Uncertainties related to freight transport costs and modelling

(A literature review)

1. Introduction

Vehicle operating costs can be divided into two main categories: standing costs and running costs.

Standing costs are defined as “the costs of having a vehicle standing and available for work”, “are not subject to frequent change and are not generally affected by the amount that the vehicle is used” (RTITB, 1989, p.6). This is therefore closest to the definition of fixed costs. Examples of standing costs include vehicle excise duty, vehicle insurance, operator’s licence fee, drivers’ guaranteed wages, depreciation and overheads.

Running costs are variable costs as their level depends on the actual use of the vehicle. The costs of fuel, lubricants, tyres and repairs and maintenance are examples of running or variable vehicle operating costs.

There are also external costs associated with vehicle operations. These are the costs which are not directly borne by those who cause them and include environmental, congestion and accident costs.

The aim of this paper is not to measure or identify trends in vehicle operating costs. Rather, it will identify various aspects of uncertainty which have impact on vehicle operating costs.

2. Uncertainties related to the level of vehicle operating costs

2.1 Fuel uncertainties

2.1.1 Uncertainties linked to mileage-related costs and benefits of transport energy conservation strategies

Litman (2005) has evaluated four transport energy conservation strategies (fuel efficiency standards and feebates (a rebate on the purchase of fuel-efficient vehicles), alternative fuels, fuel tax increase, mobility management) and their mileage-related costs and benefits. The main conclusion from his research is that energy conservation strategies which increase vehicle mileage (such as fuel efficiency measures) have smaller total benefits, while strategies that reduce mileage (such as fuel tax increases) provide larger total benefits to society.

In this paper Liman evaluated four strategies which all provided the same energy savings, but their other impacts varied significantly. Fuel economy standards and some alternative fuels reduce the cost of driving, which increases annual vehicle travel and associated costs. Fuel tax increases and mobility management strategies, on the other hand, reduce vehicle travel, providing additional benefits to society (through reduction in other impacts and transport costs such as congestion, road and parking facility costs and accidents).

His main recommendation is therefore that a comprehensive framework for transportation planning and policy analysis should be used, rather than using separate measures in isolation.

2.1.2 Uncertainties related to future prices of fuel, including alternative fuels, the cost of technologies to produce alternative fuels, suitability and costs of alternative fuels and emission savings

Stern (2006) and Anderson (2006) elaborate on these issues. The main focus of these works, however, is on the energy sector as a whole and findings do not specifically relate to the freight sector.

The Stern Report provides estimates of emissions from transport between 2005 and 2050 as well as estimates of the emission saving potential and cost of using biofuels. These estimates are provided on a ‘well-to-wheel’ basis, which takes into account the emissions resulting from the whole lifecycle of a fuel. The ‘well-to-wheel’ concept entails all stages and costs of the fuel lifecycle, from obtaining the material form its raw state (drilling for oil and gasses and growing and cultivating the raw material for biofuels), the transportation of the fuels in their raw state, the production and distribution of fuels, to its final stage of consumer use. The Climate Analysis Indicators Tool (CAIT), quoted in the Stern report, is an information and analysis tool on global climate change developed by the World Resources Institute. This tool may have potential for use in subsequent work modules of the Green Logistics project to obtain greenhouse emissions data.

2.2. Labour uncertainties

In recent times, there has been considerable uncertainty over:

- The impact of the working time directive, though this has largely worked through the system by now;
- Future labour shortages, including provision of training and skill shortages;
- Uncertainties about the labour cost impacts of increasing levels of congestion (see next section on congestion uncertainties).

Skills for Logistics (2005a), the official UK Sector-specific Skills Council for the freight transport industry, recognises the shortage of large goods vehicle (LGV) drivers as a problem which is having wider cost implications for the logistics industry. Lack of time and facilities, the substantial costs involved in sending a trainee to a driving school, recruitment costs in excess of £1,000 and difficulties in retaining staff are quoted as factors causing this shortage (op. cit., 2005a, p.19).

On the other hand, the situation with the van drivers seems to be much better compared to that of LGV drivers, the following reasons for this being:

- There is no requirement for any specialist qualification to drive a goods vehicle up to a 3.5 tonnes mean gross weight vehicle (a category B licence is sufficient);
- Low barriers to entry into this sub-sector of the logistics business;

- Many of the fixed costs (including responsibility for training) that are associated with larger operations are either avoided or off-loaded on to drivers (op. cit., 2005a, p.21).

However, basic driving skills are perceived as rather insufficient on their own for successful employment in the modern freight industry. Additional skills such as customer-facing skills, navigational skills and other ancillary skills (e.g. installation and use of equipment) are considered highly desirable in the case of van drivers (op. cit., 2005a, p.22).

Future scenarios addressing the uncertainties in the provision of training and skills development in the logistics sector

Skills for Logistics (2005b) identified the main drivers of change in the logistics industry and their implications for future skills needs. In two areas – government policy and environmental agenda – the conclusion was that "the industry is characterised by a very reactive approach, with (in many cases) little ability to anticipate change or plan effectively for it" (op. cit., 2005b, p.54). Therefore, a "need for greater current awareness of the implications of policy" was identified.

When considering the ways in which the logistics sector should address its future needs and seek improvements, "one of the key challenges for the logistics sector will be to define the most cost-effective approach to the improvement of skills and performance in the industry" (Skills for Logistics, 2005b, p.58).

Whether the sector will be successful or not in meeting its future training and skills needs will depend largely on its integrity and rapport with government. Four future scenarios addressing the uncertainties in the provision of training and skills development in the logistics sector have been considered: 'constructive engagement', 'managed decline', 'toe the nail' and 'every man for himself' (op. cit., 2005b, 73). The impacts of each of these scenarios on skill levels, productivity, wages, profits and the public perception of the industry are summarised in table 2.1.

