CO_2 Emissions from Freight Transport in the UK

Report prepared for the Climate Change Working Group of the Commission for Integrated Transport

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Executive Summary

The contribution of the freight sector to global warming has so far received less attention than CO_2 emissions from car traffic and aviation. This paper should help to redress the balance by shedding more light on the subject.

It begins by assessing the validity of government statistics on CO_2 emissions from the freight sector and reveals significant discrepancies between estimates derived in different ways. For example, time-series data for CO_2 emissions from road freight in the UK Environmental Accounts and rail freight in the National Atmospheric Emissions Inventory appear to give a misleading impression of trends in these sectors. The growth of emissions from heavy lorries between 1990 and 2004 appears to have been exaggerated while recent estimates of CO_2 emissions per tonne-km for railfreight services substantially under-estimate the relative environmental benefits of using this mode.

Using what are considered the most reliable estimation methods, it is suggested that domestic freight transport in the UK generated 33.7 million tonnes of CO_2 in 2004, roughly 21% of emissions from the transport sector and 6% of total emissions from all sectors. Road transport accounted for 92% of these freight-related CO_2 emissions. The movement of freight in vans, which represented only around of 35% of all van-kms, was responsible for 13% of total freight emissions.

An analytical framework is presented which shows how the relationship between freight tonnage and CO_2 emissions depends critically on seven key ratios. These include the average length of haul, the proportion of empty running and fuel efficiency. Between 1990 and 2004 trends in most of these key ratios moved in a direction which reduced the carbon-intensity of the freight transport system per tonne of freight moved. There is, nevertheless, significant potential to reduce this carbon-intensity further.

Two scenarios are constructed to illustrate how changes in the key ratios collectively impact on total CO_2 emissions from the freight sector. A hypothetical 'aspirational' scenario could cut emissions by around 28%.

The paper examines each of the key ratios in turn, reviewing recent trends and assessing opportunities for further CO_2-reducing changes. A range of public policy measures are currently being deployed in the UK to reinforce some of these changes. These are focused mainly on freight modal shift, vehicle load factors and fuel efficiency. The paper reviews these initiatives and considers the possibility of supplementing them with other more radical measures. Available data suggests that the measures currently being applied are relatively cost-effective in terms of CO_2 saved per £ of public expenditure.

1. Methods of Estimating CO_2 Emissions from Freight Transport

Estimates of CO_2 emissions from freight transport per tonne-km vary widely both within the UK and internationally. This makes it difficult to establish the contribution of freight transport to climate change and to examine how this has been changing through time. To understand why these statistical discrepancies arise, it is necessary to examine the various methods that have been used to calculate CO_2 emissions from the freight sector.

A distinction can be drawn between two types of estimate:

Input-based measures: these are based on estimates of the fuel purchased by / supplied to companies in particular sectors. They are industry-specific and apply only to UK-registered companies. Many of these companies operate in other countries, as well as the UK, and so CO_2 emissions from their freight transport operations are not confined to the UK.

Output-based measures: these are derived from estimates of the amount of freight movement, expressed either in tonne-kms or vehicle-kms. They are activity- or mode-specific and not confined to the operations of UK-registered businesses. These output-based measures permit greater geographical targeting. For example, surveys of lorry traffic in the UK, comprising both British and foreign-registered vehicles, can be used to calculate total CO_2 emissions from all trucks operating in the UK regardless of their origin and ownership.

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.

1.1 Caveats

One must exercise caution in interpreting data on CO_2 emissions from the freight sector. The data can be misleading in several respects:

(i) *Assumptions about the utilisation of vehicle capacity:* Many estimates of CO_2 emissions from freight transport are based on standard mode-specific ratios of grams of CO_2 per tonne-km. In deriving these ratios, researchers often make assumptions about the utilisation of vehicle capacity. As Figure 1 shows, the amount of fuel consumed, and hence CO_2 emitted, is very sensitive to vehicle load factors, particularly in the case of road transport. Agencies promoting particular transport modes as being more 'green' have sometimes based CO_2 calculations for their mode on high levels of utilisation while using average load factor data for competing modes.

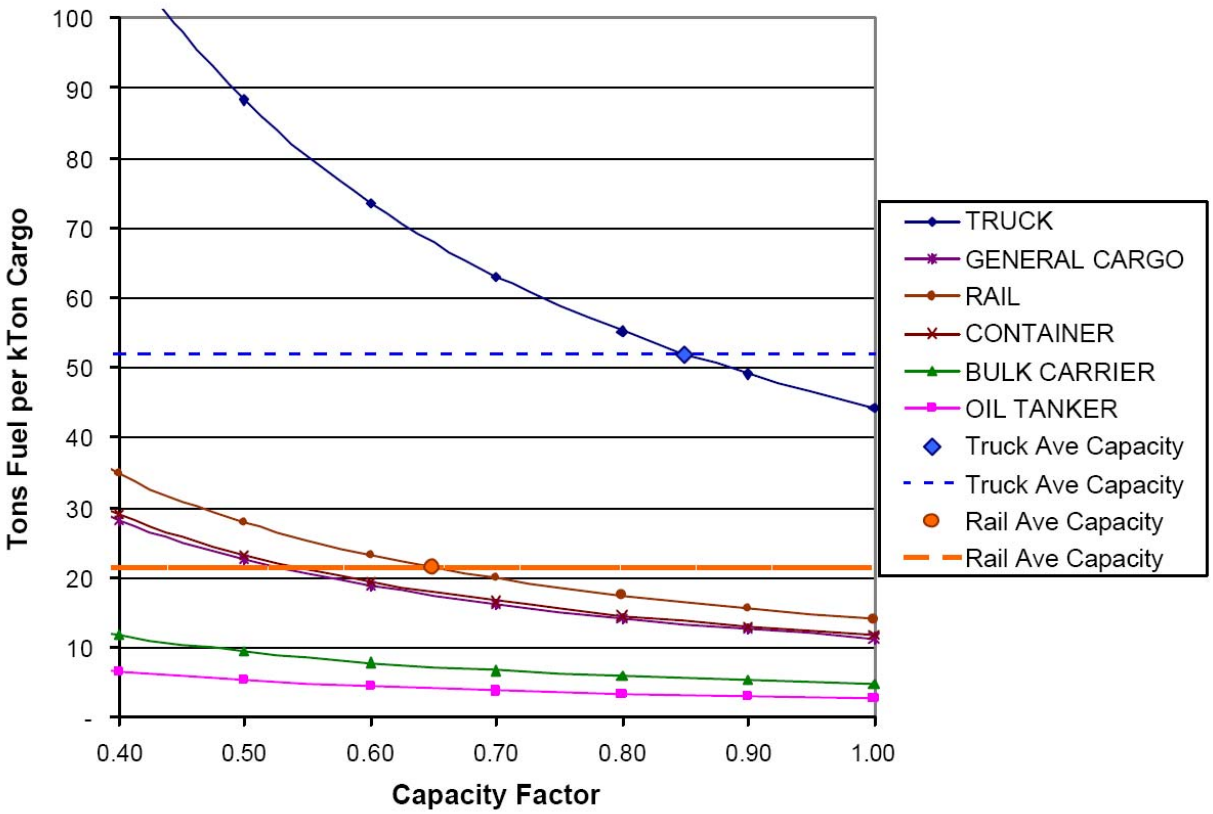

Figure 1: Effect of Capacity Utilisation on Fuel Efficiency of Freight Modes (source: Marintek et al, 2000)

(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) *National 'emissions accounting' typically quantifies CO_2 emissions by industry sector*. Freight transport is an activity which is highly diffuse within an economy, often undertaken on an ancillary basis by companies whose main activity is not transport. This makes it difficult to obtain a comprehensive, cross-sectoral measure of CO_2 emissions from freight transport.

(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. Associated CO_2 emissions are then included in environmental audits for the freight transport sector. The integration of passenger and freight movement in the same vehicles also complicates CO_2 auditing in the aviation sector. A large proportion of air cargo moves in the bellyholds of passenger aircraft, making it difficult to decide how much of a plane's CO_2 emissions should be attributed to the airfreight.

(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 in the UK. This report is solely concerned with CO_2 emissions from freight transport operations and ignores emissions of other global warming gases, such as methane and nitrous oxide.

1.2 Road Freight:

Heavy Goods Vehicles (HGVs)

CO_2 emissions from these vehicles, defined as lorries with a gross weight of 3.5 tonnes or more, can be measured in three ways:

1. Input-based measure: The United Kingdom Environmental Accounts, maintained by ONS, contains data on CO_2 emissions for 'road transport of freight' (EA code 67). This is based on estimates of fuel purchases obtained from the DTI. Its published estimates of CO_2 emissions for road freight relate solely to companies whose main activity is freight transport i.e. road hauliers. 'Data users' are now asked to be 'aware that the road freight industry comprises solely the specialist road haulage companies and not all road freight activities' (Department for Transport, 2006a). This was not made clear when official statistics were released in 2004, suggesting that CO_2 emissions from HGVs had risen by almost 40% between 1990 and 2003. These statistics, however, excluded many 'own account' operators of lorries whose main activity was not transport. 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 in CO_2 emissions. It was subsequently recognised that there had been ‘a misallocation between industry groups’ and the estimated CO_2 growth rate was revised downward (Department for Transport, 2006a).

2. Output-based measure using Continuing Survey of Road Goods Transport (CSRGT) data: The *CSRGT* is the main government survey of road freight operations in the UK. 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. Respondents are asked, ‘How many litres of fuel were purchased or taken from your own own supplies for this vehicle during the survey week.’ By relating this amount of fuel to the distance the vehicle travels over the survey week, it is possible to calculate the average fuel efficiency. Grossing up this data for the UK lorry fleet as a whole and applying standard fuel-CO_2 conversion factors yields CO_2 estimates for the activities of UK-registered lorry operators in the UK.

3. *Output-based measure using data from the National Road Traffic Survey (NRTS) and CSRGT:* Road-side traffic counts are also used to measure the amount of lorry movement on the road network. 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.

These two output-based measures yield markedly different figures for CO_2 emissions from the road freight sector. In 2005, measure 3 indicated that emissions were 30% higher than measure 2. This is the result of wide differences in the underlying estimates of lorry-kms. NRTS estimates of lorry-kms have traditionally been much higher than CSRGT estimates and the gap has been widening in recent years. This issue was investigated during the last quinquennial review of the CSRGT. Although no definitive explanation was established, several possible causes were identified:

> *Mis-classification of lorries*: staff making the traffic counts can confuse lorries and vans around the 3.5 gross weight threshold. They would have to do this on a large scale with a consistent upward bias to cause the present degree of discrepancy.
>
> *Exclusion of foreign-registered lorries from the CSRGT*: This survey is confined to UK registered operators and takes no account of the activities of foreign hauliers operating in the UK. The movement of foreign trucks is, however, monitored by the NRTS. The Foreign Vehicle Survey of 2003 provided a separate estimate of the distance run by foreign lorries on UK roads (Department for Transport, 2003). In 2003, foreign lorry-kms accounted for only 15% of the discrepancy between the CSRGT and NRTS distance estimates. This figure for foreign lorry-kms run on UK roads may be an under-estimate, however. The Eurostat estimate of road cabotage (i.e. domestic haulage undertaken by foreign-registered carriers) in the UK

in 2003 was 2.6 times higher than the DfT figure, suggesting that the exclusion of foreign trucks from the CSRGT might be responsible for 40% of the discrepancy. It seems likely that much of the divergence of the CSRGT and NRTS estimates of lorry-kms since the late 1990s is associated with the sharp increase in foreign penetration of the UK road haulage market since the full liberalisation of cabotage in 1998.

Under-reporting of distance travelled by CSRGT respondents: in completing the CSRGT questionnaire, operators could omit trips or under-estimate their mileage. An analysis of the tachograph records of a sample of operators did reveal significant under-estimation of distance travelled.

As the second and third causes are likely to be much more important than the first, the NRTS estimate is considered the more comprehensive and hence more accurate. The output-based measure combining NRTS and CSRGT data will therefore be used for CO_2 emissions from road freight operations.

Van Traffic

CO2 emissions from vans carrying freight have been estimated using an output-based approach. This used data from the 2004 Survey of Van Activity (Department for Transport, 2004) and estimates of average fuel consumption from other sources. Allowance was made 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 will simply be 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.

It is not possible to monitor trends in the amount of CO_2 emitted by vans carrying freight. Unlike the CSRGT survey of lorries over 3.5 tonnes, the Van Activity survey is only conducted occasionally. Indeed there have only been two official surveys of van traffic over the past 16 years which measured the weight of goods transported in these vehicles (in 1992-3 and 2004). The National Atmospheric Emissions Inventory (NAEI) contains data for the period 1990-2004 for CO_2 emissions from vans. This does not differentiate emissions by trip purpose, however. This is important as the balance of freight-related and non-freight work undertaken by small vans is likely to have changed significantly over the past fifteen years, reflecting the growth and transformation of the service sector.

1.3 Rail Freight

Approximately 90% of tonne-kms moved on the rail network are hauled by diesel locomotives[1]. 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).

