



Advice on CO₂ Emissions from the UK Freight Transport Sector

Prepared for the Shadow Committee on Climate Change

Professor Alan McKinnon

**Logistics Research Centre
Heriot-Watt University
EDINBURGH**

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<http://www.cfit.gov.uk/docs/2007/climatechange/pdf/2007climatechange-freight.pdf>

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1. Differing Estimates of CO₂ Emissions from the Freight Sector

The CfIT report highlighted discrepancies in the estimation of CO₂ emissions from HGV and rail freight operations in the UK. These have yet to be resolved.

HGVs

Two different methods can be used to estimate CO₂ emissions from lorries. These are outlined in Figure 1:

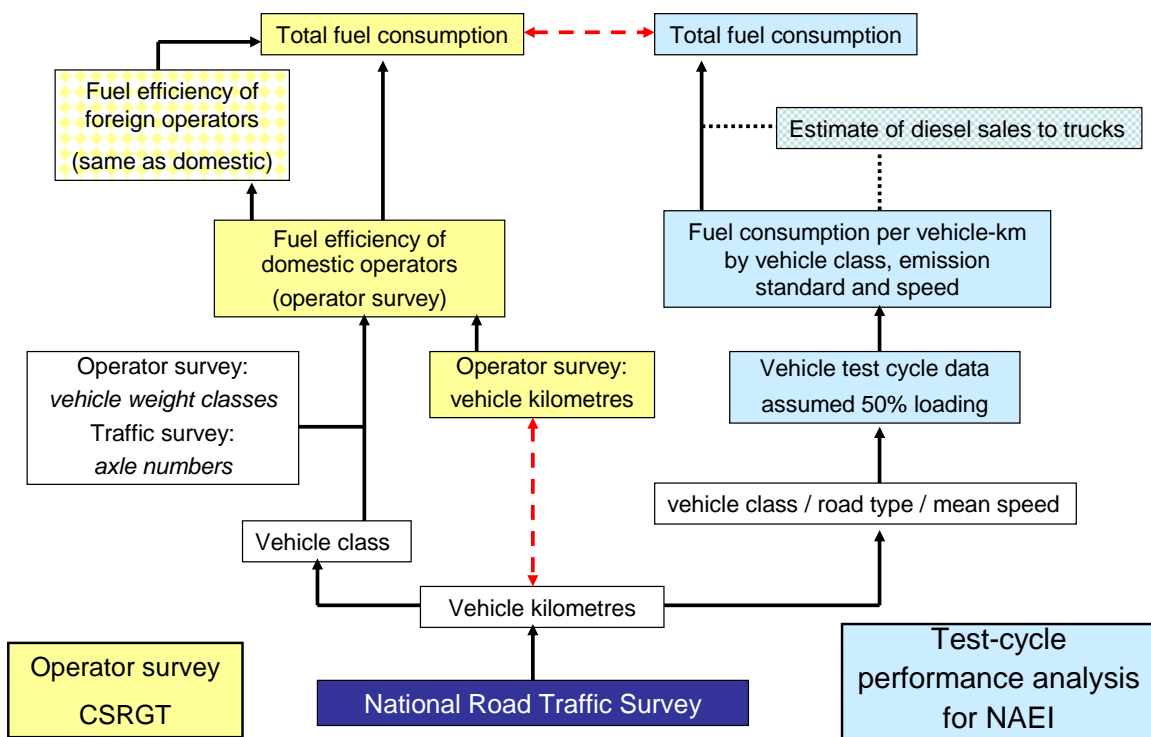


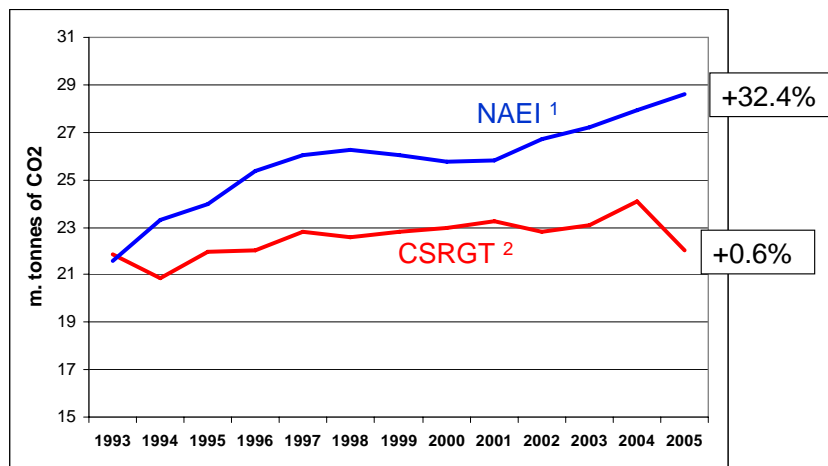
Figure 1: Survey-based and Test-cycle-based Estimates of Fuel Consumption by HGVs

National Atmospheric Emission Inventory (NAEI) approach: this is largely based on the results of vehicle test cycle trials undertaken by TRL. Different classes of HGV are run at differing speeds on roller-beds and the levels of emission monitored. For each of the main classes of HGV speed-emission curves are constructed. From the National Road Traffic Survey (NRTS) data is obtained on the proportions of HGV-kms run on different types of road and at different average speeds. The speed-emission relationships derived from the test cycle trials are then combined with the NRTS data to estimate total CO₂ emissions from each class of vehicle. These estimates are summed across the

entire HGV fleet. The test cycle trials also yield fuel consumption data which can be aggregated in a similar manner to produce an estimate of total diesel consumption for the HGV fleet. When compared with estimates of total diesel fuel sales to HGVs in 2003, there was a discrepancy of around 7.1% ¹. It is understood that an algorithm is used to reconcile these two estimates and the resulting value presented in the NAEI. The most recent NAEI figures for the trend in HGV CO₂ emissions were released in a Parliamentary Answer on the 16th January 2008.

Survey-based approach: this uses survey data on the activities of approximately 17000 vehicles monitored for a period of one week by the Continuing Survey of Road Goods Transport (CSRGT). Operators are required to provide data on distance travelled and quantity of fuel added to the vehicle during the survey week. This is used to calculate average fuel efficiency values for different classes of vehicle. NRTS data on the distances travelled by different classes of vehicle is then multiplied by the average fuel efficiency values derived from CSRGT to estimate total fuel consumption. The analysis undertaken for the CfIT report calculated this total figure for the entire HGV fleet. The Freight Transport Association (FTA) subsequently disaggregated this calculation by vehicle class for the period 1995 to 2005. This analysis has now been extended to cover the period 1993 to 2006.

Figure 2 compares the latest NAEI and CSRGT-NRTS estimates and shows that there remains a substantial difference both in the latest values (for 2006) and the trend since 1993.



- 1 House of Commons Parliamentary answer (16th Jan. 2008)
- 2 Vehicle-km data from the National Road Traffic Survey
Fuel efficiency data from Dept for Transport 'Road Freight Statistics'

Figure 2: Differing Estimates of the Trend in CO₂ Emissions from HGVs

¹ AEA Technology 'Development of Regional Estimates of Energy Consumption by the Road Transport Sector – Stage 2' (March 2005)

Several reasons can be offered for this disparity:

1. It is not uncommon for test-cycle-based emissions estimates to differ markedly from estimates derived from actual on-the-road operations. At a recent International Energy Agency workshop, delegates reported that the differences as great as 100% have been observed.
2. There is considerable uncertainty over the actual distance run by HGVs on UK roads. There are two sources of HGV-km data:

NRTS: road count data which relates to all HGVs on UK roads and covers foreign as well as UK-registered haulage operations

CSRGT: data on distances travelled by sample vehicles is collected in two ways: a question about the total annual distance travelled by the vehicle and records of the lengths of trips made by the vehicle during the survey week (subsequently verified by use of the Autoroute software package). This survey excludes foreign-registered vehicles.