Table 2.1: Future scenarios addressing the uncertainties in the provision of training and skills in the logistics sector

	'Constructive engagement'	'Managed decline'	'Toe the line'	'Every man to himself'
Relations within the logistics sector and with government	The logistics sector sees the value of working together and government recognises and supports the sector as a key part of the economy	The logistics sector is aware of the benefits of working together but government takes a less supportive role overall	Government takes an interested and active approach to development of logistics. Logistics firms, however, act in an individualistic way.	The players in the transport and logistics sector all act independently; no interest and support from government
Availability of support and funding	Funding is available even down to the smallest companies	Lack of funding	Large companies develop their own training schemes; training providers are given support and funding on an individual basis	Funding support for training from government both nationally and regionally declines substantially; companies are expected to find the funds themselves
Impact on skill levels	Skills levels rise across the sector	Small companies are worst affected; course take-up remains low	Fragmentation of provision and variation of quality of training, leading to a lack of take-up; slow decline in skill levels across the sector	Decline in skills levels. National standards are not maintained; they lose their relevance and become ignored by employers and employees.
Impact on productivity, wages, profits, etc	Increased productivity, higher profits for companies and better remuneration for employees	Not discussed	Falls in productivity	Falls in productivity across the whole sector; lack of skills has negative impact on wages and profits.
Public perception of the industry	Logistics is a dynamic and forward-looking sector that is a good career choice	The lack of support from government leads to its being seen as environmentally unfriendly, congestion causing and generally not attractive as a career choice	Decline in the public perception of the sector as a good career choice	The sector is no longer recognised as a world leader. Severe shortfall in LGV drivers forcing companies to recruit from overseas; major firms relocate overseas

Source: Adapted from Skills for Logistics, 2005b, pp.73-77

2.3. Uncertainties resulting from congestion and journey time variability

Congestion is identified as a source of uncertainty as it results in delays, unreliable travel times and a less reliable service.

Van Schijndel and Dinwoodie (2000) have investigated the impact of congestion in the Netherlands through a questionnaire survey sent to 91 transport companies. The delays associated with congestion resulted in a less reliable service and higher costs. Trucks spent on average between 7.5% and 14.5% of their working time in congested conditions. Larger companies were found to be less affected as they used better planning, more night driving and IT to plan and communicate with drivers. This study also found that the greatest impact of congestion on vehicle operating costs resulted from a decrease in the annual kilometres travelled and an increase in drivers' wages. Overall, congestion reduced the annual distance travelled per vehicle resulting in higher costs per km.

The paper did not provide a definitive answer as to the point at which companies will start to switch from road to multimodal transport, but it suggested that although congestion had become serious, the problem was not yet so severe as to have reduced the break-even distance for rail sufficiently so far. Another reason for the lack of modal switching was the lack of sufficient economies of scale to justify companies' capital costs in rail equipment.

Congestion uncertainties were also identified in a study by Golob and Regan (2001) who conducted a survey of 1200 managers of all types of trucking companies operating in California. In this study, a structural equations model (SEM) was used to estimate how five aspects of congestion (slow average speeds; unreliable travel times; driver frustration and morale; higher fuel and maintenance costs; higher costs of accidents and insurance) differ across sectors of the trucking industry (e.g. intermodal operations, refrigerated transport).This paper also identified how these five aspects combine to predict the perceived overall magnitude of the congestion problem. The following three aspects of congestion (1) unreliable travel times (2) driver frustration and morale and (3) slow average speeds were identified as most problematic.

A UK study by Fowkes et al (2004) identified various sources of delays to freight transport, other than congestion, which cause variability in journey times. Forty interviewees (either shippers, hauliers or third party logistics operators) were questioned. Three kinds of delay to freight transport (causing variability in journey times) were identified: (1) Delay resulting from an increased journey time, with fixed departure time; (2) An increase in the spread (or range) of arrival times for a fixed departure time; (3) Schedule delay, where the departure time is effectively put back.

Adaptive stated preference methodology was employed to provide valuations of each kind of delay.

The authors argued that a high level of certainty and reliability of journey times is an essential requirement for an effective operation. Reasons for such a requirement are: (1) demand considerations (just-in-time and Quick Response strategies; port deadlines; 'hub and spoke' operations) and (2) supply-side issues (two-way loading; consolidation of deliveries; driving hours implications; scope for round-the-clock operation; order management and warehousing regimes).

Journey time reliability was also deemed important in the context of rising operating costs, narrow profit margins and attempts to improve the efficiency of transport operations.

This survey, however, was not able to provide robust estimates of values of travel time delays or to compare the valuations of the three different types of delay under consideration. Hence, this leaves scope for future research.

2.4 Uncertainties in measuring and evaluating supply chain performance

Lai et al (2004) and Danielis et al (2005) point out the need to integrate quality and cost-related performance criteria for evaluating supply chain performance.

Lai et al (2004) conducted a cross-sectional survey of firms in three sectors (air and sea transport, freight forwarding and third-party logistics service providers) to measure supply chain performance. A general conclusion of their paper was that "…cost-related performance criteria are "non-integrated" and fail to consider chain-wide opportunities to improve performance". Adopting criteria for evaluating supply chain performance should be considered from a systems perspective (Holmberg, 2000 quoted in Lai et al, 2004) and supply chain performance should rather be composed of multiple dimensions such as time, speed, agility, flexibility, quality and productivity.

Danielis et al (2005) in a study in an Italian context, employing Stated Preference and adaptive conjoint analysis methodology, attempted to estimate logistics managers' preference for freight transport service attributes such as freight cost, travel time, risk of delay, risk of loss and damage. A strong preference for quality attributes over cost was reported, especially for reliability and safety. These preferences, however, will not be easily met due to increasing congestion on the roads and the inefficient intermodal transport system in Italy. Therefore, the paper concluded that "…successful modal shift policies should focus mainly on the quality aspects of the mode to be promoted" (Danielis et al, 2005, p. 214). Hence, there is a pressing need to improve the quality of freight and intermodal transport.

3. Cost impacts of uncertainties at a policy level

3.1 Uncertainties related to the regulation of freight transport and redistribution of freight transport demand

Responses of policy makers to the problems caused by road transport may include manipulation of transport costs (through taxation) to influence freight transport demand (Runhaar and van der Heijden, 2005).

European policy has shifted from expanding infrastructure in response to increasing traffic volumes to an approach based on a mix of traffic and demand management measures. Influencing the use of freight transport through taxation employs new taxes on road freight transport and offers the possibility of full internalisation of all external costs produced by transport.

Runhaar and van der Heijden (2005) reported a move in the Netherlands to restructure general tax regimes by replacing fixed annual taxes by taxes more directly related to the actual transport volume (fuel duties and per-kilometre taxes). Amongst their findings, conclusions and recommendations they included:

- manipulation of transport costs does not seem to be a very effective instrument in reducing the negative effects of freight transport;
- expansion of infrastructure should be combined with pricing strategies, in order to provide sufficient incentives for raising transport efficiency;
- suggested measures to reduce the transport-intensity of production and distribution, possibly involving the clustering of companies in order to reduce transport distances and increase goods flows (this would favour multimodal transport) and raising awareness in consumers of the environmental impact of the products they purchase.

A study conducted in an Italian context about the redistribution of freight transport demand calls for a more effective redistribution of trade flows among existing links on the freight network as an important scenario to protect the environment (Campisi and Gastaldi, 1996). This research, based on evaluating substitution elasticities before and after the introduction of a pollution tax and numerical simulations regarding the reduction of pollution emissions and transportation costs, argued in favour of pollution tax as a less bureaucratic and punitive policy measure for reducing the environmental impact of economic activities.