The NAEI contains measures of CO_2 emissions from diesel-hauled railfreight over the period 1990 to 2004. In this data-base the CO_2 emission factor has remained constant at approximately 49 gms of CO_2 / tonne-km. This ratio may have been broadly representative of railfreight operations in the early 1990s. The Royal Commission on Environmental Pollution, for example, used a figure of 41 gm / tonne-km for railfreight in 1994. Since then, however, much of the freight locomotive fleet has been replaced and operational efficiency substantially improved. For example, up until the late 1990s it was standard practice in the railfreight sector not to switch off diesel locomotives during the working day as drivers had little confidence in the ability of the batteries to restart the engines. Large amounts of fuel were consumed and CO_2 emitted while the engines were idling. The amount of idling has now been sharply reduced, as a result of the renewal of the locomotive fleet, improved battery maintenance and adoption of new driving procedures. Overall, CO_2 emissions per tonne-km of railfreight have dropped sharply over the past decade.

This is confirmed by an alternative output-based measure used by the DfT. It is calculated by multiplying rail tonne-kms by an estimate of the average amount of CO_2 produced per tonne-km. The CO_2 / tonne-km ratio it uses, however, is derived from much more recent operational data obtained mainly from EWS, Britain's largest railfreight operator. This takes account of differences in fuel consumption and empty running between bulk / heavy haul operations and intermodal services. This calculation relates to diesel-powered operations. It has been possible to derive a comparable CO_2 emission factor for freight trains hauled by electric locos using data from the SRA Rail Emissions Model (AEA Technology, 2001), and the Association of Electricity Producers (2006).

1.4 Waterborne Freight

The NAEI contains 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

[1] INFRAS (2004, p.126) estimates that in 2000 roughly 88% of rail tonne-kms in the UK were diesel-hauled. This proportion is likely to have declined slightly since then. No statistics have been published in recent years on the division of railfreight traffic between electric and diesel power.

emissions from these shipping operations are again 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 Inter-governmental Panel on Climate Change (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 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 international waterborne trade.

A crude application of the output-based approach can be used to estimate the amounts of CO_2 generated by inland waterway and maritime operations over different spatial scales. This requires 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.

1.5 Air Freight

The CO_2 estimates for aviation in the NAEI are essentially output-based measures. The Civil Aviation Authority provides data on the distances flown by British-registered airlines on domestic and international routes 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 on the same aircraft 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). 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 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 airfreight operations of different types in different aircraft over varying distance ranges.

2. Results of the CO_2 Estimation Process

This section reviews the available statistics on CO_2 emissions derived by the methods described above.

2.1 Road Freight

HGVs

Figure 2 shows the trends in CO_2 emissions from road freight operations between 1990 and 2005 calculated using the three methods outlined above. The input-based estimates obtained from the UK Environmental Accounts (UKEA) have been consistently lower than the other two, but experienced a much steeper increase during the 1990s. As explained above, the estimates are lower because they relate solely to the activities of road hauliers and under-estimate CO_2 emissions from the 'own account' road freight operations of companies whose main activity is not transport. The sharp increase in CO_2 emissions during the 1990s can be largely attributed to the greater outsourcing of road transport over this period. It was mainly the result of a redistribution of CO_2 emissions between sectors.

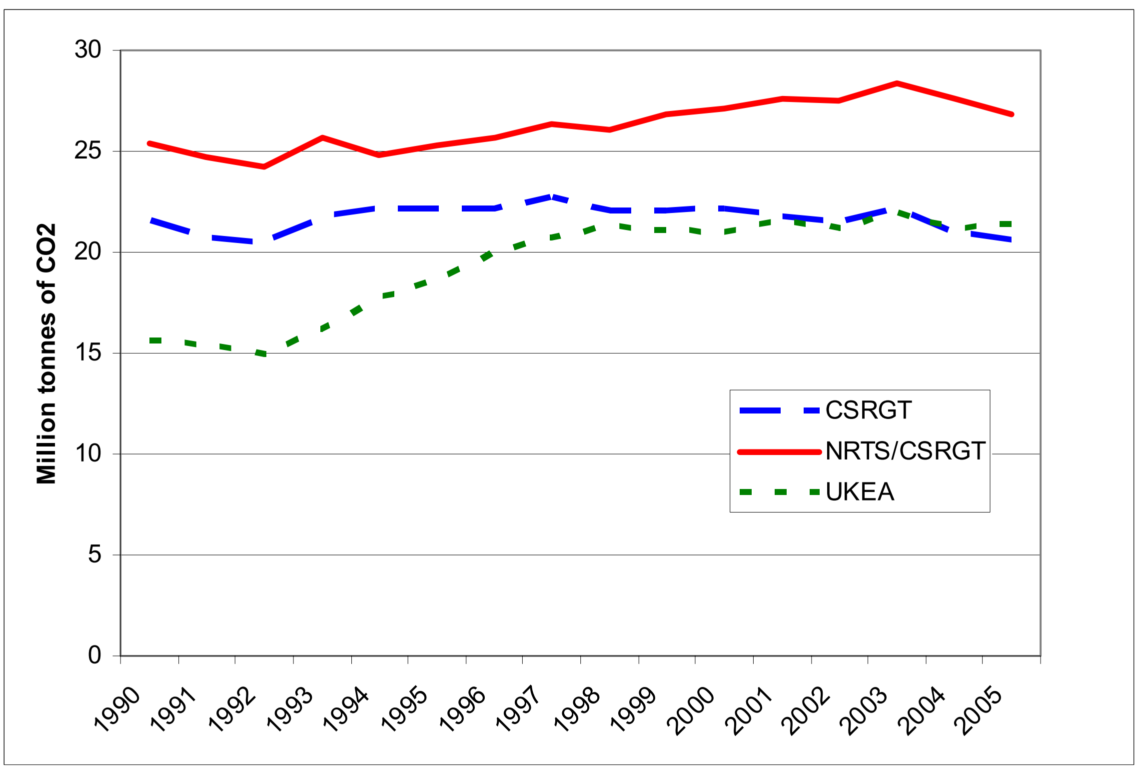

Figure 2: CO_2 Emission Trends for HGVs Calculated in Three Different Ways

The output-based estimates using solely CSRGT data suggest that CO_2 emissions from the road freight sector have remained fairly flat since 1990. They indicate that HGV-related CO_2 emissions actually fell by 2.6% between 1990 and 2005, despite the fact that, over this period, total tonne-kms rose by 17%. As discussed earlier, however, the CSRGT under-estimates lorry-kms and the degree of under-estimation appears to have been increasing. For this reason, CO_2 estimates based on NRTS measures of lorry traffic are likely to be more accurate. These estimates suggest that there was a steady increase in emissions over most of the period since 1994 to 2003 to a peak of 28.4 million tonnes, but that it has sinced declined slightly to 26.7 million tonnes. Overall, CO_2 emissions from HGVs increased by 5.4% between 1990 and 2005. The growth in CO_2 emissions from road freight transport grew at roughly a third of the rate of road tonne-kms (in UK registered lorries) over this period. As discussed later, the declining CO_2 intensity per tonne-km for HGVs can be attributed mainly to a reduction in empty running, net consolidation of loads and improved fuel efficiency.

A government pocket book on 'Sustainable Development Indicators' (DEFRA, 2006a) 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 operations.

Vans

Assuming an average fuel efficiency for freight-carrying vans of 8 kms / litre (23 mpg)[2], 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 suggests 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[3]. It reflects the much higher level of CO_2 emissions per tonne-km from vans than from lorries (360 gm per tonne-km as opposed to 138 gm per tonne-km for HGVs).

As explained earlier, it is not possible to monitor to changes through time in CO_2 emissions from freight-carrying vans.

[2] 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.

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

2.2 Rail Freight

The NAEI contains an estimate that 1.014 million tonnes of CO_2 was emitted by the consumption of gas oil in railfreight operations in 2004. As explained earlier, this is based on a CO_2 emission factor of 49 kms / tonne-km, a much higher ratio than those recorded in other studies. 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 alternative output-based method of calculation was used to derive a CO_2 estimate for railfreight in 2004 (based on diesel traction). This yielded a figure of 309, 000 tonnes of CO_2 and a gm / tonne-km figure of only 14.7. Using data from the Rail Emissions Model and Association of Electricity Producers and assuming the same levels of train loading as for diesel-hauled services, it is estimated that electrified freight services emit a similar amount of CO_2 per tonne-km (13.9 gms)[4].

These CO_2 intensity values are roughly a third of those contained in the NAEI. This discrepancy may be partly the result of two factors:

Large improvement in the energy efficiency of railfreight operations since the early 1990s. The Class 66 freight locomotive is roughly 11% more energy efficient than the Class 56/58 locos which it has replaced over the past decade. EWS, for example, which holds roughly three-quarters of the UK railfreight market, has acquired around 250 Class 66 locos since 1997. These now constitute roughly two-thirds of its loco fleet. Railfreight operators have also altered operating practices and scheduling in ways which has reduced fuel consumption and CO_2 emissions per tonne-km.

Utilisation of railfreight capacity: the alternative output-based method assumed high utilisation of trains (at 1700 tonnes on bulk train and 850 tonnes on an intermodal train). If average load factors are significantly lower than this, as seems likely, the energy- and carbon-intensity of railfreight operations will be correspondingly higher.

[4] 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.

Further work is required to reconcile differences in emission factors from different sources. The estimated emission factors for UK railfreight operations seem low by comparison with the average European figures derived by WRI-WBCSD (2003), INFRAS (2004)and IFEU (2005). On the basis of the available evidence, an emission factor of 20 gms of CO_2 per tonne-km has been assumed for railfreight, similar to that used in the Rail Emissions Model (AEA Technology, 2001), giving a total CO_2 output of 420,000 tonnes for this mode in 2004.

The only time-series data available on CO_2 emissions from railfreight are found in the NAEI, though this data set makes no allowance for improvements in energy efficiency and is likely to over-estimate the recent level of emissions by a significant margin.

2.3 Waterborne Transport

Inland waterways

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 (Dings and Dijkstra, 1997, INFRAS/WWW, 2004). 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.

Coastal shipping

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, 2005). Given the diversity of vessel types, tonnages and operations it is difficult to establish an average CO_2 emission factor for coastal shipping. DEFRA (2005) quotes emission factors for several types of vessel ranging from a small roro vessel at 60gm of CO_2 per tonne-km to 7 gm per tonne-km for a large bulk carrier. For the purposes of this study a mid-range value of 30 gms per tonne-km had been adopted. Multiplying this emission factor by the total tonne-kms moved by coastal shipping in 2004 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.

International Shipping

As discussed earlier, figures for CO_2 emissions from international shipping are only available for vessels operated by UK-registered companies. They cannot, therefore, be used to estimate the amount of CO_2 released in moving Britain's international trade by sea, as most of this trade is carried by foreign-registered ships. NAEI data indicates that there has been a sharp increase in CO_2

emissions from the international shipping operations of British companies. This is mainly the result of many more vessels joining the UK shipping register to take advantage of the system of 'tonnage tax' introduced in 2000. 'Flagging into the UK' has extended the coverage of the CO_2 data base for international maritime traffic in the NAEI. This makes it difficult to monitor the underlying growth in CO_2 emissions associated with the growth of UK international trade.

2.4 Air Freight

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. No general statistics are available on the division of this domestic airfreight traffic between the bellyholds of passenger aircraft and dedicated all cargo aircraft. Also, as mentioned earlier, the NAEI does not differentiate freight from passenger services.

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 (Dings and Dijkstra, 1997), 1580 (Network for Transport and Environment, 2003) and 1925 gms per tonne-km (World Business Council for Sustainable Development, 2004) for short haul airfreight services within a distance range of 425-500 km. On this basis, domestic air cargo services in the UK would have generated between 40 and 55,000 tonnes of CO_2 in 2004.

A similar method of calculation can be used for international air cargo services operated by British-registered airlines. Four studies have assigned ratios of 637, 800, 800 and 867 grammes of CO_2 per tonne-km for long haul airfreight movements (respectively Dings and Dijkstra, 1997, World Business Council for Sustainable Development, 2004; INFRAS, 2004; Network for Transport and Environment, 2003). This suggests that the 6 billion tonne-kms of international airfreight handled by British airlines in 2004 would have generated between 3.8 and 5.2 million tonnes of CO_2.

3. 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 3. 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.