In 2006, the NRTS estimate was 29% greater than the CSRGT estimate. This gap has roughly doubled since 1996 and appears to be the result of three factors:

(i) Exclusion of foreign-registered lorries from CSRGT: The earlier CfIT paper suggested that this might account for between 15 and 40% of the discrepancy.

(ii) Mis-classification of vans and rigid vehicles around the 3.5 tonne weight threshold. As van traffic has grown sharply in recent years and much of this growth has been in the largest / heaviest category of vans, the opportunities for mis-classification have increased

(iii) Under-reporting by CSRGT respondents of the number and / or length of trips that sample lorries undertake during the survey week. The separate question about annual distance travelled and Autoroute validation should help to improve accuracy, though a separate analysis of the tachographs of a sample of vehicles surveyed by CSRGT did show significant under-estimation.

DfT statisticians have prepared a confidential internal memo on this issue and proposed formulae for reconciling the two sets of vehicle-km estimates. Until this new approach is formally adopted, the NRTS estimate is likely to be the more accurate and reliable value. As this estimate has been used by both the NAEI and survey-based methods to scale up fuel efficiency and emission factor values, the aggregate vehicle-km figure cannot be the source of the discrepancy.

The CSRGT distance estimates, however, also feed into the fuel efficiency values and it may be at this level that much of the inconsistency arises. If, however, the CSRGT records of fuel consumption are accurate and the vehicle-km figures under-estimate the true distance travelled, the fuel efficiency values should be higher. This would then reduce the estimate of the total amount of fuel consumed by HGVs and level of emissions, widening rather than narrowing the gap with NAEI estimates. If, on the other hand, there was greater under-reporting of the amount of fuel purchased during the survey week than of vehicle-kms, fuel efficiency would be lower and the gap somewhat narrowed.

Independent validation of the CSRGT fuel efficiency data is very difficult at present, given the nature of the available data. Both the FTA and RHA publish survey data on the average fuel efficiency of lorries, but differences in the systems of vehicle classification prevent direct comparison (Table 1). Some corroboration of the CSRGT fuel efficiency values has come from the Transport KPI surveys commissioned by the DfT (discussed in Section 8) though these are sector-specific and based on 'self-selected' rather than random samples of companies. Participating companies may be more progressive and attach above-average importance to cutting fuel consumption / emissions.

Fuel consumption by vehicle type ² (mpg)	Rigid					Articulated	
	Over 3.5 tonnes - not over 7.5 tonnes	Over 7.5 tonnes – not over 14 tonnes	Over 14 tonnes – not over 17 tonnes	Over 17 tonnes – not over 25 tonnes	Over 25 tonnes	Over 3.5 tonnes – not over 33 tonnes	Over 33 tonnes
Road Freight Statistics (2005)	13.2	10.5	9.4	9.0	6.6	9.1	8.0
Road Freight Statistics (average 1989- 2005)	12.3	10.5	9.1	7.5	6.4	7.9	7.1

Fuel consumption by vehicle type (mpg)	Rigid						Articulated			
	3.5 tonne s gv w	7.5 tonne s gv w	12-14 tonne s gv w	17-18 tonnes gv w	24-26 tonnes gv w	32 tonne s gv w	33 tonne s gv w	38 tonne s gv w	40 tonnes gv w	44 tonne s gv w
FTA ³	25.0	15.5	12.0	13.0	10.0	8.0	9.0	7.8	7.6	7.3
RHA ⁴	27.0	18.0	14.0	12.0	9.5	8.0	9.0	8.0	7.8	7.2
Difference (RHA/FTA-1)%	8%	16%	17%	-8%	-5%	0%	0%	3%	3%	-1%

Table 1: Comparison of Fuel Efficiency Estimates from CSRGT, FTA and RHA Surveys (Compiled by M.Piecyk)

² Department for Transport, *Road Freight Statistics*, 2006

³ Freight Transport Association, 2007, *Managers' Guide to Distribution Costs*, Tunbridge Wells.

⁴ DFF International, 2007. *Goods Vehicle Operating Costs 2007*. Road Haulage Association, Weybridge.

2. Possible Use of Tachographs and Telematics Data to Improve Freight Modelling

One possible way of reconciling differences in vehicle-km estimates for lorries would be to use distance data collected by tachographs and tracking devices. Data can be systematically downloaded from digital tachographs when lorries go in for their annual inspection. It is understood that VOSA officials do record the vehicle mileage during these tests but that this information is not used for statistical purposes.

As the proportion of lorries and vans with tracking devices increases, the potential for supplementing official traffic counts with telematics data will expand. Large corporate databases already exist with the historic records of many millions of lorry and van trips, with information about the vehicle schedule, route, locations of collection and delivery points and speed. Research commissioned by the DfT several years ago examined the practicalities and cost of accessing this telematics data.

Opportunities exist to link the tachograph and telematics devices to the 'canbus' (or electrical control network) within the vehicle. This permits the monitoring of various vehicle systems including fuel consumption and could become a valuable source of on-the-road fuel consumption data. In the longer term, the installation of load sensors on the vehicle would permit the automated recording of vehicle loads. Linking company records of the consignments loaded and unloaded with vehicle telematics data would offer an alternative means of measuring road tonne-kms and vehicle load factors. All of this requires a high level of company co-operation. There is also a danger that, until telematic systems are widely diffused throughout the haulage industry, the samples of co-operating companies may not be representative of the sector as a whole.

3. Construction of Revised Scenarios for CO₂ Emissions from the Freight Sector

3.1 Specification of the Scenarios

The scenarios constructed for the CfIT report have been revised in several ways:

- The base year has been updated from 2004 to 2006
- The time horizon has been extended to 2022
- Forecasts of the growth of HGV and van traffic have been aligned with the National Road Traffic Forecasts for England and Wales published in November 2007. It has been assumed that the trends between 2015 and 2025 are linear to permit the interpolation of values for 2022.
- Future estimates of key parameters have been varied partly to reflect the different time-scale, but also to take account of new evidence.

These new scenarios are based on five key parameters:

1. Total quantity of freight movement, measured in tonne-kms
2. Division of this freight movement between transport modes (i.e. modal split)
3. Utilisation of vehicle capacity: measured in terms of the % of vehicle distance run empty and the average payload weight on laden trips
4. Fuel efficiency
5. Carbon intensity of the fuel used

Table 2 compares the parameter values used for the two scenarios:

- a baseline scenario
- an optimistic scenario (from a climate change perspective) with parameter values set at the upper end of the range that might be expected given the present policy mix and the projection of business-as-usual (BAU) trends

Like those presented in the CfIT report, these scenarios are illustrative and not based on detailed modelling. They reflect the author's 'expert judgement'. A two-round Delphi survey is currently underway at Heriot-Watt University (as part of the Green Logistics research project) in which a panel of 100 freight transport / logistics specialists are expressing their views on BAU trends in freight and

environmental variables up to 2020. The provisional results of this work will be published in the summer of 2008.