3.2 Uncertainties related to the external costs of transport, their valuation and internalisation

3.2.1 The social costs of intermodal freight transport

Ricci and Black (2005) provide an understanding of the damage cost approach (based on the Impact Pathway methodology) for estimating the environmental externalities of intermodal transport. This bottom-up approach, adopted by the RECORDIT and several other projects, involves the following steps:

- "Starts from the technical characteristics of the activity (technology and type of vehicle, load factor, corridor length)
- Then calculates the so-called "burdens" associated with the activity (i.e. emissions of pollutants, emissions of noise, frequency of accidents)
- Then models the physical impact of these burdens on human health, crops, materials, etc
- Finally estimates the monetary value of these damages (through market values when available, as with crops and materials, or through Willingness-to-Pay values otherwise)" (Ricci and Black, 2005, p.268).

A comparison between intermodal transport and an all-road option per load unit moved across three European corridors has shown that the external costs of intermodal transport are 50-70% lower than for all-road transport.

The approaches to internalising external costs, as suggested in this paper, should lead to "fair and efficient charges to reflect the application of the user pays principle through the internalisation of external costs" (Ricci and Black, 2005, p.279). These charges can be calculated in €/tonne km or in €/vehicle km. However, it was pointed out that it is difficult to establish a transparent and standardised system across the whole chain as intermodal movements involve a multitude of operators.

3.2.2 Internalising externalities

The expansion of road freight transport in Europe is a significant contributor to congestion, pollution and accidents. Beuthe et al (2002) present results from detailed GIS modelling of the Belgian multimodal freight transport network. The paper argues in favour of the promotion of transportation modes with less negative effects. This study, which employed the NODUS virtual network methodology, conducted simulation of the flows over the Belgian network in 1995 to estimate some of the external costs of freight transport such as the costs of pollution, congestion, accidents, noise and road damage. This paper also provides “the simulated impacts on modal choice of a marginal external cost internalisation and an estimation of the corresponding external cost savings.”

Nash et al (2001) claim that “…failing to take account of external costs, transport prices has led to excessive growth of the more polluting modes of transport, and constrained the growth of more environmentally friendly modes.” Results from 5 case studies were presented and methodologies for the valuation of externalities were applied to these examples to provide estimates of the marginal costs mainly of air pollution and global warming. Conclusions on transport pricing regarding inter-urban and urban car transport, road freight and inter-urban public transport were reported. The overall conclusion was that “…the impact of optimal pricing on transport volume and mode split appears likely to achieve a significant improvement in air quality in major congested urban areas, but to make little contribution to more general air pollution or greenhouse gas reduction” (Nash et al, 2001, p. 429).

3.2.3 Pricing and Regulatory instruments to internalise externalities

The European Commission's Green Paper entitled 'Towards Fair and Efficient Pricing in Transport: Policy Options for Internalising the External Costs of Transport in the European Union' discusses different policy options for internalising the external costs of transport in the European Union. Policy approaches to reduce the size of the externality include:

(1) the internalisation approach, which aims at ensuring that each transport user pays the full social costs associated to each individual trip and therefore this approach offers an incentive to reduce the underlying problem;

(2) the regulatory approach which tries to achieve a reduction in the externality without relying on the price mechanism for altering transport behaviour, e.g. by introducing rules for products which reduce the environmental consequences of transport (e.g. enforced use of cleaner engine technology).

The paper argues that policy in this area should aim for achieving an optimal level at which, in economic terms, the marginal costs equal the marginal benefits. It also suggests the following approaches to measuring externalities: "Externalities can be measured in monetary terms either by inferring their value from observed market transactions (e.g. expenditure on damage avoidance, health costs, property value loss, etc) or by asking people how much they would be willing to pay for the reduction of a specific negative transport externality by a certain amount" (CEC, 1995, p. 6). Existing estimates, however, measured as % of GDP, were found insufficient. CEC (1995) argued in favour of more detailed estimates of externalities, distinguishing between transport modes, times, location and types of externality.

The main transport externalities were identified and ranked in the following order: (1) external congestion costs; (2) accidents and (3) environmental problems (air pollution and noise).

Suggested policy instruments to curb externalities are presented in the table below.

Table 3.1: Possible policy instruments for efficient and equitable pricing

	Short/Medium Term		Long Term	
	Road	**Other Modes**	**Road**	**Other Modes**
Infrastructure Costs & Congestion	- more differentiation according to use and damage in existing charging systems - kilometre tax for HGV (axle based) - tolls	- infrastructure use related charges	- electronic road pricing for congestion and infrastructure costs	- track charges and other infrastructure-use related charges
Accidents	- progress in gearing assurance systems to the desired long term structure - labelling		- insurance systems covering full social costs and differentiating according to risk (e.g. bonus/malus)	
Air Pollution & Noise	- for cars: emission (and possibly mileage) dependent annual taxes - for HGVs: surcharges on kilometre tax - differentiated excises according to environmental characteristics of fuel - CO_2 tax for global warming – identical across modes	- introduction of emissions based charges e.g. landing charges in aviation based on noise emissions	- fees based on actual emissions/noise with differentiated costs according to geographical conditions (and, possibly, time of day)	

Source: CEC (1995), p. 45

3.2.4 Optimal pricing

Proost et al (2002) analyse the gap between present transport prices and efficient transport prices in Europe. Efficient transport prices are defined as "those prices that maximise economic welfare, including external costs (congestion, air pollution, accidents)" (Proost et al, 2002, p. 41). Six urban and interregional case studies covering both passenger and freight transport were covered in this study, which employed an enhanced version of the TRENEN model.

The general conclusion of this paper was that "…prices need to be raised most for peak urban passenger car transport and to a lesser extent for interregional road transport" (op. cit., 2002, p. 41). The paper also concluded that "…current external costs on congested roads are a bad guide for optimal taxes and tolls: the optimal toll that takes into account the reaction of demand is often less than one third of the present marginal external cost" (op. cit., 2002, p. 41).

3.2.5 Valuation of externalities: policy implications (Sansom et al, 2001) and sources of methodological uncertainty which affect the value of external cost estimates (Ricci, 2002)

Sansom et al (2001) provide estimates of the marginal external costs of congestion, accidents, air pollution, noise, climate change, etc. Some tables with more detailed results of the study are enclosed in Appendix A.

The policy implications of the estimate results were considered in turn for:

- ***Charging***

The paper provided an answer to the following questions:
(1) "What should the direction of change in prices be if existing charges are set to maximise economic welfare? Existing charges include fuel duties and vehicle excise duty for road and charges to rail passengers and freight customers."

For road transport, a major increase would be necessary in most cases in order to bring prices in line with marginal costs. In the case of rail transport, some reduction would be justified.