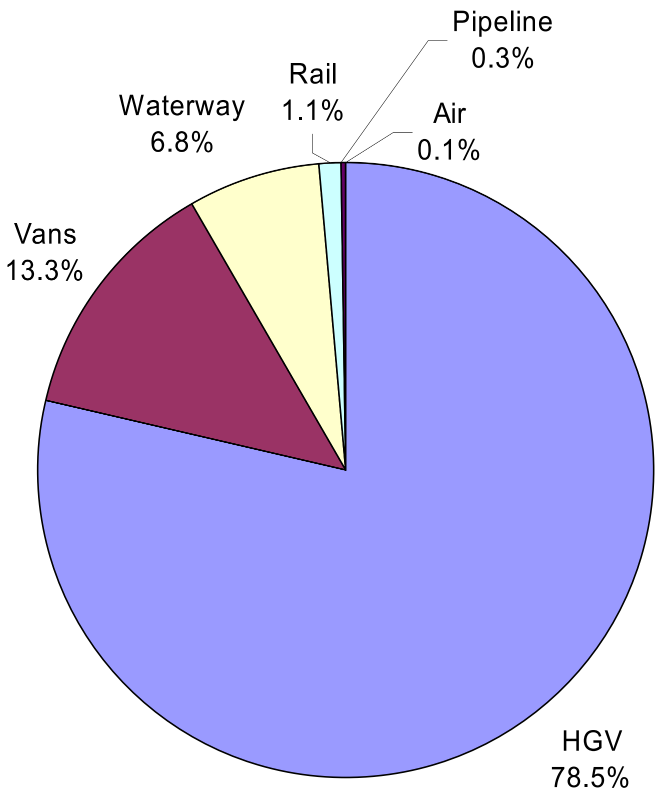

Figure 3: Modal Shares of CO_2 Emissions from Domestic Freight Transport (2004)

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].

[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).

4. Framework for Assessing the Potential for Cutting CO_2 Emissions

To conduct a systematic review of the opportunities for reducing CO_2 emissions from freight transport it is necessary to construct an analytical framework incorporating all the factors which influence freight traffic levels and related energy consumption. It is also important that this framework illustrates the links between freight transport and the economic activities that it serves.

The framework shown in Figure 4 meets these requirements. It is based on a series of earlier studies and will form the basis of the current review. The framework links the weight of goods produced / consumed to CO_2 emissions from freight transport operations. This relationship can be decomposed into a series of seven key ratios each of which converts one output value into another. The *handling factor* ratio converts the weight of goods in the economy into freight tonnes-lifted, allowing for the fact that, as they pass through the supply chain, products are loaded onto vehicles several times. For this reason, the handling factor can be considered a crude measure of the number of links in a supply chain. The *average length of haul* (which is the mean length of each link in the supply chain) converts the tonnes-lifted figure into tonne-kms. The handling factor and average length of haul together determine the 'transport intensity' of an economy. This can be defined as the amount of freight movement generated for every tonne of product produced / consumed. The *modal split* indicates the proportion of tonne-kms carried by different transport modes. Figure 4 charts the subsequent relationships for road transport, which is by far the dominant freight mode in the UK, though similar diagrams could be compiled for other modes. The amount of lorry traffic required to move these tonne-kms is determined by two other ratios, the *average payload on laden trips* and *proportion of kms run empty*. The quantity of fuel consumed will be a function of the *fuel efficiency* of with which vehicles are operated. This will be partly determined by traffic conditions at particular times of day on particular roads. The seven ratios discussed so far vary by industrial sector, nature of the distribution operation, vehicle type etc. In contrast, the ninth ratio, of *fuel consumption to CO_2 emissions*, is fixed for a particular type of fuel / power source. Life-cycle CO_2 emissions per litre from different types of fuel can, nevertheless, vary widely, depending on the nature and location of the raw material and the efficiency of the fuel production and distribution systems.

The remainder of the report will focus on each of these critical ratios and seek answers to the following questions:

- What is the current trend in this ratio?
- Is this trend reducing or increasing CO_2 emissions?
- What is the potential for modifying this trend to cut CO_2 emission?

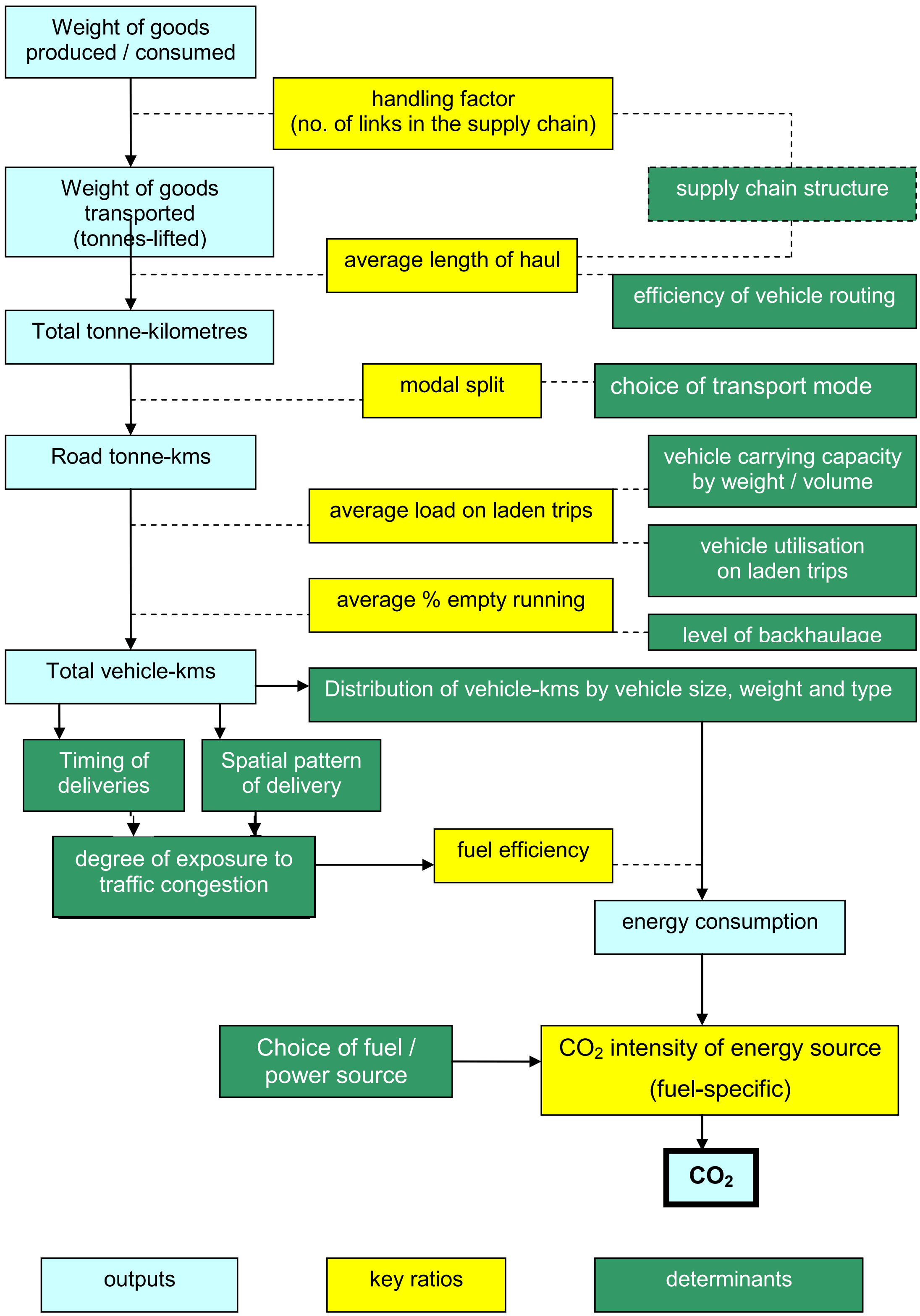

Figure 4: Framework for Analysing Opportunities for CO_2 Reduction

4.1 Divergence of Freight Transport and Economic Growth Trends

For several decades there was a close correlation between economic growth and the growth of freight movement measured in tonne-kms. These two trends have decoupled over the past decade, with GDP increasing steadily at 2.5-3% per annum, while tonne-kms have remained fairly stable (Figure 5). Possible reasons for this trend are explored in a separate paper (McKinnon, 2007). They include:

- Change in the composition of GDP, with services accounting for a greater proportion of total output. Services generate less freight movement per unit of output than production activities.

- Off-shoring of manufacturing capacity / increasing import penetration. When manufacturing relocates to other countries, so do the inbound supply links, reducing the freight transport intensity of the economy.

- Weakening of centralisation / wider sourcing trends. These trends were major drivers of freight traffic growth between the 1960s and 1990s. They could not continue indefinitely and appear now to be at an advanced stage in the UK.

The UK has experienced much more pronounced decoupling of GDP and tonne-km trends than most other EU countries. Indeed, in some other countries, such as Spain and Ireland, the decoupling has occurred in the opposite direction, with freight tonne-km growth exceeding economic growth (Eurostat, 2005). In theory, the breaking of the link between increasing prosperity and freight traffic growth should make it easier for the UK to meet its CO_2 targets within an expanding economy. The following two sections examine the potential for further reducing the freight transport intensity of the UK economy.

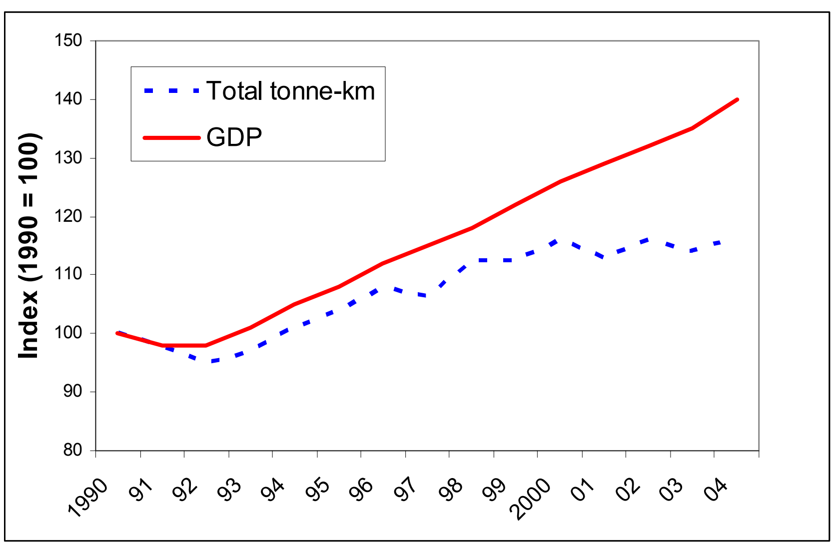

Figure 5: Decoupling of GDP and Total Tonne-km Trends

4.2 Handling Factor

Trends

The transport intensity of a supply chain can be reduced by cutting the number of separate journeys that a product makes in travelling from raw material source to point of sale or consumption. On the basis of available statistics, it is very difficult to determine changes in this average number of journeys (i.e. handling factor). Handling factors for different sectors of the UK economy were last calculated in 1998 and related to the period 1985 to 1995. When averaged across twelve commodity classes, the handling factor rose by 7% between 1985 and 1990 and showed no change between 1990 and 1995. Individual commodity classes, however, were subject to widely varying handling factor trends over this period. Some, most notably transport equipment, machinery and food, exhibited a steep increase in average handling factor. In the case of transport equipment and machinery this may be attributed to the vertical disintegration of the manufacturing process as a result of the outsourcing of non-core processes to sub-contractors (Campbell and McKinnon, 1998). In the grocery sector it could be partly related to the growth of food processing and refrigeration, the insertion of a primary consolidation stage in the retail supply chain and increase in the cross-shipment of products within the distribution networks of supermarket chains (Aujla et al, 2004). On the other hand, bulk, primary products, such as coal, coke and metals, experienced a substantial reduction in handling factors indicating a rationalisation of their supply chains. A similar trend observed for textiles and clothing was probably associated with increased import penetration. Many of these trends are likely to have continued during the past ten years, though their net effect on the handling factor is not known.

Opportunities for cutting CO_2 emissions

It would be possible to streamline many domestic supply chains by reducing the nodes and links. This would involve eliminating intermediate locations for processing, storage and handling and achieving higher degrees of vertical integration of at particular manufacturing or distribution sites. In some sectors this would require a reversal of the process of vertical disintegration that as been prevalent over the past 20 years, while in others it would simply reinforce existing trends. It could be induced by increasing freight transport costs and, thereby, altering the cost trade-offs that companies make between transport and other logistical / production activities. In most sectors, however, the transport cost increases would have to be very large to induce such a structural change.

It is also worth noting that, in some cases, eliminating links in the supply chain would either be ineffective or counter-productive:

i) some nodes act as consolidation points where goods are assembled into larger loads for more efficient delivery. By raising the average payload and cutting vehicle-kms, they serve a very useful purpose and can effect a net reduction in CO_2 emissions.

ii) where the links in a supply chain are aligned along a direct route between the raw material source and final point of sale / consumption, little vehicle mileage would be saved by eliminating them.

Very little general information is available on the geographical structure of supply chains. Most government freight data is collected for individual journeys and give no indication of how these journeys are connected into supply chains.

4.3 Average Length of Haul

Trends

Until recently freight traffic growth in the UK was due mainly to increases in the average distance that each freight consignment is transported. Between 1953 and 2004 the average length of haul for all transport modes rose from 72 km to 117 km. In the case of road freight, it increased from 35km to 87km. In recent years, however, this long term trend appears to have ended, with average length of haul stabilizing and then, in the case or road and rail, declining slightly.

