Structure of Costs and Charges Review – Environmental Costs of Rail Transport

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1 Executive Summary

The principal environmental impacts associate with rail operations are:

- Greenhouse Gas Emissions
- Air Pollutant Emissions
- Noise and Vibration
- Water and Land Pollution and Contamination
- Land-take
- Visual intrusion

The most significant of the environmental impacts listed above are greenhouse gas emissions, air pollutant emissions, and noise. For these three impact categories, detailed methodologies have been developed to measure, model, or calculate the impacts of railway operations, and work has also been carried out to estimate the costs to society associated with these impacts. Research into the other railway environmental impacts is much less well developed.

Greenhouse gas emissions are much lower for rail than for other modes. Within rail, there are significant differences in CO_2 emissions between train types, based on power requirements, a function of train weight and acceleration characteristics and the type and amount of equipment fitted. Many modern trains have high power requirements.

Air pollutants emissions from rail are, apart from SO_2, much lower than from road transport and account for less than 1% of total emissions for each of the six pollutants from all transport and industrial sectors. However, air pollutant emissions from road transport have decreased very significantly in the last fifteen years, despite a large increase in road traffic over that period, but the percentage reductions from the rail sector, over the same period, have not been as large. There are large variations in the level of air pollutant emissions between different classes of passenger trains and between different types of freight locomotives.

The total noise burden of the road network and the railways is not currently accurately known. Only airport noise is accurately mapped at present. However, the European Commission's Environmental Noise Directive (European Commission, 2002)[1] requires that noise maps must be prepared for all major agglomerations by the end of 2007, and hence all of these sources will be soon be characterised in detail.

For each of the environmental impacts described, it is possible to quantify these impacts in monetary, or cost terms. The major studies that have provided data on the environmental costs of rail transport are:

- Surface Transport Costs and Charges 1998 (ITS Leeds, 2001)[2]
- External Costs of Transport: Accident, Environmental and Congestion Costs of Transport in Western Europe (INFRAS 2000[3] and INFRAS, 2004)[4]
- Internalising the Social Costs of Transport (OECD, 1994)[5]

The current use of externality values can be split into two main categories:

- Those based on specific environmental externalities, such as greenhouse gas emissions (social cost of carbon), air quality or noise;
- Those that capture all environmental externalities related to transport (greenhouse gas emissions, air quality, and noise together).

There are also two main applications across UK government for the values:

- Appraisal – particularly in regulatory impact assessments;
- Design of taxes and charges.

Externality assessments have continued to change, as the scientific and economic information has improved. A number of major studies have taken place since the STCC study in the UK and Europe – particularly in relation to air quality externalities.

There are three EU examples where rail's external costs have been at least partially internalised through the use of taxes/charges. These are track access charges in Sweden and Finland that are differentiated according to marginal environmental (air pollution and CO_2 emissions) and accident costs, and additional track access charges in Germany to take into account energy use, and hence CO_2 emissions. Switzerland has also used access charges to incentivise railway noise reduction.

The role of government (EU and member state) in modifying rail environmental impacts comprises:

- Legislation to limit current impacts, and encourage focus on reducing impacts in future.
- Engagement with industry to encourage the development of technical and procedural initiatives to reduce environmental impacts and facilitate tighter legislation in future.
- Funding for research and pilot projects

Several EU directives have a bearing on this area, although only a few, such as 2001/14/EC on charging, and 2001/16/EC on interoperability, were developed specifically for rail. The UNITE and CAFÉ research programmes have helped further the understanding of environmental impacts.

There are serious implications associated with the translation of rail's environmental costs into access charges. These relate principally to the effect on rail's competitive position as a mode were such charges to be introduced unilaterally and to the effectiveness of using track access charges as the mechanism for levying environmental charges.

If rail access charges in Great Britain are to include an environmental charge, further research will be needed to update the figures for the total and average environmental costs of rail transport. The Department for Transport has indicated that whilst the environmental externality for road transport has been updated recently, no such work has been undertaken for rail transport. Further work may also be required to examine the options on how environmental externalities could be included within a charging regime.

2 Introduction

The Office of Rail Regulation (ORR), as part of its overall review of the structure of Network Rail's costs and charges, is seeking to understand better the current state of knowledge that exists about the environmental impact of rail transport. It has therefore commissioned this scoping study to examine and report on these impacts and the potential implications of introducing a charge to reflect environmental costs within the access charging regime.

The given objectives of the study are to:

- Identify the main environmental impacts of rail transport;
- Review current knowledge on the monetarisation of environmental costs and benefits of rail transport;
- Identify the main drivers of these environmental costs and benefits;
- Assess confidence in the monetarised values for environmental impacts;
- Describe the current use of monetarised environmental impacts in the appraisal of UK transport schemes;
- Identify ongoing work in the UK and Europe on the monetarisation of the environmental impacts of transport;
- Provide recommendations for further work to increase the understanding of the environmental costs of rail transport; and
- Identify, in a broad way, the possible implications if environmental costs were translated into rail access charges.

3 Main environmental impacts of rail transport

3.1 Literature review of studies examining the environmental impacts of rail operations

A literature search was carried out to identify relevant studies that have examined the environmental impacts of rail operations, as well as studies that have investigated the environmental costs associated with the railways. In many cases, such studies have been carried out as part of wider research into the environmental impacts and costs associated with transport more generally. The key publications identified during the literature review were as follows:

- "Surface Transport Costs and Charges Great Britain 1998", carried out by the University of Leeds and AEA Technology Environment for the Department of the Environment, Transport and the Regions (2001)
- "SRA's Environmental Agenda", carried out by AEA Technology Environment for the Strategic Rail Authority (2001)
- "Clearing the Air: Public Transport and Cleaner Vehicles – New Technologies and Public Transport", by OXERA (
- "Internalising the Social Costs of Transport", Organisation for Economic Co-operation and Development (1994)
- "External Costs of Transport; Accident, Environmental and Congestion Costs of Transport in Western Europe", by INFRAS Zurich (2000 and 2004)

3.2 Identification of the main environmental impacts associated with rail operations

In reviewing previous literature on the topic, a picture was built up of the main environmental impacts associated with railways. In particular, as part of the SRA's Environmental Agenda (SRA, 2001)[11], a comprehensive list of all the environmental impacts associated with UK rail operations was developed. These were as follows:

3.2.1 Greenhouse Gas Emissions

Emissions of greenhouse gases are the result of burning fossil fuels either to directly provide tractive power (diesel traction), or to provide electricity for electric traction.

3.2.2 Air Pollutant Emissions

A wide range of air pollutant emissions is produced from burning fossil fuel to provide either diesel or electric traction.

3.2.3 Noise and Vibration

Powertrains, wheel-rail interactions, braking systems, and aerodynamic effects all produce unwanted noise.

3.2.4 Water and Land Pollution and Contamination

Fuel spills, de-icing chemicals, chemical releases from operations such as cleaning/maintenance, and waste generation/disposal are all sources of water and land pollution/contamination associated with rail operations.

3.2.5 Land-take
There are some issues for the railways in terms of its land use, and in particular the impacts that railway land-take can have on natural habitats and bio-diversity. The main points of concern are the total land-take of the railways (and how this compares with other modes), and the type of land affected. Most previous studies have shown that railway land take is less than for roads.

3.2.6 Visual intrusion
Railway lines, and in particular, overhead power lines for electrified track can be a source of visual disamenity.

The most significant of the environmental impacts listed above are greenhouse gas emissions, air pollutant emissions, and noise. For these three impact categories, detailed methodologies have been developed to measure, model, or calculate the impacts of railway operations, and work has also been carried out to estimate the costs to society associated with these impacts. Research into the other railway environmental impacts is much less well developed, and in some cases it is not straightforward to quantify the impacts of railway operations. For these reasons, the remainder of this study will concentrate on discussing the environmental impacts and environmental costs associated with railway greenhouse gas emissions, air pollutant emissions, and noise. However, a much less detailed discussion of the railways' impacts on water and land pollution, land-take, and visual intrusion has also been provided.

3.3 Greenhouse gas emissions and climate change

3.3.1 Climate change impacts
It is now almost universally accepted that emissions of manmade greenhouse gases are having a significant effect on the world's climate patterns. Climate models have been used to predict that over the next 100 years, average global temperatures could rise by between 1.4˚C and 5.8˚C due to the effects of greenhouse gases. The most important global impacts of climate change have been published on the Defra website[a], and are as follows:

- Sea levels are expected to rise by more than 40 centimetres by the 2080s due to melting of land ice and thermal expansion of the oceans. The existence of some small island states is threatened.

- Many countries in southern Asia will be at increased risk of flooding due to climate change impacts.

- Africa, the Middle East and India are expected to experience a significant reduction in cereal yields.

- An additional 290 million could be exposed to malaria by the 2080s.

- Reduced rainfall and/or salination of ground water in coastal areas due to rising sea levels may lead to significant reductions in water resources available for drinking and irrigation. People's lives may be put at risk from an increased risk of flooding or drought. Northern Africa, the Middle East and the Indian subcontinent are expected to be the worst affected areas.

- Reduced rainfall could lead to the depletion of tropical rainforests in large parts of northern Brazil and central southern Africa.

[a] Climate change: what is climate change? Department for the Environment, Food, and Rural Affairs, www.defra.gov.uk/environment/climatechange/01.htm

Details of the expected climate change impacts in the UK have also been published by Defra. These are as follows:

- Average annual temperature may rise by between 2˚C and 3.5˚C by the 2080s. Higher average temperatures may exacerbate poor air quality during the summer months.
- Winters are expected to become wetter, and summers are expected to become drier across all of the UK. An increased risk of extreme weather events such as floods and storms is also expected. As summers become drier, water resources may be stretched.
- Sea levels are expected to continue to rise, and could be between 26 and 86 centimetres higher than they currently are in the south east of England, contributing to the increased risk of flooding.

3.3.2 Greenhouse gas emissions from rail transport

The most important greenhouse gases are carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride (SF_6). With respect to transport, emissions of CO_2 are the most important contributor to total greenhouse gas emissions; in 2002, the transport sector as a whole produced 127,200 kilotonnes of CO_2 emissions (24% of total UK CO_2 emissions). However, CO_2 emissions from rail transport are a very small proportion of the total. CO_2 emissions are produced from both diesel traction and electric traction; combustion of gas oil/diesel in the internal combustion engines of diesel trains produces direct emissions of CO_2 (CO_2 emissions are directly proportional to train fuel consumption) whilst the fuels burnt at power stations to provide the electricity for electric trains also lead to CO_2 emissions. A summary of total CO_2 emissions from the road and rail sectors for 2002, taken from the National Atmospheric Emissions Inventory (NAEI, 2003)[12] is provided below in Table 3.1.

Table 3.1: UK emissions carbon dioxide (CO_2) in 2002

	Emissions source	**Mass of emissions in 2002 (kiloTonnes)**	**Emissions as a % of total UK emissions of CO_2**
All sectors	All sectors (transport, industry, domestic, etc)	**536279**	**100%**
Road Transport			
	Cars	68974	
	Light vans	14245	
	Heavy duty trucks and buses	33290	
	Motorcycles	517	
	All road transport	**117025**	**21.82%**
Rail			
	All diesel traction	1049	
	which consists of:		
	Diesel freight	*277*	
	Diesel intercity	*679*	
	Diesel regional	*94*	
	All electric traction	1167	
	All rail traction	**2215**	**0.41%**

Source: NAEI, AEA Technology Environmment

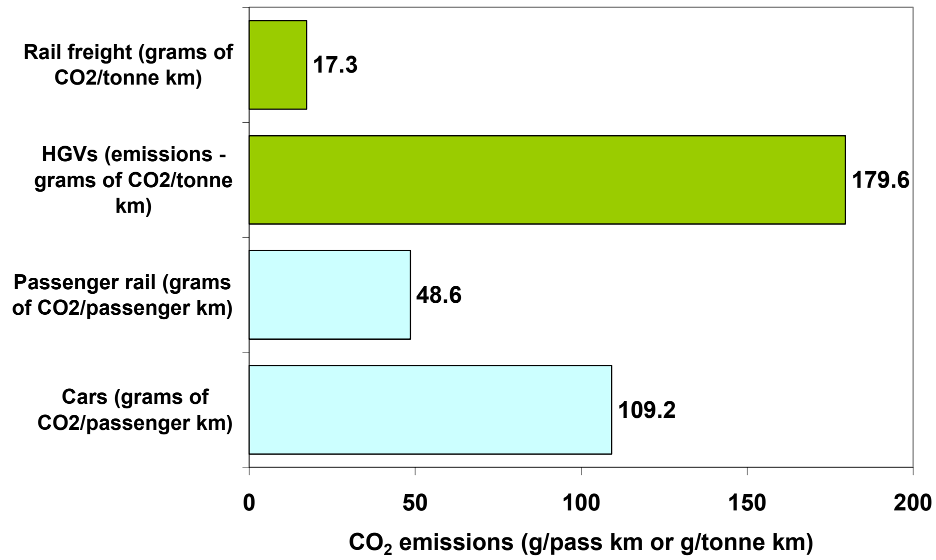
As can be seen from the table, road transport is a very significant contributor to total UK emissions of CO_2, accounting for almost 22% of total emissions. By contrast, the contribution from rail is very small, making up less than 0.5% of total UK CO_2 emissions. It is worth noting that the Department for Transport[b] anticipates that total CO_2 emissions from the rail sector will

[b] "The National Transport Model: Overview", Department for Transport, http://www.dft.gov.uk/stellent/groups/dft_econappr/documents/pdf/dft_econappr_pdf_024013.pdf

increase by 50% between 2000 and 2010, due to actions taken in the 10 year Plan for Transport. In 2010, CO_2 emissions from the rail sector are forecast to be approximately 4,400 kiloTonnes. The reason for this increase is that the medium and long-term strategy is to encourage a significant shift from road to rail transport, with a consequent increase in rail journeys. This increase in rail CO_2 emissions is expected to be outweighed by a significant reduction in road transport CO_2 emissions, due to the shift from road to rail.

Previous work carried out by AEA Technology Environment for the Strategic Rail Authority has estimated the CO_2 impacts of rail transport on the basis of emissions per passenger kilometre (or per tonne kilometre for rail freight). A summary of the findings of this work is presented below in Figure 3.1 and Table 3.2 with comparative data for various other modes of transport.

Figure 3.1: Comparison of emissions per passenger kilometre/per tonne kilometre for rail and road transport



Source: AEA Technology Environment, as part of work carried out for the SRA

As can be seen in Figure 3.1 above, both passenger rail and rail freight have significantly lower CO_2 impacts than road transport. In particular, the CO_2 impacts of rail freight are more than ten times lower per tonne kilometre than for road freight. For passenger transport, Table 3.2 below provides a more detailed breakdown of CO_2 impacts by specific types of road and rail transport.

Table 3.2: Comparison of CO_2 emissions from different modes of passenger transport and for different classes of trains

Transport mode	CO_2 emissions per passenger kilometre (grams of CO_2 per passenger km) based on AVERAGE passenger loads	CO_2 emissions per passenger kilometre (grams of CO_2 per passenger km) based on MAXIMUM passenger loads
Petrol cars (fleet weighted average)	110	43
Diesel cars (fleet weighted average)	106	41
All Cars (fleet weighted average)	109	43
Modern petrol cars	104	41
Modern diesel cars	100	39
Bus	76	-
Mopeds	75	-
Motorcycles	94	-
Passenger rail (fleet average - diesel)	**41**	**-**
Passenger rail (fleet average - electric)	**56**	**-**
Passenger rail (average UK - electric and diesel combined)	**49**	**-**
Older diesel passenger locomotive (Class 43 HST train set - London-Bristol route - Year in service: 1976)	**71**	**31**
Modern passenger DMU (Class 180 Adelante DMU 5-car trainset - London-Bristol route - Year in service: 2002)	**55**	**26**
Older electric passenger locomotive (Class 91 locomotive set - London-Edinburgh route - Year in Service: 1988)	**19**	**13**
Older electric passenger EMU (Class 318 EMU 3-car trainset - Glasgow-Ayr route - Year in service: 1985)	**Not available**	**21**
Modern electric passenger EMU (Class 373 - Eurostar-type - 16-car trainset - Year in service: 1993/1995)	**22**	**15**
Air - long haul	110	-
Air - short haul	180	-

Source: AEA Technology Environment, as part of work carried out for the SRA and DfT

The table above presents emissions data using both average passenger load factors for each mode of transport, and theoretical maximum load factors based on every seat being occupied by a passenger. Average load factors for cars were obtained from the DfT's Transport Statistics publication (1.56 occupants per vehicle), whilst average load factors for the different classes of trains were obtained from the relevant train operating companies. As can be seen from the above table, average CO_2 emissions per passenger kilometre are lower from trains than from any of the other modes of transport. It should also be noted that whilst fleet average CO_2 emissions from electric trains have been estimated to be higher than from diesel trains, individual classes of both modern and older electric trains have significantly lower CO_2 emissions than equivalent diesel trains. The reason for this apparent discrepancy is due to the different methodologies used to calculate fleet-averaged emissions and emissions from individual classes of trains. The emission factors for individual classes of trains are more robust than the fleet-averaged emission factors.

