the optimal share of the shipments to be sent using the fast mode. According to the results, dual supply models, incorporating both inventory and transportation mode considerations with respect to cost and service level can be helpful in reassessing the mode selection decision in most industries. The frequency of service appears to be an important factor in mode choice, especially for the sectors of manufactured goods. As expected, the reliability of transit time appears to be very important for exporters and also important for the manufacturing sector due to the effect it can have on the production process (Shinghal & Fowkes, 2002). The recent developments in the ocean industry where slow steaming practices are applied are a sound proof of the implications that lead time variability can have on the supply chain performance and its environmental effects (Arıkan, Fichtinger, & Ries, 2013; Cariou, 2011; Corbett, Wang, & Winebrake, 2009; Lee, Lee, & Zhang, 2015; Psaraftis & Kontovas, 2010).

Identifying more environmentally friendly modes via the use of subsidies and their environmental implications has been examined by Matute and Chester (2015). They compared the California High-Speed Rail with other urban transportation modes. Based on their results when public subsidy for capital is used, none of the projects appear to be a cost-effective means to reduce GHG emissions. Carbon emission costs have been studied by Chao (2014) in the airline industry. In his study he presents a set of models that calculate carbon emissions in individual phases of flight during air cargo transportation. His results show that the impact may be subject to various factors including unit carbon emissions per aircraft, aviation emission allowances per airline, and carbon trading prices.

The relationship between transportation cost, transit time and service level literature related to choice of transportation, have been reviewed also. Carbon emissions directly affect material flow costs involving inventory levels, backorder costs and pipeline inventory. The prevailing perception in the industry is that the transportation mode with lowest cost would be the most economical choice but on closer observation the lower cost is subjected to higher lead-time, higher consumption and variability. In general, a transportation mode that offers a shorter transit time is typically more expensive than the one that requires longer transit times. The situation may lead to lost sales and eventually