CO_2 Emissions from Freight Transport: An Analysis of UK Data

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Abstract
As governments are setting targets for CO_2 reduction, it is important that the contribution of different sectors to greenhouse gas emissions is accurately measured. This paper summarises the results of an analysis of CO_2 emissions from the freight transport sector within the UK. It reveals significant discrepancies in the available statistics and highlights serious difficulties in calculating emission values for waterborne freight and air cargo. Using the best available available data, it is estimated that 33.7 million tonnes of CO_2 were emitted from freight transport operations in 2004, approximately 6% of total UK CO2 emissions.
Key Words: CO_2, climate change, freight transport, carbon intensity,

Introduction

In recent years, the issue of climate change has risen up political and corporate agendas at an astonishing rate. Widespread acceptance of the basic science of climate change and recognition of the potential threat that it poses to our ecosystem and way of life has made the pursuit of CO_2 reductions a major priority for many governments and companies. At an early stage in the development of a carbon reduction strategy it is necessary to analyse the main sources of CO_2 emissions and identify those activities upon which carbon mitigation measures should be targeted. National governments have been establishing more elaborate systems for monitoring CO_2 emissions, in accordance with guidelines proposed by the Inter-governmental Panel on Climate Change (IPCC). Some, such as the UK government, have also given companies advice on how to collect, analyse and report data on their 'carbon footprints' (DEFRA, 2005). Detailed carbon auditing at an individual company level and across supply chains is still at a formative stage, however.

This paper summarises the results of a macro-level analysis undertaken for the UK Government's Commission for Integrated Transport of CO_2 emissions from domestic freight transport operations. This work revealed discrepancies in different sets of government statistics and identified areas where, at best, only crude estimates could be made, often involving extrapolation from research done in other countries. Subsequent analysis has been conducted as part of a multi-university research project called Green Logistics.

Interpreting CO_2 Data for Freight Transport

Great care must be exercised in interpreting the available CO_2 for freight, for several reasons:

(i) *Differing assumptions about the utilisation of vehicle capacity:* The amount of fuel consumed, and hence CO_2 emitted, is very sensitive to vehicle load factors. Agencies promoting particular transport modes as being more 'green' sometimes base CO_2 calculations for their mode on high levels of utilisation while using average load factor data for competing modes.

(ii) *Use of parameters derived from international studies:* in the absence of carbon intensity data for freight transport operations in a particular country, researchers often rely on intensity values calculated for other countries or international averages. This is risky as there are wide international differences in the nature and efficiency of freight transport operations, in the primary source of electricity (for rail and pipeline) and in the condition of transport infrastructure.

(iii) *Sectoral allocation of CO_2 emissions*. In the UK Environmental Accounts (Office of National Statistics, 2007), sectors are typically defined by their dominant activity. Where freight transport is undertaken on an 'own account' basis by companies whose main activity is not transport, the related freight emissions are excluded. This makes it difficult to obtain a comprehensive, cross-sectoral measure of CO_2 emissions from freight transport. The UK government now advises 'data users' to be 'aware that the road freight industry comprises solely the specialist road haulage companies and not all road freight activities'

(Department for Transport, 2006). This was not made clear when official statistics were released in 2004, suggesting that CO_2 emissions from HGVs had risen by almost 50% between 1990 and 2002. These statistics, however, excluded many ‘own account’ operators of lorries. During the 1990s, there was a significant switch from own account to hire and reward transport operations as more companies outsourced their distribution. This had the effect, *ceteris paribus*, of increasing fuel purchases by the ‘hire and reward’ sector. This represented a transfer of the demand for fuel between different road freight sectors rather than a net increase in the total demand for fuel and CO_2 emissions.

(iv) *Use of tonne-kms as the output measure for freight transport:* Analyses of the carbon intensity of freight transport invariably express CO_2 emissions as a ratio of tonne-kms, i.e. weight transported multiplied by the distance travelled. For some modes and commodity types it would be more appropriate to measure freight movement in terms of volume rather than weight. Lack of government statistics on the cubic volume of freight makes this impossible, however.