Baseline Scenario

Change in total tonne-km	16%	Changes in fuel efficiency	HGV	8%
Change in road tonne-km	11%		Van	8%
Change in van tonne-km	62%		Rail	5%
Change in rail tonne-km	23%		Waterborne	5%
Change in waterborne tonne-km	23%		Pipeline	0%
Change in pipeline tonne-km	0%			
Change in HGV empty running	0%	Change in CO2 intensity of fuel	HGV	-5%
Change in van empty running	0%		Van	-5%
Change in average payload weight on laden HGVs	5%		Rail	-5%
Change in average payload weight on laden vans	10%		Waterborne	0%
Change in rail capacity utilisation	5%		Pipeline	-5%
Change in waterborne capacity utilisation	5%			

Optimistic Scenario

Change in total tonne-km	12%	Changes in fuel efficiency	HGV	15%
Change in road tonne-km	4%		Van	10%
Change in van tonne-km	37%		Rail	10%
Change in rail tonne-km	27%		Waterborne	5%
Change in waterborne tonne-km	27%		Pipeline	0%
Change in pipeline tonne-km	0%			
Change in HGV empty running	-10%	Change in CO2 intensity of fuel	HGV	-15%
Change in van empty running	0%		Van	-10%
Change in average payload weight on laden HGVs	10%		Rail	-5%
Change in average payload weight on laden vans	25%		Waterborne	0%
Change in rail capacity utilisation	10%		Pipeline	-5%
Change in waterborne capacity utilisation	10%			

Table 2: Values for Key Parameters in the Baseline and Optimistic Scenarios

3.1 Key Parameters

Each of the five key parameters requires some commentary:

1. Total quantity of freight movement, measured in tonne-kms

The DfT forecasts the growth of HGV and van traffic but does not compile forecasts of the trend in total freight demand across all modes. It is not known therefore how the NRTF 2007 forecasts of HGV- and van-kms will relate to the overall UK freight market. Within the National Transport Model (NTM), which has been used to compile the latest set of traffic forecasts, freight is fairly peripheral (Figure 3). External variables such as GDP, land use and employment are shown as inputs into the car ownership model, but the external inputs into the freight model are unspecified. The supporting text provides no elaboration on how the HGV traffic forecasts have been derived. In the absence of clear guidance on the NRTF freight forecasting procedure, estimates of future tonne-km growth have been based on trends since 1980. These suggest that the rate of total tonne-km growth has been slowing and that the tonne-km trend has been diverging from that of GDP.

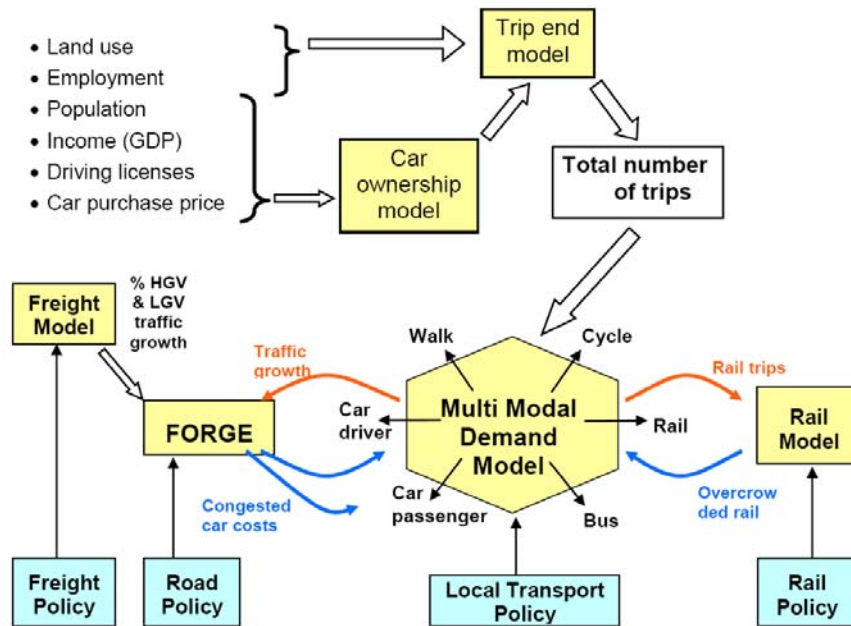


Figure 3: Structure of the National Transport Model. (Source: Dept for Transport)

Baseline scenario: It is assumed that the average rate of total tonne-km growth will be 1%. This is slightly higher than the rate experienced so far in this decade, though markedly lower than the rates prevailing in the 1980s and 1990s (Table 3). It suggests that the freight transport intensity of the UK economy (ratio of tonne-kms to GDP) will continue to decline.

Optimistic scenario: this assumes that the average rate of tonne-km growth will continue to decline and average 0.75% per annum over the 16 years to 2022. It suggests a steeper decline in freight transport intensity.

	Average annual % growth of HGV tonne-kms
1980-90	4.6
1990-2000	2.2
2000-2006	0.9
Baseline to 2020	1
Optimistic to 2020	0.75

Table 3: Average annual rates of road tonne-km growth: past and projected

2. Freight modal split:

Baseline scenario: this adopts the NRTF 2007 projections of the growth of HGV and van traffic and uses BAU estimates of future trends in empty running and average payload weight to convert these projected amounts of vehicle-kms into tonne-kms. Within the ceiling set by the overall forecast of

tonne-kms, this limits the degree of modal shift to rail and water. (It is assumed that the pipeline tonne-kms will remain constant.) It, nevertheless, allows for a 23% increase in tonne-kms moved by rail and waterborne transport. Within an overall freight market enlarged by 16%, however, their shares of total tonne-kms increase only marginally. The NRTF 2007 report does not explain how the HGV forecasts relate to changes in modal split. Brief reference is made to the GB Freight Model, which is multimodal, and to ongoing work on this subject.

Optimistic scenario: in this scenario road freight traffic grows much more slowly than predicted by the NRTF: HGV traffic by 4% as opposed to 12% and freight-related company van traffic by 30% rather than 67%. This scenario envisages a 27% growth of freight tonne-kms moved by rail and water.

3. Utilisation of vehicle capacity:

Baseline scenario: the average payload weight on laden HGVs, rail and water are predicted to increase by 5% over the period to 2022, while on company vans it is forecast to rise by 10%, partly reflecting the growth in online retail volumes. No reductions in the % of empty running are envisaged for vans.

Optimistic scenario: the projected improvements in empty running and average payload weight in the original CfIT report are retained as these were considered to be the maxima that could be achieved within standard commercial and operating practices. More radical reorganisation of production and distribution systems would probably be required to push vehicle utilisation to higher levels. It should be noted, however, that the use of average payload weight as a parameter is sub-optimal, as it takes no account of the cubic volume occupied by loads. As the average density of freight is generally thought to be declining in the UK, as greater use is being made of high cube / double-deck vehicles and as loading gauge enhancement on the rail network is allowing taller containers and swap-bodies to be carried, it would be desirable to factor cube utilisation of transport capacity into future versions of the scenario. This is not possible at present given the paucity of volumetric data for freight.

4. Fuel efficiency:

Baseline: According to the CSRGT, since 1990 the fuel efficiency of road haulage operations has been increasing at approximately 0.75% per annum. It is assumed that this rate of improvement will slacken to an average of 0.5% per annum over the period to 2022. A similar rate of improvement is forecast for vans and slightly lower rates for rail and water. These values are higher than those used for the 'realistic' scenario in the CfIT report, reflecting the

longer time period and more positive evidence to emerge over the past two years on the potential for technical improvements in fuel performance over the next 15-20 years (discussed in Section 5).

Optimistic: the fuel efficiency projections for road and rail have also been inflated, relative to the 'aspirational' scenario in the CfIT report, for similar reasons.

5. Carbon intensity of the fuel used:

Since the original scenarios were constructed for CfIT in mid-2006, enthusiasm for increasing the biodiesel content of conventional diesel beyond 5% has waned. Several companies which were planning to reduce the carbon footprints of their supply chains by switching to high biodiesel mixes (of 50% or more) are now reconsidering the situation. Concern has mounted over the environmental sustainability of biodiesel production, the true life-cycle CO₂ benefits and the potentially adverse effect on engine maintenance and performance. The development of second-generation biodiesel should address these problems, though it is uncertain when its production on a large-scale will be technically and commercial feasible. The optimistic scenario assumes that it will be widely available by 2022 yielding significant net reductions in CO₂ emissions on a life-cycle basis. The baseline scenario is much more conservative, suggesting only modest reductions in the average carbon intensity of freight transport fuels by 2022. The optimistic scenario for rail also assumes greater use of electric traction by freight trains and less use of fossil-fuels in electricity generation.