Increases in the average length of haul have been attributed mainly to the centralization of economic activity and the wider sourcing of supplies. Does the stabilization of the average length of haul trend indicate that these trends have run their course?

Centralisation of Economic Activity

There are good grounds for believing that the spatial concentration of economic activity is weakening. The process of centralisation is inevitably finite. Factories and warehouses eventually reach their maximum economic size. Once a company centralises all its production or inventory at a single location the process is complete. It appears that some sectors are approaching this maximum degree of centralisation though this is very difficult to demonstrate empirically. The only macro-level data that can be used to assess the degree of spatial concentration is that held on the government's Inter-departmental Business Register. This records information about employment and sales in 'local units', disaggregated by industrial sector and district (Office of National Statistics, 2005a). An analysis of local units with 20 or more employees found wide inter-sectoral variation but suggested that, overall, there has been a small degree of concentration over the period 1998-2003. The total number of local manufacturing sites declined by 6.6% while the total amount of gross value added rose by 2%. During the 1980s the spatial concentration of manufacturing output was much more pronounced, particularly among larger firms (McKinnon and Woodburn, 1993).

Wider Sourcing of Supplies

The wider sourcing of supplies and expansion of market areas have been intrinsic features of economic development in the UK, and other countries, for centuries. As transport and communication networks have improved, companies have extended their 'logistical reach' to find better, cheaper and more diverse sources of supply and sell their products to more distant customers. This process is currently very active at both European and global scales. It is possible, however, that it has begun to slacken at a national scale, as domestic supply chains reach their maximum extent. This would suggest that, within a mature market such as the UK, national distribution has become the norm for many products and sectors. Those that have not achieved this degree of geographical coverage by now may remain confined to particular regions as a result of resource endowments, consumer tastes and / or transport costs. The CSRGT provides some statistical evidence to support this view. It shows that the proportion of road freight tonnage moved inter-regionally increased from 22% to 32% between 1982 and 1997. Since then it has been fairly stable at 30-32% of total road tonne-kms (Department for Transport, 2005).

The extent of the area over which a company sources supplies and markets finished products is partly a function of the cost, speed and reliability of transport services. Rising levels of traffic congestion may therefore have been discouraging further lengthening of supply chain links, though testing of this hypothesis will require new empirical research.

Off-shoring of Production

The restructuring of domestic supply chains cannot be examined in isolation. As the UK is a major trading trading nation, with imports and exports of physical goods representing respectively 17% and 21% of GDP (Office of National Statistics, 2005b), it is important to explore the effects of international trade on internal supply chains. Over the past decade there has been a massive redistribution of industrial capacity from developed countries to the low labour cost countries of the Far East and Eastern Europe. This trend has accelerated in recent years as a result of China joining the World Trade Organisation, market liberalisation the accession of Central and Eastern European states to the EU. Many UK-based companies have relocated manufacturing plants to these countries or been forced to scale down / close their operations in the face of intensifying global competition. This is reflected in the steep increase in the degree of import penetration in most industrial sectors over the period 1997 – 2003. Across 21 manufacturing sectors (SICs) for which data are available, the import penetration ratio increased by an average of 50% over this six year period (Office of National Statistics, 2005b).

When a manufacturing plant is relocated to another country or its output is replaced by imports, the upstream and downstream supply networks can be dramatically altered. Many of the upper links in the supply chain also transfer to the foreign country as new overseas vendors are found. This is well illustrated by the case of the British household appliance manufacturer, Dyson, which relocated the production of its vacuum cleaners from the UK to Malaysia in 2002. Materials and components that had previously been sourced from the UK and other EU countries were thereafter purchased from Far Eastern suppliers. Where manufactured goods are imported to the UK in their finished form, primary flows of raw materials and intermediate flows of components and sub-assemblies are removed from the British transport system. The net effect will be a significant reduction in the freight transport-intensity of the British economy.

The off-shoring of production activities reduces freight-related CO_2 emissions within the UK but increases them in other parts of the world. The increase elsewhere is likely to exceed CO_2 savings in the UK for two reasons:

i) freight transport operations in the low labour cost countries to which production capacity is migrating are less energy efficient than in the UK and generate more CO_2 per tonne-km than the UK. For example, a comparison of road freight operations in the UK with those of the Asia Pacific region reveals that the latter are between 25 and 30% less energy-efficient. This can be attributed to the greater age of the vehicle fleets, lower standards of driving and vehicle maintenance and poorer infrastructure.

ii) the additional long haul movement of imports to the UK generates large amount of CO_2. For example, in 2004 a total of 4.3 million tonnes of imports arrived at major UK ports from China. According to the Swedish Network for Transport and Environment (NTM) deep-sea shipping emits an average of 15 gm of CO_2 per tonne-km. Ships sailing between China and the UK travel approximately 10,000 nautical miles (18,500 kms). This indicates that approximately 1.2 million tonnes of CO_2 were emitted in shipping Chinese imports to the UK in 2004 - equivalent to 4.3% of the annual emissions of CO_2 from lorries in the UK in that year.

Opportunities for cutting CO_2 emissions

In theory it would be possible to reduce the average length of haul, or at least moderate its rate of increase, by reconfiguring production and distribution systems, sourcing products from local suppliers and finding shorter routes between collection and delivery points.

(i) Reconfiguring production and distribution systems: These systems are relatively fixed in the short- to medium-term. It would be very difficult to reverse the geographical concentration of production, given the magnitude of the scale economies that firms have achieved. Simulation modelling of logistical systems in a range of industrial sectors indicates that the cost trade-offs which companies make between transport, inventory and warehousing are very robust (McKinnon, 1998a). Tilting these cost trade-offs sufficiently to induce a return to more localised and decentralised patterns of production and distribution would require very large increases in transport costs (generally in excess of 100%)[6]. Increases of this magnitude would not only be politically unpalatable; they would also be difficult to defend on environmental grounds. If the environmental costs of freight transport were internalised (at current valuations) in higher taxes on freight operators, the increment in transport operating costs would be unlikely to cause much logistical restructuring. It might, nevertheless, slow the rate of freight traffic growth, particularly in sectors making and distributing products with a low value

[6] It is likely too that this modelling exercise will have under-estimated the transport cost threshold as it failed to incorporate all the benefits that firms claim to derive from centralisation and took no account of restructuring costs.

per tonne. The inclusion of freight transport and logistics within a revised emissions trading scheme with much tighter caps on permitted CO_2 emissions could provide a stronger financial incentive to develop low-carbon production and distribution systems.

Alternatively, the government could re-impose physical controls on the movement of freight, particularly on road haulage. Quantitative licensing was abolished in the UK road freight sector in 1970 and would be virtually impossible to reintroduce within the liberalized EU market for road haulage services. For reasons discussed elsewhere (McKinnon, 1998b), this would run counter to the prevailing trend of liberalisation in the world's freight markets and probably prove counter-productive.

Increasing traffic congestion could force a return to more decentralized production and logistics systems. This could not be advanced as a serious policy option for curbing CO_2 emissions in the road freight sector. It would also have a countervailing effect - in reducing the fuel efficiency of freight vehicles running on congested roads.

<u>(ii) Return to more localised sourcing</u>: The geographical expansion of trade areas appears so fundamental to the process of economic development that it is difficult to see how it can be contained. On the contrary, trade liberalization, the development of ecommerce and advances in information and communication technology are strongly promoting the extenuation of supply lines at different geographical scales.

In many industries, factor cost differentials are very wide relative to transport costs, making it very profitable to move products long distances. For most product groups, only a very steep increase in transport costs and/or transit times would be likely to offset these production cost differentials and promote a return to more localised sourcing from low cost locations. Several authors have advocated the development of regional supply structures within which firms would source as much as possible from local suppliers. If widely applied, this practice would dramatically reverse the recent extenuation of supply chains, but at the expense of customer choice and, possibly, higher prices. Strutyniski (1994) showed how rationalisation of the supply networks of large car assembly plants, with greater 'vertical integration' at the regional level, could reduce freight transport requirements by 70%. He conceded, however, that huge increases in transport costs (at least 5-fold) would be needed to induce this process of rationalisation.

Local sourcing strategies would also need to be based a full life cycle analysis of the CO_2 emissions. Recent analysis of energy consumption and greenhouse gas emissions in the production of a range of foodstuffs has illustrated how it can be environmentally beneficial to source some products from distant locations where production is more energy efficient (e.g. Saunders et al, 2006).

(iii) Vehicle Routing: The efficiency with which vehicles are routed between collection and delivery points influences the average length of haul and carbon emissions. It has been estimated that the use of computerised vehicle routing and scheduling CVRS) packages can, on average, reduce the distance travelled by around 5-10%, though instances of 20% distance savings are quoted in the literature (Department for Transport, 2005), Minimising the distance traveled need not minimise CO_2 emissions, however, as the shortest route may involve traversing minor or congested roads. At present most CVRS systems are designed to minimize travel time, maximize asset utilization and / or minimize cost. They could be recalibrated to find routes that minimized fuel consumption and CO_2 emissions or, at least, gave greater priority to cutting these emissions..

The development of vehicle tracking and mobile data communication systems has created the opportunity to replan vehicle schedules and routes in real-time while the vehicle is on the road in response to short-term changes in customer requirements and traffic conditions. It is too early to predict the net effect of the widespread adoption of this dynamic form of CVRS on road freight traffic levels and CO_2 emissions.

4.4 Modal Split

Average CO_2 emissions per tonne-km are substantially lower for rail and waterborne transport than for road and air (Figure 6). Shifting freight to these more environmentally-friendly modes can therefore cut CO_2 emissions. As relatively little freight is moved domestically by air in the UK, modal split trends and potentials will only be examined with respect to road, rail and waterborne modes.

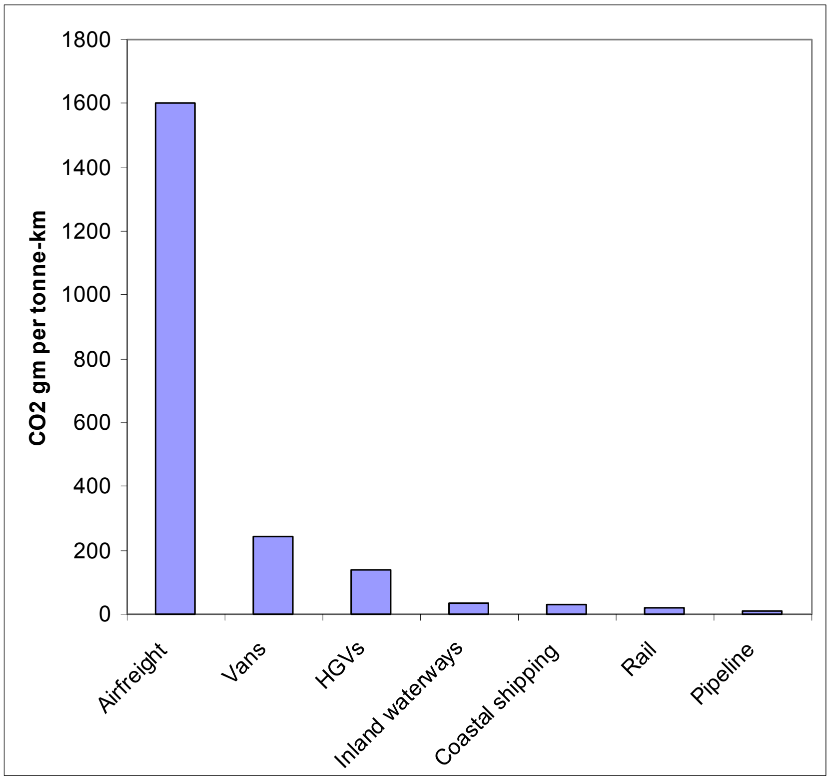

Figure 6: Average CO_2 Intensity Values for Freight Transport Modes

Trends

The year 1997 marked a watershed in the development of the British freight market. Up to that year, road had been increasing its share of total tonne-kms. Some of the long-term growth in road tonne-kms had therefore been attributable to an increase in road's share of the freight market. Between 1997 and 2004, road's share of total tonne-kms declined from 67.4% to 62.7% (Department for Transport, 2005d). This break in the earlier trend was partly associated with the privatisation of railfreight services in 1996. Between 1997 and 2004, rail increased its share of the freight market from 7% to 8%. The share of the market held by water-based services increased by a greater margin, from 21% to 24%. In terms of CO_2 mitigation these trends are heading in the right direction. The government is also committed to further increasing the proportion of freight moved by rail and water.

Opportunities for Cutting CO_2 Emissions

Railfreight

The potential for transferring freight from road to rail and water has been investigated in detail in other studies (e.g Strategic Rail Authority, 2004; Freight Study Group, 2002). In this report, it will be possible only to highlight some of the key points.

