Project SLAM: Single Logistics Activity Measure

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Overview

Monitoring freight emissions for the assessment of company performance is essential if future reductions in CO_2 are to be realised. Current measures, however, have limitations. The SLAM project addresses the question of how to rationalise CO_2 measurements against the backdrop of highly diverse operating characteristics between different freight companies. Traditionally, freight movements are measured using distance, weight or a combination of the two, e.g., by multiplying the weight of goods by the distance they have been moved.

Most data relating to logistics activity in the UK economy are still collected and reported by Government in this way. However, because the British economy is no longer based on heavy manufacturing (or its low-value/high-density products) light-weight/high-volume products increasingly constitute the freight mix. Consequently, measures based solely on the weight of freight movements are less relevant than they used to be.

Aims

The aims of the project are to identify:

- Characteristics of modern logistics activity, which can relate to weight, volume and time constraints.
- Measures that are more representative of modern logistics activity based on volume limitations as well as weight limitations.
- A method that allows the reporting of logistics efficiency in order that different companies can be compared to best practice.

Freight activity

Existing freight activity measures (weights and distances)

Freight activity underpins the flow of commodities within an economy and there are three main measures used to characterise different aspects of this flow (McKinnon and Piecyk 2012). These are *tonnes-lifted*, *vehicle-kms*, and *tonne-kms*. Tonnes-lifted is a *weight-based* measure (McKinnon 2012). From production to sale, commodities are lifted at different stages in the supply chain. The weight (in tonnes) can be recorded. The measure is thus proportional to the amount of commodity moved and the number of times it is handled. Vehicle-kms is a *distance-based* measure. It is simply a record of the distance travelled by vehicles that carry out various logistics tasks. Tonne-kms combines weight and distance. It is calculated by multiplying the tonnes of commodity by the distance that the commodity has travelled.

As mentioned, volume-limited loads are a very important part of modern logistics activities. Deriving measures from only two physical dimensions (*weight* and *distance*) is, therefore, insufficient. The number of vehicles used to execute the tasks determines the kms driven and the volume shifted is becoming a more meaningful predictor of the number of vehicles used.

Incomplete data (volume)

Similarly to the idea of a carbon footprint (Carbon Trust, 2007; Piecyk, 2012), a wider context of performance is important and it is difficult the make simple comparisons. For example, making multiple drops of relatively light loads in urban areas has a different purpose to hauling heavy goods longer distances. Furthermore, one company might have a wider set of logistics tasks than another, more specialised freight firm; specialised companies themselves by definition occupy niche markets. In addition, companies that have similar logistics tasks perhaps have different fleet characteristics. Thinking of vehicles types alone, e.g., where it can be shown that larger, heavier vehicles are more efficient (Piecyk 2015), does not capture the richness of logistics context. A more inclusive measure must satisfy a range of comparisons.

A key missing measure is that of *volume*. With this we could define, for example:

- Volume-kms: this measure combines volume and distance. It is calculated by multiplying the volume of commodity by the distance the commodity has travelled.

This is analogous to tonne-kilometres, but would represent the fact that products have *volume* as well as *weight*. The addition of such a measure would allow representation for the loads that are volume limited.

Figure 1: The kinds of 'units' in use, reported within the LCWG meeting, January 2013.

Requirements for CO2 reporting and comparing

Reporting GHG emissions from a company is straightforward, if the total amount of emissions are required. That is (as is explained through the FTA's LCRS initiative[1]) as long as the total amount of fuel used in known, GHG emissions can be easily derived. Comparing outputs within a company over time can be achieved using a chosen KPI and as long as there are no changes in operational drivers the KPI should provide a useful measure. Furthermore, when comparing results *across* companies a common 'normaliser' is required. In other words, GHG need to be reported per unit of logistics

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See 'Guidance on measuring and reporting Greenhouse Gas (GHG) emissions from freight transport operations' available here: http://www.fta.co.uk/policy_and_compliance/environment/logistics_carbon_reduction_scheme/recording_and_reporting_carbon_emissions.html activity. For example, GHG per *kilometer, tonne-kilometer, pallet-kilometer, litre-kilometer, kilogram, tonnes lifted, pallet, pallet equivelents, cubic metre, container, or litre?* . The illustration above gives an extended indication of this variety in terms of possible measures employed within existing members of LCWG (see Figure 1.).