3.1 Results of the Revised Scenario Analysis

Table 4 presents summary statistics for the two scenarios. Two sets of aggregate CO₂ values have been calculated for each of the scenarios. One set is based on the CSRGT estimates of tonne-kms carried by HGVs. The other makes allowance for the fact that the CSRGT estimate of lorry-kms is substantially lower than that derived from NRTS, partly because of the exclusion of foreign-registered trucks from the CSRGT. These 'NRTS-adjusted' values have been scaled up by the ratio of NRTS to CSRGT vehicle-km estimates. This increases total freight-related CO₂ emissions and also the HGV share.

The baseline scenario suggests that total CO₂ emissions from the freight sector may reduce by 1-2% despite a growth in tonne-kms of 16% between 2006 and 2022. In the optimistic scenario, freight tonne-kms grow by a smaller margin (12%) and favourable trends in all the key parameters offer the potential of cutting CO₂ emissions by 28-29% below their 2006 level. This figure is very similar to that estimated for the 'aspirational' scenario in the CfIT report, though this is largely coincidental. In this new scenario several of the key parameter values have been

significantly altered, particularly those relating to total freight tonne-kms, modal split and the carbon intensity of freight transport fuel.

	<i>2006 Data</i>	<i>2022 Baseline Scenario</i>		<i>2022 Optimistic Scenario</i>	
	m. tonnes CO2	m. tonnes CO2	% change	m.tonnes CO2	% change
CSRG-based	29.34	28.92	-1.4	21.17	-27.8
NRTS-'adjusted	36.55	35.55	-2.7	25.93	-29.0

Table 4: Results of Revised Scenario Analysis

4. Fuel Economy Standards for Road Freight Vehicles

Fuel economy standards have been developed for cars and applied around the world either by voluntary agreement with vehicle manufacturers or on a mandatory basis. To date, only the Japanese government has imposed statutory fuel economy standards on road freight vehicles. The European Commission is proposing to introduce a CO₂ standard for vans of 180g per vehicle-km, but there are no similar plans for trucks in Europe or North America.

Several reasons can be offered for the absence of fuel economy / CO₂ standards for lorries:

1. There are much stronger commercial pressures on lorry manufacturers and operators to achieve high fuel efficiency. These pressures are stronger than in the private car market, reducing the need for public policy intervention. This 'conventional wisdom that commercial operators are more conscious of fuel costs than private drivers' was, however, challenged by specialists attending an International Energy Agency workshop in 2007⁵. Many argued that public policy measures could accelerate improvements in fuel efficiency though did not necessarily see the adoption of fuel economy standards as the most effective means of achieving this.

2. The HGV fleet is much more heterogeneous than the car fleet. Figure 4 illustrates the diversity of body types. Multiplying these types by gross weight class, axle numbers and variations in the nature of auxiliary equipment hugely increases the number of possible permutations. The degree of variety is much greater for articulated vehicles than for rigid.

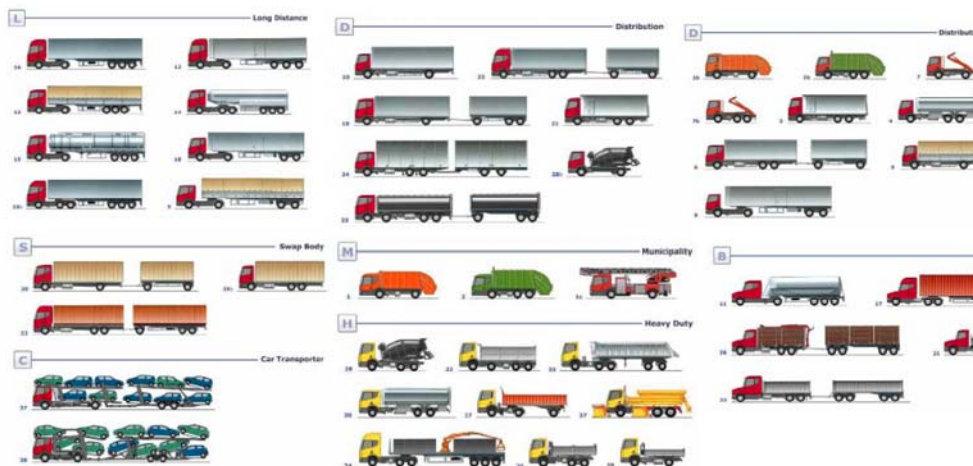


Figure 4: Variety of truck types⁶

⁵ http://www.iea.org/textbase/work/workshopdetail.asp?WS_ID=306

⁶ Larsson, S., 2008, *Data and Indicators for Road Freight Transport*. ACEA, Brussels

3. Lorries combine sub-systems produced by different manufacturers. For example, in the case of articulated vehicles, this includes engines, vehicle body, trailers and ancillary equipment such as refrigeration which is sometimes powered by the main engine. Individual manufacturers, therefore, have much less control over the fuel performance of the final lorry than their counterparts in the car sector.

Despite these practical constraints the Japanese government's Energy Conservation Law made provision for the adoption of a 'top runner' fuel efficiency standard for trucks. The 'top runner' concept aims to make the best-in-class performance the average by a target date. For trucks this will entail improving the average fuel efficiency from 6.30 kms / litre in 2002 to 7.09 kms / litre in 2015. Average CO₂ emissions will fall from 415 to 370 per vehicle-km, a 12% decrease. Different target improvements have been specified for different vehicle weight classes. Tax incentives are being used to promote this move to higher efficiency standards. The purchase tax is being reduced by 1-2% for new vehicles meeting the target fuel efficiency standards.

5. Potential for Further Improvements in Lorry Fuel Efficiency

5.1 Fuel Efficiency Trends

The CfIT report outlined a range of ways in which the average fuel efficiency of the lorry fleet might be improved. This section elaborates and updates the discussion of this topic in the earlier report. The new information has come from various sources including presentations and discussions at two IEA workshops, the 2008 Asilomar conference, journal and trade press articles and the websites of vehicle manufacturers, trade associations and the Freight Best Practice programme.

It has been estimated that over the past 40 years the average fuel efficiency of new HGVs has been improving at a rate of around 0.8-1% per annum⁷. This rate and sources of improvement have varied between vehicle size and weight classes. For example, for the heaviest category of vehicles, roughly two-thirds of the increase in fuel efficiency has come from advances in engine performance and the remainder from better aerodynamics and tyres.

The main improvements were made in the 1970s and 80s. As shown in Figure 5, the rate of fuel efficiency improvement has been relatively slow since 1990. This is partly because the incremental improvements from the refinement of existing vehicle technology have been diminishing, but it is mainly because of the need to meet tightening emission controls, particularly on NO_x. It has been estimated that if these controls had not been imposed, average lorry fuel efficiency today could be around 7-10% higher. One estimate for the US trucking industry puts this fuel penalty at 15-20% over the period 1988 – 2010. This illustrates the environmental trade-off that has been made in giving the reduction of noxious emissions priority over fuel economy and CO₂ savings.