In future years, average CO_2 emissions from electric trains are likely to decrease (without the need for any actions from the rail industry), as a greater proportion of UK electricity will be obtained from renewable energy sources. The fleet average emission factors (grams of CO_2 per passenger kilometre) have been calculated using a different methodology to the emission factors for individual classes of train, and this is one of the main reasons that fleet-averaged CO_2 emissions from electric trains appear to be higher than from diesel trains.

CO_2 emissions from trains will vary depending on the power requirements of the train. For example, high-speed diesel trains tend to use more fuel than regional trains, and hence CO_2 emissions tend to be greater. Some examples of variations between different classes of trains are given in Table 3.3 below.

Table 3.3: CO_2 emissions per seat kilometre travelled for different classes of diesel trains

Train class	Type	Configuration	Power output	Seating capacity	CO_2 emissions per seat km
Class 43 HST	Diesel intercity	2 locomotive power cars + 8 carriages	3360 kW (2 x 1680 kW)	477	31
Class 180 Adelante	Diesel intercity	5 car DMU trainset	2800 kW (5 x 560 kW)	265	26
Class 150 Sprinter	Diesel regional	3 car DMU trainset	639 kW (3 x 213 kW)	222	15.3
Class 168 Turbostar	Diesel regional	4 car DMU trainset	1260 kW (4 x 315 kW)	278	24.8

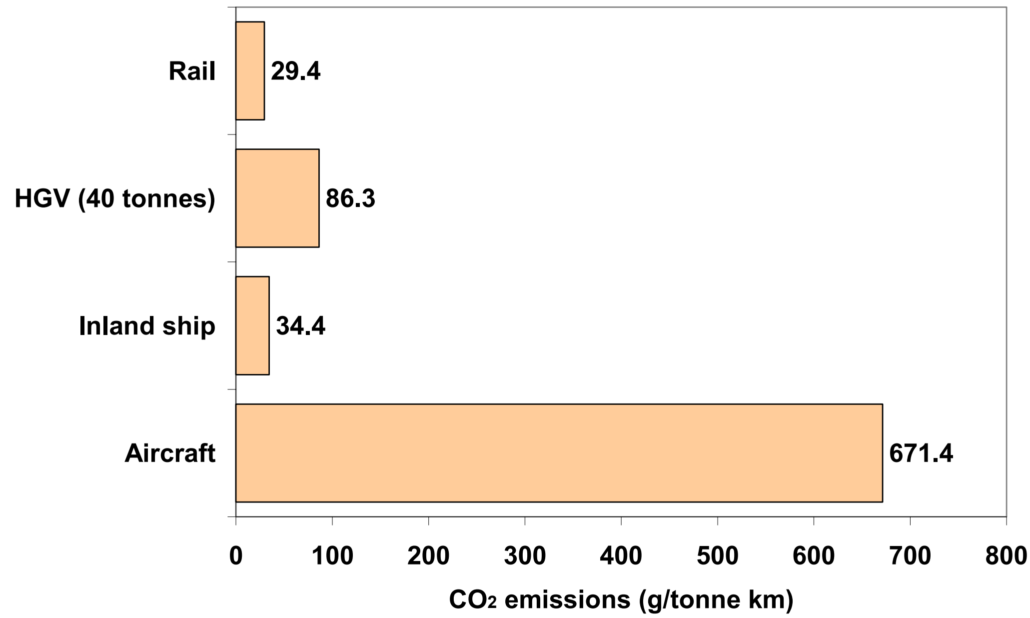
Source: AEA Technology Environment (as part of work carried out for the SRA)

As can be seen from Table 3.3 above, CO_2 emissions per seat kilometre travelled are significantly less for an older train servicing regional routes such as the Class 150 Sprinter, when compared to a more modern regional train such as the Class 168. The main reason for these differences is due to the additional weight and equipment fitted to modern trains, which leads to increased fuel consumption. The improved acceleration performance of modern trains also contributes to increases in fuel consumption.

The differences are even more pronounced if the Class 150 is compared to high-speed diesel rolling stock such as the Class 180 Adelante or Class 43 HST. CO_2 emissions per seat kilometre from HSTs are more than double those from Class 150 trainsets.

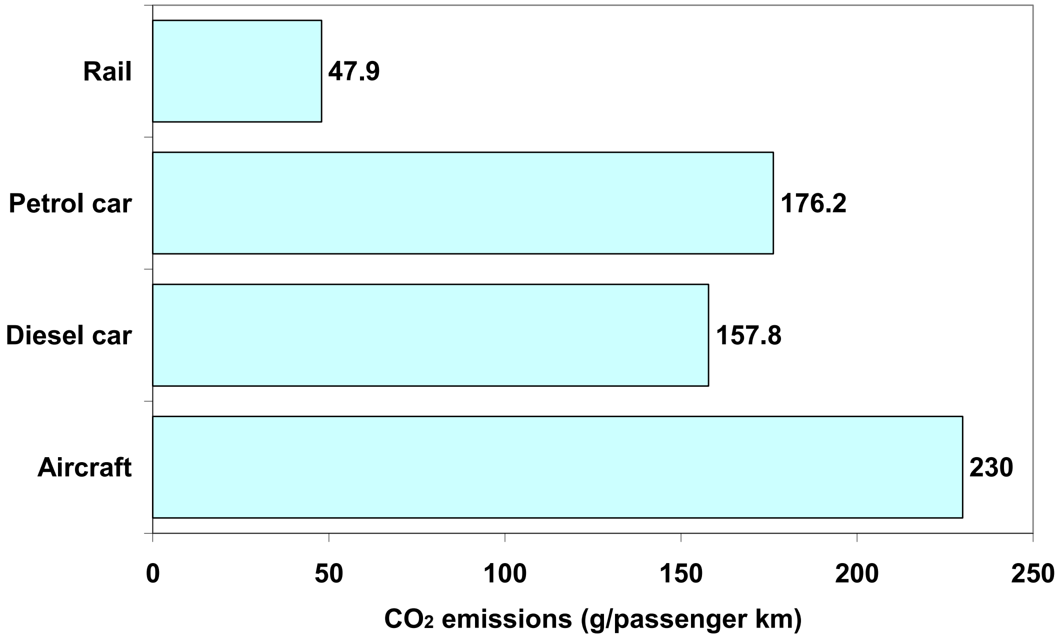
Across Europe, work has also been done to quantify CO_2 emissions from rail transport and compare this to other modes. In particular, the Institut für Energie und Umweltsforshung (IFEU) Heidelberg (IFEU, 2004)[13] has estimated the CO_2 impacts of rail, road, air, and marine freight transport, as well as the impacts of long distance passenger road, rail and air transport. Some of the results from this work are presented below in Figure 3.2 and Figure 3.3.

Figure 3.2: CO_2 emissions per tonne kilometre for different modes of freight transport



Source: IFEU, 2004

Figure 3.3: CO_2 emissions per passenger kilometre for different modes of passenger transport



Source: IFEU, 2004

As can be seen from the data in Figure 3.2 and Figure 3.3, the average CO_2 emissions performance for passenger rail estimated by IFEU (47.9 g CO_2 per passenger kilometre) is very similar to the figure calculated by AEA Technology Environment for the SRA (48.6 grams of CO_2 per passenger kilometre) presented in Figure 3.1 and Table 3.2. However, there are significant differences between the IFEU and AEA Technology figures for rail freight emissions and road transport emissions. This should be expected, as the IFEU figures have been calculated at the European level, whilst the AEA Technology figures are for the UK situation only. The data presented in Figure 3.1 and Table 3.2 is therefore more representative of the UK situation. It should, however, be borne in mind that the analysis of rail's emissions performance is limited to a certain extent, by the accuracy of the input data on energy consumption. It is thought likely that the UK emissions analysis could be improved by using more complete datasets on total gas oil and electricity consumption by the rail sector.

3.4 Emissions of air pollutants and their impacts on air quality

3.4.1 Impacts of air pollution

Air pollutants include (amongst others) the following compounds: oxides of nitrogen (NOx), particulate matter (PM), sulphur dioxide (SO_2), volatile organic compounds (VOCs), and carbon monoxide (CO). Local air pollutants have important effects on human health, the natural environment, and the man-made environment. Studies of pollution episodes (such as the London smog episodes of the 1950s) have shown that very high levels of ambient air pollution are associated with large increases in adverse health effects. Recent studies have also shown that the levels of ambient air pollution present today also lead to adverse health impacts. These impacts include premature deaths, respiratory and cardio-vascular hospital admissions, and other respiratory symptoms (e.g. asthma, bronchitis, etc). The evidence for a link between air pollution and health impacts is strongest for the pollutants PM_{10} and ozone, and it is now widely accepted that there is a direct link between exposure to these pollutants and the health effects described above. It should be noted that ozone is not directly emitted by transport or industrial sources, but is a secondary pollutant formed in the atmosphere through reactions between nitrogen dioxide, hydrocarbons, and sunlight. Studies have also indicated that long-term exposure to these pollutants (especially particulate matter) may also damage health. It has been estimated that between 12,000 and 24,000 people die each year in the UK from the effects of air pollution, and the number of people that suffer from pollution-related respiratory illnesses is many times greater than this.

In addition to the significant impacts on human health described above, air pollution also has impacts on buildings. Soiling of buildings through exposure to air pollution is one of the most visually noticeable impacts of air pollution. Such damage is due to the deposition of particulate matter on the surfaces of buildings, which leads to discolouration of stone and other materials. SO_2 emissions can erode certain building materials, whilst ozone is known to damage materials such a plastics and rubbers.

Further to these effects, it is also known that air pollution can have impacts on natural and semi-natural ecosystems. Exposure to ozone has been implicated in reduced crop yields, and the impacts of air pollution on ecosystems ranging from forests to freshwater have also been examined.

The following gives a brief summary of the major impacts of each the main air pollutants, as published by Defra on the UK National Air Quality Information Archive (Defra, 2005)[14]

Nitrogen Dioxide (NO_2)

NO_2 is one of the oxides of nitrogen, and is formed during high temperature combustion processes. Transport, power stations, and industrial processes are some of the most important sources of NO_2. NO_2 can irritate the lungs and lower resistance to respiratory infections. It is also thought that continued or frequent exposure to high concentrations of NO_2 may lead to an increased incidence of acute respiratory illness in children.

Particulate Matter (PM)

Airborne particulate matter varies widely in its physical and chemical composition, and in its size. Particles with a diameter of less than 10µm are collectively known as PM_{10}. Such particles are of concern as they are small enough to penetrate deep into the lungs, where they can cause inflammation and a worsening of lung and heart disease conditions. Particulate matter may also carry carcinogenic compounds into the lungs.

Sulphur dioxide (SO_2)

Sulphur dioxide is an acidic gas that combines with water vapour in the atmosphere to produce acid rain. SO_2 has been implicated in the damage and destruction of vegetation and in the degradation of soils, building materials, and watercourses. The principal source of SO_2 is power stations burning fossil fuels that contain sulphur. As many power stations are now located away from urban areas, SO_2 emissions may affect air quality in both rural and urban areas. With regard to impacts on human health, even relatively moderate concentrations of SO_2 can lead to a reduction in the lung function of people suffering from asthma. At higher levels of exposure, tightness of the chest and coughing may occur, and the lung function of asthmatics may be impaired to the extent that medical treatment is required. SO_2 pollution is considered more harmful when other pollutant concentrations are high.

Volatile Organic Compunds (VOCs)

VOCs are emitted from vehicle exhaust gases either as unburned fuels or as combustion products. The evaporation of solvents and motor fuels is another source of VOCs. Examples of VOCs include benzene and 1,3-butadiene. The impacts of VOC emissions on human health include increased incidence of cancer, central nervous system disorders, liver and kidney damage, and birth defects.

Carbon monoxide (CO)

Carbon monoxide is a toxic gas, which is emitted into the atmosphere as a result of combustion processes, and is also formed by the oxidation of hydrocarbons and other organic compounds. In European urban areas, CO is produced almost entirely from road traffic emissions. CO survives in the atmosphere for a period of approximately one month but is eventually oxidised to carbon dioxide. CO prevents the normal transport of oxygen in the blood, and this can lead large reductions in the supply of oxygen to the heart, particularly in people suffering from heart disease.

Ozone (O_3)
Ground-level ozone, unlike the other pollutants discussed above, is not directly emitted into the atmosphere, but is a secondary pollutant produced from the reaction between NO_2, VOCs, and sunlight. Sunlight provides the energy to initiate ozone formation, and consequently, high levels of ozone are generally observed during hot, still, sunny summer weather. Ozone irritates the airways of the lungs, increasing the symptoms of those suffering from asthma and lung diseases.

3.4.2 Current emissions of air pollutants

Air pollutants are emitted by diesel trains via their exhaust tailpipes during the combustion of fuel to provide motive power. Electric trains do not directly emit these pollutants, but as with CO_2 emissions, air pollutants are emitted during the electricity generation process at power stations. The following tables provide a summary of total emissions of air pollutants from the road and rail sectors in 2002 (NAEI, 2003)[12]. In addition, each table gives details of road transport and rail transport emissions as a proportion of total UK emissions of each particular pollutant.

Table 3.4: UK emissions of oxides of nitrogen (NOx) in 2002

	Emissions source	Mass of emissions in 2002 (kiloTonnes)	Emissions as a % of total UK emissions of NOx
All sectors	All sectors (transport, industry, domestic, etc)	**1582.0**	**100%**
Road Transport			
	Cars	313.0	
	Light vans	67.0	
	Heavy duty trucks and buses	330.0	
	Motorcycles	1.0	
	All road transport	**711.0**	**44.94%**
Rail			
	All diesel traction	9.3	
	which consists of:		
	Diesel freight	*1.7*	
	Diesel intercity	*6.1*	
	Diesel regional	*1.6*	
	All electric traction	2.8	
	All rail traction	**12.1**	**0.77%**

Table 3.5: UK emissions of particulate matter (PM_{10}) in 2002

	Emissions source		Mass of emissions in 2002 (kiloTonnes)	Emissions as a % of total UK emissions of PM_{10}
All sectors	All sectors (transport, industry, domestic, etc)		**161.0**	**100%**
Road Transport				
	Cars		8.0	
	Light vans		12.0	
	Heavy duty trucks and buses		9.0	
	Motorcycles		1.0	
	All road transport		**30.0**	**18.63%**
Rail				
	All diesel traction		0.5	
	which consists of:			
	Diesel freight	*0.1*		
	Diesel intercity	*0.4*		
	Diesel regional	*0.0*		
	All electric traction		0.1	
	All rail traction		**0.6**	**0.37%**

Table 3.6: UK emissions of volatile organic compounds (VOCs) in 2002

	Emissions source		Mass of emissions in 2002 (kiloTonnes)	Emissions as a % of total UK emissions of VOCs
All sectors	All sectors (transport, industry, domestic, etc)		**1364.0**	**100%**
Road Transport				
	Cars		119.0	
	Light vans		12.0	
	Heavy duty trucks and buses		29.0	
	Motorcycles		11.0	
	All road transport		**171.0**	**12.54%**
Rail				
	All diesel traction		0.1	
	which consists of:			
	Diesel freight	*0.3*		
	Diesel intercity	*0.8*		
	Diesel regional	*0.0*		
	All electric traction		1.1	
	All rail traction		**1.2**	**0.09%**

Table 3.7: UK emissions of sulphur dioxide (SO_2) in 2002

	Emissions source		Mass of emissions in 2002 (kiloTonnes)	Emissions as a % of total UK emissions of SO_2
All sectors	All sectors (transport, industry, domestic, etc)		**1002.0**	**100%**
Road Transport				
	Cars		2.0	
	Light vans		0.0	
	Heavy duty trucks and buses		1.0	
	Motorcycles		0.0	
	All road transport		**3.0**	**0.30%**
Rail				
	All diesel traction			
	which consists of:		1.0	
	Diesel freight	*0.3*		
	Diesel intercity	*0.6*		
	Diesel regional	*0.1*		
	All electric traction		5.0	
	All rail traction		**6.0**	**0.60%**

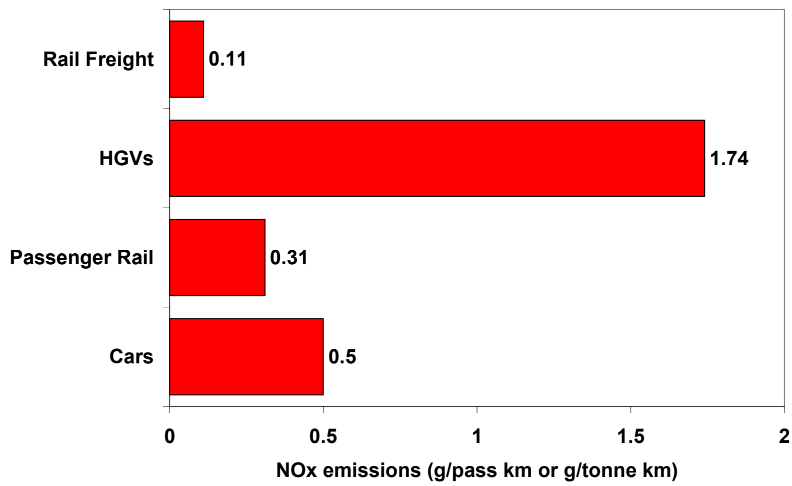
Table 3.8: UK emissions of carbon monoxide (CO) in 2002

	Emissions source	Mass of emissions in 2002 (kiloTonnes)	Emissions as a % of total UK emissions of CO
All sectors	All sectors (transport and industry)	**3238.0**	**100%**
Road Transport			
	Cars	1620.0	
	Light vans	135.0	
	Heavy duty trucks and buses	70.0	
	Motorcycles	91.0	
	All road transport	**1916.0**	**59.17%**
Rail			
	All diesel traction	2.5	
	which consists of:		
	Diesel freight	*0.5*	
	Diesel intercity	*1.8*	
	Diesel regional	*0.2*	
	All electric traction	0.5	
	All rail traction	**3.1**	**0.09%**

As can be seen from the above tables, emissions of air pollutants are, in general, much greater from road transport than they are from rail transport (SO_2 emissions are the one exception to this). Additionally, if rail emissions are compared to total UK emissions of each of the six pollutants from all transport and industrial sectors, it can be seen that in each case, rail emissions account for less than 1% of total emissions. However, it is worth noting that air pollutant emissions from road transport have decreased very significantly in the last fifteen years, even though there has been a very large increase in road traffic over the same time period. These reductions in emissions are primarily due to the influence of the EC's Auto-Oil programme (better known as the "Euro standards"), and reductions in the sulphur content of road fuels. Whilst emissions from the rail sector have also decreased over the same time period, the reductions have not been as large (in percentage terms) as for the road sector.