(v) *Movement of freight in passenger vehicles*: A significant amount of freight (mainly shopping) is moved in cars or public transport vehicles. This does not appear in any official statistics and so has not been included in CO_2 calculations for freight transport. With the growth of online shopping, responsibility for the ‘last mile’ delivery to the home is transferring from the consumer to the retailer / delivery company. The movement of online retail purchases in vans increases its statistical visibility. Around 70% of airfreight moves in the bellyholds of passenger aircraft (Department for Transport, 2003), making it difficult to isolate its CO_2 contribution.

(vi) *CO_2 and other global warming gases:* CO_2 is only one of several gases which contribute to global warming. It is estimated to account for around 84% of the global warming impact of the transport sector. This paper is solely concerned with CO_2 emissions from freight transport operations.

General Approaches to Measuring CO_2 Emissions

A distinction can be drawn between two approaches:

> *Input-based measures*: these are derived from estimates of the fuel / energy purchased by / supplied to companies in particular sectors. These are essentially ‘top-down’ measures. As discussed earlier, however, the practice of defining sectors with respect to dominant activities makes it difficult to obtain disaggregated CO_2 estimates for ancillary services such as logistics.
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> *Output-based measures*: these are derived from estimates of the actual amount of work done and the energy consumed per unit of output. The ‘output’ of freight transport operations is generally measured by tonne-kms and energy consumption by litres of fuel or kilowatt-hours of electricity used per tonne-km. When based on extensive surveys of freight transport operators, these ‘bottom-up’ measures usually provide accurate estimates of CO_2 emissions

For most freight transport modes both types of CO_2 measure are available. In the case of aviation, only output-based measures are available and these do not differentiate passenger from freight movements. Most of the statistics presented in the remainder of the paper are derived from output-based measures.

Estimation of CO_2 Emissions for Different Transport Modes

Road Freight

Heavy Goods Vehicles (HGVs)

The Continuing Survey of Road Goods Transport (CSRGT) is the main government survey of road freight operations in the UK (Department for Transport, 2005a). Since 1989 it has included a question about fuel consumption. This survey covers around 16,000 vehicles and monitors their activities over a period of one week. By relating the amount of fuel the vehicle consumed in the survey week to the distance it travelled, it is possible to calculate the average fuel efficiency. Road-side traffic counts are used to measure the amount of lorry movement on the road network. Unlike the CSRGT which only monitors the activities of UK-registered trucks, the road traffic surveys record the movements of domestic and foreign vehicles (Department for Transport, 2005b). Estimates of lorry-kms based on these counts can be combined with fuel efficiency ratios from the CSRGT to calculate total fuel consumption and CO_2 emissions. Deriving CO_2 estimates in this way makes it possible to disaggregate emissions by road type and location.

This output-based analysis suggests that there has been an increase in emissions of 8.8% to 27.6 million tonnes over the period 1990 to 2004. As road tonne-kms grew at twice this rate, the average CO_2-intensity of HGV operations declined, mainly as a result of a reduction in empty running, an increase in average payload weight and improved fuel efficiency (McKinnon, 2007).

A government pocket book on 'Sustainable Development Indicators' (DEFRA, 2006) claims that 'CO_2 emissions from heavy goods vehicles' rose by 29% between 1990 and 2004. It is not clear how this was calculated. This figure is more than three times higher than what we believe is the most accurate estimate of CO_2 growth from this sector and is likely to give a misleading impression of the environmental effects of road freight movement in HGVs.

Small Vans

The estimation of CO_2 emissions from vans also employed an output-based approach and relied on data from the 2004 Survey of Van Activity (Department for Transport, 2004). Analysis of this data had to allow for the fact that vans, unlike trucks, are used for purposes other than the carriage of freight. In 2004, only 35% of the distance travelled by company-owned vans involved the collection and/or delivery of goods or related empty running. Commuting to and from work accounted for a similar proportion of the distance travelled. It is not possible, on the basis of available data, to calculate fuel efficiency and CO_2 emissions specifically for freight collections and deliveries. It was simply assumed that freight-carrying vans account for around 35% of total van kilometres and a similar proportion of the CO_2 output from the van sector.