This varied collection of potential normalisers presents a problem. Finding an existing measure that is representative of all logistics activity is not possible, precisely because specialised companies employ a variety of measures in characterising their activity. We argue (see below) in addition that the problem of normalisers is fundamental to the problem of benchmarking with simple ratio-based KPI.

Minimal data required for performance measurement

We propose that a combination of cube & weight **utilisation** is what companies should be reporting on. Given the above list of current measurements, and the need to report CO2 outputs, key data to be collected within a company (and ideally related to each separate logistics task) is summarised here:

- CO2 emissions (*kg*) or fuel used (*kg*).
- Volume of product moved (m^3).
- Weight of product moved (*t*).
- Distance travelled (*km*).

These are the minimal data requirements a company should record in order that more accurate ways of reporting can be developed (please also see appendix). We now turn our attention to performance indicators derived from these suggested recordings.

Preferred data required for performance measurement

Preferable data should also include the total capacity of the 'fleet' used to transport the freight in terms of weight and volume, in addition to the above minimal requirements, i.e.:

- CO2 emissions (*kg*) or fuel used.
- Volume of product moved (m^3).
- Weight of product moved (*t*).
- Distance travelled (*km*).
- Capacity of the vehicle (s) used in terms of weight.
- Capacity of the vehicle (s) used in terms of volume.
- Time constraint information regarding the logistics task.[2]

[2] See section 'What about time constraints'.

Again, ideally, it should be related to each separate logistics task.

GHG performance indicators: simple weight-or-volume approach (KPI)

Key performance measures are often in the form of a simple ratio (McKinnon 2012). For freight activity, and in terms of weight-limited loads, the following performance (P) indicator can be applied for vehicle (v) (Léonardi and Baumgartner 2004).

$$P = \frac{GHG}{tkm}$$

By analogy, for volume-limited loads the following measure could be applied:

$$P = \frac{GHG}{m^3 km}$$

Generally these kinds of performance indicators have the advantage of being pragmatic in the sense they are simple to understand and very easily applied, if data is collected. One the other hand, they have limitations, if the objective is to compare across different logistics operators. The question is which normaliser to use, the one based on tonne-kilometres or the one based on volume-kilometres. If you use both, then it is likely (given we already know different companies have different operating characteristics) that inconsistent outcomes will result. This is illustrated in Figure 1. Firm 1 might be a company mainly associated with the movement of heavy goods, such as steel, whereas Firm 2 might deliver a product such as bread, which is high volume/low density.

Consequently, we know that treating volume and weight as separate key performance indicators does not satisfy the requirement implied by the SLAM project – i.e., a *single* measure is required, which can be applied across *different* freight operators. With this critique of KPI and the aims of SLAM in mind, a more advanced technique was explored. This technique is known as *Data Envelopment Analysis*.

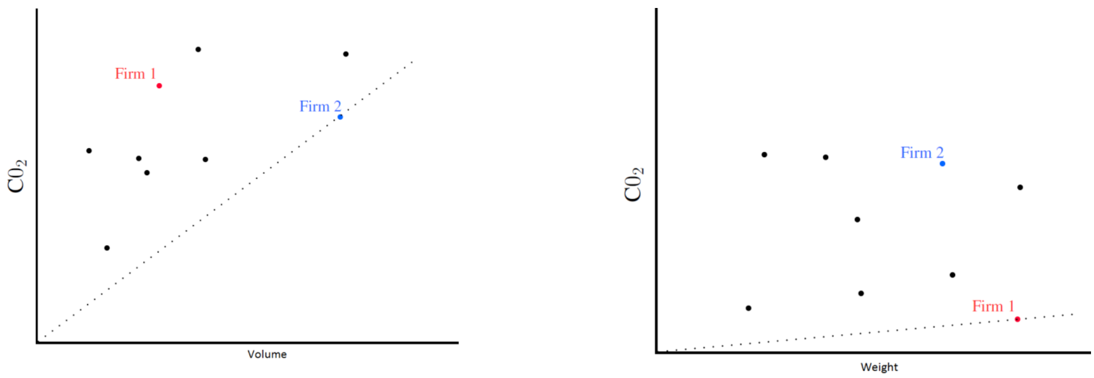

Figure 2 Simple measures can easily result in inconsistent results.