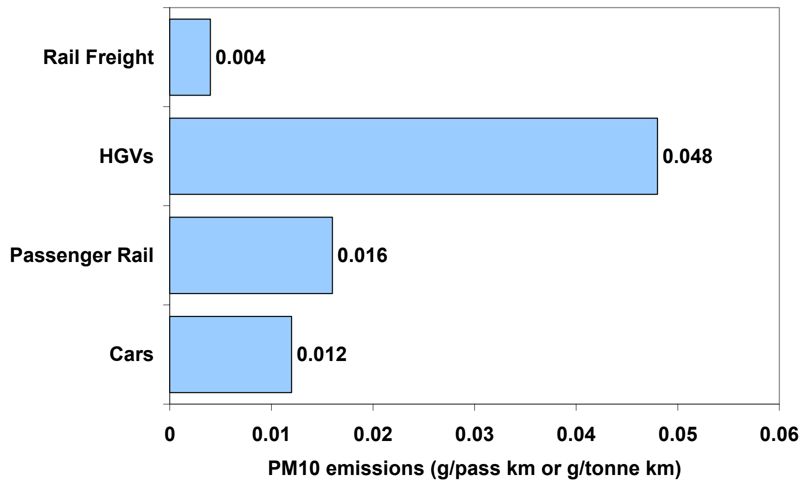
The figures in Table 3.4 to Table 3.8 give details of total emissions from the rail and road sectors and it is useful to supplement this with data on performance in terms of emissions per passenger kilometre travelled (or per tonne kilometre travelled in the case of rail freight). In 2004, AEA Technology Environment carried out work for the Strategic Rail Authority to quantify emissions from rail transport on this basis, and the results from this work are summarised below.

Figure 3.4: Comparison of NOx emissions from rail and road transport



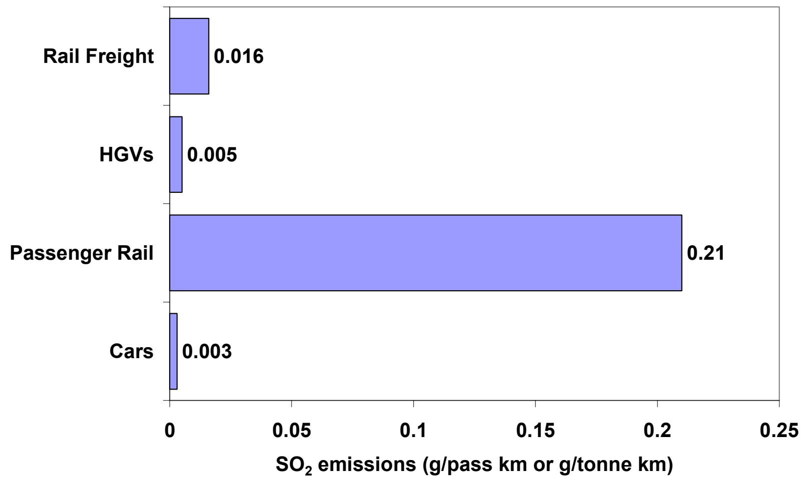
Source: AEA Technology Environment (as part of work carried out for the SRA)

Figure 3.5: Comparison of PM_{10} emissions from rail and road transport



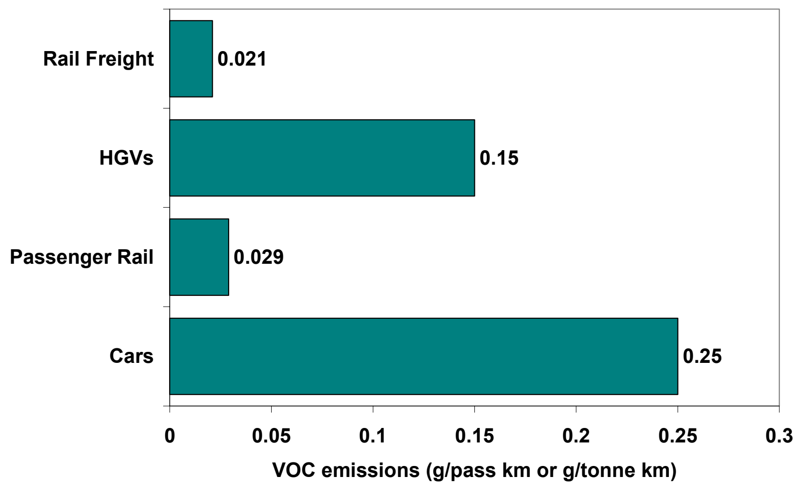
Source: AEA Technology Environment (as part of work carried out for the SRA)

Figure 3.6: Comparison of SO_2 emissions from rail and road transport



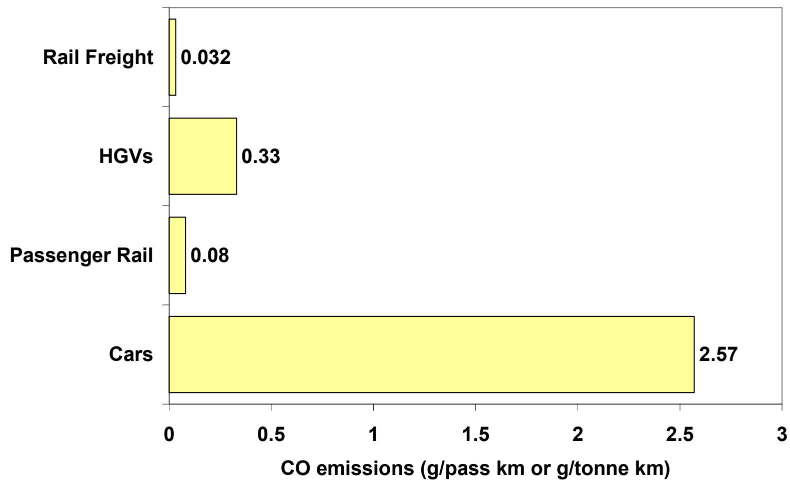
Source: AEA Technology Environment (as part of work carried out for the SRA)

Figure 3.7: Comparison of VOC emissions from rail and road transport



Source: AEA Technology Environment (as part of work carried out for the SRA)

Figure 3.8: Comparison of CO emissions from rail and road transport



Source: AEA Technology Environment (as part of work carried out for the SRA)

As can be seen from the above graphs, rail transport has significantly lower emissions of regulated air pollutants than road transport when emissions are compared on a "per passenger kilometre" or "per tonne kilometre" basis. The above figures are, however, aggregate figures that are effectively average values across the whole rail sector. Work carried out by AEA Technology for the SRA has also been used to assess the emissions impacts of different classes of locomotives and multiple units. Comparative data for a selection of different classes are presented below in Table 3.9, with data presented in terms of emissions per seat kilometre travelled.

Table 3.9: Pollutant emissions from selected classes of passenger trains

Train class	Diesel or Electric	Average Maximum seating capacity	Emissions (grams per seat km) NOx	CO	VOCs	PM	SO2
Class 357	Electric	734	0.032	0.006	0.004	0.001	0.701
Class 43 HST	Diesel	477	0.413	0.123	0.046	0.011	0.026
Class 180 Adelante	Diesel	265	0.208	0.119	0.033	0.004	0.022
Class 150 Sprinter	Diesel	222	0.208	0.018	0.010	0.007	0.013
Class 168 Turbostar	Diesel	278	0.212	0.035	0.009	0.004	0.021

Source: AEA Technology Environment (as part of work carried out for the SRA)

As can be seen from the above data, it is clear that emissions from the electric Class 357 are, with the exception of SO_2 emissions, significantly lower than from diesel locomotives and DMUs. Comparing the Class 357 commuter EMU with the diesel Class 168 Turbostar, it can be seen that NOx emissions from the Class 168 are approximately 6.6 times greater, PM_{10} emissions are four times greater, CO emissions are almost six times greater, and VOC emissions are more than doubled. However, SO_2 emissions are significantly higher from the Class 357 than they are from the Class 168. It is also clear that there are significant differences between old and new trainsets. First Great Western operates Class 180 Adelante DMU trainsets and Class 43 HST trainsets on routes into London Paddington, but it is clear that the more modern Class 180 has much better emissions performance. For example, it can be seen that NOx and PM_{10} emissions from the Class 180 are less than half of those from the Class 43, and levels of carbon monoxide are also much lower.

With regard to freight locomotives, the RSK Group published data on the emissions performance of a number of different locomotives, and this data is reproduced below in Table 3.10. It should be noted that this data was originally published in the mid to late 1990s when RSK held a contract to prepare the UK's National Emission Factors Database, and was collated in conjunction with the London Research Centre. Whilst some of the locomotives included in the data below are still in service (and the corresponding emission factors should still be valid), the Emission Factors Database does not currently exist in the same format, and detailed data disaggregated by locomotive classes is no longer published in this format.

Table 3.10: Pollutant emissions from selected classes of diesel freight locomotives

Diesel locomotive class	Emissions (grams per km)				
	NOx	CO	VOCs	PM	SO2
Class 37 (per pair of locomotives - typical load)	132.8	62.4	32	10.2	30.2
Class 47 (per locomotive - typical load)	80.1	26.1	5.4	5.1	22.4
Class 60 (per locomotive - typical load)	129.6	21.6	10.8	4.7	26.9
Class 66 (per locomotive - typical load)	120	6.8	3.3	2.9	6

3.4.3 Future emissions of air pollutants

As with CO_2 emissions, it is anticipated that air pollutant emissions from the rail sector will increase in the next few years due to significant increases in passenger and freight kilometres. This point was highlighted in the SRA's Environmental Agenda (SRA, 2001)[11], and there it was commented that such an increase in railway emissions is justified as long as the predicted shift from road to rail transport occurs at the same time.

3.5 Noise and vibration

3.5.1 Railway noise

Noise is defined as "unwanted sound". It is measured using a logarithmic decibel (dB) scale. However, as the ear responds differently to different frequencies of sound, a weighting is usually used that represents the human response for typical sound environments (the A-weighting), which measures or predicts sound in terms of 'dB(A)'. When a noise level is fluctuating, it is often measured in terms of an average level. The most commonly applied averaging technique for environmental noise is to specify the continuous noise level over a period of time that contains the same acoustic energy as the fluctuating noise over that time. This is known as the Equivalent Continuous Sound Level (L_{eq}, or L_{Aeq} when A-weighting has been applied), and this metric is often used to quantify noise levels from transport sources. Transport noise is a major nuisance and is widely recognised as a factor affecting daily life. It may also lead to a number of health impacts through a variety of direct and indirect effects, although there is considerable debate on the reliability of the evidence. Key UK legislation relating to railway noise includes:

- Noise Insulation (Railways and Other Guided Transport Systems) Regulations apply (HM Government, 1996)
- Environmental Protection Act (1990)

- "Railway Operations and the Environment – Environmental Guidance". Guidance issued by the Office of the Rail Regulator in 1996

The total noise burden of the road network and the railways is not currently accurately known. Only airport noise is accurately mapped at present. However, the European Commission's Environmental Noise Directive (European Commission, 2002a)[15] requires that noise maps must be prepared for all major agglomerations by the end of 2007, and hence all of these sources will be soon be characterised in detail.

At the national level, noise is certainly an issue. Objective measurements of exposure to environmental noise were carried out in 2000 as part of the National Noise Incidence Study 2000 (England and Wales) (BRE, 2002a)[16]. This study found that 55% (±3%) of the population live in dwellings that are exposed to daytime noise levels that exceed 55 dB $LA_{eq,day}$. 8% (±1%) of the population were found to live in dwellings that were exposed to noise levels greater than 68 dB $LA_{10,18hr}$. Dwellings exposed to noise levels above this value qualify for sound insulation under the Noise Insulation Regulations. Whilst the National Noise Incidence Study was able to quantify the proportion of the population exposed to noise levels greater than a certain level, it was not able to determine the split between different sources of noise.

A separate study entitled "1999/2000 National Survey of Attitudes to Environmental Noise" (BRE, 2002b)[17] has been used to build up a picture of the relative importance of different sources of environmental noise. The study was based around a survey of members of the public to identify which sources of noise they could hear in their homes, and which sources of noise caused them annoyance or disturbance. A total of 2876 people were surveyed for this study, and some of the results relating to transport noise are presented in Figure 3.9 and Figure 3.10 below.

Figure 3.9: Results from the National Survey of Attitudes to Environmental Noise: Percentage of people who reported hearing different sources of noise

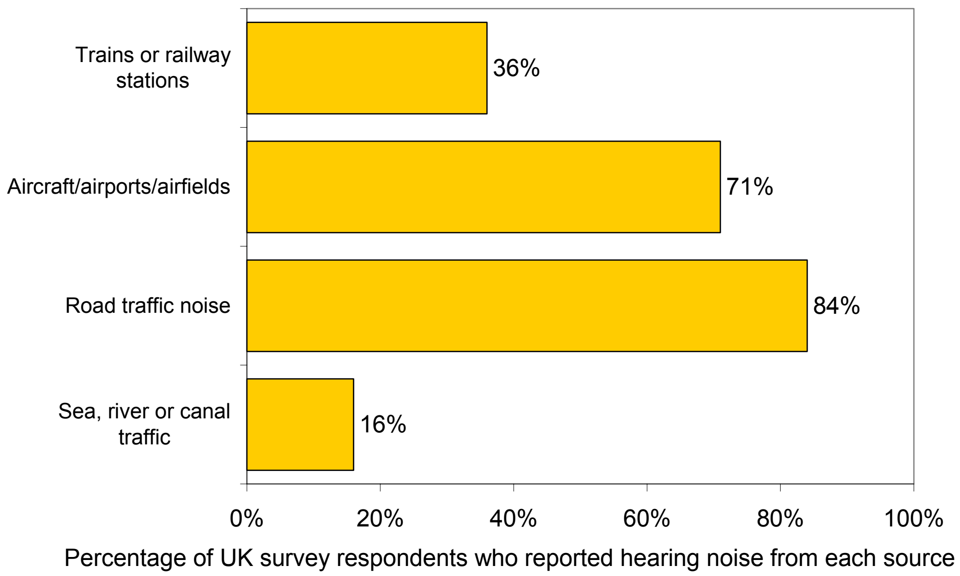
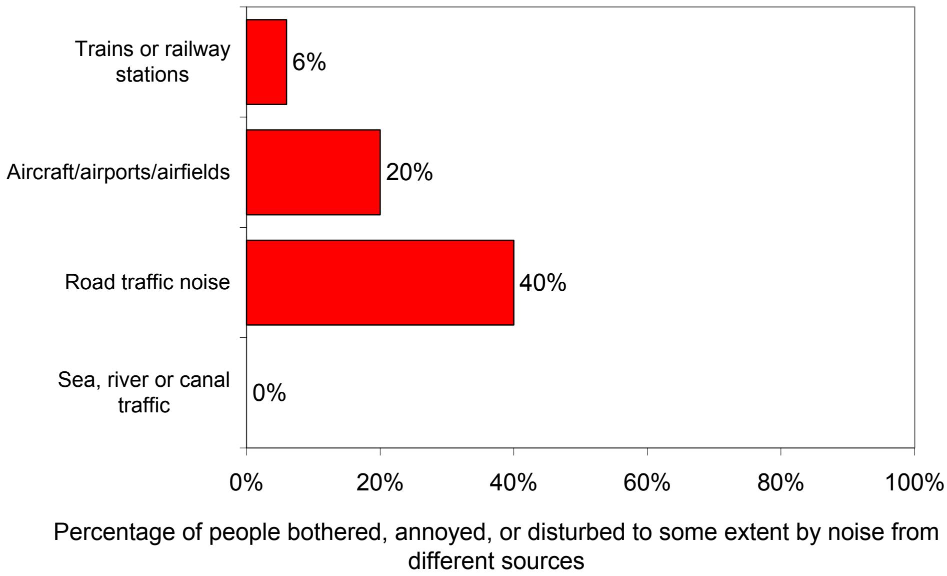


Figure 3.10: Results from the National Survey of Attitudes to Environmental Noise: Percentage of people who reported being bothered, annoyed, or disturbed by different sources of noise



As can be seen from the survey results road traffic noise was shown to be the most commonly heard noise category and transport noise (from aircraft, trains and road traffic) was identified by the survey as affecting large numbers of respondents in some way. Railway noise was reported far less frequently, and caused far less annoyance or disturbance than either road traffic noise or aircraft noise.