Assuming an average fuel efficiency for freight-carrying vans of 8 kms / litre (23 mpg)[1], freight-related van movement would have generated 3.84 million tonnes of CO_2 in 2004. In that year vans handled 10.7 bn tonne-kms of freight. This means that they produced 14.5% of the total CO_2 emissions from the road freight sector to carry only 6.6% of road tonne-kms[2]. It is not possible to monitor trends in the amount of CO_2 emitted by vans carrying freight. Unlike the CSRGT survey of lorries which been running annually for over 50 years, the van activity survey only began in 2003 and the results of two earlier van surveys in during the 1990s are not comparable.

Rail Freight

Approximately 90% of tonne-kms moved on the UK rail network are hauled by diesel locomotives. The remainder are hauled by electrified services. Previous studies have indicated that CO_2 emissions per tonne-km are significantly lower for electric traction. At a European level, for example, INFRAS (2004) estimates that diesel-hauled railfreight operations have twice the CO_2-intensity of electric-hauled operations. This ratio partly depends on the mix of fuels used in electricity generation and the average thermal efficiency of power plants. This has been analysed at a European level by IFEU (2005).

It was also possible to adopt an output-based approach for railfreight using data on tonne-kms and fuel consumption for typical bulk and intermodal trains operated by a large railfreight operator. Rail tonne-kms were multiplied by estimates of the amount of fuel consumed per tonne-km and a CO_2 conversion ratio for gas oil. The calculation took account of differences in fuel consumption and empty running between bulk / heavy haul operations and intermodal services, which constituted, respectively, 80% and 20% of total tonne-kms. It was possible to derive a comparable CO_2 emission factor for freight trains hauled by electric locos using data from the Rail Emissions Model (AEA Technology, 2001) and the Association of Electricity Producers (2006).

[1] This average has been estimated using fuel efficiency data for different types of van in the FTA's 'Manager's Guide to Distribution Costs 2004' and distance data from the DfT's 2004 Van Activity Survey. It was assumed that 10% of the distance traveled by smaller car-derived vans carried freight, while freight-related movement accounted for 45% of the mileage of other, larger / heavier vans.

[2] This estimate includes an allowance for empty running by vans engaged in freight distribution

This calculation yielded a figure of 309, 000 tonnes of CO_2 for UK railfreight in 2004 and a CO_2-intensity of 14.7 gm / tonne-km. Assuming the same levels of train loading as for diesel-hauled services, it was estimated that electrified freight services emitted a similar amount of CO_2 per tonne-km (13.9 gms)[3]. This suggests that the weighted average CO2-intensity for railfreight operations in the UK is 14.5 gms per tonne-km[4]. This estimate appears relatively low by comparison with the results of previous studies in the UK and elsewhere in Europe. For example, the Rail Emissions Model constructed by AEA Technology (2001) for the SRA used a ratio of 20 gm of CO_2 per tonne-km for railfreight. The TREMOVE study, undertaken by the University of Leuven, assigns a value of 33 gm of CO_2 per tonne-km for UK railfreight operations. Four other recent studies by NTM (2005), WRI-WBCSD (2003), INFRAS (2004) and IFEU (2005) suggest average ratios for European railfreight operations of, respectively, 17, 30, 38 and 18 (electric) / 35 (diesel) gms / tonne-km.

The estimate of total CO_2 emissions from UK railfreight in 2004 is also much lower than the figure in the official national Environmental Accounts (EA) (1.014 million tonnes) which was derived from an input-based calculation (Office of National Statistics, 2006). This suggests that the CO_2-intensity value for rail was 49 gm per tonne-km. In the EA statistical series this ratio has remained constant since the early 1990s, despite the fact that, in the intervening period, much of the freight locomotive fleet has been renewed and operational efficiency substantially improved. As a consequence, CO_2 emissions per tonne-km have dropped sharply. The EA figures appear therefore to grossly exaggerate railfreight's carbon footprint and under-estimate its CO_2 advantage over road transport.

Waterborne Freight

The EA contain no greenhouse gas emission data for freight movement on inland waterways. The only forms of waterborne transport included are coastal shipping and 'international marine'. The input-based estimates of CO_2 emissions from these shipping operations are confined to UK-registered companies. Figures for the bunker fuel purchased by these companies in the UK and overseas are multiplied by emission ratios from the IPCC to calculate the quantities of CO_2 produced.