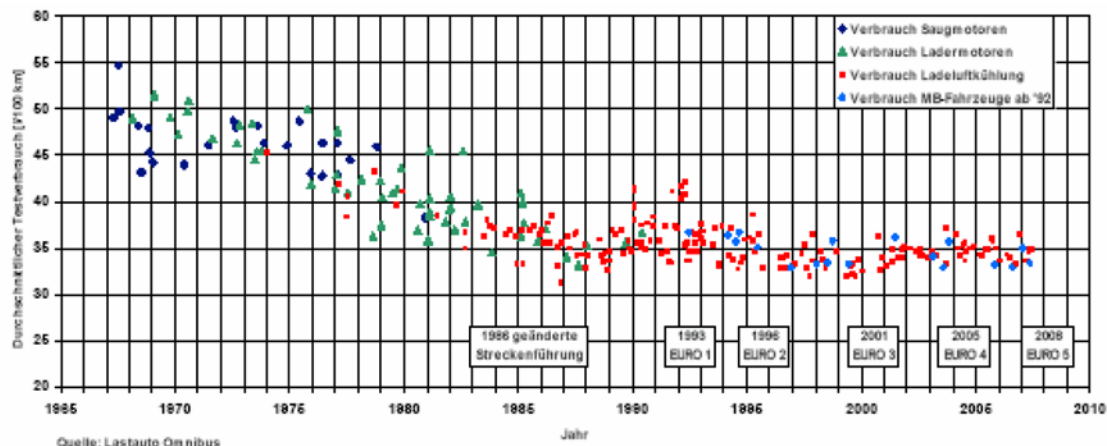


Figure 5: Average Fuel Consumption of New 38/40 Tonne Trucks: 1966-2010
(Source: Daimler quoted by Larsson⁸)

⁷ IEA, 2007, Fuel Efficiency for HDVs *Standards and other Policy Instruments*
http://www.iea.org/textbase/work/2007/vehicle/Workshop_Summary.pdf

⁸ Larsson, op.cit.

This trade-off has been further complicated in recent years by the need to introduce new systems to enable lorries to achieve Euro 4 and 5 emission standards. Most truck manufacturers have opted for the Selective Catalytic Reduction (SCR) system which, it is claimed, yields better fuel efficiency than the alternative Exhaust Gas Recirculation (EGR) system, but which requires the addition of a urea-based chemical called Ad-Blue to the combustion system. This significantly increases the emission of nitrous oxide (N₂O) from lorry exhausts. Although not a controlled pollutant, N₂O is a very powerful greenhouse gas, with a global warming potential 320 times greater than CO₂. Analysis of NAEL data suggests that N₂O currently accounts for around 1% of the global warming potential of truck exhaust emissions in the UK, though this percentage is likely to increase as more of the vehicle fleet is upgraded to the higher Euro emissions standards.

In launching its 'Top runner' programme for HGVs, the Japanese government has estimated that the potential exists to increase the fuel efficiency of new lorries by 12% between 2002 and 2015. Improvements to the fuel performance of new lorries is only one source of fuel savings, however. Potentially greater savings may accrue from the subsequent operation and maintenance of vehicles. It is very difficult to assess the overall potential for improving the average fuel efficiency of road haulage operations for several reasons:

- there are many different sources of efficiency improvement
- there is a complex interaction between different types of improvement measure: in some cases there is mutual reinforcement while in others they are counteracting
- there are often quite wide variations in the estimates of potential fuel savings from different sources
- it is often unclear from what baseline potential savings are being calculated, particularly when they are generalised at an international level

The earlier CfIT paper outlined some of most promising and cost-effective ways of raising the fuel efficiency of road freight operations. This list has now been extended to provide a more comprehensive list of fuel economy measures. These measures can be divided into four categories: vehicle design; vehicle maintenance, fleet management and driver performance:

5.2 Vehicle Design

Engine and exhaust systems:

The US Department for Energy expects that about two-thirds of future fuel efficiency gains in trucks will come from improvements to engine and exhaust systems⁹. The largest gains are likely to come from:

⁹ IEA, 2007, op.cit.

1. *Use of turbocharging to make possible the downsizing of engines:* this will make it possible to obtain the same power rating with lower fuel consumption
2. *Application of hybrid technology to rigid lorries engaged in local delivery / collection operations:* research by Volvo suggests that combining diesel and battery power could ultimately increase fuel economy by 50%. The limited range and stop-start nature of local delivery operations make them particularly suited to the use of hybrids. Most of the main European truck manufacturers are currently developing hybrid rigs. Because of the limited range and relatively heavy weight of the battery coupled with the greater fuel efficiency of diesel engines operating at constant speeds over long distances, hybrid technology is likely to have very limited application in long haul operations.
3. *Improving the energy efficiency of auxiliary equipment on the vehicle, such as pumps, fans, air compressor, heating, air conditioning and power steering.* The installation of separate power systems for this equipment can also save fuel, as it decouples their operation from that of the main vehicle engine. Separate batteries can be used for this purpose. The US Dept for Energy has indicated that fuel efficiency gains of 50% can be achieved by overhauling these auxiliary systems¹⁰.
4. *Technology can also be used to correct poor driving practice.* For example, anti-idling devices automatically switch off the engine when the vehicle is not moving. Automatic gearboxes can be adjusted to ensure that gear changes minimise fuel consumption.

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. ETSU¹¹) and case studies (e.g. Dept for Transport¹²) have reported potential fuel savings in the range 6-20% for improved aerodynamic styling of trucks. Delegates at the IEA workshop¹³ in 2007 indicated that improved aerodynamics could represent 10-20% of all potential fuel efficiency improvements to the HGV fleet, with most of the benefits accruing to larger articulated vehicles making high-speed, long distance trips. Over-cab spoilers have been the most widely used form of profiling, though it is now recognised that around 85% of the potential fuel savings from improved

¹⁰ IEA, 2007, op.cit.

¹¹ ETSU 2001, *Truck Aerodynamics – A Good Practice Guide*, GPG 208, Harwell

¹² <http://www.freightbestpractice.org.uk/download.aspx?pid=135&action=save>

¹³ IEA, 2007, op.cit.

aerodynamics come from the trailer design, particularly in the case of the high-cube / double-deck trailers which are much more common in the UK than any other developed country. (According to the CSRGT double-deck vehicles accounted for 3.5% of articulated HGV-kms in the UK in 2006¹⁴.) An increasing number of double-deck trailers in the UK now have sloping fronts, permitting up to 10% fuel savings. It has recently been recognised that improved profiling of the rear of trailers can have a significant impact on fuel efficiency. So-called 'teardrop' trailers have begun to appear on UK roads which slope downwards at the front and rear. Marks and Spencer, which claims to be the first company in the world to operate such a trailer, reports CO₂ reductions per unit load of 20% relative to emissions from a standard articulated lorry.

Where aerodynamic profiling involves the use of spoilers, side-skirts and 'spats' over the wheels, additional weight is added to the vehicle, offsetting some of the fuel efficiency benefits.

Reduction in vehicle tare weight:

Fuel efficiency can also be enhanced by reducing the tare (or empty) weight of the vehicle. Use of lighter materials, such as aluminium or carbon fibre, and fittings can substantially cut the tare weight. One major truck manufacturer has indicated that it is relatively easy to remove just over half a tonne from the tare weight of an articulated truck.

Improved tyre performance:

The so-called 'next generation' tyres should be able to raise fuel efficiency by 3.5-8% by reducing 'rolling resistance'. Improvements of this magnitude will only be achieved on motorway running, however. Larger % fuel savings can probably be achieved by ensuring that existing tyres are properly inflated. It is estimated that 20% under-inflation of tyres results in a 2% reduction in fuel efficiency.

Summary

Research by Woodroffe and Assocs for the US Dept of Energy has assessed the overall prospects for improving the fuel efficiency of new heavy trucks with gross weights in excess of 25 tonnes (quoted by Duleep¹⁵). This suggests that a 36% increase is possible. Although North American trucks have different design features from their European counterparts, these figures may be taken as indicative of what, according to Duleep, is technically possible by 2020.