3.5.2 Railway vibration

In addition to nose, railway vehicles are also a source of vibration. This vibration falls into two categories: sub-audible vibration that is felt rather than heard (falling in the frequency range 1-80 Hz), and audible ground-borne noise (also known as “rumble”) caused by train vibrations propagating from the track, through the ground and into the structure of nearby buildings. As the building structure vibrates, sound is radiated into the interior of the building, typically at frequencies between 25 Hz and 250 Hz.

Both sub-audible, and audible vibration are caused by excitation of the railway track and the nearby ground as the train travel over the track. The causes of this vibration are mainly due to wheel and track roughness, with vehicle and track masses, and dynamic characteristics also contributing.

As with noise, there are thresholds below which vibration is not noticeable. For sub-audible vibration, the perception threshold is an acceleration of 4 mm/s^2. This value is often exceeded at properties that are close to railway lines. Damage to buildings (even very minor damage) only occurs at accelerations much greater than this – typically at values around 600 mm/s^2. Such values are very rarely found in properties adjacent to railways.

It should be noted that there is not standard method for quantifying the level of ground-borne vibration, but levels are often measured in dB(A). A level of around 40 dB(A) is sometimes considered to be the point where annoyance starts to occur; levels around 40 dB(A) and greater are often measured in properties above and near to railway tunnels. The level of population exposure to railway vibration across the UK is not known.

3.6 Water and land pollution and contamination

3.6.1 Overview

The main issues regarding water and land pollution relate to the control of pollutants from railway operations and the risk of accidents or spills. AEA Technology Environment carried out work for the SRA in 2001 to assess the most significant potential problems. These were found to be as follows:

- Fuel spills from train refuelling and from fuel storage
- De-icing chemicals applied to train tracks and leaf removal
- Releases during operations such as cleaning and maintenance
- Waste generation and disposal

3.6.2 Fuel spills

There is the possibility of fuel spills occurring whilst diesel engines are refuelled, leading to possible contamination of ground water and soil. The most significant problems are associated with the storage of diesel for refuelling traction units. Additionally, leaks may occur at fuel storage facilities.

3.6.3 De-icing chemicals

During adverse weather conditions, it is often necessary to de-ice train tracks; this is especially the case for electric trains. De-icing trains are used to spray de-icing fluid along tracks. Additionally, trains are sometimes run at night to ensure that tracks are kept clear.

3.6.4 Minimising the impacts of leaves on lines

Leaves on rail lines can cause significant operational problems for railway companies. Leaves crushed between train wheels and track, are compacted and carbonise to form a hard, slippery coating that adheres to rail lines. The reduced friction means that there is a greater likelihood of wheel-slip and hence trains have to travel slower to ensure safety. In order to minimise the problems associated with leaves on rail lines, Network Rail carries out trackside vegetation management. Where necessary, trees are removed, or their branches are cut to minimise the incidences of leaves on lines. Herbicides are also used to keep vegetation under control. Additionally, Network Rail has a fleet of special “sandite” trains which spread a gritty paste on the track to give trains better grip. Static machines that apply sandite are also used by track workers to apply the paste at known trouble spots. High-pressure water jets are also used to remove leaves before they for a hard coating.

3.6.5 Chemical releases

Maintenance operations are also a potential source of land and water pollution. Lubricants and chemicals (e.g. coolants, hydraulic oils, and cleaning chemicals) used during maintenance and cleaning operations can potentially end up polluting land wand water courses.

3.6.6 Contaminated land

Probably the most important issue that falls under the scope of this category of environmental impact is the historic legacy of contaminated land. In 2000, Railtrack identified 600 sites which could be contaminated, and subsequently risks have been identified for 54 of these sites. The majority of these risks are due to storage of diesel for maintenance and refuelling of traction units.

3.6.7 Relative importance of land and water pollution impacts

The railway’s impacts on nature and landscape (including water and land pollution) are very minor compared to the impacts of greenhouse gas emissions, air pollutant emissions, and noise. The relative scale of these impacts can be seen from work carried out by the Swiss consultancy INFRAS to estimate the environmental costs of rail transport across Europe. This work is discussed in detail in Section 4.3, but in short, the results of this study indicated that the monetary value of rail’s environmental impacts on nature and landscape (which includes water and land pollution as a subset) accounted for between 2% and 3.5% of all environmental costs. It is clear from these data, that land and water pollution are very minor components of the total environmental costs associated with rail operations.

3.7 Visual intrusion

The impacts of the railways on landscape and townscape are primarily due to visual intrusion associated with railway infrastructure, including tracks and overhead power lines. The issue of visual intrusion falls under planning legislation, and to date there has not been any work at the UK level to quantify or put a value on the total visual intrusion caused by railway infrastructure. For new rail infrastructure, the issue of visual intrusion is dealt with using Strategic Environmental Assessment (SEA). SEA is a planning tool that enables the environmental impacts associated with a policy, programme or plan to be assessed using a strategic approach for a whole region or area rather than focusing on single projects or single sites.

As with land and water pollution, the railway's visual intrusion impacts are minimal compared to greenhouse gas emissions, air pollutant emissions and noise. In the INFRAS study on external costs, visual intrusion was included as one of the impacts on nature and landscape. As discussed in Section 3.6.7, the environmental costs associated with nature and landscape accounted for only 2% to 3.5% of all environmental costs.

3.8 Land take

There are environmental issues for the railway industry for land-use and, in particular, the protection of natural habitats and bio-diversity. There are two issues – the total land-take from the railways, and the type of land affected, especially if this natural habitat.

Comparison of land-take by mode can be made, although some care must be taken in interpreting this data because of activity levels, lifetimes and capacity issues. Railway land-take includes the track area and ancillary infrastructure, stations and depots.

The width of a four track line is approximately 27m, whilst that of a busy two track line is 20m. Other two line tracks are typically 9 – 12 m.

The land taken includes all area between the outer rail and the boundary fence. This land is either covered in ballast or will be managed vegetation. There is 16,652 km of rail route open for traffic in the UK (around 5,000 km of which is electric) (TSGB, 2004)[18]. These values will rise further with the inclusion of railway stations, maintenance depots, and other areas. Added to these are 2508 national railway stations (TSGB, 2004) and around 50 freight depots.

The other key issue is the type of land affected. The majority of railway infrastructure/land-take within the EU and the UK is built in agricultural areas. A detailed distribution of land-take is not available for the UK railways. The Transport and Environment Reporting Mechanism (TERM) report estimated that the total UK land take of railways is under 0.2% of the total country area.

The railways can have positive and negative effects on habitat. They can be important habitats for many species (flora and fauna). They can provide important wildlife corridors, especially in urban areas, though some line-side vegetation management is undertaken (e.g. to reduce problems with leaves are avoided). However, when railways run through areas of natural habitat or conservation areas, they can have detrimental effects from fragmentation of habitat areas. The number of Ramsar (wetland) sites in the UK affected by rail infrastructure has been analysed in the TERM report (2000). Approximately 52% of wetland sites had rail infrastructure within 5km of their centre, the highest percentage in the EU. The report also concluded that 44% of special bird areas have major rail infrastructure within 5km of their centre. Network Rail estimates that the rail network runs through 408 Sites of Special Scientific Interest (SSSI) (Network Rail, 2005)[19].

4 Monetisation of the environmental costs and benefits of rail transport

4.1 Overview

The previous sections have provided an overview of some of the environmental impacts associated with railway operations. For each of the environmental impacts described, it is possible to quantify these impacts in monetary, or cost terms. The costs associated with environmental impacts are known as "external damage costs"; external damage costs (or externalities) occur when the social or economic activities of one group of persons has an impact on another group of persons, and when the impact is not fully accounted for or compensated by the first group. The transport sector provides good examples of activities that have environmental externalities; the costs of damage caused by transport-related greenhouse gas emissions, air pollutant emissions, and noise are not fully accounted for in the costs of using transport.

The major studies that have provided data on the environmental costs of rail transport are as follows:

- Surface Transport Costs and Charges 1998 (ITS Leeds, 2001)[20]
- External Costs of Transport: Accident, Environmental and Congestion Costs of Transport in Western Europe (INFRAS 2000[21] and INFRAS, 2004)[22]
- Internalising the Social Costs of Transport (OECD, 1994)[23]

Surface Transport Costs and Charges 1998 was a UK study that investigated the social (including environmental) costs of road and rail transport in the UK. Across Europe more generally, the most significant study was that carried out by INFRAS and IWW for the International Union of Railways (UIC), which examined the external costs of various modes of transport. The following sections provide some details of the methodologies used in the above studies for estimating the environmental costs of rail transport, and provide a summary of some of the most important results.

4.2 Surface Transport Costs and Charges 1998

4.2.1 Overview of the study

The key UK study into the external costs of transport is the DETR publication "Surface Transport Costs and Charges 1998" (referred to as STCC from here onwards), which was produced by the Institute for Transport Studies at the University of Leeds, and AEA Technology Environment. This study carried out a comprehensive assessment of all of the social costs associated with road and rail transport in 1998, and determined to what extent these costs would be covered by taxes, charges, and other payments in 1999. The study covered track costs, environmental costs, and an element of accident costs, and hence went much further than just covering the environmental impacts of surface transport. From the environmental perspective, the costs associated with climate change, air pollution, and noise were analysed during the study. An overview of the methodology used in this study for calculating the environmental costs of rail transport is provided in the following sections.

4.2.2 Climate change valuation methodology

4.2.2.1 Quantifying CO_2 emissions from rail vehicles

Data on CO_2 emissions from diesel trains were taken directly from the National Atmospheric Emissions Inventory (NAEI). Emissions data were collated for the passenger trains, based on factors for Class 14X Pacer, Class 15X Sprinter, and Class 16X Turbo diesel multiple units, as well as factors for Class 43 (HST) and Class 47 locomotives. For freight trains, separate emissions data were collated based on factors for Class 37, Class 47, Class 56, Class 58, and Class 60 locomotives. For electric trains, data on emissions from electricity generation were taken from the NAEI, and used in conjunction with data from the Digest of United Kingdom Energy Statistics (DUKES) to estimate total CO_2 emissions from electric traction. All of this information was used in conjunction with data on electric and diesel train kilometres that was supplied by Railtrack in order to compile a set of 1998 fleet emissions for the following categories of train: inter-city, Passenger Transport Executive (PTE), rural, cross-country, and London suburban.

4.2.2.2 Valuation of CO_2 emissions

CO_2 emissions were valued using damage cost estimates for climate change. At the time of the study, the recommended low, central, and high values for the damage costs associated with climate change impacts were as follows: £7.3/tonne of CO_2 (low), £14.6/tonne of CO_2 (central), and £29/tonne of CO_2 (high). These values were recommended by the then Department for Environment, Transport and the Regions, with the central value taken from the EC ExternE project (European Commission, 1997)[24]. At the time of the study, it was stressed that there was much uncertainty associated with climate change, and hence the values used were only to be considered as illustrative. Subsequent and ongoing research has tried to refine the damage cost values used for climate change impacts.

4.2.3 Air pollution valuation methodology

The valuation of air pollution impacts followed a step-by-step approach:

- Quantify emissions of air pollutants from all rail vehicles
- Assess the effect of these emissions on local and regional air concentrations
- Quantify the health and environmental impacts of pollution concentrations
- Value these health and environmental impacts in monetary terms

4.2.3.1 Quantifying emissions from rail vehicles

As with climate change impacts, data from the NAEI was used to estimate the air pollution impacts of rail operations, with data on diesel trains taken directly from the NAEI and split into different classes in the same manner as for CO_2 emissions. Again, data on pollutant emissions from electric trains were based on electricity generation emission factors and data from DUKES. As with CO_2, fleet emissions of air pollutants were compiled for inter-city, PTE, rural, cross-country, and London suburban categories of train.

4.2.3.2 Modelling air pollution concentrations

To model the impact of emissions from trains on pollution concentrations, and to estimate the health and non-health impacts of these pollutant concentrations, the EC's ExternE computer tool was used. The modelling allowed the effects of pollutant concentrations on people, crops, and buildings to be estimated

4.2.3.3 Quantifying the impacts of pollution on human health, buildings and crops

To estimate the effect of rail-related air pollution on health, dose-response functions from two major studies were used; these studies were the UK Department of Health's Committee on the Medical Effects of Air Pollutants (COMEAP, 1998), and the European Commission's ExternE study. The dose-response functions allowed the relationships between exposure to air pollution and impacts on human health (incidence of respiratory hospital admissions, acute mortality (i.e. the number of deaths brought forward), years of life lost, etc) to be quantified. It should be noted that there was greatest confidence in the dose-response relationships for the incidence of respiratory hospital admissions and acute mortality.

Non-health impacts were also assessed using a dose-response methodology, based around the Extern-E computer model. The specific impacts included in the analysis were soiling of buildings, material corrosion, and crop damage.

4.2.3.4 Valuing the impacts on human health, buildings and crops in monetary terms

For the valuation of impacts on human health, recommendations from the following sources were used:

- Ad-hoc group on the Economic Appraisal of the Health Effects of Air Pollution (EAHEAP)
- European Commission ExternE study

The EAHEAP values were used for the health impacts where there was the greatest confidence (i.e. acute mortality and respiratory hospital admissions), whilst ExternE recommendations were used for all other health impacts. The values used for acute mortality and respiratory hospital admissions are presented in the table below.

Table 4.1: Examples of the valuation of health impacts used in Surface Transport Costs and Charges 1998

	Low	Medium	High
Acute mortality	£2,600	£110,000	£1,400,000
Respiratory hospital admissions	-	£2,668	£3,235

Primary source: EAHEAP

4.2.4 Noise valuation methodology

4.2.4.1 Quantifying noise emissions from rail vehicles

As discussed in Section 3.5, transport noise has been shown, both through measurement studies, and through surveys, to be a major nuisance. Noise may also lead to a number of health impacts through both direct and indirect effects, although it should be noted that there is much debate on the reliability of the supporting evidence for these assertions. As stated in Section 3.5, there is currently no national data on the noise burden due to rail (or road) transport; such data will become available once the noise-mapping programme required by the EC Environmental Noise Directive is complete. To assess and value the noise impacts due to rail transport in the UK, it was therefore necessary to use a modelling approach for the STCC study. The Department for Transport's Calculation of Rail Noise (CRN) methodology was used to calculate total noise emissions and noise dispersion due to rail operations, using a series of assumptions regarding average speed, sound level, and passage of time for various classes of passenger and freight trains. For the purposes of the analysis, a "damage threshold" of 55 dB was also used; noise levels below 55 dB were assumed to have no environmental impact and hence no damage cost. This is consistent with guidance from the World Health Organisation on the limits above which daytime noise levels cause annoyance. It should be noted, however, that many assumptions were made in assessing the noise burden of the railways in order to simplify the analysis. These assumptions include the following:

- It was assumed that noise from rail operations was the only source at any given location. In reality, noise from multiple sources will influence the overall noise level at a particular location.

- The CRN methodology assumes that trains are running at speeds near to the maximum for any given line section. Also, detailed data on speeds and traffic flows across the network was not available for the modelling, and case study examples from specific locations were used to represent the whole UK network. This inevitably led to some errors when trying to calculate the noise burden at the national level.

- It was not possible to take local conditions into account. This is important as noise is very much a localised effect, and the impacts of railway noise may, in practice only extend tens of metres from the source. Additionally, screening effects due to buildings and barriers tend to reduce the impacts of noise. Screening was not taken into account, except for a simple barrier effect for urban areas.