The movement of freight by sea to, from or around the UK in foreign-owned vessels is excluded from the emissions inventory. On the other hand, CO_2 produced by cargo movements in UK-registered ships between ports elsewhere in the world are included in the database. As Britain's coastal, short-sea and deep-sea traffic is handled by a mix of UK- and foreign-registered vessels, there is no easy way of using the input-based approach to estimate the CO_2 emissions associated with the country's maritime freight services. A crude application of the output-based approach was used to estimate the amounts of CO_2 generated by inland waterway and maritime operations over different spatial scales. This required estimates of the number of tonne-kms moved and the CO_2 / tonne-km ratios for the different types of waterborne transport. Most of these ratios are derived from foreign studies (INFRAS / WWW, 2004; IFEA, 2005).

Inland waterways account for only 2.5% of all waterborne tonne-kms and 0.6% of total tonne-kms by all modes. The movement of freight on inland waterways is also relatively energy efficient, generating around 30-40 gm of CO_2 per tonne-km. Assuming an average ratio of 35 gm per tonne-km, total CO_2 emissions from inland waterways would have been only 53,000 tonnes in 2004. The other forms of domestic waterborne freight transport in the UK are coastwise traffic between UK ports and one-port traffic from and to these ports (mainly servicing off-shore rigs) (Department for Transport, 2005c). Adopting a similar output-based approach and using a slightly lower CO_2-tonne-km ratio (of 30 gms per tonne-km) yields an estimate of 1.74 million tonnes of CO_2 for the domestic shipping sector. This excludes coastal shipping undertaken in UK territorial waters by foreign-registered vessels.

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[3] This contrasts with the results of other European studies which show that the average carbon intensity of electrified railfreight services are substantially lower. This may reflect the greater use made of nuclear and hydro-electric power in electricity generation in some other European countries and differences in the average thermal efficiency of power stations.

[4] This relates to the railway line-haul and excludes road feeder movements to and from intermodal terminals.

Air Freight

The CO_2 estimates for aviation in the EA are essentially output-based measures. The Civil Aviation Authority provides data on the distances flown by British-registered airlines on domestic and international flights regardless of where the kerosene was purchased. Standard ratios are then used to convert flying distances into CO_2 emissions for different types of aircraft, making a distinction between take-off / landing and cruising on domestic or international legs. No attempt is made to differentiate passenger and freight movement. The integration of passenger and freight services makes such differentiation very difficult. It is estimated that 'around 70% of all air freight and parcels traffic is carried in the baggage holds of passenger aircraft', while at Heathrow this percentage rises to over 90% (Department for Transport, 2003). Among British-registered airlines, the proportion of airfreight tonne-kms moved in the bellyholds of passenger aircraft averaged 95% in 2005-6 (CAA, 2006). As mentioned earlier, where passenger and freight movement is combined in the same aircraft, it is difficult to establish a fair allocation of CO_2 emissions between the two types of traffic.

An alternative output-based approach, much used in previous, mainly foreign, studies, involves the application of standard CO_2 / tonne-km ratios to tonne-km statistics for airfreight. This yields freight-specific CO_2 values but raises questions about the origins of the standard ratios and the extent to which they are representative of different types of airfreight operations in different aircraft flying over varying distance ranges. In 2004, only 29 million tonne-kms of freight were moved domestically by air within the UK by British-registered airlines. This represented only 0.01% of total domestic tonne-kms. In estimating CO_2 emissions from domestic airfreight services, all that one can do is multiply tonne-kms of airfreight by CO_2 / tonne-km ratios. Three studies have estimated this ratio to be 1420, 1580 and 1925 gms per tonne-km for short haul airfreight services within a distance range of 425-500 km (Dings and Dijkstra, 1997, Network for Transport and Environment, 2003 and WRI-WBCSD, 2003). Multiplying airfreight tonne-kms by the average of these three estimates indicates that domestic air cargo services in the UK would have produced around 47,600 tonnes of CO_2 in 2004.