(2) “In broad terms, does there appear to be a need for the introduction of new pricing instruments in the road sector? These include urban and inter-urban pricing systems (both low technology and more sophisticated solutions) and electronic tachographs for HGVs.”

It was concluded that “…a clear case for the introduction of more differentiated charging mechanisms in the road sector. In addition to area, road and vehicle type, the underlying environmental analysis confirms the issue of reflecting strong differentials by fuel type (petrol/diesel) and Euro vehicle emissions standard.” (Sansom et al, 2001, p. 64).

(3) “How do weighted short run marginal costs compare to charges for the road and rail sectors at the national level? Weighting by overall vehicle or train kilometres yields an overall measure of the overall direction of change in charges.”

For road transport, the marginal costs substantially exceed revenues for the five vehicle classes analysed (car, light delivery, rigid lorries, articulated lorries and public service vehicles). In the case of rail transport, costs exceed revenues for the passenger sector but not in the freight sector.

(4) “How do total costs on the fully allocated cost basis compare to overall charges for the road and rail sectors at the national level?”

For the road sector it was suggested that “…revenues are in excess of fully allocated costs by a fairly substantial margin when low estimates are used…a more ambiguous picture emerges with high cost estimates” (op. cit., 2001, p. 65). In case of rail freight, “…overall costs on the fully allocated cost basis are in balance with average revenues” (op. cit., 2001, p. 65).

- ***Taxation***

It was concluded that “…the implication from an efficiency perspective would be that fuel duty should be increased in order to reduce the gap between marginal costs and revenues. Price increases would result in demand reductions that would lower the marginal cost of congestion.” (op. cit., 2001, p.65). Furthermore, a more highly differentiated system of vehicle excise

duties “could reward cleaner vehicles and potentially encourage a more rapid turnover of older, more polluting vehicles”.
The introduction of differentiated road charging mechanisms was considered as a long-term prospect. In the medium term the role of fuel duty as an important contributor to efficiency was acknowledged.

- ***Subsidy***

“Are current levels of subsidy justified on economic efficiency grounds? If marginal costs are lower than (or equal to) existing charges this implies that to maximise economic welfare the current level of subsidy is insufficiently high (or is appropriate)”
For rail freight a greater degree of subsidy than at present was suggested.

Ricci (2002), amongst other things, claims to have contributed to the enhancement of the credibility of valuation methodologies for estimating external costs. Three sources of methodological uncertainty which affect the value of the external costs estimates were identified:
(1) the scale of the production unit (emissions from vehicles, accident rates)
(2) the model of the physical impact (on a population’s health and damage to crops for instance)
(3) the final translation into monetary terms (the value attached to better health for instance)

The RECORDIT project quoted in Ricci (2002) has developed a dedicated tool (the RECORDIT DSS), which allows simulation of the impacts on policy packages on costs and price formation.

3.3 Uncertainties related to future scenarios and their implications for travel demand and transport provision

At the top level, there are inherent uncertainties relating to the long-term direction of world economic philosophy. Will the current trend towards global capitalism and market forces continue unabated, leading to global logistics and its inherent problems, or will there be a trend towards localisation, greater co-operation and self-sufficiency, putting recent trends into reverse?

Beecroft and Chatterjee (2003) contribute to the existing debate about whether the production and consumption of goods should be on a global basis or whether these activities should be limited within the boundaries of the nation or even the local community. The report outlines three possible scenarios:

- **Going Global**

“Society will function on a global level with national and regional boundaries becoming increasingly insignificant. People will consider that spatial range should not act as a barrier to the production and consumption of goods with a resultant stimulation of existing and new international markets.”

- **Nation State**

“The nation state will constitute the most important context for economic, political and social development. Society will decide that the best way to provide for the production and consumption of goods will be from within its national boundaries with regional development and specialisation replacing international markets wherever possible.”

- **Local Living**

“Society will operate primarily on a local level. Society’s production and consumption of goods will be provided, as far as is possible, from within the local community – be that a city, town or village – with local diversity rather than national and international markets being the means of satisfying the demands of consumer choice.”

A range of objectives to improve the efficiency and sustainability of the movement of goods under each of the scenarios is suggested (see the table below).

Table 3.2: Approaches to Achieving Efficiency and Sustainability under Each Scenario

Objective	Vision Ideas to Meet Objectives		
	Going Global	**Nation State**	**Local Living**
To reduce freight tonne-kilometres travelled	Virtual Globalisation	Regional Specialisation	Retailer Consolidation
To promote use of more sustainable modes	Product Preservation and Modification	Freight Villages	Bus-Trucks
To make better use of transport infrastructure and services	Trans-European Rail Freight Network	Freight Lanes	Local Authority Freight Transport Fleet
To reduce development pressures on the environment	Trans-Shipment Hubs	Conveyor Distribution Systems	Recycle and Exchange Culture

Source: Beecroft et al (2003)

Although these ideas are rather 'futuristic', non-conventional and a demonstration of good will and positive thinking, they also provide an important and innovative framework for the businesses and policy-makers of the future. The ideas themselves have been generated by young professionals under 35 years of age and reflect the views of the future decision-makers about the role of the logistics and transportation sector in society.

Chatterjee and Gordon (2005) also contribute to the existing debate about the long-term direction of society by considering the implications of four future scenarios for Great Britain and a ‘business-as-usual’ scenario for travel demand and transport provision by 2030.

Methodological approaches for dealing with uncertainty in long-term planning (such as ‘scenario planning’ and ‘system dynamics modelling’) have also been discussed. The SCENES project is quoted for having adopted an alternative approach to modelling long-term scenarios. This project has employed a system dynamics model, ASTRA, “to generate transport forecasts for the European Union in 2026 for a business-as-usual scenario and for an increased road investment scenario and higher car costs scenario” (Chatterjee and Gordon, 2005, p.261). Comparing the two methodological approaches, ‘scenario planning’ was regarded as a “more appropriate approach for taking account of uncertainty in long term planning” as the ‘system dynamics modelling’ approach will fail to represent reliably the complexity of our social and economic systems and their evolution.

4. Uncertainties associated with freight modelling

4.1 Uncertainty related to the accuracy and availability of data for freight modelling

In order to be meaningful, freight modelling must be undertaken at the appropriate level of detail and data disaggregation. Accuracy and availability of data for freight modelling are equally important (Whiteing et al, 2004; Fowkes et al, 2006; ME&P, 2002; Chatterjee and Gordon, 2005). There are some aspects for which some disaggregation will generally be needed. *Commodity type* is one such dimension, though very fine disaggregation is rarely possible here. Other potential disaggregations might include the *method of rail freight operation* (i.e. trainload, wagonload, intermodal) and *length of haul*.