Rail tonne-kms grew by 24% between 1998 and 2004, though this upward trend was constrained in 2001 and 2002 by the reduction in service quality following the Hatfield train crash and related programme of emergency track repairs. Just over 60% of the growth in rail tonne-kms between 1998 and 2004 was in coal and coke, much of it due the sharp increase in the amount of imported coal transported relatively long distances from Ayrshire to power stations in Yorkshire and the Midlands. In 2004, bulk commodities, such as coal and coke, petroleum products, metal products, minerals and building materials accounted for roughly two-thirds of railfreight traffic. Rail's future share of the freight market will therefore be heavily dependent on the performance of these primary industrial sectors and the future development of their supply chains. Reductions in the use of coal for electricity generation and the transfer of coal imports from Hunterston to ports closer to the main generating capacity, most notably Teesport, could cause a net contraction in railfreight's market share. Shortening of the average length of haul for inbound coal movements would, nevertheless, cut CO_2 emissions overall.

To reduce its dependence on a small number of basic commodities, rail needs to diversify, particularly into the movement of higher value manufactured goods and retail supplies. It has had some success in recent years in winning contracts from major retailers, such as Tesco, ASDA and IKEA. Although the amounts of freight transferred are relatively small, these contracts have considerably enhanced the credibility of the railfreight option and augur well for future expansion of fast-moving consumer goods (FMCG) traffic. Rail has also managed to regain most of the container traffic moving to and from ports that it lost following the Hatfield incident. Its share of cross-Channel traffic remains very low, however. It has proved very difficult to rebuild these international freight services following the disruption caused by the illegal entry of asylum seekers. This has been made more difficult by the recent reduction in the level of state subsidy for Channel Tunnel railfreight services

The ability of rail to attract freight traffic has traditionally been constrained by the relatively low accessibility of the rail network and short average length of haul for freight consignments. Very few industrial and distribution premises in the UK have a direct rail link, making them depend on intermodal services. The government's Freight Facilities Grant scheme supported the installation of rail sidings between 1974 and 2003, when the scheme was suspended in England and Wales. (It has continued to operate in Scotland with increased funding).

Company Neutral Revenue Support has been used to attract inter-modal container traffic to rail and is estimated in 2005-6 to have removed around 710,000 lorry journeys from UK roads. In April 2007 a new 'mode-neutral' system of government financial support was introduced to promote sustainable distribution, with railfreight likely to be one of the main recipients of this state aid. This financial support, coupled with improvements to rail infrastructure, should help rail to capture an increasing share of the freight market. Worsening traffic congestion on the road network will also give companies a negative incentive to switch traffic to rail.

The Route Utilisation Strategy for freight, published by Network Rail (2006), forecasts a a growth of just under 30% in railfreight tonnes by 2014-5, equivalent to an extra 240 freight trains per day (including empty return trips). The main growth is anticipated in deep-sea container traffic. Substantial investment in rail infrastructure (mainly on gauge clearance, loop lengthening and improved signaling) will be required to accommodate this forecast growth.

These optimistic projections of the future growth of railfreight require some qualifications.

1. Given the short average length of haul in the UK, the very low proportion of industrial premises connected to the rail network, the country's industrial mix and the heavy use of our rail network by passenger traffic, it is unlikely that rail will be able to capture more than 10-12% of total freight tonne-kms in the UK in the foreseeable future.

2. In the case of intermodal services, a major growth sector for rail, rail's CO_2 advantage is lower when emissions are measured on a door-to-door basis. The road leg at either end of the rail trunk haul has significantly higher CO_2 emissions per tonne-km and the need to route the consignments via railhead terminals can add significantly to the total distance traveled.

3. Much of the future growth of freight traffic will be in low-density consignments requiring large amounts of cubic capacity. The relatively low loading gauge restrictions on much of the UK rail network will limit the ability of rail freight operators to attract this traffic. In its rail utilization strategy for freight, however, Network Rail plans to expand the loading gauge in key routes such as between Nuneaton and Peterborough and Southampton and the West Coast Mainline.

4. The Department for Transport is currently examining the possibility of longer and heavier lorries being allowed onto UK roads. If permitted, these vehicles could divert traffic from rail. It is likely, however, that the government would only approve this change in regulations if any environmental disbenefit from modal shift would be more than offset by the environmental benefit of load consolidation within the road freight sector.

Waterborne

Waterborne transport in the UK is even more dependent on a single commodity than railfreight. In this case the dominant commodity is ‘crude petroleum and petroleum products’. It accounted for three-quarters of coastal traffic in 2004 and 89% of one-port traffic, most of which services Britain’s offshore oil industry. The waterborne share of the freight market is therefore highly sensitive to levels of oil production and distribution. Efforts are, nevertheless, being made to diversify the range of products moved by sea around the UK coast. Opportunities for developing coastal ro-ro services, similar to those operating in Italy and Japan, were investigated in 2000-2. This ‘Marine Motorways’ project concluded that given current levels of road vehicle operating costs and transit times, they would not be economically viable (Napier and Heriot-Watt Universities, 2002). Since 2002, the economic conditions for such a service have improved, mainly as a result of increased congestion on Anglo-Scottish routes, the application of the working time directive to road haulage and higher fuel prices.

The government has awarded Water Freight Grants since 2001 to encourage the use of shipping services where this yields a net environmental benefit. Between 2001 and 2005, a total of £28.3 million was spent on this scheme removing around 1.4 billion lorry-miles from UK roads. Waterborne services are also eligible for ‘mode-neutral’ support.

4.5 Vehicle Utilisation

By raising vehicle load factors it is possible to reduce the amount of commercial vehicle traffic (measured in vehicle kms) required to move a given quantity of freight (measured in tonne-kms). There is a corresponding reduction in energy consumption and CO_2 emissions. In addition to reducing these externalities, improved loading also increases the efficiency of delivery operations. This measure therefore has the advantage of yielding economic as well as environmental benefits and, in most cases, being self-financing.

Most of the discussion of vehicle utilisation is confined to road transport. It is, after all, by far the dominant freight mode and the most energy-intensive and polluting of the surface modes. It is also the mode to which most of the available utilisation data relate. This is not to deny that there is also considerable scope for improving vehicle load factors on other modes.

Trends

In assessing the utilisation of vehicle capacity it is important to distinguish empty running from vehicle loading on laden trips:

Empty running: The proportion of lorry-kms run empty in the UK steadily declined between the early 1970s and 2001, but has risen slightly over the past three years. Other things being equal, had the empty running proportion remained at its 1973 level, an extra 1 million tonnes of CO_2 would been emitted in 2005, roughly 3% of all freight-related CO_2 emissions in that year.

Research suggests that the downward trend in empty running has been the result of a series of factors including the lengthening of freight journeys, growth of reverse logistics, expansion of load matching agencies and online freight exchanges and various corporate initiatives to increase the level of backloading (McKinnon and Ge, 2006). For example, supermarket chains now use returning shop delivery vehicles to collect a substantial proportion of their inbound supplies.

The future trend in empty running is uncertain. Regional imbalances in freight flows, vehicle incompatibility and scheduling constraints impose a lower limit on the proportion of empty running. It is possible that the recent reversal of the long term downward trend signifies that this base level has been reached. Increasing traffic congestion combined with the application of the working time directive to lorry drivers in April 2005 is reducing the delivery flexibility that companies require to find, collect and deliver suitable backloads. This may partly explain the recent increase in empty running. The use of telematics, however, can help fleet managers to organize backhauls across congested road networks.

There is little that the government can do to promote a reduction in empty running. It is currently using advisory and best-practice programmes to encourage companies to put greater effort into finding backloads (Department for Transport, 2006b). Market pressures to do this are already very strong, however, as the availability of backloads is a critical determinant of profitability in the trucking industry. The growth of on-line freight exchanges is both intensifying these pressures and giving carriers a means of improving the loading of their vehicles in both directions.

Utilisation of Laden Vehicles: The average weight-based utilisation of lorries on laden trips declined from 62% in 1997 to 57% in 2003 and has remained stable at this level. This decline is likely to have been due, at least in part, to increases in maximum truck weight in 1999 and 2001 raising the carrying capacity of the heavy vehicle fleet. Average payload weight actually rose slightly from 6.5 tonnes in 1997 to 6.8 tonnes in 2004. This meant that the number of vehicle-kms required to move a given number of tonne-kms fell by around 4% over this period. As this was associated with a redistribution of vehicle-kms from the lighter classes of vehicle to heavier ones with higher fuel consumption, the net effect on CO_2 emissions of this increase in average payload weight has been small.

Opportunities for Reducing CO_2 Emissions

The utilization of vehicle capacity is subject to five sets of constraints: regulatory, market-related, inter-functional, infrastructural and equipment-related. One of the most critical factors affecting utilisation is the inter-functional relationship between transport and other activities such as production, procurement, inventory management, warehousing and sales. Companies often quite rationally give these other activities priority over transport efficiency. For example, inventory savings from just-in-time replenishment or reductions in handling costs accruing from the use of roll-cages may exceed the additional cost of running a truck only part-loaded. It can also be economically justifiable to deliver small orders to important customers in an effort to secure their longer term loyalty.

Much under-utilisation of vehicle capacity, however, is not based on careful analysis of logistical cost trade-offs or any related sales benefits. It is often unplanned and reflects the relatively low status given to transport within corporate hierarchies dominated by production, marketing and sales departments. The most that a logistics manager can do is to optimise transport within the targets and constraints set by other departments. This inevitably limits the opportunity for cutting fuel consumption and CO_2 emissions by rationalizing the transport operation. There are, nevertheless, a series of measures that companies have been taking, within broader organizational constraints, which have markedly improved vehicle loading, saved fuel and cut CO_2 emissions. These include:

Consolidation of Loads in Heavier and / or Larger Vehicles

Since the UK government increased maximum lorry weight from 41 to 44 tonnes (for 6-axle vehicles) in February 2001, companies transporting dense, weight-constrained loads have been able to economise on the number of lorry movements they have to make. An impact study conducted three years after the maximum weight was raised predicted that the full annual benefits of this measure would not be experienced until 2007. By then, as a result of the weight increase, CO_2 emissions from HGVs would be roughly 170,000 tonnes per annum lower than they would otherwise have been (McKinnon, 2005).

Companies carrying less dense loads that 'cube out before they weigh out' have derived much greater benefit from the increase in vehicle dimensions. The main increase in recent years has been in the vertical dimension, taking advantage of the high bridge and tunnel clearances in the UK. There has been a rapid increase in the number of double-deck / high cube vehicles capable of carrying a second layer of pallets. By replacing two single-deck vehicles with one double-deck it is possible to achieve dramatic reductions in fuel consumption. In a government-sponsored trial involving the Focus DIY chain, using a double-deck vehicle rather than two single-deck vehicles cut total fuel consumption by 49% (Department for Transport, 2005e). These load consolidation benefits are partly offset by the aerodynamic penalty associated with the greater height of the double-deck trailer, though new trailer designs with sloping fronts are addressing this problem.

Drawbar trailer combinations (comprising a rigid vehicle and trailer) have also been increasing their share of road tonne-kms, though from a very low base. Between 1995 and 2005, there was a 169% increase in tonne-kms carried by these vehicles, but in 2005 they still accounted for only 2% of the total. As they cater mainly for companies moving low density loads, their share of the cubic volume of freight moved would be significantly higher.

The government is currently commissioning research on the cost and benefits of a further increase in the maximum weight and size of lorries to permit the running of longer and heavier vehicles (LHVs) on UK roads. Lorries that are 25 metres long and capable of operating at 60 tonnes gross weight currently operate in Sweden and Finland and are being trialled in the Netherlands and Germany. Preliminary results from the Dutch trial suggested that CO_2 savings of 3.7%-5% were possible from the use of LHVs (Arcadis, 2006). A report by the German Environment Ministry (2007), on the other hand, argued that there would only be net environmental benefit from allowing these vehicles onto German roads, if they achieved a much higher average load factor than the current generation of heavy trucks. The forthcoming DfT-funded study will estimate the likely impact of different LHV combinations on CO_2 emissions from the UK freight sector.

Use of More Space-Efficient Handling Systems and Packaging.
The efficiency with which the cubic capacity of a vehicle is used partly depends on the nature of the packaging and handling equipment. Companies must reconcile the desire to maximise vehicle fill with the need to protect products from damage in transit and to minimise handling costs. Improvements in the design of packaging and handling equipment are allowing companies to squeeze more product into the available space, cutting delivery mileage, fuel consumption and CO_2.

Adoption of More Transport-efficient Order Cycles.
The nature of the order-fulfilment process can have a significant impact on the efficiency of the transport operation. By using the 'nominated day delivery' system companies achieve much higher levels of transport efficiency by encouraging customers to adhere to an ordering and delivery timetable. Replacing the monthly payment cycle with a system of rolling credit could also smooth the flow of product through a distribution system, improving average vehicle load factors, raising fuel efficiency and cutting CO_2, though in many companies would be resisted by financial and sales managers.

Inter-company Collaboration
There is a limit to how much any individual company can do to improve the utilisation of vehicle capacity. To reach high levels of utilisation it is often necessary to collaborate with other companies, either trading partners at upper or lower levels in the vertical supply chain or businesses at the same level in the supply chain (so called 'horizontal collaboration'). This can either be done directly or with the assistance of logistics service providers.