- The response to noise is extremely subjective; the level of annoyance depends on many factors including the type and duration of the noise, background noise levels, as well as perceptions towards the noise source itself. There is also some literature on what has been termed the "rail-bonus". This refers to the findings from some studies that people generally find railway noise less annoying than road traffic noise or aircraft noise (typically a 5 to 10 dB(A) advantage for railway noise) (European Commission, 2002b)[25], (European Commission, 2002c)[26]. These studies were based on dose-response relationships for noise from different modes of transport, although it must be stressed that it is by no means certain that such a rail-bonus exists in reality. This effect was not taken into account in the valuation of railway noise for the STCC study. It should be noted that a more recent, and very comprehensive, hedonic pricing study has attempted to value transport-related noise in Birmingham (Bateman et al, 2004)[27]. The results of this study indicate that householders in Birmingham place a greater value on reductions in railway noise than on road traffic noise. It is clear that these findings contrast with the above-mentioned previous research. The relationship between reported annoyance and Willingness To Pay requires further research to resolve this anomaly.

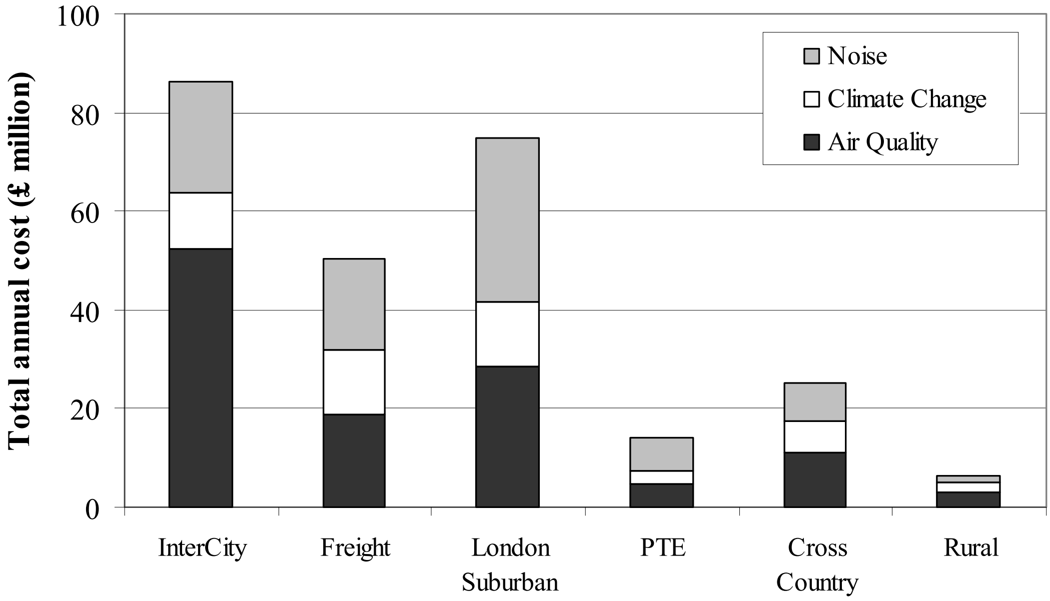
4.2.4.2 Valuing the impacts of railway noise

In order to value the impacts of environmental noise, the majority of studies use a technique known as hedonic pricing. This methodology examines properties where differences in noise levels are reflected in the market value of the property in order that a relationship (known as the Noise Depreciation Sensitivity Index (NDSI)) between average noise levels and changes in property prices can be determined. The NDSI is usually quoted in terms of the percentage reduction in property value for a 1 dB increase in noise levels. For the Surface Transport Costs and Charges study, the values of NDSI used were 0.2% (low), 0.436% (central), and 0.67% (high).

4.2.5 Environmental costs of rail transport as assessed using the STCC methodology

Using the valuation methodologies detailed in the foregoing sections, the total environmental costs for both the rail and road sectors were estimated. Furthermore, it was possible to calculate the environmental costs per kilometre travelled, with further disaggregation by vehicle type. For rail operations, the total annual environmental costs were calculated for intercity, freight, London suburban, Passenger Transport Executive, Cross Country, and Rural services, along with the environmental costs per train kilometre travelled. The rail results from Surface Transport Costs and Charges are reproduced below.

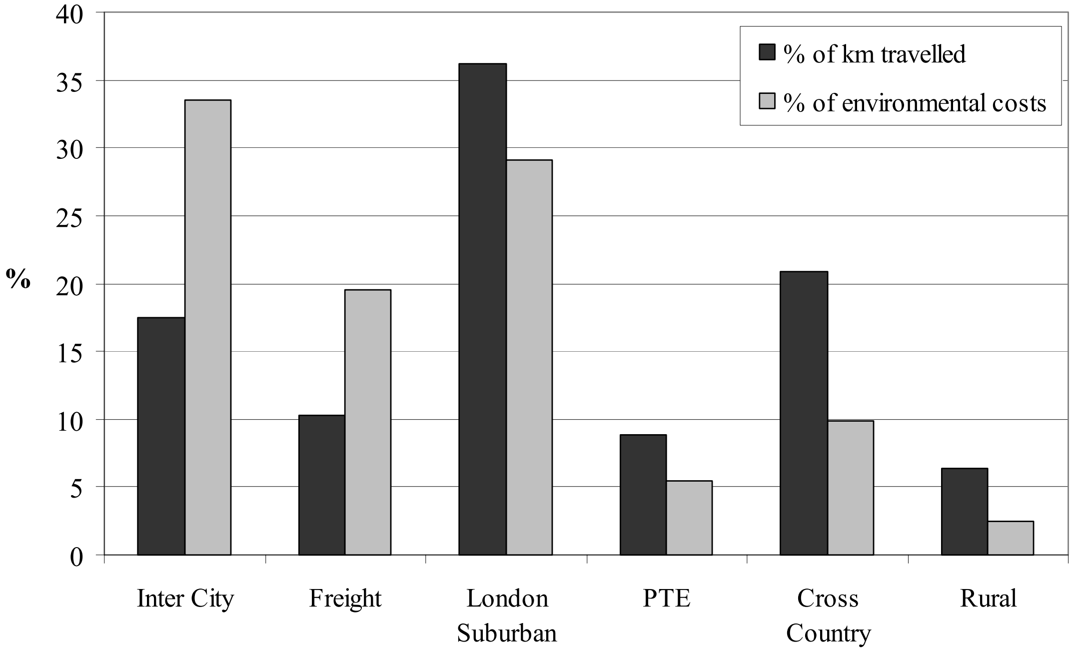
Figure 4.1: Total environmental costs for the rail sector (1998) by service type



Source: Surface Transport Costs and Charges 1998

As can be seen from the figure above, inter-city services have the largest total environmental costs, followed by London suburban services and freight operations. In most cases, the analysis showed that climate change costs were relatively low compared to air pollution costs and noise costs, although it should be noted that climate change costs would account for a much greater proportion of total environmental costs if updated CO_2 damage cost values were used. Air pollution costs dominated the environmental impacts of inter-city rail operations, and accounted for a significant proportion of the environmental costs for all other types of service. When the proportions of total environmental costs accounted for by each type of service are compared to the proportion of total train kilometres travelled across the whole network, it can be seen that both inter-city and freight operations were found to account for a much higher share of the environmental costs than their share of train kilometres might initially suggest (see Figure 4.2). For inter-city services the higher environmental costs can be explained by the increased energy required to travel at high speeds when compared to the energy requirements of commuter, cross country, and rural services.

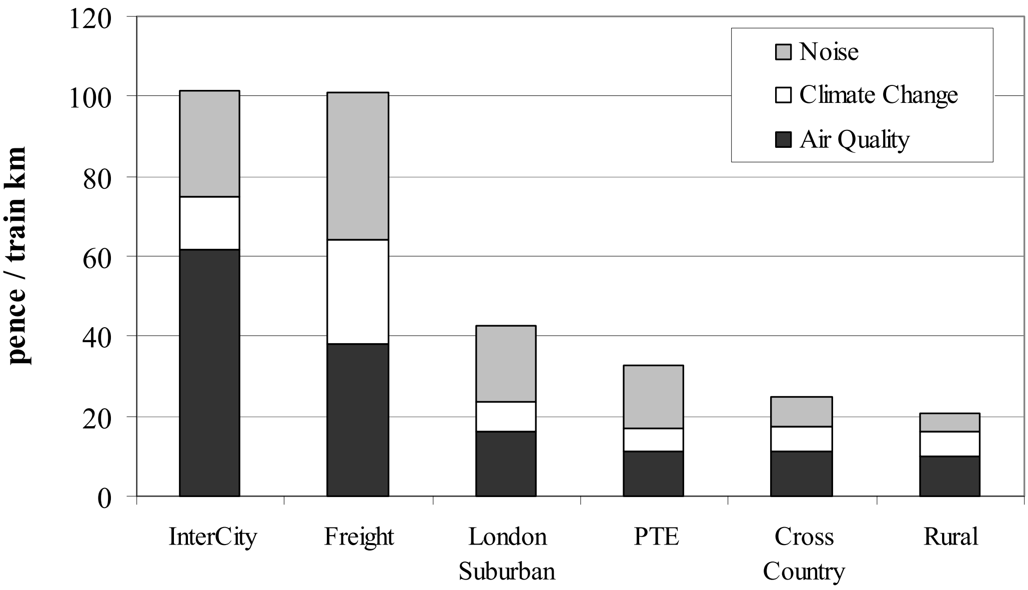
Figure 4.2: Proportion of total rail environmental costs and total train kilometres travelled by train type (1998)



Source: Surface Transport Costs and Charges 1998 (Department for Transport)

Data on the environmental costs per train kilometre travelled for different types of service are presented below in Figure 4.3, and it can be seen that the total costs for inter-city and freight services in 1998 were far higher (at just over £1.00 per train kilometre travelled) than any of the other service types. London suburban services were found to have the next highest environmental costs, but at approximately 42 pence per train kilometre, these costs were significantly less than half of the costs associated with intercity and freight services. As might be expected, rural services have the lowest costs; by their nature, rural services operate through areas of the country with low population densities, and hence the environmental impacts and costs tend to be lower.

Figure 4.3: 1998 environmental costs (per train kilometre travelled) for different types of rail service



Source: Surface Transport Costs and Charges 1998 (Department for Transport)

4.3 External Costs of Transport in Western Europe (INFRAS)

4.3.1 Overview of the study

In 2000, the Swiss consultancy INFRAS, in association with the University of Karlsruhe carried out a study for the International Union of Railways (UIC) to examine the external costs of transport (INFRAS, 2000)[21]. In a similar manner to the Surface Transport Costs and Charges project, this study examined not only the environmental costs of transport, but also the accident and congestion costs associated with all modes of transport. The study provided details of the external costs of transport across Western Europe for the year 1995. In 2004, UIC commissioned INFRAS to update this study with data for the year 2000 (INFRAS, 2004)[22]. The following sections provide a description of the methodology used in the updated study for valuing environmental costs, as well as providing some of the results from the study. All values are reported in Euros with conversion to Pound Sterling using an assumed exchange rate of €1.65 for every £1.00 (this was the average exchange rate for the year 2000).

4.3.2 Climate change valuation methodology

4.3.2.1 Quantifying CO_2 emissions from rail vehicles

CO_2 emissions from the rail sector were estimated for each country using a combination of traffic volume data from UIC statistics, and rail emission factors from the EC's TRENDS1 (**TR**ansport and **EN**vironment **D**atabase **S**ystem version **1**) database. Emissions data were obtained for both passenger and freight rail for each country.

4.3.2.2 Valuation of CO_2 emissions

The climate change valuation methodology used in the INFRAS study differs substantially from that used in STCC. Whereas the STCC study used values for the damage (or social) costs associated with carbon dioxide emissions, the INFRAS study used the marginal abatement costs associated with CO_2 emissions (i.e. the cost to avoid emitting one tonne of CO_2). This is an important difference, and highlights variations in the methodologies that can be used for valuing CO_2 emissions. For this study, INFRAS used an upper value €140 per tonne of CO_2 avoided, and lower value of €20 per tonne of CO_2 avoided. Data on CO_2 emissions from the rail sector were obtained from UIC statistics.

4.3.3 Air pollution valuation methodology

4.3.3.1 Quantifying emissions of air pollutants

As for CO_2 emissions, railway air pollutant emissions were quantified using UIC data for traffic volumes, in combination with TRENDS1 data for rail emission factors for the following pollutants: NO_X, PM_{10}, CO, non-methane VOCs, CH_4 (methane), and SO_2. The next step was to estimate the proportion of the population exposed to air pollution for each country. Two approaches can be used: a detailed, bottom-up approach that examines emissions and exposure levels to each pollutant for each country included in the study, or a simplified, top-down approach using one pollutant as a "tracer" pollutant which can be used to represent exposure to all other pollutants as well. Within the scope of the study, it was this second approach that was used, with PM_{10} being used as the tracer pollutant. Population exposure to PM_{10} was estimated for each country, and this data was used as the basis of estimating exposure to all other air pollutants.

4.3.3.2 Valuation of the impacts of air pollutant emissions

As with the STCC study, INFRAS considered three main parameters in order to value the impacts of air pollution; these were impacts on human health, damage to buildings, and damage to crops. With respect to impacts on human health, the values presented in Table 4.2 below were used in the study. It should be noted that the costs given in the table are in 1995 prices; these were updated to 2002 prices using GDP deflators.

Table 4.2: Average European values for the valuation of air pollution health costs (1995 prices)

Impact	Value		
Long-term mortality	€ 915,000	*(£554,545)*	per life lost
Respiratory hospital admission	€ 7,870	*(£4,770)*	per admission
Cardiovascular hospital admission	€ 7,870	*(£4,770)*	per admission
Chronic bronchitis incidence	€ 209,000	*(£126,667)*	per case
Bronchitis (children younger than 15 years)	€ 131	*(£79)*	per case
Rrestricted activity days	€ 94	*(£57)*	per day
Asthmatics: asthma attacks (children < 15 years)	€ 31	*(£19)*	per attack
Asthmatics: asthma attacks (adults >= 15 years)	€ 31	*(£19)*	per attack

Source: INFRAS/IWW (2000), World Health Organisation (1999)

After calculating the total environmental costs of transport related air pollution, these costs were allocated to different transport modes based on each mode's share of total PM_{10} emissions.

4.3.4 Noise valuation methodology

4.3.4.1 Quantifying the proportion of the population exposed to environmental noise

Data on the number of people exposed to noise above particular levels was based on data compiled by the OECD as part of their Environmental Compendium (OECD, 1993)[28]. This data was updated and supplemented with more recent data from specific national studies. With regard to exposure to rail noise, updated values were obtained from the EC-funded STAIRRS study (STAIRRS, 2003)[29]. There were problems in obtaining complete datasets for all countries, and hence it was necessary to estimate values for some countries by using extrapolation techniques. The noise exposure data used in the study is presented below in Table 4.3.

Table 4.3: National populations exposed to railway noise, as used in the INFRAS study

	Number of people exposed to different levels of railway noise (millions of inhabitants)				
Country	**55-60 dB**	**60-65 dB**	**65-70 dB**	**70-75 dB**	**>75 dB**
Austria	0.10	0.05	0.04	0.03	0.02
Belgium	0.52	0.31	0.14	0.05	0.02
Denmark	0.08	0.05	0.02	0.01	0.00
Finland	0.02	0.01	0.01	0.00	0.00
France	0.22	0.23	0.11	0.06	0.05
Germany	8.57	5.11	1.90	0.58	0.08
Greece	0.08	0.04	0.01	0.01	0.00
Ireland	0.03	0.02	0.01	0.00	0.00
Italy	3.59	2.59	1.35	0.42	0.18
Luxembourg	0.02	0.01	0.01	0.00	0.00
Netherlands	0.67	0.14	0.04	0.03	0.02
Norway	0.02	0.00	0.01	0.00	0.00
Portugal	0.36	0.21	0.10	0.04	0.02
Spain	0.49	0.30	0.14	0.05	0.02
Sweden	0.24	0.13	0.05	0.01	0.00
Switzerland	0.48	0.22	0.11	0.05	0.01
UK	0.66	0.50	0.16	0.04	0.02

Source: INFRAS/IWW (2004) (primary sources, OECD Environmental Compendium and EC STAIRRS project)

4.3.4.2 Valuation of the impacts of railway noise

In the STCC study, society's willingness to pay for reductions in noise levels was the only metric taken into account when trying to estimate the environmental costs associated with transport noise. The INFRAS study has also used a WTP approach, but this has also been supplemented with estimates of the health costs associated with prolonged exposure to transport noise. With regard to WTP values, data from Germany were used as reference values, and these were assumed to be representative of Europe as a whole. The values used in the study are given below in Table 4.4. It is worth noting that the INFRAS approach to noise valuation takes into account the likelihood that higher levels of noise will cause more damage, and therefore will incur greater costs. As can be seen in the table, higher noise levels have higher WTP values associated with them. This is a different approach to that used in the STCC study, where all changes in noise levels above 55 dB(A) were assumed to have the same unit damage cost. It is thought likely that the INFRAS approach more closely represents the true situation. It is also worth noting that the INFRAS study takes into account the "rail-bonus", which was referred to (but not used) in the STCC study. The rail bonus relates to the findings from some studies that railway noise is less annoying, and causes less disturbance than road traffic noise or aircraft noise. In the table below, it can be seen that this was taken into account in the INFRAS study by shifting the noise costs for rail by one category when compared to road and aircraft costs (thereby equating to a 5-10 dB benefit for railway noise).