The requirement for further disaggregation and detail depends very much on the purpose of the modelling exercise. One such case in point is the need for spatial detail, relating both to the *zonal* detail for freight generation and attraction and to the *network* detail. Such detail will be required, for example, if the aim of modelling is to identify particular bottlenecks on networks most in need of capacity enhancement for any given scenario. For a purely strategic appraisal of broad policy options, such network detail is not likely to be required.

Another relevant issue relates to the range of transport modes incorporated into the model. In most cases the emphasis is likely to be on road and rail. If international movements are being considered (which is quite likely) then air and sea transport may also need to be modelled, or at least airports, seaports and the Channel Tunnel may need to be incorporated as places of entry/exit to and from the UK. The increased interest in coastal shipping may call for improved capability to model maritime flows between UK ports.

4.2 Uncertainty related to policy objectives of government or industry

Uncertainty related to policy objectives of government or industry influence model outputs. The outputs required from any modelling exercise will depend largely on the reasons for undertaking that exercise. Given that recent stated objectives of government and the rail industry, as set out in the Ten Year Plan, have been to increase rail freight by 80% in terms of tonne-kilometres, then there is a clear need for models to produce outputs expressed in physical measures such as *tonnes* lifted and *tonne-kilometres* moved.

Other output measures may however also be important. Tonnage-based measures may need to be converted into levels of traffic on the relevant networks. Hence we may need to estimate measures such as *gross freight-train kilometres operated* or changes in *road vehicle kilometres operated*, Emphasis might also be placed on implications for externalities, in which case it will be important to estimate accident impacts or emissions levels, for example, or to estimate the impact of changes in the various categories of ‘*sensitive lorry miles*’. Measures of vehicle-kilometres rather than tonne-kilometres are particularly relevant if we wish to capture the full use of freight vehicles and the resulting levels of pollution – including that caused by empty running.

It is conceivable that the focus of policy might move away from physical growth in rail freight towards increasing rail’s market share. Hence it is important that freight models can produce forecasts of *modal shares* for the scenarios to which they might be applied.

Other studies will focus on *modal choice*, i.e. understanding and evaluating the factors that are considered to influence decision-makers with respect to their choice of freight transport mode. In such cases the required model outputs will be rather different, and will focus on the relative valuations placed on the range of factors deemed to be appropriate.

Tavasszy (2006) provides an overview of the key issues in freight policy and the associated modelling needs in a predominantly (though not entirely) European context (see table 4.1). Two major requirements of freight modelling in European context have been outlined: (1) the need for more detail (vehicle types, logistics and spatial detail); (2) the requirement to link transport and the economy, i.e. to extend the dimensions of freight modelling, both geographically and functionally, into the broader transport system.

The importance of technology, especially the use of cameras and radar technology as new methods for monitoring of freight flows, was acknowledged as a means of enhancing the ability to collect data for freight modelling.

Table 4.1: Key policy issues and associated modelling needs

Policy Issues	***Modelling needs***
Growth of freight: a doubling of freight flows by 2050, worldwide (WBCSD, 2004), is expected. Within Europe, international flows are growing at twice the rate of domestic flows.	Forecasting international freight growth. Decoupling freight/economy. Sensitivity to cost changes.
Growing freight shares on the roads: as passenger traffic growth is slowing down and freight is moved by more and smaller trucks, freight is becoming more dominant on the streets.	Truck traffic behaviour Influence on freight intensities on car drivers.
Creation of seamless multimodal networks, new focus on Motorways of the Sea and inland waterways	Linking sea- and land transport models, EU multimodal networks
Concerns about international competitiveness of the EU economy, two-way relation between worldwide networks and global trade. "Freight and the economy" discussion: what are the costs and (mainly indirect) benefits of freight investments?	Develop suitable worldwide models and continental models. Improve relation between SCGE and network models.
Pricing: Additional charging all modes of transport what they can bear (or, what is fair, given external costs unaccounted for) is becoming reality. EU and member states have different attitudes and strategies towards pricing.	Situational response to cost changes (truck type, road type, time of day)
Logistic performance: the freight logistics sector is customizing its products and is creating complex, flexible networks using advanced logistics concepts such as hybrid supply chains, collaborative networks, e-logistics (both business-to-consumers and business-to-business) and return logistics.	Differentiating between goods with different logistic backgrounds; making detailed statistics available.
Changes in vehicle types HGV/LGV: light vehicle growth figures surpass other categories and appear to be more difficult to capture (both in terms of measurement and public policy).	Forecasting (causes and impacts of) choice of vehicle type
Local environmental damage: new regulations of noise and emissions require more accurate prediction of freight impacts. New technology requires investments. Citizen involvement in freight planning.	Accuracy of forecasts and level of detail (type of traffic, spatial, temporal)
24-hrs economy: to deal with congestion, firms are spreading production and logistics over day and night.	Explaining sprawl of flows to different periods of the day.
Security and safety: traffic needs to be monitored for degree of risk depending on contents or origin of freight.	Modelling critical global movements: containers, oil, dangerous goods, food
City distribution: as more stern policies are developed for city access and activities, freight requires new delivery concepts	Forecasting of tours at urban level, time of day dependent

Source: Tavasszy (2006), p. 2

4.3 Uncertainty related to strategic information flows

In a dynamic business environment characterised by globalisation of economic activities and supply chains, the availability of information at the strategic level is crucial for decision-making and yet increasingly uncertain. A model called SMILE (Strategic Model for Integrated Logistic Evaluations), quoted in Tavasszy et al (1998), is a Decision Support System (DSS) constructed to provide strategic information on expected future developments of freight flows to public and private decision makers in the transport and logistics sector. The system is designed in a way to generate "forecasts of freight flows related to the Netherlands for a large number of products and modes of transport" and "by means of a graphical user interface, the DSS assists the user with designing scenarios for simulations up to 25 years ahead and visualises the impacts of policy measures on freight flows and the environment" (Tavasszy et al, 1998, p. 447).

Following a review of the model and explaining the theory behind DSS, Tavasszy et al (1998, p.458) made the following recommendations for further research into:

- The information needs of policy makers, focusing also on conceptual information by means of reasoning models;
- Different ways to improve the modelling of logistics processes in freight transport system models.

5. Summary

This paper has reviewed various literature sources in the area of freight transport costs, demand and modelling. The following categories of uncertainty which have (either direct or indirect) impact on vehicle operating costs have been identified:

1. Uncertainties related to the level of vehicle operating costs, including:

- Fuel uncertainties: (price and availability) of conventional and alternative fuels and the cost of technologies to produce them;
- Labour uncertainties: labour shortages and the cost of provision of training and skills development in the logistics sector;
- Impact of congestion and variability in journey times on vehicle operating costs.