What the government calls the 'lorry intensity' of the UK economy (i.e. the ratio of lorry-kms to GDP) declined by almost 20% between 1990 and 2004, partly as a result of companies using vehicle capacity more efficiently. There, nevertheless, remains considerable potential for improving 'vehicle fill'. Companies can adopt a range of vehicle utilization measures which collectively could significantly cut lorry-kms and CO_2 emissions. In some cases this will require changes to current business practice.

4.6 Energy Efficiency

Over the past three decades, a huge amount of research has been done on ways of improving the fuel efficiency of road haulage. Much less work has been done on the energy efficiency of other freight transport modes. In the case of rail this may be partly attributable to the fact that, in the UK, the vast majority of freight trains are hauled by diesel locomotives and the red diesel which they consume is taxed at only 6.7p per litre – a tiny fraction of the duty paid by road hauliers (currently 47.1p litre for ultra-low sulphur diesel). As a result 'fuel prices constitute a relatively small proportion of train operators' operating costs'.

As road accounts for 93% of the fuel consumption and CO_2 emissions in the freight sector and as most of the available data relates to road, attention will focus here on the fuel efficiency of trucks.

Trends

Between 1990 and 2005, average fuel efficiency across the entire UK truck fleet increased by roughly 10.5%. Most of this increase occurred over two time periods: 1994 -1998 and 2004-5 (Figure 6). These were periods of high fuel price inflation. The first coincided with the first four years of the government's fuel duty escalator policy. In 2004-5, the surge in fuel prices occurred as a result of the increase in the world price of oil. The close correlation between fuel efficiency and fuel price trends suggests that demand for fuel from the haulage industry is price-sensitive and that companies respond to sharp fuel price increases by running their vehicles more fuel efficiently. This relationship requires more detailed analysis, however.

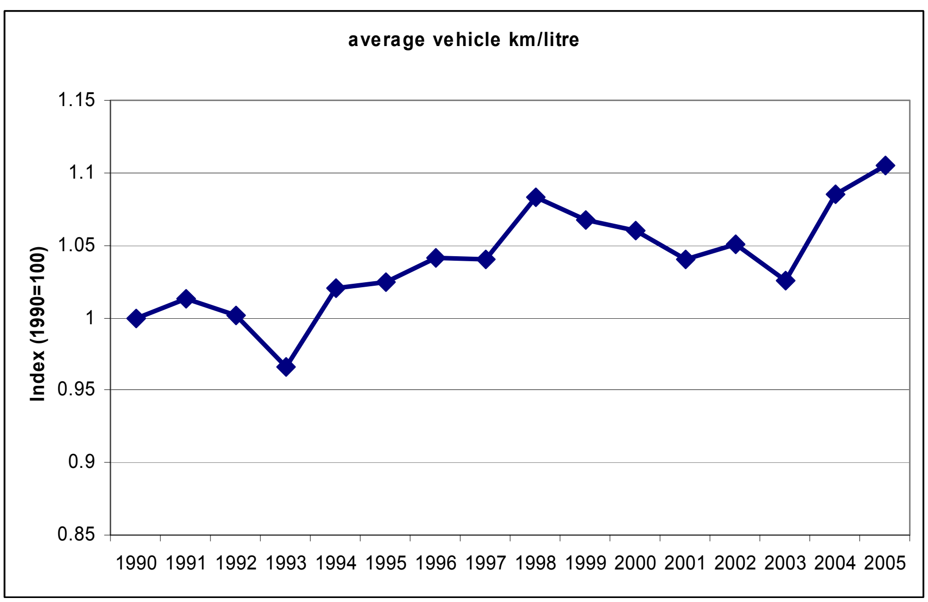

Figure 7: Trend in Average Fuel Efficiency of HGVs in the UK

Most of the gains in fuel efficiency occurred in the articulated vehicle fleet. The greatest improvement, of 26%, was recorded by lighter artics, with the heavier artics increasing their fuel efficiency by 21%. The fuel efficiency of rigid vehicles, on the other hand, was only 4% higher in 2005 than in 1990. Several reasons can be offered for the different fuel efficiency trends for rigids and artics. First, by travelling uninterrupted at higher average speeds for longer periods, artics have derived greater benefit from a range of fuel conservation methods, including aerodynamic profiling, driver training and engine redesign. While, in terms of fuel efficiency, the technical performance of rigids has also improved over the past fifteen years, the improvements have been more modest and offset by worsening traffic congestion, particularly in urban areas.

Expressing fuel efficiency in kms per litre (or miles per gallon) provides only a partial view of the energy efficiency of a road haulage operation. After all, a company can achieve relatively high mpg but still under-utilise its vehicles. Average load factors may be poor and the percentage of empty mileage relatively high. A more comprehensive measure of the energy efficiency of a freight transport operation is provided by litres of fuel consumed per tonne-km. This is essentially a composite measure which assesses both the fuel efficiency and the loading of the vehicle. In sectors characterised by lower density of freight and a high level of unitisation, litres per pallet-km can be a more meaningful statistic.

Between 1990 and 2005, average tonne-kms per litre of fuel consumed increased by 22.1% (Figure 7), roughly twice as fast as fuel efficiency. This suggests that the improvement in fuel efficiency was substantially reinforced by an improvement in vehicle loading. Deeper analysis of the statistics, however, reveals a more complicated process at work.

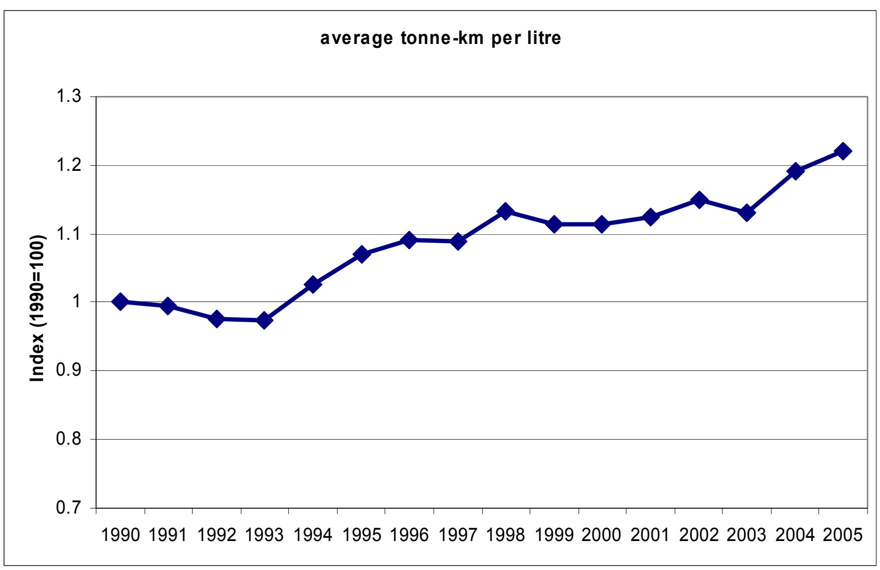

Figure 8: Trend in Average Energy Efficiency of HGVs in the UK

Over the 15 year period, the average energy efficiency of rigid vehicles and the two weight-classes of artic remained remarkably stable (Figure 8). Within each vehicle class, therefore, there is little evidence that trucks were being more heavily loaded. On the contrary, the main reason for the overall improvement in energy efficiency was the redistribution of freight away from rigids and lighter articulated vehicles towards the heavier artics. The latter increased their share of tonne-kms from 52% to 72% over this period, while that of the rigids dropped from 31% to 24% (Figure 9). The lighter artics suffered an even greater collapse of market share from 17% to 4% of tonne-kms. So the improvement in overall energy efficiency can be attributed to the greater consolidation of freight in heavier articulated vehicles.

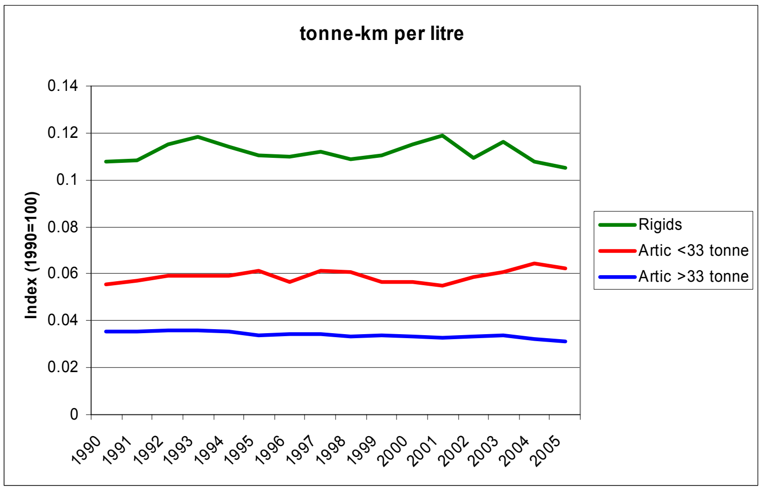

Figure 9: Energy Efficiency of Different Classes of Lorry: 1990-2005

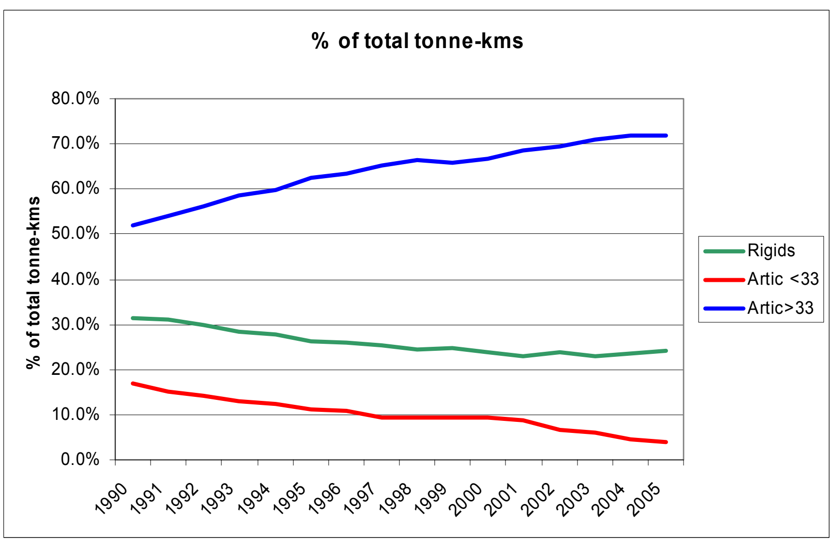

Figure 10: Distribution of Freight Movement among Classes of Lorries

Opportunities for Reducing CO_2 Emissions

Companies can improve their fuel efficiency in many different ways. Several manuals have been published by government agencies, trade associations, magazines and oil companies providing advice on the broad array of measures that can be applied (e.g. Department for Transport, 2006d). Many of the checklists of fuel economy measures give the impression that all the resulting savings are additive. Claims are often made that individual measures yield fuel savings of 1-3%. In theory, if a haulier implemented twenty of these measures, they might cut their fuel consumption by 20-60%. Research in the US, for example, has assessed the % fuel savings that an average trucker might achieve by applying a range of ten measures (Figure 10). These savings vary from under 1% for automatic tyre inflation systems to almost 8% for a reduction in maximum speed from 65 mph to 60 mph. If all these savings were cumulative, aggregate savings of 33% might be achieved. In practice, this is unrealistic. Some measures, after all, are counteracting. For example, cutting maximum speed will reduce the effectiveness of 'improved trailer and tractor aerodynamics'. A fuel economy initiative should not, therefore, comprise a loose collection of measures. It is much more effective to integrate a specific set of measures into a well-structured programme tailored to the needs of particular operators. As part of its Freight Best Practice programme, for example, the government has developed a fuel management guide, which not only outlines some of the more promising fuel economy measures. It also sets out a management framework within which these measures can be implemented and their effects evaluated.