¹⁴ Dept for Transport, 2007, *Road Freight Statistics 2006*.

¹⁵ Duleep, K.G., 2007, 'Fuel Economy of Heavy Duty Trucks in the USA' Presentation to the IEA workshop on 'Fuel Efficiency for HDV Standards and Other Policy Instruments' Paris.

	base	target	% reduction	saving	% of total saving
Engine losses (kWh)	240	143	40%	97	67%
Aerodynamic losses (kWh)	85	68	20%	17	12%
Tyres - rolling resistance (kWh)	51	31	39%	20	14%
Transmissions (kWh)	9	6.3	30%	2.7	2%
Auxiliary equipment (kWh)	15	7.5	50%	7.5	5%
Total	400	255.8	36%	144.2	100%

Table 5: Target Reductions in the Energy Consumption of Heavy Trucks:
(Source: Woodroffe and Assocs., quoted by Duleep)

For these technical improvements to be widely diffused and truck manufacturers to be incentivised to make them, operators will have to attach greater importance to fuel efficiency in their vehicle purchasing decisions. Research in Finland¹⁶ has found variations of 5-15% in the fuel efficiency of different brands of new truck. Comparing the results of the vehicle tests reported in UK trade publications reveals that 10% variations in fuel consumption over a standard trial route are not uncommon for a particular class of vehicle.

This review has assumed that vehicle construction and use regulations remain unchanged. Increases in the maximum size and weight of lorry would, other things being equal, permit reductions in fuel consumption and CO₂ emissions per tonne-km. A report prepared by TRL and Heriot-Watt University for the DfT on this subject will be published shortly.

5.3 Vehicle Maintenance:

There is a wide range of technical imperfections which can prevent a lorry from operating at optimum fuel efficiency. Typical defects include: poor combustion, fuel leaks, under-inflated tyres and axle mis-alignment. For example, 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%.

5.4 Fleet Management:

One of the key tasks of a fleet manager is to ensure that vehicles are deployed in a way that maximises their operational efficiency, in terms of load capacity and engine power rating. Data from the CSRGT on vehicle utilisation suggests that vehicles often have much more weight-carrying capacity than required for the load. Efforts to match the capacity of the vehicle to the size / weight of the load would run counter to the general practice of standardising vehicle weights and dimensions within a fleet. There is scope, however, for improving this match, particularly with the use of fleet management software. A road user charging

¹⁶ Nylund and Erkkila, 2007, *HDV Fuel Efficiency: Methodology, Vehicle Performance and Potential for Fuel Savings*, Presentation to the IEA workshop on 'Fuel Efficiency for HDV Standards and Other Policy Instruments' Paris.

system in which per km tolls varied with vehicle gross weight class would incentivise closer tailoring of vehicle capacity to load size and weight. It is also generally acknowledged that a large proportion of lorries in the UK have engines that are over-powered relative to the loads they carry and terrain they cross. This is partly because lorries with more powerful engines tend to retain higher residual values.

5.5 Driver Performance

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

Improved driver training: it is generally accepted that, for a particular vehicle fleet, 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 recently been extended to van drivers. The available evidence suggests that in terms of carbon mitigation, these schemes are relatively cost-effective. Truck simulators have been used to provide training in safe and fuel efficient driving techniques. The experience of the Scottish truck simulator programme suggests that this method of driver training is much less cost-effective.

Driver incentive schemes: To derive longer term benefit from driver training companies have to give drivers an incentive to continue driving fuel-efficiently. It is becoming increasingly common for companies to introduce such schemes, though it can be difficult to implement them in a manner that is fair and consistent to drivers.

6. Price Elasticity of Demand for Freight Transport

There has been a serious lack of research on the price elasticity of demand for freight transport. This has been highlighted by the recent study for the DfT of the case for and against allowing longer and heavier trucks to operate in the UK. Reference is frequently made to a study undertaken by Oum, Waters and Young for the World Bank in 1989¹⁷. It reviewed estimates of demand elasticities for road and rail freight based mainly on the North American freight market. Beuthe et al (2001) developed a series of 'freight transportation demand elasticities' using Belgian data. Their study inferred cross-modal elasticities from an analysis of the costs of operating different types of transport service within origin and destination matrices on the assumption that companies would always aim to minimise 'generalised cost'. Their analysis, however, did *'not take account of any demand induced by the cost changes'* so the elasticity values they derived could not be used to assess, for example, the effect of fuel price increases on freight traffic levels.

Figure 6 compares changes in the real cost of road haulage services (as estimated by the ONS Corporate Services Price Index) with changes in total road tonne-kms over the past ten years. It suggests that there is little direct correlation between these variables.

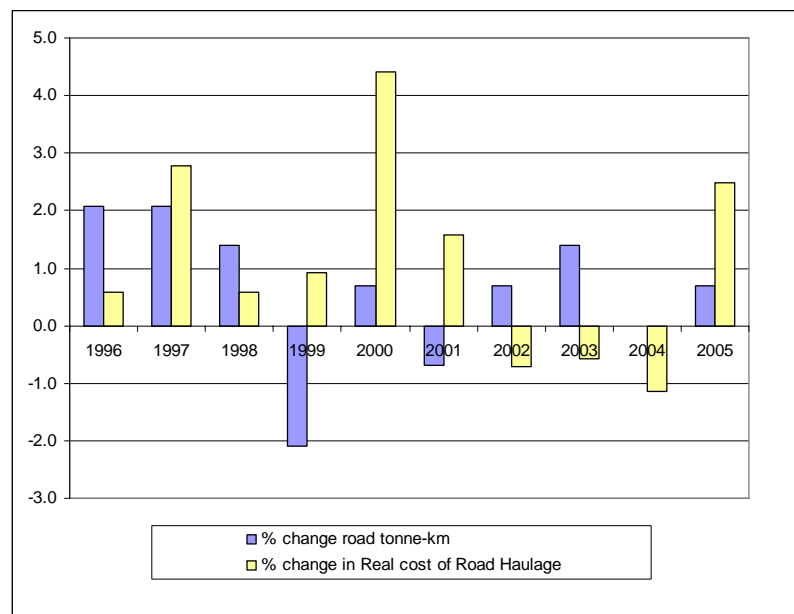


Figure 6: Trends in road tonne-kms and the real cost of road haulage: 1996-2005
(Sources: Dept for Transport, 200, Road Freight Statistics; ONS Corporate Services Price Index)

¹⁷ Oum, T., Waters, W. and Jong, Y., 1990, *A Survey of Recent Estimates of Price Elasticities of Demand for Transport*, Working Paper, World Bank, Washington D.C.

7. Use of Benchmark Surveys to Incentivise the Improvement of Energy Efficiency in the Freight Sector¹⁸

7.1 Review of the Transport KPI Programme

In 1997 the British government established a programme for benchmarking vehicle utilisation and energy efficiency across large samples of lorry fleets. Since 1997, ten surveys have been undertaken in the food, automotive, non-food retail, pallet-load (LTL), air cargo, pallet-load sectors and building sectors. Table 6 presents the summary statistics on these surveys.

Sector	Date	Fleets	Articulated vehicles	Rigid vehicles	Total	Trips	Distance Travelled (km)
Refrigerated food	1997	11	795	0	795	2981	519963
Food	1998	36	1393	182	1575	4024	1161911
Automotive	2001	7	143	50	193	679	179428
Food	2002	53	1446	546	1992	6068	1454221
Non-food retailing	2002	26	705	145	850	2496	744087
Pallet-load networks	2004	17	34	105	139	295	65880
Next day parcel delivery	2005	12	42	107	149	863	111464
Building Merchants	2006	35	3	113	116	379	23120
Food and drink	2006	113	4,696	1,600	6,296	8,000	1,300,000
Totals		310	9257	2848	12105	25785	5,560,074

Table 6: Summary statistics on DfT Transport KPI surveys 1997-2007.