Table 4.4: Willingness To Pay (WTP) values for reductions in transport noise, as used in the INFRAS study

Mode	Willingness To Pay values for reductions in Transport Noise in different noise level bands (€ per dB reduction per person) (values in brackets converted to £)				
	55-60 dB	60-65 dB	65-70 dB	70-75 dB	>75 dB
Road and aircraft noise	€ 53 *(£32)*	€ 159 *(£96)*	€ 265 *(£161)*	€ 371 *(£225)*	€ 477 *(£289)*
Railway noise	€ 0 *(£0)*	€ 53 *(£32)*	€ 159 *(£96)*	€ 265 *(£161)*	€ 371 *(£225)*

Source: INFRAS/IWW (2004). Conversion of values from Euros to Pound sterling assumes exchange rate of €1.65 to £1.00.

4.3.5 Other environmental costs

Unlike the STCC study, the INFRAS study also included the environmental costs associated with impacts of railway operations on nature and landscape. These impacts include land-take issues, visual impacts, soil and water pollution. The study makes clear that it was not possible to provide full cost data for these environmental impacts as it is not possible to quantify some of the impacts on nature and landscape. The detailed methodology used for estimating these wider impacts is not considered further in this review, although it should be noted that the summary of rail's environmental costs presented in the following section does include these wider impacts.

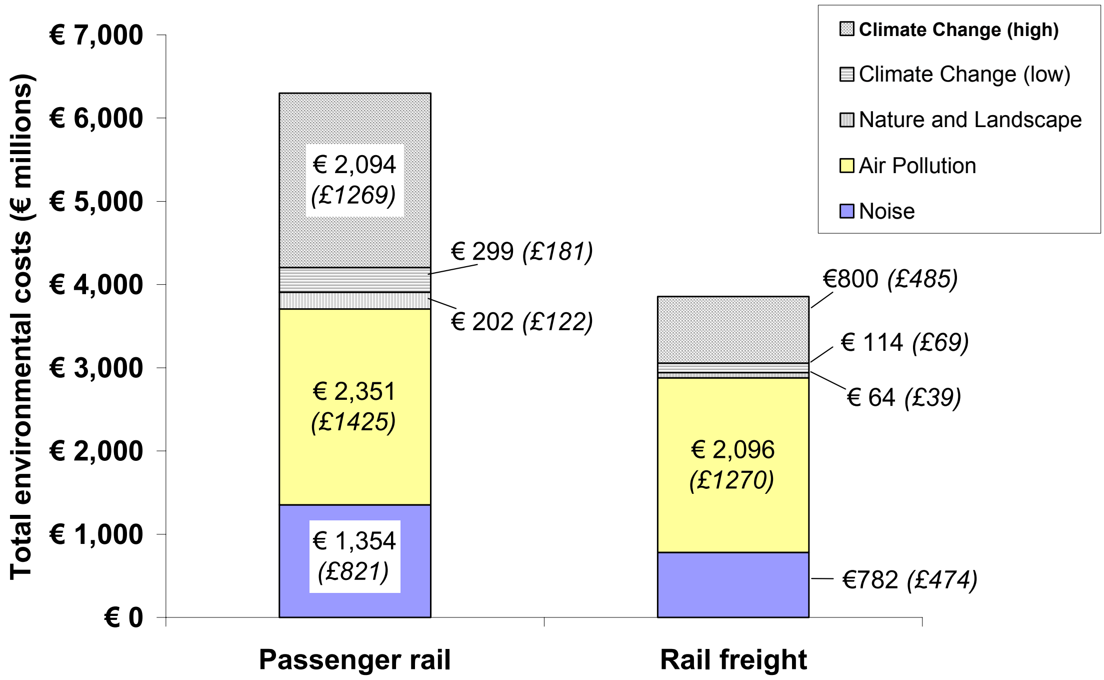
4.3.6 External costs of rail transport as assessed using the INFRAS methodology

Some of the results from the INFRAS study are reproduced below. Figure 4.4 provides details of the total environmental costs of rail transport across the 17 European countries included in the study. The total costs vary depending on which value is used for the costs of avoiding CO_2 emissions (lower value of €20 (£12) per tonne of CO_2, and upper value of €140 (£85) per tonne of CO_2); for passenger rail, the total environmental costs range from €4.2 billion to €6.0 billion (£2.5 billion to £3.6 billion), whilst for freight operations, the costs range from €3.1 billion to €3.7 billion (£1.9 billion to £2.2 billion).

As can be seen from the chart, air pollution costs make up the largest proportion of environmental costs for both passenger and freight rail operations. For passenger operations, the costs of air pollution account for between 29% and 56% of all environmental costs (depending on whether low or high values are used for CO_2 avoidance costs). For freight operations, air pollution costs account for between 56% and 69% of all railway environmental costs. Noise costs are a significant contributor to total costs, accounting for between 23% and 32% of passenger rail's environmental costs and for between 21% and 26% of rail freight environmental costs. The proportion accounted for by climate change costs is heavily dependent on the choice of avoidance cost used for CO_2 emissions. Using the low value of €20 per tonne of CO_2, climate change costs account for 7% of passenger rail's environmental costs, and around 4% of rail freight costs. Using the higher value of €140 per tonne of CO_2, the proportion of environmental costs accounted for by climate change costs increases dramatically; 34% of the total costs of passenger rail are due to climate change costs, whilst the figure is 21% for freight operations. It is clear from the figures that nature and landscape costs account for only a very small proportion of the total environmental costs associated with rail transport. For passenger operations, nature and landscape costs account for between 2% and 5% of total environmental costs. The corresponding range for freight operations is 2% to 3%.

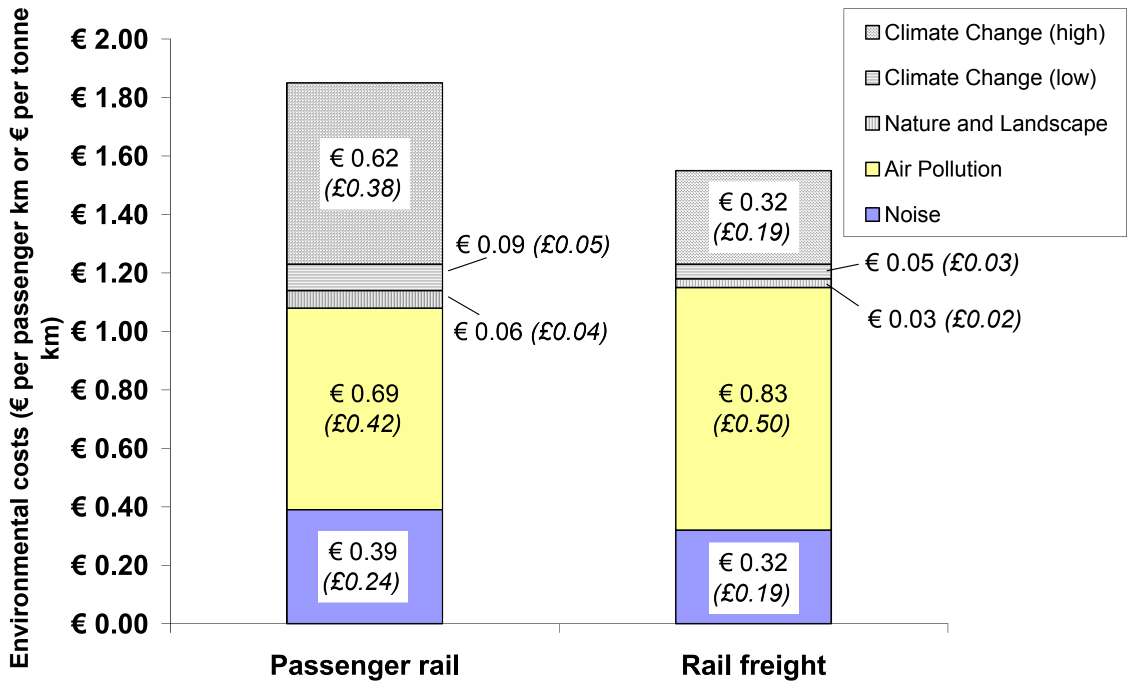
Figure 4.5 gives details of the average environmental costs (per passenger km or per tonne kilometre) associated with rail transport, as calculated in the INFRAS study. With a low estimate for the costs of abating CO_2 emissions, the average total environmental costs of passenger rail have been estimated to be €1.23 (£0.75) per passenger kilometre, rising to €1.76 (£1.07) per passenger kilometre if the upper CO_2 abatement cost of €140 per tonne is used. For freight operations, the costs range from €1.23 (£0.75) per tonne kilometre (low CO_2 abatement cost) to €1.50 (£0.91) per tonne kilometre (high CO_2 abatement cost).

Figure 4.4: Total environmental costs associated with rail transport, Year 2000



Source: INFRAS/IWW (2004)

Figure 4.5: Average environmental costs per passenger kilometre and per freight tonne kilometre for rail transport, Year 2000



Source: INFRAS/IWW (2004)

4.4 Level of confidence in the values presented in the STCC and INFRAS studies

The STCC study and the INFRAS study have both provided detailed information on the environmental impacts of railway operations, and the external costs associated with these environmental impacts. It must, however, be recognised that whilst the two studies are to some extent comparable, the scope of each study is different, and different valuation methodologies have been used to estimate the total and average environmental externalities associated with rail.

The STCC study focuses solely on the externalities of transport in the UK and does not include data from other countries. The INFRAS study on the other hand provides average data on environmental external costs across 17 European countries (figures for the environmental externalities for individual countries are not reported in the study), and hence it is difficult to compare the results directly. There will clearly be differences in the external costs of rail transport in different countries due to differences in the proportion of diesel vs. electric traffic in each country, differences in rolling stock, and the operational performance of rail transport in each country (e.g. total train kilometres travelled, passenger load factors, etc). It should also be noted that the INFRAS study reports average environmental externalities in terms of costs per passenger kilometre or per freight kilometre travelled. The STCC study, on the other hand, quotes average externalities in terms of costs per *train* kilometre travelled.

The two studies are also now based on relatively old data. Surface Transport Costs and Charges was carried out in 2001 and used 1998 data on transport activity to estimate the total and average environmental externalities associated with different transport modes. The INFRAS study was carried out in 2004 and uses data from 2000 to estimate the total and average environmental externalities of transport.

In addition to this limitation, the methodologies used for valuing the environmental impacts of rail transport in the two studies include some notable differences. The methodology used for valuing the CO_2 emissions is very different (social cost of carbon in the STCC study vs. marginal abatement cost in the INFRAS study), and there have been a number of updates to the values used since these studies were carried out. There are also some differences in the methodologies used for valuing air pollutant impacts and noise impacts.

All of these issues mean that it is recommended that the data from STCC should be used in preference to the INFRAS study, primarily because the valuation methodologies used in the STCC study are closer to current UK practice. It should be noted that there is a high level of confidence in the quality of the outputs from the INFRAS study, but that its strong European focus means that it is less directly relevant to the situation in the UK. Whilst the broad findings from INFRAS study are similar to the STCC study, the fact that the detailed methodologies used for valuing environmental impacts are different means that the study is of less relevance to the UK situation. However, there are still some limitations with regard to how applicable the results of the STCC study are to the situation today. In particular, it must be recognised that the figures used for valuing the impacts of climate change have been comprehensively revised since the STCC study was carried out, and are due to be revised again later this year. There have also been some changes to the figures used for valuing air pollution impacts and again, a revised set of figures is due to be released later this year. The methodology used for valuing noise impacts has not changed, but the Noise Depreciation Sensitivity Index used in the STCC study takes account of average UK house prices. Since 1998, there have been very large increases in house prices which means that the value of noise impacts will have increased significantly as well. In general, it can be stated that there is a high level of confidence in the results of the STCC study, **based on the methodologies and values used at the time.** However, there is a need to update the findings of this work with more recent railway activity data and with the latest values for climate change, air pollution, and noise impacts. It is thought likely that if the environmental externalities of rail transport in the UK were calculated again for a more recent year (say 2004) using the latest valuation methodologies and railway activity data, then the total and average environmental external costs would be higher than the values estimated for 1998 using the STCC methodology. It is difficult to estimate how much higher the costs would be without carrying out further, more detailed analysis of railway activity data.

5 Current use of monetised environmental impacts

5.1 Overview

Some of the key documents that refer to the use of monetised environmental impacts are the UK Government's White Paper on Transport 'a New Deal for Transport' and the 1999 SACTRA report on "Transport and the economy". In the latter, SACTRA called for comparisons of price and marginal social cost to be made for a range of contexts, in order to understand the degree to which transport pricing covers external costs, and so to move "towards a more efficient allocation of resources in the economy". Similarly, the European Commission has sought to promote transport infrastructure pricing based on marginal social costs in its green and white papers (European Commission 1995[30], 1998[31], 2001[32]); e.g. the Green Paper 'Towards fair and efficient pricing in transport'). A "High Level Group" on infrastructure charging was established and this identified the need for empirical evidence on existing prices and marginal social costs. This has led to a number of countries, including Austria, Finland, Spain, Sweden and the UK, to initiate studies on the social costs of transport use.

In response to these initiatives, the Department of the Environment, Transport and the Regions (now DfT) commissioned the Surface Transport Costs and Charges project (ITS Leeds 2001[20]) to assess these costs and to look at transport policy development in relation to charging, taxation and subsidy. This updated earlier work on road transport externalities (for DETR on Lorry Track and Environmental Costs (NERA 2000[33])).

The current use of externality values can be split into two main categories:

- Those based on specific environmental externalities, such as greenhouse gas emissions (social cost of carbon), air quality or noise;
- Those that capture all environmental externalities related to transport (greenhouse gas emissions, air quality, and noise together).

There are also two main applications across UK government for the values.

- Firstly, and most commonly, for use in appraisal – particularly in regulatory impact assessments;
- Secondly, in the design of taxes and charges.

This chapter summarises these applications.

5.2 Greenhouse Gas Emissions

Traditionally the policy debate on climate change has focused on the costs of emissions reductions, i.e. the mitigation of greenhouse gas emissions. For externalities, it is the cost of climate change impacts that is important (the social costs from climate change actually occurring), known as the **Social Cost of Carbon (SCC)**.

The SCC is the marginal global damage cost of carbon emissions. It is usually estimated as the net present value of the impact over the next 100 years (or longer) of one additional tonne of carbon emitted to the atmosphere today. This should not be confused with the total impact of climate change or the average impact (the total divided by the total emissions of carbon). The SCC is expressed as the economic value (in US$, € or GB£) per tonne of carbon (tC).

Since the Surface Transport Costs and Charges project was carried out, the recommended value for the social cost of carbon has been comprehensively revised. In early 2002, the UK Government Economic Service (GES) paper *Estimating the Social Cost of Carbon Emissions*

(GES, 2002)[34] presented a review of the available literature on the social cost of carbon (SCC). The GES paper suggested a value of £70 per tonne of Carbon (within a range of £35 to £140 per tonne of Carbon) as an *illustrative* estimate for the global damage cost of carbon emissions. It is important to note that these figures relate to ***carbon*** and not carbon dioxide. Converting to obtain figures for CO_2 emissions, gives a value of £19 per tonne of CO_2 (within a range of £9.50 to £38 per tonne of CO_2). It also suggested that as the costs of climate change are likely to increase over time, the estimates should rise in real terms by £1 per tonne of Carbon (£0.27 per tonne of CO_2) per year. In the STCC study, a much lower value of £14.60 per tonne of CO_2 was used, and hence it can be inferred that perhaps the STCC study undervalued the climate change impacts associated with road and rail transport.

There has been widespread use of the GES values for the social costs of carbon across Government, including in the transport area. Selected applications are summarised below and include appraisal and the setting of taxes and charges, with a number of examples in the transport sectors.