2. Cost impacts of uncertainties at the policy level, including:
   - Regulation of freight transport (e.g. through taxation);
   - Measuring and evaluating supply chain performance;
   - Valuation of external costs and policy measures to internalise them;
   - Uncertainties related to future scenarios for the long-term direction of society and their implications for travel demand and transport provision.

3. Uncertainties associated with freight modelling, including:
   - Uncertainty related to the accuracy and availability of data for freight modelling;
   - Uncertainty linked to policy objectives of government or industry, which influence model outputs and modelling needs.

Overall, it can be concluded that there are many uncertainties relating to the future direction of transport costs and to the future direction of transport policy (which will influence freight users' strategic decision-making and hence the longer term costs of their logistics operations). Whilst there is much agreement about the nature of the external effects emanating from the use of freight transport, there is much less clarity about how future transport policy should attempt to ameliorate these effects. The various papers discussed in this review do not, for example, paint a clear picture of the efficacy of road pricing as a means of reducing congestion and/or pollution. The lack of clarity in policy direction is caused, at least in part, by shortcomings in the current state of freight demand modelling and freight forecasting. Existing models do not provide policymakers with a robust forecasting base on which to develop (and perhaps more importantly to justify) their policy decisions, partly because weaknesses in the models themselves and partly by shortcomings in the data that underlies them. The result is a lack of clear direction of future policy, leading to inability on the part of industry to make decisions which would improve the environmental performance of freight transport. Operators and shippers are not in a position, for example, to make informed decisions on which modes of transport to use in future, or on which of the various alternative fuels to invest in, because they are uncertain as to whether government policies in the future will support the decisions they have made.

A much better understanding of the use of freight transport in supply chains, better freight data and improved modelling and forecasting methods are therefore key to informing the policy debate, leading to much greater certainty as to route towards the more sustainable use of freight transport in the future.

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Appendix A

Table A.1: Fully Allocated Cost and Revenue Analysis – by Vehicle Class (pence/vkm, low cost estimates)

Categories	Costs									Revenues					Difference
	Cost of capital	Infrastructure operating cost & depreciation	Vehicle operating cost (PSV)	External accident costs	Air pollution	Noise	Climate change	VAT not paid (PSV)	Total	Fares (PSV)	Vehicle excise duty (part)	Fuel duty	VAT on fuel duty	Total	Costs – Revenues
Car	0.70	0.33	-	0.07	0.18	0.16	0.12	-	1.6	-	1.03	3.86	0.68	5.6	-4.0
LDV	0.83	0.38	-	0.04	0.71	0.30	0.18	-	2.4	-	1.03	3.86	0.68	5.6	-3.1
HGV-rigid	1.45	4.61	-	0.04	1.65	0.87	0.44	-	9.1	-	2.25	13.11	2.29	17.6	-8.6
HGV-artic	1.88	8.74	-	0.03	1.41	1.31	0.71	-	14.1	-	2.50	14.47	2.53	19.5	-5.4
PSV	1.67	6.29	79.61	0.18	3.16	1.24	0.56	13.44	106.1	76.77	0.61	5.26	0.92	83.6	22.6

Source: Sansom et al (2001), p. 48

Table A.2: Fully Allocated Cost and Revenue Analysis – by Vehicle Class (pence/vkm, high cost estimates)

Categories	Costs									Revenues					Difference
	Cost of capital	Infrastructure operating cost & depreciation	Vehicle operating cost (PSV)	External accident costs	Air pollution	Noise	Climate change	VAT not paid (PSV)	Total	Fares (PSV)	Vehicle excise duty (part)	Fuel duty	VAT on fuel duty	Total	Costs – Revenues
Car	1.21	0.43	-	0.82	0.88	0.52	0.47	-	4.3	-	1.03	3.86	0.68	5.6	-1.2
LDV	1.43	0.49	-	0.46	3.35	1.00	0.72	-	7.5	-	1.03	3.86	0.68	5.6	1.9
HGV-rigid	2.49	6.00	-	0.61	8.26	2.89	1.74	-	22.0	-	2.25	13.11	2.29	17.6	4.3
HGV-artic	3.22	11.36	-	0.50	7.63	4.35	2.86	-	29.9	-	2.50	14.47	2.53	19.5	10.4
PSV	2.87	8.18	79.61	2.33	15.35	4.11	2.24	13.44	128.1	76.77	0.61	5.26	0.92	83.6	44.6

Source: Sansom et al (2001), p. 48

Table A.3: Marginal Cost and Revenue Analysis – by Vehicle Class (pence/vkm, low cost estimates)

Categories	Costs										Revenues					Difference
	Infrastructure operating cost & depreciation	Vehicle operating cost (PSV)	Congestion	Mohring effect (PSV)	External accident costs	Air pollution	Noise	Climate change	VAT not paid (PSV)	Total	Fares (PSV)	Vehicle excise duty (part)	Fuel duty	VAT on fuel duty	Total	Costs – Revenues
Car	0.05	-	8.98	-	0.79	0.18	0.01	0.12	-	10.1	-	-	3.86	0.68	4.5	5.6
LDV	0.06	-	9.26	-	0.53	0.71	0.02	0.18	-	10.8	-	-	3.86	0.68	4.5	6.2
HGV-rigid	3.79	-	16.78	-	1.39	1.65	0.06	0.44	-	24.1	-	2.25	13.11	2.29	17.6	6.5
HGV-artic	7.55	-	24.15	-	0.99	1.41	0.08	0.71	-	34.9	-	2.50	14.47	2.53	19.5	15.4
PSV	5.23	79.61	15.22	-14.70	3.74	3.16	0.09	0.56	13.44	106.3	76.77	0.61	5.26	0.92	83.6	22.8

Source: Sansom et al (2001), p. 49

Table A.4: Marginal Cost and Revenue Analysis – by Vehicle Class (pence/vkm, high cost estimates)

Categories	Costs										Revenues					Difference
	Infrastructure operating cost & depreciation	Vehicle operating cost (PSV)	Congestion	Mohring effect (PSV)	External accident costs	Air pollution	Noise	Climate change	VAT not paid (PSV)	Total	Fares (PSV)	Vehicle excise duty (part)	Fuel duty	VAT on fuel duty	Total	Costs – Revenues
Car	0.07	-	10.44	-	1.38	0.88	0.52	0.47	-	13.8	-	-	3.86	0.68	4.5	9.2
LDV	0.08	-	10.61	-	0.89	3.35	1.00	0.72	-	16.6	-	-	3.86	0.68	4.5	12.1
HGV-rigid	4.92	-	18.45	-	1.96	8.26	2.89	1.74	-	38.2	-	2.25	13.11	2.29	17.6	20.6
HGV-artic	9.82	-	24.89	-	1.40	7.63	4.35	2.86	-	51.0	-	2.50	14.47	2.53	19.5	31.5
PSV	6.80	79.61	18.19	-14.70	6.58	15.35	4.11	2.24	13.44	131.6	76.77	0.61	5.26	0.92	83.6	48.0