Several major findings have emerged from these surveys:

1. They have revealed that significant differences in energy efficiency exist both within and between industry sub-sectors. Since the range can be skewed by one or two rogue values, the coefficient of variation (CoV) generally provides a more consistent basis for comparing the variability of energy intensity values within particular sub-sectors. This is calculated by dividing the standard deviation by the mean and

¹⁸ This section summarises a paper presented at the World Conference on Transport Research in June 2007. The full paper can be downloaded from <http://www.greenlogistics.org>. Reports of all the Transport KPI surveys can be downloaded from the www.freightbestpractice.org.uk website.

multiplying by 100%. Of the sub-sectors for which variability data has been published, this coefficient is highest for the primary movement of ambient-temperature food and lowest for non-food retailing (Table 7).

	mean	Standard deviation	Coefficient of Variation
Ambient Food (primary distribution)	12.2	6.5	53%
Food (local wholesale dist.)	37.3	12.3	33%
Pallet-load (trucking)	9.5	2.7	28%
Food (secondary distribution)	19.2	4.9	26%
Refrigerated Food (primary distribution)	19.3	4.9	25%
Pallet-load (C&D)	41.2	6.9	17%
Non-food retailing	22.1	2.3	10%

Table 7: Mean and variability of energy intensity values for sub-sectors: ml of fuel per pallet-km

The greater the variability in energy intensity at a sub-sectoral level, the more opportunity there should be for reducing average energy consumption through the dissemination of best practice. Estimates have been made of the potential savings in fuel, CO₂ emissions and operating costs that would accrue if fleets with relatively low efficiency could match either the best performing fleet or their sectoral / sub-sectoral mean. For example, in the non-food retail survey, fuel efficiency for 40 tonne trucks running on 5 axles varied from 3.1-3.8 kms per litre. In this case, 'for the worst to match the best a 22.6% improvement is required. At 100,000 kms per annum and a cost of 75 pence per litre this would give a saving of approximately £6000 per vehicle. With 74.1 gm of CO₂ / mJoule and 35.6 joules per litre, this is a reduction of over 21 tonnes of carbon dioxide emissions per vehicle per annum. Estimates of potential energy savings in the food supply chain have been based on differences in energy intensity, rather than fuel efficiency, and envisaged situations in which fleets with below average energy efficiency raise their performance either to the sub-sectoral mean or to that of the top third of companies in the sample. Within these scenarios, based on 2002 data, total fuel consumption would drop, respectively, by 5% and 19%.

2. The surveys have shown that companies which achieve high km-per-litre figures do not necessarily have the most energy-efficient distribution operations. High fuel efficiency can be offset by poor utilisation of vehicle capacity. This demonstrates that total energy consumption is also critically dependent on the utilisation of vehicle carrying capacity and highlights the importance of reporting fuel consumption on a pallet-km or tonne-km basis rather than vehicle-km basis.

3. Energy intensity varies much more widely across fleets of rigid vehicles than articulated vehicle fleets, regardless of sector. This can be partly attributed to wider differences in the nature of the delivery work they undertake. Analysis of the benchmark data at sub-sectoral and individual company levels, however, indicates that this provides only a partial explanation and that some operators run their rigid vehicles very inefficiently both in terms of loading and fuel consumption. This was

particularly evident in the automotive survey where just-in-time pressures were intense and some fleets' weight and volume utilization factors averaged under 20%. Local collection and delivery of express parcels, which mainly involves rigid vehicles and vans, is also characterized by wide variations in energy efficiency. Figure 7 shows the wide variations observed in this sector both in fuel efficiency (vehicle kms per litre) and consignments delivered per litre of fuel consumed.

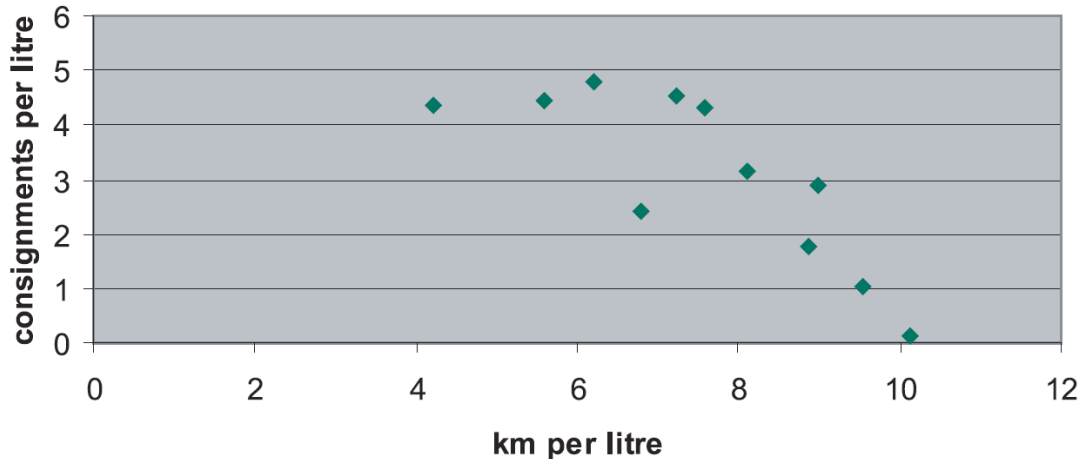


Figure 7: Relationship between fuel efficiency (kms per litre) and consignments per litre in the collection and delivery operations for express parcels: 11 sample fleets. (Source: Freight Best Practice Programme¹⁹)

7.1 Problems and Limitations

The research and consultancy teams that have undertaken the transport KPI surveys over the past decade have encountered a number of problems.

1. *Difficulty of securing adequate company involvement.* The KPI surveys completed to date have varied widely in the level of industrial support. A planned survey in the home delivery sector had to be abandoned because too few firms were prepared to supply the necessary operational data. At the other extreme, the food and non-retail surveys in 2002 attracted a great deal of interest. Success in recruiting companies appears to be related to the following factors:

- Support of a trade association
- Backing of industrial 'champions' who are respected within the industry
- Continuing engagement with the companies during the preparatory phases of the survey
- Participation of a few major companies against whom other business are keen to benchmark their transport operations.

¹⁹ *Key Performance Indicators for the Next Day Parcel Delivery Service* at www.freightbestpractice.org.uk

2. *Failure to survey logistical activities other than transport:* Companies that appear to have energy inefficient delivery operations may be behaving perfectly rationally, sacrificing transport efficiency for greater gains in the management of production, inventory or warehousing operations. It would be beneficial to explore the logistical trade-offs that companies make.

3. *Non-random sampling:* Companies participating in the transport KPI surveys have been self-selecting and not been chosen randomly. The aim of the marketing has been to encourage as many companies as possible in the targeted sectors to volunteer for the survey. Care must therefore be exercised in interpreting the aggregate results as these may not be representative of particular sectors and sub-sectors.

4. *Difficulty of measuring particular KPIs:* Several KPIs have proved difficult to measure accurately and this degree of difficulty varied between sectors. The benchmarking of vehicle utilisation and energy efficiency in the automotive sector, for example, was inherently much harder than in other sectors because of the diversity of handling equipment and large proportion of non-unitised freight. In the automotive sector, most loads comprise relatively low density products, making volumetric measurement much more important than weight-based measures.

5. *Limited analysis of the reasons for observed differences in performance:* Benchmarking is more likely to have a beneficial impact on behaviour when the causes of under-performance are diagnosed and guidance offered on improvement measures. Until recently, the DfT contracts awarded for transport KPI surveys made no allowance for causal analysis or follow-up advice to specific companies.

