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Towards a common measure of greenhouse gas related logistics activity using data envelopment analysis

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ABSTRACT

Monitoring company emissions from freight transport is essential if future greenhouse gas (GHG) reductions are to be realised. Modern economies are characterised increasingly by lower density freight movements. However, weight-based measures of freight transport activity (tonne-kilometre, tonnes lifted) are not good at describing volume-limited freight. After introducing the need for performance measurement, the problem of benchmarking is outlined in more detail. A context-dependent undesirable output data envelopment analysis (DEA) model, designed to be sensitive to business context, is then tested on a simulated set of fleet profiles. DEA can produce more consistent measures of good-practice, compared to ratio-based key performance indicators (KPI), providing emission reduction targets for companies and an aggregate reporting tool.

1. Introduction

In response to the climate change challenge, greenhouse gas (GHG) emissions reduction targets are being set at corporate (eg. DB Schenker, Deutsche Post DHL, Tesco), sector (e.g., the UK Freight Transport Association aims for an 8% reduction by 2015, relative to a 2010 baseline, and the European Commission, in its 2011 White Paper, postulates at least 60% reduction in GHG emissions from the transport sector by 2050), or national level (e.g., the UK Government has committed to achieve at least 80% reduction in GHG emissions by 2050, against the 1990 baseline) (Piecyk, 2015). The freight transport sector contributes a significant proportion of total surface transport emissions (McKinnon, 2007), and must therefore incentivise radical changes to achieve substantial improvements in its environmental performance. Various authors investigate measures to reduce supply chain carbon intensity, which reflects a genuine and world-wide motivation within the sector to reduce negative environmental impacts (e.g., Guerrero et al., 2013; Guerrero, 2014; Liimatainen et al., 2012; Li et al., 2013; Piecyk and McKinnon, 2010; Arvidsson et al., 2013; Larson et al., 2013).

For desired changes to be achieved, it is vital that the sector acquires a common language, identifies best practice, and compares companies along common yardsticks—i.e., benchmarking, grounded in solid research, is needed. This is a common theme in supply chain performance where applications of mathematical models are under-utilised (Wong and Wongk, 2008), and the importance of quantitative approaches highlighted (Dullaert and Zamparini, 2013; Hassini et al., 2012; Lättilä et al., 2013). At the same time, a balance must be struck—models must be simple-enough so they can be used in practice, but not so simple they misrepresent the problem in hand.

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We contribute by applying a mathematical model to a key freight transport problem—i.e., how to rationalise GHG measurements against the backdrop of highly diverse operating characteristics among different freight transport companies. Traditionally, freight movements are measured with simple ratio indicators (see Section 2 for more detail), e.g. the tonne kilometre (*tkm*)—most data relating to logistics activity across the globe are still collected and reported by governments in this way (Piecyk and McKinnon, 2009). The proportion of low density/high volume products in the freight mix, however, increases as economies develop. For example, data collected by the UK Department for Transport indicate that low density products increasingly constitute the freight mix and a significant amount of freight is purely volume limited (Department for Transport, 2011).

Consequently, there is a need to incorporate volume-based measures into freight transport performance benchmarking. Unfortunately, finding an appropriate measure of performance is problematic; specialised companies employ a variety of measures—tonne kilometres, tonnes handled, number of drops, etc.—in characterising their logistics activity, precisely because freight activity has become so diverse. On the other hand, representative and accurate measures are important tools in the process of change, and the danger of accepting limited tools is to risk slower progress towards GHG reduction targets.

Thus, the development of an adequate freight transport activity measure requires a fresh perspective and a novel approach. Realising an appropriate measure would see poor-performing companies identified relative to best practice and motivate appropriate company-level changes. At a reporting level, the creation of normalised data would also help monitor progress towards national-scale emission reductions. These are all desirable objectives from the point of view of the road freight sector. However, the objectives are also in line with more general ones previously outlined—i.e., the need for practical contributions from the road transport sector to address this global issue (Beuthe et al., 2007).

In this paper, we develop a benchmarking approach that integrates weight utilisation, volume utilisation, distance travelled, and related GHG emissions. This is achieved by exploiting data envelopment analysis (Cooper et al., 2000, 2007; Thanassoulis, 2001). The result, to the best of our knowledge, is the first attempt to benchmark environmental performance (expressed in terms of GHG emissions) of road freight transport operators with diverse operating characteristics. The rest of the paper is organised into five sections. Section 2 highlights the green logistics background, the problem of characterising freight activity, and the potential usefulness of DEA. The conceptual model, its mathematical formulation, and computational schemes are then covered in Section 3. The approach to data generation is described in Section 4, before results are presented and discussed (see Section 5). Finally, we summarise our findings and conclude by considering future research directions (see Section 6).

2. Background

2.1. Benchmarking emissions from road freight transport

Measuring a carbon footprint can be complicated for a number of reasons, including problems of measurement normalisation (Piecyk, 2015; Carbon Trust, 2007). Guidelines, principles, and the benefits of carbon foot-printing have been reviewed (Piecyk, 2015; Piecyk et al., 2015; McKinnon et al., 2015), and conceptual approaches that are specific to road freight transport offered (Pérez-Martínez, 2012; Liimatainen and Pöllänen, 2010). A key question for the freight sector is *how should logistics practice be organised to help drive-down GHG emissions?*

For example, evidence on fuel use per vehicle type shows that fewer heavier vehicles achieve smaller carbon footprints, given the same amount of freight as more numerous smaller vehicles (Piecyk, 2015); load consolidation is clearly an effective way of reducing GHG emissions from this point of view. However, any proposed solution will depend on how the logistics system is conceived.

Generally, freight movement can be considered a system defined by an objective—i.e. the efficient movement of physical entities from origins to destinations. Physical entities are variously referred to as 'products', 'commodities', or simply 'freight', but these classifications are vague. The *commodity* description accommodates a potentially diverse range of products with very different weight and volume characteristics. *Products* are too specific for a generic description of the freight system. The green logistics framework (McKinnon et al., 2015) fails to take account of key factors, such as product handling characteristics (liquid/bulk vs. palletised, for example), which constrain the type of vehicle suitable for the logistics task.

It is the wider context that is most difficult to pin down when developing measures of road freight performance. For example, making multiple drops of relatively light loads in urban areas has a different purpose to hauling heavy goods longer distances. Larger vehicles suited to the latter are more efficient in absolute terms, but more numerous smaller vehicles may be more suitable, e.g. for urban deliveries, than one large vehicle. That is, more numerous vehicles would be required for frequent deliveries, but given the constraints of the urban infrastructure, such vehicles are likely to be much smaller in size and the vehicle-level efficiency obtainable regarding long-haul is simple not attainable. The design of a transport fleet will be influenced by many such operational necessities. Additionally, one company might have a wider set of logistics tasks than a more specialised freight firm. Specialised companies have different niches and companies that have similar logistics tasks perhaps have different fleet characteristics. A general measure must satisfy this range of comparisons and an important stepping-stone towards accurate benchmarking is how to define efficiency in terms of a broad-enough definition of fleet capacity utilisation.

A more general formulation of a logistics system can be developed by adopting a process perspective (e.g., Cooper et al., 2009; Stewart, 2009). In determining the best logistics operation, a service provider/purchaser must first consider what