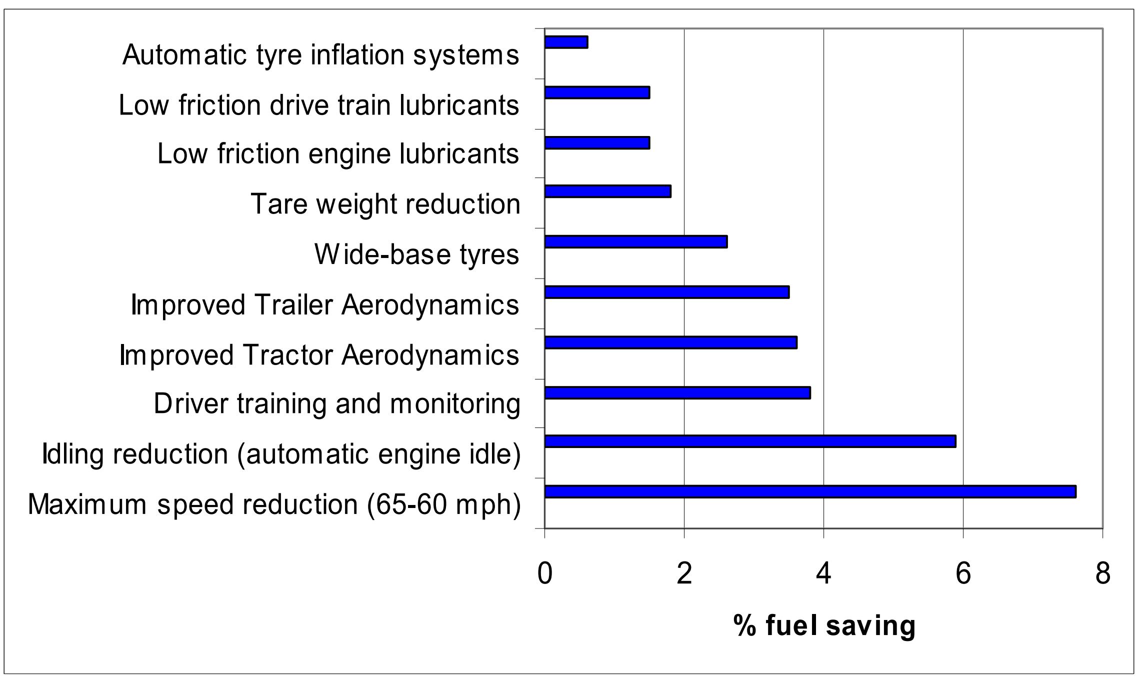

Figure 11: Estimated Fuel Savings from Fuel Economy Measures: US Trucking
(source: Ang and Schroeer, 2003)

A broad range of fuel economy measures can be adopted, including:

Improved driver training: it is generally accepted that driving style is the single greatest influence on fuel efficiency. Driver training programmes have been shown to improve fuel efficiency by as much as 8-10%. To date over 7000 HGV drivers have received training under the UK government's Safe and Fuel Efficient Driving (SAFED) programme. This scheme has been extended to van drivers. Truck simulators have been used to provide training in safe and fuel efficient driving techniques. .

Driver incentive schemes: To derive longer term benefit from driver training companies have to give drivers an incentive to continue driving fuel-efficiently.

Promote purchase of more fuel efficient vehicles:
There are significant variations in fuel efficiency between different makes and models of new truck on the market. Comparing the results of the vehicle tests reported in trade publications reveals that 10% variations in fuel consumption over a standard trial route are not uncommon for a particular class of vehicle. Four vehicle attributes have a particular bearing on fuel consumption:

Reduce power-rating: It is common for companies to purchase tractor units that are more powerful than they need to be for a particular type of distribution operation.

Reduce vehicle tare weight: Fuel efficiency can also be enhanced by reducing the tare weight of the vehicle. Use of lighter materials, such as aluminium or carbon fibre, and fittings can substantially cut the tare weight.

Aerodynamic profiling: British Transport Advisory Committee (BTAC) trials in 1999 found that trucks travelling at speeds of 50mph and 56mph could achieve fuel savings of respectively, 9.3% and 6.7%, following 'aerodynamic intervention'. . A series of good practice guides (e.g. ETSU, 2001) and case studies (e.g. Dept for Transport, 2006) have reported potential fuel savings in the range 6-20% for improved aerodynamic styling of trucks.

Raise standards of vehicle maintenance:
There is a huge range of technical imperfections which can prevent a lorry from operating at optimum fuel efficiency. Typical defects include: fuel leaks, under-inflated tyres (according to a government report, 20% under-inflation of tyres will result in a 2% reduction in fuel efficiency), mis-alignment of axle (a 1 degree misalignment of a single axle on a multi-axle trailer will raise fuel consumption by roughly 3%, while a 2 degree misalignment will increase it by 8%) and poor combustion.

Improve fleet management:
Once the right vehicles are purchased and adequately maintained, the fleet manager must ensure that they are deployed in a way that maximises their operational efficiency. This includes assigning the 'right vehicles to the right jobs'. Fleet management can also be reinforced by the appointment of a 'fuel champion' whose job it is to analyse the pattern of fuel consumption, promote fuel saving initiatives and generally instil a fuel-saving culture in the workforce.

Benchmarking Fuel Efficiency and Energy Intensity
One method of estimating the opportunity for further energy efficiency gains is to benchmark companies' road freight operations against a series of energy-related key performance measures (KPIs). Over the past decade the British government has funded transport KPI surveys in seven sectors[7]. Most of these surveys have employed a similar methodology. Participating companies monitor the efficiency of their vehicle fleets over the same 48 hour period against a standard set of five KPIs (vehicle fill, empty running, time utilisation, fuel efficiency and deviations from schedule). By combining KPIs it is possible to calculate composite indices such as energy intensity. As most of the product moved in the sectors that have been surveyed is unitised, these studies have used litres of fuel consumed per pallet-km as the measure of energy intensity.

The general message to emerge from these surveys is that even within relatively homogenous sub-sectors there are significant variations in fuel efficiency, energy intensity and CO_2 emissions. Similar companies competing in the same market can require widely varying amounts of fuel to move the same quantity of product the same distance.

By benchmarking other companies against the most energy-efficient operator in their sector, it is possible to estimate the potential for fuel savings. For example, the KPI data were used to estimate by how much energy consumption and CO_2 might be reduced in the UK grocery supply chain if companies whose energy-intensity value was above the average for their sub-sector could bring it down to this mean (Table 1). According to the results of the 2002 survey, this would cut the amount of fuel consumed and CO_2 emitted by 5%. If the target energy-intensity value were lowered even further to the mean of the one third of companies with the lowest fuel consumption per-pallet-km, energy and CO_2 savings of 19% could be achieved. Similar analyses have been conducted for KPI data collected in other sectors and, in each case, they demonstrate significant potential for cutting fuel consumption while maintaining the same level of freight movement.

Counteracting Trends
Some developments are likely to constrain future improvements in fuel efficiency. For example, increasing traffic congestion will increase the proportion of lorry–

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[7] Food, non-food retailing, automotive, pallet-load networks, parcel networks, road movement of air cargo and building supplies.

kms run below fuel-efficient speeds. For trucks, crawling in heavy traffic carries a high fuel penalty. By rescheduling more deliveries into the evening / night and using telematics systems to avoid heavily congested roads, companies can ease this constraint. Also, tightening emissions of noxious gases to meet Euro 4 and 5 emission standards will cause a small loss of fuel efficiency. This essentially involves trading off one set of environmental costs against another.

Table 1: Potential Fuel Savings from Raising Energy Efficiency to Benchmark Levels: UK Food Supply Chain (Source: McKinnon and Ge, 2004)

		If fleets below mean of performance achieve mean performance within each subsector	If fleets below mean of the 'top' third of fleets achieve their mean within each subsector
Fuel savings (motive)	litres	3,407,811	11,787,934
% Fuel savings	%	5	19
Reduction in CO2 emissions	tonnes	9,065	31,356
Total fuel cost savings	£	2,593,344	8,970,618
Fuel cost savings per vehicle	£	1,115	2,231

4.7 CO_2 Intensity of Energy Sources

There are wide variations in the amounts of CO_2 emitted per unit of energy consumed in a freight transport operation both within and between modes. To gain a full appreciation of the environmental benefits of alternative fuels, however, one must conduct a detailed life cycle analysis (LCA). Such an analysis highlights the benefits of biodiesel. It is the product of a 'closed carbon cycle' with CO_2 absorbed by the growth of the plants which produce the fuel.

At present biodiesel accounts for a tiny proportion of the fuel consumed by lorries and vans in the UK and none of the fuel consumed by other modes. Most of this biodiesel comes from recycled vegetable oil. Woods and Bauen (2003) present comparative greenhouse gas (GHG) emission data for biodiesel derived from waste vegetable oil and ultra low sulphur diesel (ULSD). They express GHG emissions as kg of CO_2 equivalent per giga Joule of fuel consumed and define ranges of values to show the variability of the estimates. According to their presentation, ultra low sulphur diesel has a range of 83-95 while biodiesel from waste oil has a range of 2-16. Taking the median values within these ranges, biodiesel from waste vegetable oil would offer a 90% saving in GHG relative to ULSD.

The supply of waste vegetable oil is very limited, however, and could not support a major shift to biodiesel. The main alternative source is likely to rape-seed oil. Mortimer et al (2002) reviewed the results of ten studies of biodiesel derived from rape seed and concluded that, when compared with ULSD on a life-cycle basis, biodiesel had much lower primary energy requirements and GHG emissions. Its production and distribution required around 60% less primary energy and emitted 53% less GHG emissions. These estimates are very similar to those reported by Concawe, Eucar and JRC (2006) in work for the European Commission (of, respectively, 64% and 52%). Concern has, nevertheless, been expressed about the wider effects of large-scale biodiesel production on agricultural markets and ecosystems, particularly where the main fuel crop is palm oil grown on deforested land in countries such as Malaysia, Indonesia and Brazil.

Biodiesel blends of up to 5% can be used in most trucks without any need for engine modification. Truck manufacturers, however, restrict the proportion of biofuel that operators can mix with conventional diesel, on the grounds that it can damage engine seals and clog the filters. With more regular maintenance it is possible to increase the biofuel percentage to 30% or more. In December 2006, Tesco announced that it would be running 75% of its distribution fleet of 2000 lorries on a 50% biodiesel mix.

The government is providing a tax incentive of 20p per litre (against ordinary diesel) to promote the use of biofuel, though, given its higher production cost, the difference in pump prices are too low to promote a major switch to biodiesel. The uptake of biodiesel is also subject to supply-side constraints both in production and the distribution network, though investment in new biofuel processing facilities is greatly expanding capacity. The EU Renewable Fuels Directive sets member states the target of having biofuels account for 5.75% of fuel consumption by 2010.

According to the DfT, the opportunities for using alternative fuels on the rail network are limited. It claims that, ‘there is limited scope for alternative fuels to be introduced into the rail network alongside gas oil (i.e. diesel) without a substantial investment in new refuelling infrastructure’ (Department for Transport, 2006c). If, in the longer term, there were to be a major switch to biofuels in the road haulage industry, rail could lose much of its current CO_2 advantage in the movement of freight.

Rail and pipeline are the only two freight modes that can employ electrical power and therefore draw upon energy sources that do not produce CO_2 such as hydro, wind, wave or nuclear. At present, only around 10% of railfreight is hauled by electric locomotives and there are no plans to increase this proportion. The proposed shift in electricity generation from hydrocarbons to renewables and nuclear power will therefore have a limited effect on the carbon intensity of railfreight operations.

5. CO_2 Scenarios for UK Domestic Freight Transport

Two scenarios have been constructed to illustrate the combined effect on total CO_2 emissions of changes in the key freight transport parameters discussed above (Table 2). These scenarios use 2004 as the base year and project forward to 2015.

	Scenario 1	Scenario 2
Volume of freight movement (tonne-kms)		
Road: HGVs	no change	10% increase
Road: vans	50% increase	100% increase
rail	30% increase	15% increase
water	10% increase	no change
pipeline	no change	no change
total	7% increase	11.4% increase
Vehicle utilisation		
empty running by HGVs	10% reduction	no change
empty running by vans	no change	no change
mean payload weight on loaded trips (HGVs)	10% increase	no change
mean payload weight on loaded trips (vans)	25% increase	10% increase
utilisation of capacity on rail	10% increase	no change
utilisation of capacity on waterborne services	10% increase	no change
utilisation of pipeline capacity	no change	no change
Energy efficiency		
HGVs	10% increase	5% increase
vans	5% increase	no change
rail	10% increase	5% increase
water	no change	no change
pipeline	no change	no change
Conversion of energy to CO2		
HGVs	10% reduction	5% reduction
vans	20% reduction	10% reduction
rail	no change	no change
water	no change	no change
pipeline	no change	no change
total CO2 emissions (m tonnes)	25.6	36.3
as % of 2004 CO2 emissions from freight sector	72%	102%

Table 2: Freight Transport Scenarios for 2015

Scenario 1, which may be described as 'aspirational', allows for a 7% increase in total tonne-kms over this period, but no further growth of heavy lorry traffic. The flat trend in HGV tonne-kms since 1998 has been projected forward to 2015. The main growth in tonne-kms would occur in van delivery operations and on the rail network. Railfreight traffic would increase by 30% in line with the recent forecast by Network Rail. In this scenario, significant improvements are made to vehicle utilisation and fuel efficiency, particularly in road and railfreight operations. It is also assumed that there is a switch to the use of biofuels by HGVs and vans, cutting the ratio of CO_2 emissions to fuel consumption by, respectively, 10% and 20% for these vehicles. In this scenario, CO_2 emissions would be roughly 28% lower than in 2004.