Combined GHG performance indicator

DEA brief background

Companies often combine multiple business inputs to assess performance against aggregated outputs. Various business costs are aggregated into a single cost, for example. Similarly, various outputs (profits, losses etc.) can be aggregated into a single output, such as revenue. This is unproblematic – i.e., such aggregations are meaningful because they share the same units.

However, meaningful aggregations are not always possible. Applications of DEA have therefore occurred in numerous contexts where simple measures seem inappropriate. Different education inputs, such as number of graduate or postgraduate students, relate, e.g., to different outputs – number of *undergraduate* degrees awarded and number of degrees awarded on a *postgraduate* basis (Johnes 2006). Such inputs and outputs clearly do not aggregate well. In a different example, Pahwa (2002) applies DEA to the performance of electricity distributors who have different *assets* (e.g., number of distribution lines), which over time acquire different maintenance *costs*. Both inputs should be expressed as they impact *overall* performance, in addition to service-level outputs (frequency and length of down-times etc.) and revenue (Pahwa 2002). This need to reduce outputs (service disruption) alongside maximizing other outputs (revenue) highlights the other limitation of ratio-based measures (single input-output formulations) for these situations. Simultaneously maximizing and minimizing desirable outputs and undesirable outputs is reflected in DEA models applied to corporate sustainability (Lee and Saen 2012). Other application areas include: banking (Ebrahimnejad, Tavana et al. 2014), agriculture (Gerdessen and Pascucci 2013), educational performance (Johnes 2006, Tóth 2009), and hospital performance (Jacobs 2001), to name a few.

Therefore, where simple measures will not suffice, the literature on DEA suggests that this method has produced some successful results over the years and in various domains. In other words, DEA discourages over-aggregation and allows us to better assess business as systems. In an relevant application of DEA to the use of trucks, as Odeck and Hjalmarsson (1996) argues, truck units should be thought of operating in a context that includes *"geographical conditions, make of truck, vintage year and the different direct costs such as labour, fuel and maintenance. This complexity of factors affecting truck performance leads to difficulty in determining one single measure for efficiency".* While rich data like this is not always possible to gather in practice, if it were, modellers need to be mindful of specifying *too many* variables - only the most salient features of a system should be captured in a DEA model. Exactly which features to include, and how, requires careful consideration.

A combined weight-volume measure (DEA)

As weight and volume *both* impact modern logistics, simultaneously treating both is desirable, especially if the purpose is to benchmark across a variety of freight companies. We thus exploit data envelopment analysis in prescribing a model that minimises CO2. The model has two key advantages over simple KPI measures.

- It is more representative of modern logistics activity in the sense that it includes an integrated treatment of weight *and* volume, simultaneously, in a *single* measure.

- As a result, the model might be used to compare companies with varying freight activities.

However, there are two key disadvantages to the model. These are:

- Though relatively simple compared with other DEA models, the technical detail relating to the model is far more complicated compared to the simple ratio based measures outlined above.

- As a result, this additional complexity in understanding is a possible barrier to adoption within the freight sector.

What about time constraints?

Not all loads are weight or volume limited, quite a lot are time limited. That is, a vehicle may complete a given task without reaching the weight or volume capacity of the used vehicle, simply because items require delivery within a given time window. In this case, the absolute efficiency of the vehicle would come into play and, given two differing fleets, one might be able to execute such journeys more efficiently. These additional constraints would point to a slightly adapted model that could account for them, simultaneously, alongside the treatment of weight and volume utilisation and GHG minimisation.

There is nothing to suggest that a DEA model along such lines could not be developed, but how this would be achieved within a DEA framework (or with another multi-dimensional approach) would need to be considered as a future model. DEA models are, ideally, data-driven at the outset. While every effort has been made to ensure relevance of the current model to the problem in hand, it is also a first iteration, and is kept as simple as possible in order to help communicate the underlying intentions.

Future modelling efforts would ideally be coupled with an open flow of data between stakeholder and modeller. This open-ended process would help reveal the best form of DEA model to use in practice.

Conclusions

From initial investigations, there are four key conclusions:

1. If there is *only* a need to report on aggregate GHG emissions, then this is unproblematic. Accurately reported company-level values can simply be summed to obtain an accurate overall GHG emission value for the road freight sector.