Source: Sansom et al (2001), p. 49

Table A.5: Marginal Cost and Revenue Analysis – by Vehicle Class and Time Period (pence/vkm, low cost estimates)

Categories	Costs										Revenues					Difference
	Infrastructure operating cost & depreciation	Vehicle operating cost (PSV)	Congestion	Mohring effect (PSV)	External accident costs	Air pollution	Noise	Climate change	VAT not paid (PSV)	Total	Fares (PSV)	Vehicle excise duty (part)	Fuel duty	VAT on fuel duty	Total	Costs – Revenues
Car, peak	0.05	-	13.22	-	0.78	0.18	0.01	0.12	-	14.4	-	-	3.86	0.68	4.5	9.8
Car, off-peak	0.05	-	7.01	-	0.80	0.18	0.01	0.12	-	8.2	-	-	3.86	0.68	4.5	3.6
LDV, peak	0.06	-	13.99	-	0.52	0.76	0.02	0.19	-	15.5	-	-	3.86	0.68	4.5	11.0
LDV, off-peak	0.06	-	7.07	-	0.53	0.68	0.02	0.18	-	8.5	-	-	3.86	0.68	4.5	4.0
HGV-rigid, peak	3.82	-	26.00	-	1.40	1.84	0.06	0.44	-	33.6	-	2.25	13.11	2.29	17.6	15.9
HGV-rigid, off-peak	3.77	-	12.75	-	1.39	1.57	0.06	0.43	-	20.0	-	2.25	13.11	2.29	17.6	2.3
HGV-artic, peak	7.57	-	33.45	-	0.99	1.42	0.07	0.72	-	44.2	-	2.50	14.47	2.53	19.5	24.7
HGV-artic, off-peak	7.55	-	19.81	-	0.99	1.41	0.08	0.71	-	30.5	-	2.50	14.47	2.53	19.5	11.0
PSV, peak	5.74	78.73	20.31	-14.43	3.82	3.17	0.09	0.58	13.33	111.3	76.19	0.61	5.26	0.92	83.0	28.4
PSV, off-peak	4.93	80.10	12.31	-14.86	3.69	3.15	0.09	0.55	13.49	103.5	77.10	0.61	5.26	0.92	83.9	19.6

Source: Sansom et al (2001), p. 56

Table A.6: Illustration of Disaggregate Output from the Road Analysis for the Outer Conurbation Area Type (pence/vkm, low cost estimates)

Categories	Costs										Revenues					Difference
	Infrastructure operating cost & depreciation	Vehicle operating cost (PSV)	Congestion	Mohring effect (PSV)	External accident costs	Air pollution	Noise	Climate change	VAT not paid (PSV)	Total	Fares (PSV)	Vehicle excise duty (part)	Fuel duty	VAT on fuel duty	Total	Costs – Revenues
Car, peak	0.04	-	23.01	-	1.68	0.32	0.02	0.13	-	25.2	-	-	3.86	0.68	4.5	20.7
Car, off-peak	0.04	-	7.73	-	1.68	0.29	0.02	0.12	-	9.9	-	-	3.86	0.68	4.5	5.3
LDV, peak	0.05	-	23.01	-	0.88	1.45	0.04	0.20	-	25.6	-	-	3.86	0.68	4.5	21.1
LDV, off-peak	0.05	-	7.73	-	0.88	1.30	0.04	0.18	-	10.2	-	-	3.86	0.68	4.5	5.6
HGV-rigid, peak	2.35	-	38.72	-	1.68	3.54	0.14	0.46	-	46.9	-	2.25	13.11	2.29	17.6	29.2
HGV-rigid, off-peak	2.35	-	13.01	-	1.68	3.11	0.14	0.42	-	20.7	-	2.25	13.11	2.29	17.6	3.1
HGV-artic, peak	7.84	-	56.59	-	1.68	4.36	0.27	0.87	-	71.7	-	2.50	14.47	2.53	19.5	52.2
HGV-artic, off-peak	7.84	-	19.05	-	1.68	3.84	0.27	0.78	-	33.5	-	2.50	14.47	2.53	19.5	14.0
PSV, peak	1.57	83.87	34.52	-14.00	4.20	4.98	0.14	0.65	13.48	129.4	77.04	0.61	5.26	0.92	83.8	45.6
PSV, off-peak	1.57	83.87	11.60	-14.00	4.20	4.45	0.14	0.59	13.48	105.9	77.04	0.61	5.26	0.92	83.8	22.1

Source: Sansom et al (2001), p. 58

Table A.7: Fully Allocated Cost and Revenue Analysis for Rail Freight (£/train km, low cost estimates)

Category	Costs						Revenue	Difference Costs - Revenue
	Infrastructure	Vehicle operating	Air pollution	Noise	Climate change	Total		
Bulk	3.53	8.60	0.166	0.170	0.131	12.60	13.01	-0.41
Other	3.33	9.70	0.166	0.170	0.131	13.50	13.61	-0.11
Freight Sector	3.41	9.28	0.166	0.170	0.131	13.16	13.41	-0.25

Note: low cost estimates apply to environmental categories only.
Source: Sansom et al (2001), p. 62

Table A.8: Fully Allocated Cost and Revenue Analysis for Rail Freight (£/train km, high cost estimates)

Category	Costs						Revenue	Difference Costs - Revenue
	Infrastructure	Vehicle operating	Air pollution	Noise	Climate change	Total		
Bulk	3.53	8.60	1.201	0.563	0.525	14.42	13.01	1.41
Other	3.33	9.70	1.201	0.563	0.525	15.32	13.61	1.71
Freight Sector	3.41	9.28	1.201	0.563	0.525	14.98	13.41	1.57

Note: high cost estimates apply to environmental categories only.
Source: Sansom et al (2001), p. 62

Table A.9: Marginal Cost and Revenue Analysis for Rail Freight (£/train km, low cost estimates)

Category	Costs						Revenue	Difference Costs - Revenue
	Marginal infrastructure usage	Vehicle operating cost	Air pollution	Noise	Climate change	Total		
Bulk	1.79	8.60	0.166	0.170	0.131	10.86	13.01	-2.15
Other	0.88	9.70	0.166	0.170	0.131	11.05	13.61	-2.56
Freight Sector	1.19	9.28	0.166	0.170	0.131	10.94	13.41	-2.47

Note: low cost estimates apply to environmental categories only.
Source: Sansom et al (2001), p. 62

