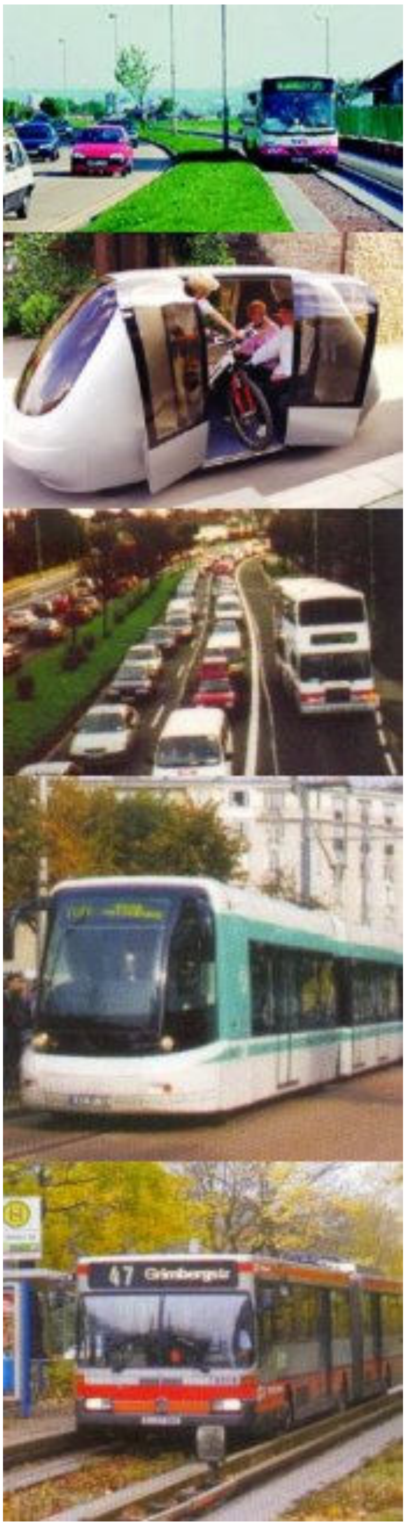


TEST:
Tools for Evaluating Strategically Integrated Public Transport

Work Package 2 – Working Paper 2:

The Wider Costs and Benefits of Urban Public Transport Systems

Christian Brand and Dr John Preston
Transport Studies Unit
University of Oxford

DRAFT 3
(14 March 2002)

EXECUTIVE SUMMARY

This working paper presents the findings of a desktop study aimed at bringing together the most up-to-date information on the wider costs and benefits associated with public transport operations for urban and inter-urban corridors. Specifically, this review goes beyond traditional analysis and includes:

- The benefits to users over and above those captured by the fare box, including time savings and reliability improvements;
- The benefits to non-users as a result of reduced congestion and reduced accidents;
- An assessment of the environmental impacts, including local and global air emissions and other more difficult to quantify impacts such as visual intrusion; and
- An assessment of the impacts on land-use, accessibility and integration.

In addition, this paper outlines the valuation framework for total social costing to be applied in further work in this project.

As outlined already in Working Paper 1 (Brand and Preston, 2001), we have covered the most common and promising urban rail and bus based systems, including light rail, metro, bus lanes, busways, guided buses and personal public transport. We have focused on existing schemes in the UK due to the inherent difficulty of transferring costs and, in particular, benefits from one country to another. Where data was not available (e.g. guided busways) we have also included a few planned and proposed schemes. On the social cost side, we have considered operating costs (bourn by the operator), users costs and non-user (external) costs. On the benefits side, we have covered user and non-user benefits. To be consistent with current UK guidance, the information has been structured according to the 5 main themes in the New Approach to Appraisal: environment, safety, economic, accessibility and integration. The results are summarised below.

Environmental costs

Users and operators of the public transport systems impact on the environment, and the external element of the associated costs are borne by non-users of the system. Recent studies have shown that for buses air pollution costs are higher (about a factor of two) than noise and global warming costs. In contrast, noise pollution is more significant for rail-based systems. Generally, environmental costs are higher than accident costs, however lower than congestion externalities.

In urban areas, however, air pollution costs can reach much higher levels due to higher population densities and congestion effects. According to one source, total environmental costs for buses are about 56 pence per bus-km in Central London, compared to the national average of about 10 pence per bus-km; air pollution costs are then about three times higher than noise costs. In comparison, suburban rail and urban (here PTE) services show average costs of about 44 and 33 pence per train-km for electric trains, and 35 and 32 pence per train-km for diesel trains. Diesel trains in urban locations show relatively high air pollution costs due to the relatively high damage cost of diesel emissions (in particular particulate matter).

This review confirmed the common view that there is still high uncertainty attached to the valuation of environmental costs, in particular health effects. As a result, cost estimates showed a wide range of values. However, our view is to include environmental costs as much as possible and conduct sensitivity analysis to allow for this uncertainty.