2. For benchmarking performance, simple ratio-based measures have limitations, in-spite of being attractive for their ease of application and understanding. Such simple measures are notoriously bad at providing consistent comparisons between companies and fail to reflect a firm’s multi-dimensional nature.

3. The additional collection of volume-related information, *at least*, is a prerequisite for the road freight sector. A normaliser (alongside *tkm*) to report GHG outputs representative of volume limited freight activity is needed. However, resulting measures are still ratio-based

(see 2.). They should only be used for comparisons of companies with very similar freight activities, and would not reliably allow a range of comparisons to be made by being combined into a SLAM.

4. A preliminary model highlights the possible benefits of using Data Envelopment Analysis towards a genuine SLAM; a full integration of weight and volume requires more complicated underpinning theory, which could act as a barrier to adoption.

5. Future research would also be needed to help define how other important constraints, such as time, might fit into such an approach. Any future work would also require robust data from road freight transport companies.

Future of data collection?

Technology that exists in hand-held devices could potentially be exploited. For example, within the Centre for Sustainable Road Freight, an app has been developed for Android mobile phones. The App accesses sensors in the mobile device (including accelerometers). Potentially these can be used to estimate the mass (of vehicle, vehicle load etc) by considering the accelerations in a particular context.

Research into existing technology that might help achieve measurements of product density is desirable, especially given that the recording of volume/density information is such an important obstacle to overcome. Volume can be measured more easily in a warehouse context than onboard a vehicle, but integration of data across organizational boundaries in the supply chain is a relevant question that could be researched.

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Appendix A: Data

Summary of data requirements (ideal case and future models)

Ideally data regarding the following should be collected:

- **CO2 emissions (*kg*) or fuel used.**
- **Volume of product moved (m^3).**
- **Weight of product moved (*t*).**
- **Distance travelled (*km*).**
- Capacity of the vehicle (s) used in terms of weight.
- Capacity of the vehicle (s) used in terms of volume.
- Time constraint information regarding the logistics task.

For a given time period of time, relating to specific logistics tasks

Minimal data requirements (for the current model)

Comma separated with the following headers:

Company_Name, GHG_kg, Weight_kg, Vol_m3, Dist_km

Example:

	A	B	C	D	E
1	Company_Name	GHG_kg	Weight_kg	Vol_m3	Dist_km
2	dmu_0	amount	amount	amount	amount
3	dmu_1	amount	amount	amount	amount
4	dmu_2	amount	amount	amount	amount
5	dmu_3	amount	amount	amount	amount
6	dmu_4	amount	amount	amount	amount
7	dmu_5	amount	amount	amount	amount
8	dmu_6	amount	amount	amount	amount
9	dmu_7	amount	amount	amount	amount
10	dmu_8	amount	amount	amount	amount
11	dmu_9	amount	amount	amount	amount
12					

Preferable data (for the current model)

Comma separated with the following headers:

Company_Name, GHG_kg, Weight_kg, Vol_m3,Dist_km, Weight_Capacity_kg,Volume_Capacity_m3

Example:

G13 *fx*

	A	B	C	D	E	F	G
1	Company_Name	GHG_kg	Weight_kg	Vol_m3	Dist_km	Weight_Capacity_kg	Volume_Capacity_m3
2	dmu_0	amount	amount	amount	amount	amount	amount
3	dmu_1	amount	amount	amount	amount	amount	amount
4	dmu_2	amount	amount	amount	amount	amount	amount
5	dmu_3	amount	amount	amount	amount	amount	amount
5	dmu_4	amount	amount	amount	amount	amount	amount
7	dmu_5	amount	amount	amount	amount	amount	amount
3	dmu_6	amount	amount	amount	amount	amount	amount
9	dmu_7	amount	amount	amount	amount	amount	amount
.0	dmu_8	amount	amount	amount	amount	amount	amount
.1	dmu_9	amount	amount	amount	amount	amount	amount
.2							

Acknowledgements

The authors gratefully acknowledge the EPSRC for funding this work through its financial support of The Centre for Sustainable Road Freight (EPSRC Reference: EP/K00915X/1). The authors would also like to thank Rachael Dillon, from the Freight Transport Association, for the time she made available for meetings and advice regarding the Logistics Carbon Working Group (LCWG). Responsibility for the information set out in this report lies entirely with the authors.