Table A.10: Marginal Cost and Revenue Analysis for Rail Freight (£/train km, high cost estimates)

Category	Costs						Revenue	Difference Costs - Revenue
	Marginal infrastructure usage	Vehicle operating cost	Air pollution	Noise	Climate change	Total		
Bulk	1.79	8.60	1.201	0.563	0.525	12.68	13.01	-0.33
Other	0.88	9.70	1.201	0.563	0.525	12.87	13.61	-0.74
Freight Sector	1.19	9.28	1.201	0.563	0.525	12.76	13.41	-0.65

Note: high cost estimates apply to environmental categories only.
Source: Sansom et al (2001), p. 63

Table A.11: Average environmental costs of road vehicles (1998 fleet, central estimate), pence per vehicle km

	Air Pollution	Climate change	Noise
Cars	0.35	0.24	0.34
Lights	1.39	0.36	0.65
Rigids	3.40	0.87	1.88
Artic	3.08	1.43	2.84
PSVs	6.48	1.13	2.68

Source: Sansom et al (2001), p.98

Table A.12: Marginal Environmental Costs for the Average LDV (1998)

	Air Quality	Climate Change	Noise
M-way (1)	5.9	0.4	2.5
T&P (1)	8.5	0.5	1.6
Other (1)	9.6	0.5	2.4
M-way (2)	4.1	0.3	2.1
T&P (2)	6.6	0.5	2.4
Other (2)	6.6	0.5	2.1
M-way (3)	2.9	0.3	1.3
T&P (3)	4.1	0.4	1.3
Other (3)	4.6	0.5	1.3
M-way (4)	5.1	0.4	1.4
T&P (4)	5.8	0.4	1.4
Other (4)	6.6	0.5	1.4
M-way (5)	2.3	0.3	1.4
T&P (5)	2.8	0.4	1.3
Other (5)	2.8	0.4	1.3
T&P (6)	2.2	0.4	1.3
Other (6)	2.2	0.4	1.3
T&P (7)	2.2	0.4	1.3
Other (7)	2.0	0.4	1.3
T&P (8)	1.5	0.4	1.2
Other (8)	1.5	0.4	1.2
T&P (9)	1.2	0.4	1.0
Other (9)	1.2	0.4	1.0
T&P (10)	0.9	0.4	0.8
Other (10)	0.9	0.4	0.8
M-way (11)	0.8	0.4	0.3
T&P (11)	0.6	0.3	0.2
Other (11)	0.6	0.3	0.3

Key: 1=Central London; 2=Inner London; 3=Outer London; 4=Central Conurbations; 5=Outer Conurbations; 6=Area>25 sq kms; 7=Area 15-25 sq kms; 8=Area 10-15 sq kms; 9=Area 5-10 sq kms; 10=Area 0.01-5 sq kms; 11=Rural
Source: Sansom et al (2001), p.101

Table A.13: Marginal Environmental Costs for the Average Rigid Vehicle (1998)

	Air Quality	Climate Change	Noise
M-way (1)	14.4	0.8	7.7
T&P (1)	25.7	1.3	5.0
Other (1)	31.0	1.5	8.7
M-way (2)	9.8	0.8	10.6
T&P (2)	19.9	1.3	8.7
Other (2)	19.9	1.3	10.6
M-way (3)	7.0	0.8	4.0
T&P (3)	10.9	1.1	4.0
Other (3)	14.2	1.3	4.0
M-way (4)	12.7	0.9	4.2
T&P (4)	15.3	1.1	4.1
Other (4)	19.9	1.3	4.1
M-way (5)	5.5	0.8	4.2
T&P (5)	7.1	0.9	4.1
Other (5)	7.1	0.9	4.1
T&P (6)	5.6	0.9	4.0
Other (6)	5.6	0.9	4.1
T&P (7)	5.6	0.9	3.9
Other (7)	4.9	0.8	4.0
T&P (8)	3.7	0.8	3.5
Other (8)	3.7	0.8	3.5
T&P (9)	3.1	0.8	3.2
Other (9)	3.1	0.8	3.2
T&P (10)	2.5	0.8	2.5
Other (10)	2.5	0.8	2.6
M-way (11)	1.6	0.9	0.8
T&P (11)	1.6	0.9	0.7
Other (11)	1.6	0.8	0.9

Key: 1=Central London; 2=Inner London; 3=Outer London; 4=Central Conurbations; 5=Outer Conurbations; 6=Area>25 sq kms; 7=Area 15-25 sq kms; 8=Area 10-15 sq kms; 9=Area 5-10 sq kms; 10=Area 0.01-5 sq kms; 11=Rural
Source: Sansom et al (2001), p.101

Table A.14: Marginal Environmental Costs for the Average Artic Vehicle (1998)

	Air Quality	Climate Change	Noise
M-way (1)	17.9	1.6	15.4
T&P (1)	30.7	2.2	9.9
Other (1)	36.5	2.4	17.4
M-way (2)	12.1	1.4	21.3
T&P (2)	23.9	2.2	17.4
Other (2)	23.9	2.2	21.3
M-way (3)	8.7	1.4	8.0
T&P (3)	13.4	2.0	7.9
Other (3)	17.2	2.2	7.9
M-way (4)	15.8	1.8	8.4
T&P (4)	18.7	2.0	8.3
Other (4)	23.9	2.2	8.3
M-way (5)	6.9	1.4	8.3
T&P (5)	9.0	1.8	8.2
Other (5)	9.0	1.8	8.2
T&P (6)	7.2	1.8	8.0
Other (6)	7.2	1.8	8.1
T&P (7)	7.2	1.8	7.9
Other (7)	6.4	1.6	7.9
T&P (8)	4.9	1.6	7.1
Other (8)	4.9	1.6	7.1
T&P (9)	4.1	1.6	6.4
Other (9)	4.1	1.6	6.4
T&P (10)	3.3	1.6	5.1
Other (10)	3.3	1.6	5.2
M-way (11)	1.9	1.5	1.5
T&P (11)	2.0	1.4	1.5
Other (11)	2.3	1.4	1.9

Key: 1=Central London; 2=Inner London; 3=Outer London; 4=Central Conurbations; 5=Outer Conurbations; 6=Area>25 sq kms; 7=Area 15-25 sq kms; 8=Area 10-15 sq kms; 9=Area 5-10 sq kms; 10=Area 0.01-5 sq kms; 11=Rural
Source: Sansom et al (2001), p.102

Table A.15: Total Environmental Costs for the Road Sector (1998) by vehicle type, £Million

	Low	Central	High
Cars	1,714	3,499	7,045
Lights	584	1,180	2,492
Rigids	393	817	1,713
Artic	419	896	1,809
PSVs	253	525	1,107

Source: Sansom et al (2001), p.106