Total CO_2 Emissions for Domestic Freight Transport

The best estimates of CO_2 emissions for all modes in 2004 have been aggregrated to produce an overall figure for freight transport: 33.7 million tonnes. The contribution of the various modes to this total is shown in Figure 1A. Road transport accounts for 92% of this total, split in the ratio 86 : 14 between HGVs and vans. Rail and waterborne transport together account for just under 8% of freight-related CO_2 emissions, with domestic airfreight representing a negligible proportion despite the high carbon intensity of this mode. According to these calculations, freight transport is responsible for just over 21% of all CO_2 emissions from the transport sector and roughly 6% of total CO_2 emissions in the UK[5].

Figure 1B also shows the wide differences in the amount of CO_2 emitted per tonne-km. This highlights the important contribution that modal shift in to rail and water-borne transport can make within a carbon-abatement strategy. It also shows the high carbon impact of airfreight services when expressed on a tonne-km basis. The total number of tonne-kms carried by air within the UK is very small, however, much of it moves in passenger aircraft and it can be argued that for the light, high value products that are transported by air product value rather than weight would be more appropriate denominator in the carbon intensity index.

Conclusions

The research reported in this paper assembled statistics from various sources to estimate the amounts of CO_2 emitted annually by domestic freight transport modes in the UK. An 'output-based' approach was adopted because sector-specific, input-based estimates do not accurately measure CO_2 emissions from an ancillary activity such as freight transport. The accuracy of the output-based figures also varies between modes. The estimates for road freight movement in HGVs are likely to be the most robust, with those for waterborne and air freight requiring the greatest degree of approximation. More research is required to improve the data for these modes, for intermodal services and for van traffic to provide policy-

[5] The estimates of total CO_2 emissions from transport and all activities are based on 'end user' values published in Department for Transport (2005d).

makers with more reliable estimates of the likely effect of sustainable logistics measures on total CO_2 emissions from freight transport.

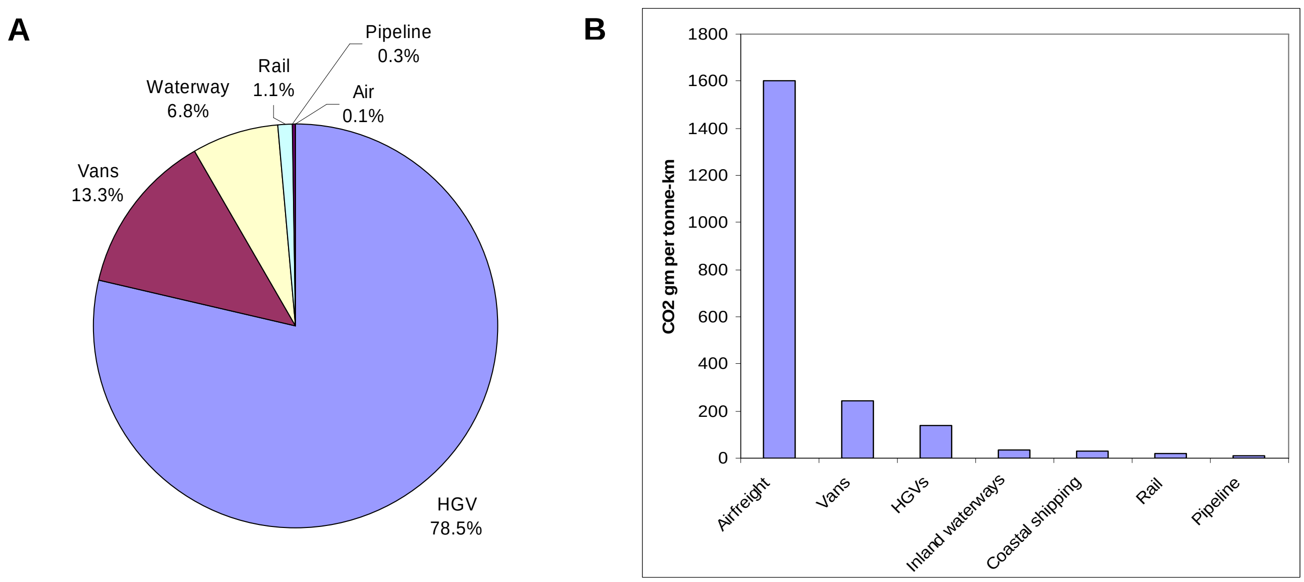

Figure 1: Modal Shares of CO_2 Emissions and CO_2 per tonne-km values for UK Domestic Freight Transport (2004)

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