Table 5.1: Selected applications of the social cost of carbon emissions in policy development and scheme appraisal

Organisation	Application	Notes
Defra	F Gas Regulatory Impact Assessment	Use of £35 - £140/tC. Number makes large difference to RIA of specific options
	Cost-benefit analysis of UK ETS	
	Used in consideration of waste tax charges as part of the review and consultation	Use of £35 - £140/tC.
	Used in cost-benefit analysis of options for reducing emissions from road transport	Use of £70/tonne of carbon, rising by £1/tonne of carbon per year
Department for Transport	**Preliminary use in New Approach to Appraisal for Road Transport infrastructure appraisal**	**Use of £35 - £140/tC. Social Cost of carbon is very low in relation to other costs or benefits in appraisal results**
	Incorporation into National Transport Model/Social Pricing Model	**Use of £35 - £140/tonne of Carbon, with central £70/tonne of carbon.**
	Used in Aviation White Paper, for possible aviation tax	**Use of £70/tC, rising by £1/tC per year to give £100/tC for 2030**
	Considered in analysis on road user charging and consultation paper	
Department of Trade and Industry	Energy White Paper	Use of £70/tC as a benchmark for costs of options to 2020
	Use in current RIA for Renewables Obligation II	
Office of the Deputy Prime Minister	Social cost of carbon is factored into ODPM proposals for amendment to Part L (energy efficiency provisions) of the Building Regulations.	Use of 0, £70/tonne of carbon and £140/tonne of carbon

Organisation	Application	Notes
(ODPM)		
Ofgem	Energy investment, notably gas network extension, some consideration of electricity transmission infrastructure (e.g. distribution losses under the distribution price control)	Use of 0 - £35/tC
Environment Agency	Asset Management Programme 4 (AMP4)	

The GES paper recommended periodic reviews of these illustrative figures as new evidence became available. Defra is currently reviewing the social cost estimates, and is planning to update the values in the summer of 2005.

The European Commission appeared to have adopted an alternative approach for shadow prices for carbon emissions, and have switched to the use of marginal abatement cost values in many policy assessments. It must be stressed that the European approach to valuing the carbon emissions is different to the UK approach. Whilst the UK approach takes into account the ***social costs*** associated with an additional tonne of carbon, the EC approach is based around providing a value for the ***cost of abating*** a tonne of CO_2. The EC marginal abatement costs have been calculated at €12 per tonne of CO_2 in 2010, €16 per tonne of CO_2 in 2015, and €20 per tonne of CO_2 in 2020. This equates approximately to £30[c] per tonne of Carbon in 2010, £40 per tonne of Carbon in 2015, and £50 per tonne of Carbon in 2020. These costs are from the report of the European Climate Change Programme (ECCP, 2001)[35]. The report identified 42 possible measures, which could lead to some 664-765 MegaTonnes of CO_2-equivalent emissions reductions that could be achieved against a cost lower than €20/tonne CO_2eq. This is about double the emissions reduction required for the EU in the first commitment period of the Kyoto Protocol with respect to 1990. These values were used to provide approximate costs for future policy (i.e. post Kyoto) for a 2020 scenario, and the likely costs for 2010 of meeting Kyoto.

5.3 Air Quality

There are no current formal values for air quality externalities used across Government (as for the social cost of carbon), but there has been some guidance on the appropriate approach for quantification and valuation.

The guidance on the quantification of health impacts from air pollution was covered in reports of the UK Department of Health's *Committee on the Medical Effects of Air Pollutants (COMEAP 1998[36]: 2001[37,38])*. These recommend quantification of deaths brought forward, respiratory hospital admissions, and chronic mortality for particulates (including secondary particulates) and deaths brought forward and respiratory hospital admissions for ozone and SO_2. The valuation of these impacts was discussed in the UK Department of Health's Ad-Hoc Group on the Economic Appraisal of the Health Effects of Air Pollution and conclusions were published in the EAHEAP report (EAHEAP, 1999[39]). Defra has recently published a research project specifically looking at health impact valuation in the air quality context (Defra, 2004[40]) and new guidance will be emerging soon.

The air quality values have been used in a number of applications, particularly in appraisal and evaluation. The approach was used in the appraisal for the air quality objectives (IGCB, 1998), and the revision of the particle objective (IGCB, 2001[41]) – which included a strong focus on the

[c] 2004 average exchange rate of €1.47 for every £1.00 has been used to calculate the Pound Sterling figures reported in this section of the report.

transport sector. The numbers have also been used in the cost-benefit analysis of certain schemes, such as the Low Emission Zone proposal for London (Watkiss et al, 2003[42]).

The values generated by the STCC study have been used by DfT for road policy development and appraisal.

- They have been incorporated into the National Transport Model (NTM)/Social Pricing Model.
- The values were used in the analysis on road user charging and consultation paper
- They were used in a preliminary update on the New Approach to Appraisal (NATA) for Road Transport infrastructure appraisal.

The values in the NTM model were updated in 2004, in order to be consistent with the updates to the methodology included in the Air Quality Strategy Evaluation. It is worth noting that there have been recent moves to include rail in a fully integrated NTM model. For the rail sector this means that the same air quality values (and Social Cost of Carbon values) as for the road analysis are being used to quantify rail's impacts within the model. Similarly, it is possible that the values in use in NATA would be extended to include rail schemes in GOMMMS (Guidance on the Methodology for Multi-Modal Studies).

For the **rail sector** there are some specific examples of the analysis of externality values. In particular, air quality values were investigated by Network Rail (as Railtrack) in **enhancement schemes**, although we understand that the application of the analysis was limited.

Environmental costs were in place for **Sensitive Lorry Miles values** (SLM) used for **Freight Facilities Grants** and **Track Access Grants** to compensate for the external costs of road freight. These values were reviewed in 2001 by the SRA[d]. The initial proposals as part of this review were not consistent with the values in the STCC study – indeed the SRA commissioned additional research to derive different figures to those in use by DfT. The new SLM values were published in 2003[e] and use an Environmental Benefit Calculator[f].

The STCC values were used in the recommended guidance from the SRA on **Environmental Appraisal**. This was published as an SRA document[g], and aims to provide a consistent approach to appraising passenger rail and rail freight proposals. The new criteria are to be used by the SRA (and its successor organisations) in assessing priorities and also by external agencies (for example local authorities) that might wish to propose investments in rail.

At a European level, there has been some generic use of air quality externalities. In February 2001, the EC published the Community guidelines on state aid for environmental protection, which explicitly foresee that "Member States may grant operating aid to new plants producing renewable energy that will be calculated on the basis of the external costs avoided." The estimates provided were based on the European ExternE study results. There is no equivalent policy support mechanism for rail at a European level.

Customs and Excise have been considering duty differentials for the rail sector, based on fuel type (Customs and Excise, 2003[43]), which has included analysis of environmental costs for air

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[d] This updated previous work for SRA on this areas. For example: Public Support for Rail Freight: A Consultation Document. 22 August, 2000.Details of Externalities (Public Interest Advantages), which used a review of the material from the Lorry Track and Environmental Costs and the OXERA analysis for the railway forum. The work was undertaken by Arup.

[e] http://www.sra.gov.uk/news/2003/5/first_new_slm_values_since_1996_show_tru

[f] The information on the Freight Facilities Grants and Track Access Grants are available at http://www.railfreightonline.com/the_guide/sra_grant/

[g] http://www.sra.gov.uk/pubs2/stratpolplan/appcrit03/appraisal03

pollution[h]. This has not led to firm proposals as yet, though there may be a 'modest duty differential' in favour of red diesel with a sulphur content of less than 0.005 per cent (50ppm)[i].

5.4 Noise

There have been fewer applications of external costs for noise in the UK. Most of the applications are constrained to the analysis in appraisal (consistent with the applications above in DfT relating to road transport and the SRA with respect to SLM and appraisal). Again, there is a current review of the values for application in NATA, although the fundamental methodology has not changed since the STCC study. The underlying survey work on the valuation of noise has been progressed (through DfT funded hedonic price studies).

Review of road transport appraisal practice in the EU in 1998 (Bristow and Nellthorp 2000[44]) has found that 6 of the EU 15 countries placed a monetary value on noise. A recent update of this work for the HEATCO project (Odgaard *et al.,* 2005[45]) which reviewed practice in the EU 25 (plus Switzerland, but excluding Luxembourg) identified 13 countries which apply a value to noise in appraisal of which 8 are from the original 15 (Austria, Denmark, Finland, France, Netherlands, Sweden and Switzerland) and 5 are new entrants (Czech Republic, Hungary, Lithuania, Poland and Slovenia).

[h] At a European level, there is Directive 2003/96/EC *Restructuring the Community Framework for the Taxation of Energy Products and Electricity.* This Directive meets the Commission's obligation under the Mineral Oils Directive 92/82/EEC to review the minimum rates of excise duty on mineral oils.

[i] A precedent for this exists in the road transport sector, for example, the *Bus Service Operators Grant* was adjusted to give financial incentive towards low-sulphur diesel.

6 Ongoing work in the UK and Europe on the monetisation of the environmental impacts of transport

6.1 Overview

The externality assessments have continued to change, as the scientific and economic information has improved. A number of major studies have taken place since the STCC study in the UK and Europe – particularly in relation to air quality externalities. The most important of these are summarised below, together with a case study showing the approach taken by Japanese railways.

6.2 Interim updates to the UK values

A number of revisions have occurred in the UK since the STCC work. The IGCB (Inter-departmental Group on Costs and Benefits – a cross government working group included Defra, DfT, DoH, DTI) provided some updates in the review of the particle objective in 2001. More recently, the approach was updated for the Air Quality Strategy Evaluation (Watkiss, 2005[46]). This assessed the monetary benefits of air pollution policy – and air quality improvements in the UK over the past decade – focusing on the road transport and electricity generation sector. DfT has adopted the values in this work in its revision to the National Transport Model. Note this model now includes rail transport as well as road transport.

6.3 European Research Studies

Earlier work by DG Research under the ExternE Transport Projects has been updated within the research projects UNITE (Bickel et al, 2003[47]). This is being taken forward for appraisal through the current DG Research Project 'HEATCO'.

6.4 European Policy work – CAFE and DG Environment

In May 2001, the European Commission launched the Clean Air for Europe (CAFE) Programme. This will lead to the adoption of a Thematic Strategy on Air Pollution, fulfilling the objectives of the Sixth Environmental Action Programme to develop long-term, strategic and integrated policy advice for '*achieving levels of air quality that do not give rise to significant negative impacts on, and risks to human health and the environment';* including '*no exceedance of critical loads and levels for acidification or eutrophication'*. Using results from the CAFE analysis, the European Commission will present its Thematic Strategy on Air Pollution during the second half of 2005, outlining the environmental objectives for future European air quality policy and measures to be taken to achieve these objectives.

The CAFE programme (DG Environment) has progressed the analysis of externalities from air pollution, building largely on the EC-funded ExternE project work. Under the CAFE CBA project (http://www.cafe-cba.org/), a new and updated methodology for air quality externalities has been produced (CAFE CBA, 2005[48]). This has been used to value the air quality changes proposed under the Thematic Strategy, and has been used to produce externalities for transport (for road and rail). It is expected that this approach will be used more consistently across European policy in relation to air quality externalities.

6.5 Revision of the Social Cost of Carbon

There is currently a major review in the UK of the social cost of carbon (for valuing greenhouse gas emissions). This is due to report this summer (see http://socialcostofcarbon.aeat.com/) and will lead to a new set of published values for use in appraisal and taxation across Government.

6.6 Revision of the UK analysis (Air Quality Review)

The most recent update (still ongoing) is on the revision to the methods for air quality externality assessment in the UK. The IGCB is developing an update to the method that includes the new valuation studies and modelling work, as part of the UK Air Quality Review. The work has also progressed a set of air quality damage costs (similar to the social cost of carbon) for use across Government. It is likely that these values will be published in 2005. They will be published as a set for use in appraisal, and consideration in the design of taxes and charges[j]. A set of values will be produced for the road transport sector. At present there are no plans to produce a specific set for the rail sector, though this would be possible.

6.7 Revision of Noise Externalities

Recent consultation by DfT has been working towards new guidance for noise valuation[k]. This follows work commissioned from the University of East Anglia to undertake research into the value of transport noise in Birmingham, combining hedonic pricing methods and an advanced GIS approach to noise mapping (Bateman *et al,* 2004[27]).

6.8 Other European experience and planned future strategies

The European Union in 1992, also signed up by the European Transport Ministers and included in the Rio Declaration in the same year, formally adopted the “polluter pays principle”. It formed the basis of the commission’s 1995 Green Paper “Fair and Efficient Pricing in Transport”, and was adopted by the later 2001 White Paper on European Transport Policy for 2010. (“Policy Approach to Internalising the External Costs of Transport”.) This calls for “full internalisation of social an environmental costs of transport.” The European Parliament has also supported this principle.

The European Environment Agency’s Transport and Environment Reporting Mechanism (TERM) includes a 2002 fact sheet on the internalisation of external costs (European Environment Agency, 2002)50. Internalisation of external costs would mean that the social costs of using transport (including environmental and congestion costs) would be included, in some manner, in the prices paid for using different transport modes. The TERM fact sheet also provides information on the areas where non-fuel related taxes and charges are currently used in different Member States to provide a link between the taxes/charges and specific external costs. These areas are summarised below in Table 6.1. It should be noted that for those areas where there is a link, it does not necessarily follow that the whole external cost has been completely internalised. The data in the table shows that the majority of examples where there is a linkage between charges and externalities relate to road vehicle generated air pollution, and aviation noise. The taxes and charges that have a direct link with rail’s environmental externalities have been highlighted in the table. As can be seen, as of 2002, there were only four examples where external costs had been at least partially internalised through the use of taxes/charges. These were track access charges in Sweden and Finland that are differentiated according to marginal environmental (air pollution and CO_2 emissions) and accident costs, additional track access charges in Germany to take into account energy use, and hence CO_2 emissions, and, beyond the EU, track charge incentives to reduce noise emissions in Switzerland.

In the Netherlands, new noise pollution charges go into effect this year. Any impact above a base decibel level incurred by passenger and freight railway operators will be levied as an environmental charge to the access agreement with Prorail the Dutch infrastructure provider. This environmental charge is precipitated by the newly enacted ability of commuters throughout the Netherlands to fine Prorail for the resulting increase in noise pollution.

[j] The underlying analysis is being undertaken by AEA Technology Environment.

[k] Developing Guidance on the Valuation of Transport-Related Noise for Inclusion in WebTAG. Transport Studies Group, Loughborough University, Leicestershire and Institute for Transport Studies, University of Leeds.

Table 6.1: Links between transport taxes/charges and external costs in the EU15

Non-fuel-related taxes and charges		Austria	Belgium	Denmark	Finland	France	Germany	Greece	Ireland	Italy	Luxembourg	Netherlands	Portugal	Spain	Sweden	UK
Air pollution	Rail transport				✓										✓	
	Aviation														✓	
	Water transport				✓							✓	✓	✓	✓	✓
	Road - freight	✓	✓	✓			✓				✓	✓		✓	✓	✓
	Road - passenger		✓	✓			✓					✓		✓	✓	
CO_2 emissions	Rail transport				✓		✓									
	Aviation															
	Water transport															
	Road - freight															
	Road - passenger	✓		✓								✓				✓
Noise	Rail transport															
	Aviation		✓			✓	✓			✓		✓			✓	✓
	Water transport															
	Road - freight	✓					✓									
	Road - passenger															

6.8.1 Sweden

Sweden has an environmental charge that takes account of the level of Nitrogen Oxide emissions from diesel traction (differentiated by locomotive) and the cost of accidents (excluding those associated with level crossings).

6.8.2 Finland

Finland has marginal emission charges, set per kgtkm (and revised triennially) differentiated between passenger, diesel freight and electric freight trains. The framework is based on a study carried out in 1998 which examined the impact VR's operations in the urban and rural environments.

Finland also has a charge relating to accidents, based on a study carried out in 2000[I]. This differentiated the kind of accident and the extent to which the costs involved are captured internally by the rail system or are residual external costs. The charges are again differentiated between passenger, electric freight and diesel freight trains.

6.8.3 Switzerland

Outside the EU, Switzerland has taken a number of initiatives to reduce the noise impact of rail services, including both direct funding of noise reduction, and a reduced track access charge for vehicles. These are administered by the Swiss Federal Office of Transport. Funding for noise reduction was agreed via a Federal Act on Railway Noise Abatement in 2000, which made available funds for replacement of iron brake blocks, construction of noise barriers and installation of sound insulating windows (prioritised in that order, with the barriers and windows only where required following the former). A refund of track access charges (the 'Low-noise bonus) is in addition available to operators whose rail vehicles have been made less noisy.

[I] Internalisation of external costs of railroad accidents, (Tervonen and Juha) Finnish Rail ADMINISTRATION strategy Unit, Helsinki, 2000

6.9 Japanese Case Study

The most advanced railway in the world as to its environmental performance and programmes is the Japanese – JNR. In Japan there is not a regulatory programme for internalising environmental external costs - it is taken upon each of the national operators to demonstrate significant efforts. The following table (Table 6.3) presents the most recent annual JNR programme of investment and operating costs internalising the cost to the environment of its railway transport.