The second Scenario, which might be characterised as 'steady state' in terms of CO_2, anticipates a 10% increase in HGV tonne-kms, doubling of the freight moved in vans and 11.4% growth of total tonne-kms overall. Allowance is made for a 15% increase in rail tonne-kms, but no further expansion of water-borne freight services. Rail maintains its 2004 share of the freight market, while road increases its share mainly at the expense of water-borne transport. In this scenario no changes are envisaged to the utilisation of HGVs, rail wagons, waterborne vessels or pipelines, though allowance is made for a small increase in the average load carried by vans, resulting from a growth in the volume of retail purchases delivered to the home. It is assumed that the average fuel efficiency of HGVs and railfreight operations will rise by 5% while the conversion of energy to CO_2 in road freight transport will decline by 5%. In this scenario the forecast changes in loading, fuel efficiency, CO_2 conversion, combined with modest growth of railfreight tonne-kms, would largely offset the growth in road and total tonne-kms, resulting in total CO_2 emissions rising very marginally above the 2004 figure.

These scenarios are illustrative and are not based on detailed forecasts of likely changes in the key freight parameters up to 2015.

6. Potential Contribution of the Freight Sector to UK CO_2 Reduction Target.

According to the government's 2006 Climate Change Report (DEFRA, 2006b), it is aiming to reduce total CO_2 emissions from the UK economy from 152.5 million tonnes of carbon equivalent (559 million tonnes of CO_2) in 2004 to 149 million tonnes (546 million tonnes of CO_2) in 2015. The target for the transport sector[8] allows for a small increase in CO_2 emissions between 2004 and 2015, from 158 million tonnes of CO_2 to 168 million tonnes. Table 3 shows the contribution that the two freight scenarios could make to the pursuit of these targets. The 10.1 million tonne reduction in CO_2 envisaged in Scenario 1 would offset the anticipated increase in emissions from the transport sector as a whole between 2004 and 2015 and represent roughly 78% of the overall targeted reduction in CO_2 for 2004. Scenario 2, which would be more realistic, would contribute slightly to the anticipated growth of CO_2 from the transport sector, representing 6% of the 'targeted' increase.

Table 3: Possible Impact of Freight Sector Changes on the Pursuit of CO_2 Targets

	CO_2 Targets for 2015		CO_2 Emissions from Freight Transport	
	UK Economy	**Transport Sector**	**Scenario 1**	**Scenario 2**
	m. tonnes CO_2	**m. tonnes CO_2**	**m. tonnes CO_2**	**m. tonnes CO_2**
2004	559	158	35.75	35.75
2014/15	546	168	25.65	36.35
change	-13	10	-10.1	0.6

Source: CO_2 targets from DEFRA '*Climate Change Report 2006*'

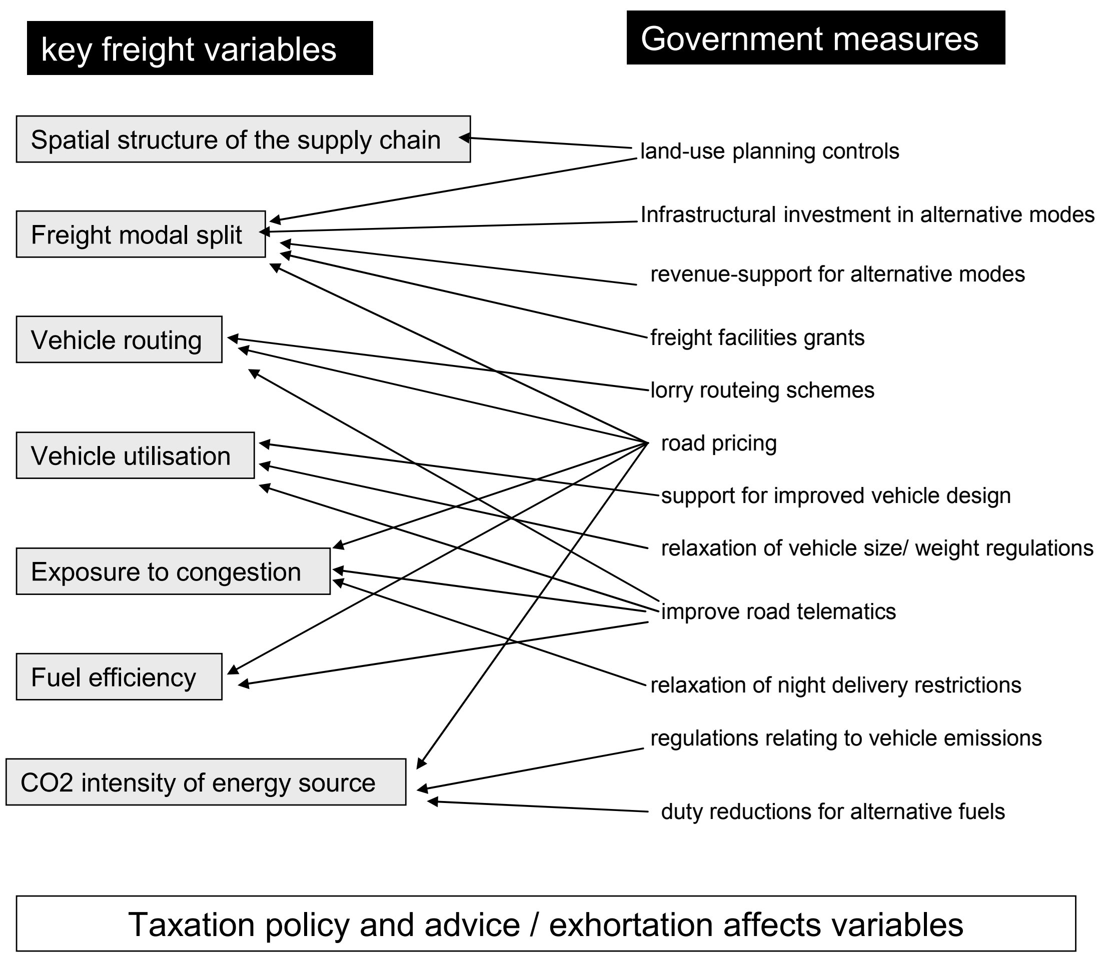
Both scenarios allow for substantial increases in the amount of freight collected and delivered by small vans. This reflects the future growth of online shopping. It is worth noting, however, that much of this van traffic will be substituted for personal shopping trips made by car and public transport. Much of the increase in CO_2 emissions from vans may, therefore, be offset by a decline in CO_2 emissions from personal travel. It is difficult to predict the extent of this offsetting on the basis of available data.

[8] Transport emissions by end user.

7. Measures to Promote CO_2 Reductions from Freight Transport

The key freight variables which were identified in Figure 4 and are pivotal to the two scenarios outlined above, can be influenced by a range of public policy measures (Figure 11). All of them are affected by tax policy, particularly relating to fuel duty and vehicle excise duty. Behaviour at all levels in the freight sector, from logistics director to lorry driver, can also be modified by specialist advice and exhortation. The government's Freight Best Programme provides guidance on how to manage and operate freight transport systems more efficiently, mainly in an effort to cut fuel consumption. Few other countries, if any, have such a broad portfolio of fuel saving initiatives. The Dutch government, however, has gone further in running a programme called 'transport prevention' which provides companies with consultancy advice on how to reduce their total demand for freight transport.

Figure 11: Public policy levers on key freight transport variables



Other measures listed in Figure 11 can have a more targeted impact on particular variables. All of these measures are currently in operation or under consideration. Several could reduce the carbon intensity of the freight sector in several ways. Road pricing, for example, could be used to promote a modal shift to rail and water, improved vehicle loading, a rescheduling of freight deliveries into the evening and night and greater use of low carbon vehicles.

Capital investment in infrastructure would be concentrated mainly in the rail network with some use of waterborne freight grants to improve terminal facilities for coastal shipping.

The inclusion of freight transport and logistics activities into the carbon trading system and imposition of tighter caps on corporate emissions of CO_2 would be likely to reinforce the effects of the measures listed in Figure 11.

8. Cost-effectiveness of CO_2 Mitigation Measures in the Freight Sector

Some of the changes anticipated in the two scenarios may be the result of business-as-usual trends and not require any additional expenditure by government or industry. For example, the suggestion that there would be no change in road tonne-kms carried by HGVs over the next decade merely extrapolates the stable course that this variable has followed since 1998. A 10% increase in the fuel efficiency of road haulage operations over 10 years would be only slightly higher than the 8% improvement experienced over the period 1995-2005. Some of this past improvement will be attributable to the government policy measures that have been in place over this period.

The cost of any additional measures that would be required to achieve the scenarios outlined earlier could be assessed in three ways:

- Direct cost to companies of implementing the measures
- Indirect costs associated with any losses in economic efficiency and sales
- Net cost to government of fiscal changes, infrastructural investment promotional activities etc.

Little information is available on these costs, particularly the first two. Many of the carbon mitigation measures incorporated into the scenarios, such as improvements in fuel efficiency, increased backloading and greater load consolidation would be self-financing, often with quite rapid paybacks. Other measures might incur an economic cost. For example, raising the mean payload on HGV trips by 10% might require some relaxation of JIT schedules with a corresponding increase in inventory levels and loss of productivity. Further research is required to model the cost-benefit trade-offs of this type and quantify the associated cost of carbon reductions.

In the case of government initiatives, it is difficult to estimate the level of expenditure required to incentivise particular levels of behavioural change. An attempt has been made by staff in the Logistics Policy division of the DfT to estimate the cost effectiveness of several fuel economy measures. This is expressed in terms of £ per tonne of carbon saved. In Table 4, this information has been supplemented with estimates of the cost effectiveness of a modal shift initiative; freight facilities and revenue-support grants awarded to Tesco and Stobarts to shift roughly 260 lorry loads per week to rail and cut CO_2 emissions by 6000 tonnes relative to current road-based distribution. It is not known to what extent this is representative of other railfreight FFGs.

Table 4 compares the cost effectiveness of these freight-related measures. It compares quite favourably with the range of initiatives proposed for the reduction of carbon emissions from personal travel in the UK (Cairns, 2004; Anable et al, 2005). Two points must be emphasised, however. First, a reduction in carbon emissions is only one of several economic and environmental benefits that will accrue from these initiatives. They would not, therefore, be justified solely on the basis of carbon mitigation. Second, this analysis of the cost effectiveness of freight measures is at an early stage and based on limited knowledge of both of the initial degree of behavioural change and the extent to which it will be maintained in the medium to long term. These estimates are therefore very approximate.

Measure	Appraisal period (years)	£ / tonne of carbon saved
Driver training in fuel efficient driving (over 5 years)	5	65-75
Financial incentive for modal shift to rail (over 3 years)	3	90
Streamlining of HGVs (over 5 years)	5	130
Company advice on HGV fuel efficiency (over 5 years)	5	190
Company advice on vehicle routing and telematics	5	240

Table 4: Estimates of the Cost-effectiveness of Several Carbon Abatement Measures.

9. Conclusions

Several general conclusions can be drawn from this review:

1. Significant discrepancies exist in the estimates of CO_2 emissions from freight transport prepared by different government departments. These estimates present differing views of recent trends in CO_2 emissions from this sector and of the relative CO_2-intensity of different transport modes.

2. There is a lack of data on CO_2 emissions associated with the movement of Britain's international trade. The 'off-shoring' of manufacturing capacity is reducing the freight-transport intensity of the UK economy, but increasing the demand for freight transport on international links. It is difficult to make an accurate estimate of the net effect of these changes on CO_2 emissions at a global scale.

3. As vans are multi-functional vehicles, it would be misleading to assign their entire output of CO_2 to the freight sector. Freight collections and deliveries account for only around 35% of total van-kms. These van-kms, nevertheless, produce a substantial proportion of CO_2 emissions from the freight sector (around 13%) and this proportion is rising quite sharply as a result of online retailing. Some of the additional CO_2 emissions from this source, however, are likely to be offset by a decline in emissions from car-borne shopping trips. The substitution of van deliveries to the home for conventional shopping trips needs further investigation.

4. It is estimated that domestic freight transport in the UK emitted 33.7 million tonnes of CO_2 in 2004, with road transport accounting for 92% of this total.

5. A framework has been presented for the analysis of CO_2 emissions from freight transport. This identifies seven key ratios which affect the overall CO_2 intensity of the freight sector. Over the period 1990-2004, several of these ratios, such as modal split, average payload weight, the proportion of empty running and fuel efficiency, have been moving in a direction which reduces CO_2 emissions per tonne-km. Total tonne-kms also appears to have stabilised over the past seven years, breaking its traditionally close link with GDP. Spatial processes, chiefly the centralisation of economic activity and wider sourcing of supplies, which have been major drivers of freight traffic growth in the past may have run their course within the UK, though are still very active at European and global scales.

6. Two scenarios were constructed to illustrate the sensitivity of total CO_2 emissions from the freight sector to sets of hypothetical changes in a series of key ratios. The 'aspirational' scenario suggests that total CO_2 emissions in 2004 could be cut by 28% by 2015.

7. A broad range of public policy measures can be used to exert an influence on the key ratios. At present government initiatives are targeted mainly on modal shift, improving the loading of road vehicles and raising fuel efficiency. Within a tougher CO_2 regime, the UK government might have to consider measures which suppress the total demand for freight movement.

8. Attempts to assess the cost-effectiveness of these measures are still at an early stage. Preliminary analysis suggests that the cost effectiveness of several freight-related CO_2-mitigation measures compares favourably with measures targeted on personal movement.

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