6. *Difficulty of finding well-matched comparators:* Even within industry sub-sectors, there can be significant differences between companies' distribution operations. Some of the variation in KPI values can be ascribed to differences in the nature of the customer base, the product range and production scheduling, all factors outside the logistics manager's control. Particular circumstances can justifiably cause a company's energy-efficiency value to deviate from the average of its benchmark group. Benchmarking at least gives managers an incentive to explain why their indicator values are below (or above) their sub-sectoral averages.

8. Carbon Abatement in the Van Sector

8.1 Do Freight-carrying Vans Merit Separate Attention?

The CfIT report noted that company-owned vans only carry freight or return empty from freight deliveries on around 35% of the total distance they travel. This raises the question of whether such freight-carrying vans should be treated differently from other vans in the analysis of carbon abatement options.

Arguments in favour of segregation:

1. The carbon intensity of freight-carrying van movements will be determined by different factors from van movements transporting people and / or equipment. The loading of the vehicle by weight and volume, the drop density in the delivery zone, the proportion of failed and repeat deliveries and the scheduling of deliveries will be much more important. Improving the energy efficiency of van deliveries will therefore require a different set of policy measures. This is not to deny that there are policy initiatives which are common to all types of van, such as raising standards of fuel efficient driving.

2. It is desirable to look at the inter-relationship between van deliveries and other types of freight transport operation. The interface between van and HGV delivery systems is particularly relevant because the break-bulk point where loads are disaggregated into small consignments for final delivery in vans is the location in the supply chain where the carbon intensity of the delivery increases by a factor of 2 or 3.

3. The 3.5 tonne gross weight, which separates vans from HGVs, is fairly artificial and the distinction is gradually blurring. As the weight and volume of goods being moved in vans is increasing, many operators are up-sizing their vehicles beyond the 3.5 tonne threshold and taking them into the 'lorry' category.

4. Much of the van population is only used for carrying freight and is therefore separately identifiable. Some vans are, nevertheless, multi-functional undertaking different types of journey such as commuting trips, repositioning workers, moving equipment and service engineers as well as moving freight. Dedicated freight-carrying vans, however, are sufficiently numerous to merit separate treatment.

8.2 Price Elasticity of Demand for Freight Movement by Vans

As in the case of other forms of freight transport, very little published research exists on this topic. The Commission for Integrated Transport recently employed Faber Maunsell consultants to review all the available data on van traffic in the UK. This did not reveal any elasticity values for van deliveries.

8.3 Is Online Retailing less Carbon Intensive than Conventional Retailing?

This question is currently being investigated in one of the modules in the Green Logistics research project²⁰ with the support of IMRG, the trade body for online retailing in the UK.

It has been argued that purchasing a product online and having it delivered to the home will produce less CO₂ than shopping for that product in the traditional way. Some online retailers, most notably Ocado, are now making such a claim in their advertising. There is very limited empirical data with which to test this hypothesis. Previous research²¹ in Finland, the US and the UK provides some empirical support for it, though this work has been underpinned by numerous assumptions and focused on particular categories of product, mainly groceries and books. The relative carbon footprints of the two types of distribution will depend on many factors such as the loading of the van, the proportion of repeat deliveries, the choice of transport mode for the shopping trip, the substitution of other personal trips for the shopping trip, the energy intensity of the retail operation, the amount that the individual buys on a shopping trip. Figure 8 highlights some of the key relationships that influence the relative amounts of personal and freight movement. This will be reflected in the carbon balance between online and conventional retailing.

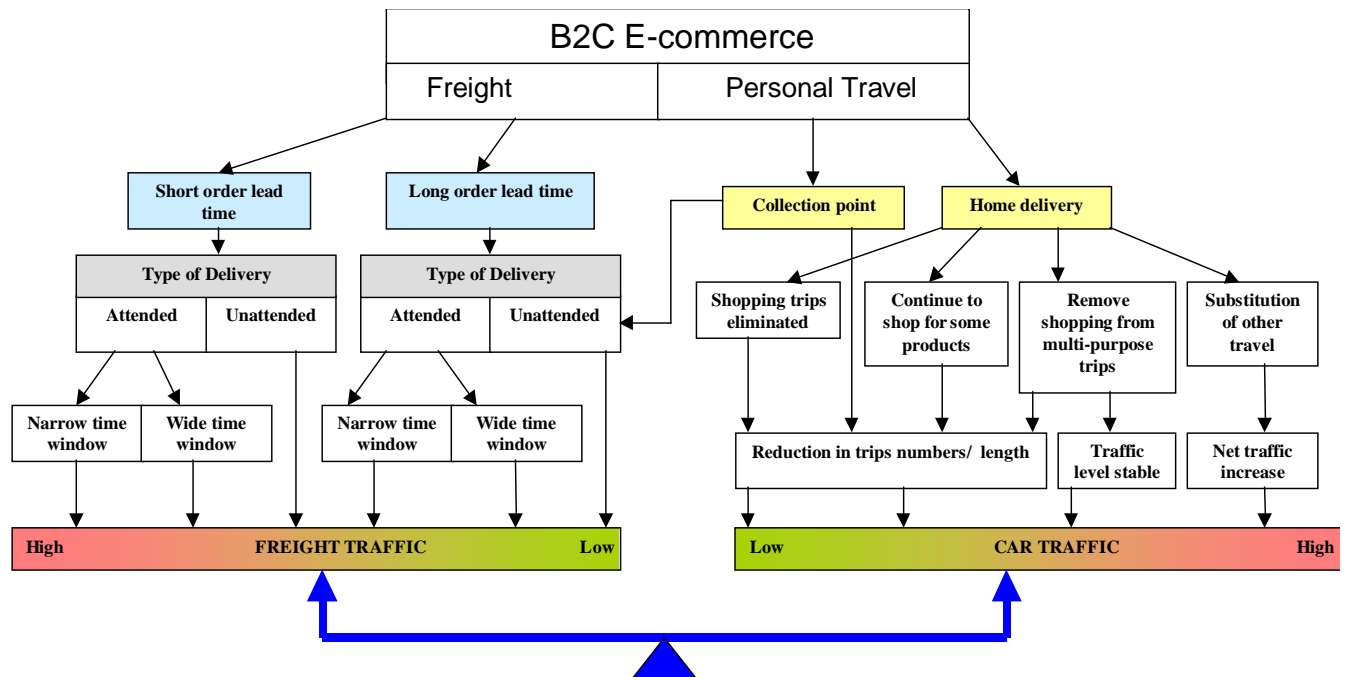


Figure 8: Relationship between B2C Ecommerce / Online Retailing and Road Traffic Levels (Source: McKinnon,

²⁰ www.greenlogistics.org

²¹ Reviewed by Cairns, S., 2005, Delivering Supermarket Shopping: More or Less Traffic, *Transport Reviews*, vol 25, no.1.

8.4 Use of Hybrid and Electric Vans

As discussed in section 5, hybrid technology has much greater potential application in stop-start local delivery operations by vans and small rigids than in long distance trunk-haul movements by large articulated lorries. Hybrids may be more widely adopted than electrically-powered vehicles given their greater range and lighter batteries. One of the UK's largest home delivery companies has examined the return on investment in electrically-powered vans and concluded that it is not financially attractive at present. Tesco and Menzies Distribution, on the other hand, are investing in battery-operated vehicles for, respectively, home and newspaper / magazine delivery to shops. Tesco is also aiming to make its deliveries by battery-operated vehicles 'carbon neutral' by using wind turbines at some of its properties to supply more power to the Grid than is required to recharge its van batteries.