Table 6.3: JNR programme on internalising environmental externalities

Classification	**Description of the main efforts**	**Environmental preservation cost (100 million Yen)**	
		Investment amount	**Expenses**
Global environmental preservation	Introduction of energy-conserving rolling stock Energy conservation in stations and office buildings Introduction of equipment shifting away from CFCs	167.4	0.1
Research and development	Development of energy-conserving rolling stock Development related to renewable energies Development related to environmental preservation along railway lines	0.6	37.4
Resource recycling	Appropriate disposal and recycling of station and train garbage Appropriate disposal and recycling of items generated from workshops and engineering work Purchase of products that take into consideration the global environment	0.3	20.5
Environmental preservation along railway lines	Measures against noise and vibrations Appropriate management of substances that present a burden to the environment	86.2	35.1
Management activities	Environmental advertising Environmental management training (concerning the construction of environment)	-	0.6
Social activities	Support toward organizations involved in environmenta preservations	-	0.1

7 Policy initiatives on rail environmental impacts

7.1 Overview

The role of government (both EU and member state) in modifying rail environmental impacts comprises:

- Legislation to limit current impacts, and encourage focus on reducing impacts in future.
- Engagement with industry groups to encourage the development of technical and procedural initiatives to reduce environmental impacts and facilitate tighter legislation in future.
- Funding for research and pilot projects

7.2 Legislation and Incentives relating to Environmental Impacts of Railways

Legislation and incentives already in place, which serve to enforce or encourage improvements in the environmental impacts of railways in Europe, includes a range of European Commission directives. The following directives of the European Parliament and Council are relevant:

- 2001/14/EC on the allocation of railway infrastructure capacity and levying for the use of railway infrastructure and safety
- 2001/16/EC on the interoperability of the trans-European conventional rail system. This lays down technical specifications for interoperability (TSIs), which have an impact on the ongoing reduction in impacts such as noise and exhaust emissions.
- 2002/49/EC relating to the assessment and management if environmental noise.
- 2004/26/EC relating to measures against the emission of gaseous and particulate pollutants from non-road mobile machinery.
- 96/62/EC on the assessment and monitoring of air quality, which obliges the Member States to take action if the limit values for selected air pollutants are exceeded.

There is an intention to tighten legislation in the areas of noise and exhaust emissions.

An important aspect of the development of legislation is the link to assessments of technical and economic feasibility. For example, the tightening of limits under 2004/26/EC will be subject to further assessments of practicality and impact on the operation of the rail industry. Industry organisations such as UIC and CER are heavily involved in this work.

The importance of this cautious approach is demonstrated by the perverse incentives possible when imposing legislation on railways. It is believed, for instance, that local legislation on rail noise emissions has led to modal shift of freight from rail to road, increasing overall environmental impacts.

7.3 Industry initiatives

There is a range of initiatives underway across Europe to implement or develop means of reducing the environmental impact of rail. This includes both ‘best practice’ schemes implemented locally (often as part of a research programme to test feasibility) and pan-European initiatives, which are designed to both facilitate and inform the introduction of legislation. Listed below are some examples, grouped by the category of impact.

7.3.1 Improving Railway Operations

Making existing operations more energy efficient is the most promising short to medium-term strategy for reducing environmental impacts of railways. For instance, energy-efficient driving techniques offer a potential energy saving of 5-15%; this is being tested by Deutsche Bahn AG through its ‘Energie Sparen’ project. Improved traffic management and optimisation of rail flows can have similar benefits.

7.3.2 Reduction in Railway Noise

A major public criticism of railway environmental performance relates to noise. It is considered more economically and environmentally beneficial to address this problem at source: reducing emissions directly, rather than constructing noise barriers. The railway industry has identified two separate initiatives to address this. Firstly, the replacement of cast iron brake blocks with composites. There are voluntary commitments to achieve this for new vehicles. However, funding to facilitate retro-fitting on existing vehicle, in the order of 3 billion Euro, is being sought from the EU, and will be required for significant action. Secondly, increased rates of rail grinding (over and above that required for safety and maintenance) play a major part in reducing noise emissions. This approach has been recommended by the UIC, but has obvious cost implications for infrastructure maintainers. An example of best practice in controlling noise emissions is the ‘Whispering Train’ (Fluistertrein) pilot project by Railion Nederland, which is testing new technology on a commercial freight train.

7.3.3 Exhaust Emissions

The area of exhaust emissions is one where there is a high level of industry research and proactive engagement. This is linked strongly to the upcoming introduction of Stage IIIA (2006-2009) and Stage IIIB (2012) limits on emissions under the Non-road mobile machinery directive (2004/26/EC). In particular, the UIC has ahead of this legislation introduced a set of limits equivalent to Stage IIIA for the approval of new railways diesel engines. UIC is also developing a ‘Diesel Action Plan’ to support the preparation of stage IIIB in respect of technical feasibility. An example of significant reductions in diesel emissions is the SNCF initiative in Paris on ‘hot spot’ emissions’, which has combined limits on engine idling and re-motorization to reduced the regulated emissions by more than 80%.

7.3.4 Procurement Processes and Standards

Harmonised procurement processes and standards have been identified by UIC and UNIFE as a means to maintain the environmental advantage of rail without risking compromises to cost or functionality. They have therefore developed two international initiatives to develop new procurement processes PROSPER (Procedures for Rolling Stock Procurement for Environmental Requirements) and REPID (Railway Environmental Performance Indicators and Data Formats). These two project will deliver common guidelines, specifications, indicators, tools and data formats agreed by railway operators and manufacturers. This intended to allow the efficient integration of environmental aspects into future procurement.

The AEIF (European Association for Railway Interoperability) has approved the establishment of a ‘European Rail Eco-Procurement Board ’, to reinforce the implementation of these schemes.

7.4 Rail Research Initiatives

ERRAC (European Rail Research Advisory Council) was founded in 2001, with high-level representatives from the European Commission, member states, railway operators and manufacturers. They have developed a Strategic Rail Research Agenda, which includes research into technologies to further improve the environmental performance of rail. The focal points relate to the legislation listed above and their technical feasibility and facilitation of implementation.

8 Possible implications if environmental costs were translated into rail access charges

8.1 Overview

There are serious implications associated with the translation of rail's environmental costs into access charges. The most important is the potential effect on rail's competitive position as a mode. Key issues here are the magnitude of the charges in relation to existing access charges and to TOCs' overall operating costs and the ways in which the additional charges are administered (and whether they apply to the rail mode rail only). There is also the question of the effectiveness of using track charges as the mechanism for levying environmental charges. There are several potential alternative approaches, other than through access charges, which could be adopted to recover rail's environmental costs and to produce appropriate incentives to reduce environmental detriment. Each of these approaches has its advantages and disadvantages.

8.2 The magnitude of the costs and charges

The size of the additional costs, by type of train service, and based on the STCC study, is shown in Figure 4.3, with Intercity services attracting broadly one pound per train kilometre, London/suburban services 30-40 pence per train kilometre and rural / cross country services 20-25 pence per train kilometre. Table 6.2 shows that as a proportion of the access charges relating to these services, a full cost recovery environmental charge would cause increases of between 20-50% for intercity (based on analysis of MML and GNER costs), around 8% for London suburban (based on analysis of Connex South East costs), but only 4-7% for rural and cross country services (based on analysis of Cross Country Trains and Central Trains costs). As a proportion of the variable access charges, which despite being the minor proportion of the total access charges may be considered to be the appropriate comparator as they vary with activity and drive incentives at the margin, the effect would be up to five times as great.

In terms of overall train operating costs, including access charges, leasing costs, train maintenance, fuel/EC4T, crew etc the introduction of a full recovery charge for environmental costs would increase current levels by around 5-6% for intercity services, 1-2% for cross country/rural services, and 3% for London suburban services.

Freight attracts environmental costs of about a pound per train kilometre but freight access charges by train kilometre vary more than in the case of passenger services, reflecting the characteristics of each freight market sector. For instance, a Class 66/0 with an Iron Ore train is charged £9.21/train kilometre; a Class 66/0 with an automotive train is charged £1.60 per train kilometre. The application of an environmental charge on a simple train kilometre basis could therefore produce widely varying uplifts in the marginal rate. A more cost reflective application (based on the sectors/commodities) could potentially dampen that effect.

These broad figures demonstrate that the introduction of a charge which would fully recover the environmental costs would produce a material increment to the cost profile of the operating companies.

Table 8.1: Illustration of the potential impact of full environmental cost recovery – selected TOCs. Increment from environmental cost recovery as a percentage of TOC total operating costs (calendar year 2003)[m].

TOC	Total Operating Costs (£m)	Access Charges (£m)	Train Kilometres (million)	Total Costs per Train km (£ per km)	AccessCharges per Train km (£ per km)	Increment from full environmental cost recovery as a percentage of TOCs total operating costs	Increment from full environmental cost recovery as a percentage of access charges
MML	172	21	10	17.2	2	6	50
GNER	384	100	19	20	5.3	5	19
Central	275	100	30	9.2	3.3	2	7
Connex SEast	396	149	29	13.66	5.1	3	8
C/Country	450	160	26	17.3	6.1	1	4

Source: Based on Rail Industry Monitor statistics

8.3 Charging for environmental costs

In its White Paper 'European Transport Policy for 2020' (2001) the European Commission has confirmed the policy goal of internalising external costs for all modes of transport. From an economics perspective this would be an appropriate outcome, as it would help create the 'level playing field' between the modes and facilitate rational decision making by consumers and providers of transport services. However, there are several problematic issues associated with this approach, and the timescale for implementation of the policy in practice is uncertain.

In terms of industry and wider social acceptability, the introduction of these charges will need careful handling. Whatever the mechanism, such a charge is likely to be seen as a tax. Arguments based on economic rigour are unlikely to be convincing without a clear appreciation of the value of the benefits. Attempts in the UK to increase fuel duty have already led to nationwide popular demonstrations (although track access charges are less publicly visible). On the positive side, an industry seen to be behaving fully responsibly in this area, incentivising environmental good practice, should be able to develop a relevant marketing benefit.

8.4 Modal effects

The key difficulty is the potential for an additional environmental charge to make the rail mode less competitive and thereby increase overall environmental detriment. Were the rail mode to bear environmental cost internalisation on a unilateral basis (in particular, without a similar process for the road mode) the likely net effect would be the transfer of passenger and freight business from rail to road, with an overall detrimental environmental effect. However, if the principal purpose of the charge is to incentivise 'cleaner' processes and design, it might be possible to design a cost neutral approach that would explicitly recognise environmental costs without increasing total costs on 'day one', and to link this with specific measures to improve environmental performance thereafter. (Such an approach would, though, import problems

[m] Figures for Midland Main Line are March 03 to Feb 04, and for Connex South East Jan 03 to Nov 03 (45 weeks only).

relating to total cost recovery. One option is a decreasing allowance over a time period appropriate to the achievement of specified environmental improvements)

Increased access charges might be offset in the case of franchised passenger operations by the pass through (to DfT) mechanism relating to increased costs arising from regulatory changes, under the terms of the Franchise Agreements. In this case, the cost would be borne by the taxpayer. Rail freight, on the other hand, is more contractually exposed and without some new protection or offsetting factor it would experience a detrimental competitive effect.

Depending on the method of application of the charge, this effect could be more pronounced in some freight markets than in others. In general, the most pronounced effect of increasing rail's costs relative to road would be felt most in the distribution sector, where competition is fiercest and rail does not have the inherent advantages that it enjoys in the bulk markets (essentially based on efficient use of resources where sources and destinations are rail connected and high throughput yields efficient loads and capacity utilisation). These factors, as well as the size of the charges, may affect how passenger and freight operators respond to the introduction of charges.

Potentially, therefore, passenger and freight operator responses could be quite different from each other and there could be a range of responses by a single operator, particularly in the freight market.

8.5 Track access charges as the mechanism to recover environmental costs

The track access charges mechanism is a potential method of recovering environmental costs in the rail sector. The existing variable charges seem to incentivise rolling stock design.

Track access charges are paid only by train operators (or, in principle, other holders of access rights). To avoid under recovery at the rail industry level, an additional method would need to be devised to recover the environmental costs imposed by the network operator(s) and other rail industry players. Some of these are not regulated, and the upstream and downstream commercial and incentives effects of an access charges approach would need to be considered.

Access charges in Great Britain are based on the costs of network provision and levied to fund that provision. The use of access charges to recover societal costs would mark a move further away from an essentially commercial (albeit regulated) relationship between two industry parties. There is also the issue of how the charge passes through the network operator rather than being treated as part of the normal revenue stream. Where should this charge end up, and for what purpose? (Similar issues of principle re hypothecation will arise here as in the case of road user charges)

8.6 Other potential routes

There are various alternatives to the access charging route that could be considered. Each has some attractions and some drawbacks. These are described below:

8.6.1 A 'Schedule 8' type programme

Where there is environment impact attribution. This type of programme could be implemented in at least two different ways.

- as an overall 'penalty' impact system much like delay attribution where there will be net receipts taken in by the Government or Network Rail. A primary consideration here (and in some of the other options) is how the funds would be used. One could imagine a green funding pool which might be placed to reduce impacts in the immediate sense such as noise barriers, station air quality improvements, etc. Another option may be to place these funds into longer term environmental based research improvements.

- As a ‘nil sum gain’ programme addressing best performers vs. polluters, where high polluters’are charged a penalty and least impact performers recovery a benefit or bonus. This would alleviate the concern of penalizing rail relative to the much higher polluting forms of transport. These programmes would need to strongly consider the impact of environmental improvements on train operation performance, particular on the main area of impacts caused by inefficient fuel consumption practises.

8.6.2 An additional fuel surcharge

The railway industry currently enjoys the relative advantage of low fuel taxes. This approach would have the merit of simplicity and direct comparability to similar charges if introduced for the road mode. If road charges were not introduced at the same time we must address the issue of penalizing the most environmentally friendly transport sector and potentially deterring additional shippers and passengers from leaving the railways for road transport. An appropriate EC4T incremental charge would need to be made for electric services. However, while this route makes recovery relatively easy, the incentives for individual companies may be blunted by a uniform tax of this kind, with the link to the full range of environmental costs rendered less obvious.

8.6.3 A fee under the environmental licence Condition in each train operators’ licences

This could be related to an appropriate metric to reflect the level of environmental costs caused by the activity. A similar approach could be adopted for the network operator via a modification to the network licence. This has the advantage of being within the regulatory regime and that it could be made sensitive to changes in real cost drivers. A disadvantage is that licence modifications can be problematical and time consuming without the cooperation of the industry – although in this case there may be available sufficient time (and possibly goodwill) to introduce an agreed modification.

8.6.4 The franchise process

The franchise process and franchise pricing going forward could take into account the operating profile and rolling stock characteristics and extract a premium for the less environmentally friendly bid proposals. Alternatively, it could be possible to require certain measures of environmental performance as part of the franchise bid template.

8.6.5 A Standards approach

The use of industry standards, for instance the Network Code, could be considered as an alternative approach.

9 Recommendations for further work to increase the understanding of the environmental costs of rail transport

The foregoing chapters have shown that some research has already been carried out to understand the environmental externalities associated with rail transport. In particular, it is clear that the DETR Surface Transport Costs and Charges study, and the INFRAS study on the External Costs of Transport, both considered rail's environmental externalities in some detail. However, the STCC study was carried out in 2001 and was based on 1998 environmental impact data, whilst the INFRAS study is more recent but covered the whole of Europe, and hence UK-specific environmental cost data was understandably lacking from the study. With regard to the STCC study, some of the damage cost values used are now out of date, and there is perhaps a need to carry out some relatively simple analysis to update the figures for the total and average environmental costs of rail transport in the UK. Discussions with the Department for Transport have indicated that whilst the environmental externalities for road transport have been updated since the original STCC study, no such work has been carried out for rail transport. Updates to the STCC analysis would need to take into account revisions to the damage cost values for climate change, air pollution, and noise impacts, as well as updated data on emissions and noise from the rail sector. Updated data would allow ORR to have a better understanding of the current environmental external costs associated with UK rail operations; such data would be necessary if it was decided that environmental externalities should somehow be included in charges to train operating companies and/or decision making.

Further work may also be required to understand how environmental externalities could be included in a charging regime or in other areas of work. This is of particular importance for two reasons. Firstly, the European Commission is developing a framework for the internalisation of external costs, and there may be a need to ensure that any proposed environmental charging regime is compatible with this framework. Secondly, it is important to note that the UK's road transport environmental externalities are currently not fully accounted for in taxes and charges. Whilst Vehicle Excise Duty (VED) for passenger vehicles takes into account CO_2 impacts, and there are reductions in VED for HGVs that meet more stringent air pollutant emissions criteria (i.e. the Reduced Pollution Certificate), the environmental externalities of road transport are by no means currently fully accounted for in taxes or charges. The introduction of charges to cover rail's environmental externalities may therefore be seen as introducing an unfair disadvantage to the rail sector, when road transport's environmental externalities are not fully accounted for through taxes or charges, and this issue will need to be researched in greater detail.

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