Safety and accident costs

Accident costs are the main component of safety related impacts. The 'wider' (external) accident costs include human costs not covered by insurance payments, and may also include the individual's willingness to pay for risk reduction. There are different views on what methodology should be used to value accident costs. Common methods range from valuing costs at the full value of statistical life to more conservative methods taking into account the years of life lost. Based on the latter approach, a recent study has shown that fully allocated costs are between 0.2 and 2.3 pence per bus-km. Marginal costs are higher at 3.7 to 6.6 pence per bus-km. For rail, external accident costs are often not estimated, since the *external* element is believed to be small once the level of liability placed on train operators is taken into consideration. If they are, however, the most common method still applies the full value of statistical life.

When comparing intermediate rail and bus-based modes it has been found that the accident rate per passenger-km is lower for light rail than for buses. However, there is also a higher proportion of serious accidents per vehicle-km than for bus. Hence, overall accident costs may not be that different.

Economic costs and benefits

Operating costs are notoriously difficult to obtain in any detail other than the total annual cost. Average operating costs have been derived from published sources, as shown together with revenue data in Table 1. Apart from the wide range in operating costs of current light rail systems, this shows no surprise. Bus-based and suburban rail systems appear to be the cheapest to operate on a per passenger-km basis, followed closely by light rail. Metro systems are almost three times as expensive to run than bus based systems on the same basis. Of course, this clearly depends on loading factors.

Table 1: Summary of annual operating costs and revenue income of systems in the UK

Values adjusted to 1999 GBP	*Light rail*	*Metro*	*Suburban rail*	*Urban bus-based systems*
Costs/vehicle-km				
- average	6.9	18.0	10.7	1.3
- std. deviation	8.1	4.9	0.6	(UK urban average)
Costs/passenger-km				
- average	0.16	0.27	0.10	0.11
- std. deviation	0.13	0.11	0.02	(UK urban average)
Revenue/vehicle-km				
- average	5.1	12.6	12.6	1.4
- std. deviation	2.5	6.0	(Thameslink only)	0.5
Revenue/passenger-km				
- average	0.12	0.18	0.11	0.12
- std. deviation	0.04	0.04	(Thameslink only)	0.02

Further data obtained on overseas systems broadly confirm the picture in the UK, with the national US average lower for light rail and suburban rail but higher for buses. For busways, the example of Pittsburgh shows that busway system operating costs are comparable to conventional bus-based systems, if not slightly cheaper (likely due to higher fixed costs offset by lower variable costs). Note that the average costs reported for Pittsburgh are, however, substantially higher than the US national average. This has been explained by the unusually high wage rates in Pittsburgh of £18.2 per hour. This highlights the fact that while the infrastructure and vehicle market is more or less international, local differences in wage rates, load factors and fuel costs can result in significant cost differences. Given the high share of wage-related costs in bus operations, high wage rates alone may render buses more expensive to run than light rail.

On a *per journey basis*, the average revenue earning capability of the two underground systems (91 pence) is slightly higher than for light rail (77 pence) or conventional buses (69 pence), whereas the example of Thameslink (355 pence) suggests that suburban rail revenues can be substantially higher. This makes sense because average trip lengths on Thameslink are a lot higher than for the other modes. In contrast, most UK systems are comparable in terms of revenue *per passenger-km*, with a slight advantage for the two underground systems.

Another key indicator of transport economic efficiency is the time needed to get from A to B. The systems differ in all three time elements: walking time, waiting time and in-vehicle time. In-vehicle time is mainly determined by factors such as number of stops, vehicle acceleration, fare collection systems and traffic priority. Clearly, the modes with higher operational speeds (e.g. guided busway, light rail on segregated tracks, suburban rail, personal public transport) and off-vehicle fare collection (e.g. underground, light rail) show journey-time advantages over some of the slower modes (e.g. buses and light rail in mixed traffic). Also, fare collection systems and traffic priority are the main factors affecting journey reliability. Off-vehicle fare collection and high traffic priority (and segregation of track) for modern rail-based systems show a slight advantage over bus-based systems. Furthermore, new systems can show user benefits in terms of vehicle operating cost savings for people who previously used other modes (e.g. fuel and wear & tear savings for car users) as well as people who continue to use this mode (e.g. decongestion benefits). In general, however, for most modes the value of vehicle operating cost savings tends to be relatively small when compared to the value of travel time savings.

As the bulk of congestion costs are internal to the transport system (increased travel time), external congestion costs are usually valued on the marginal cost basis (e.g. congestion cost of one additional vehicle on the road or rail network). This review found typical external marginal congestion costs for buses and coaches at 15 to 18 pence per bus-km (national average), going up to about 35 pence for weekday peak travel in outer conurbations. In contrast, the marginal congestion costs for adding another train service to the London network is about 0.3 pence per train-km. Unfortunately, we have not found any data on light rail systems.

The wider economic impacts can be assessed qualitatively, however quantification is often not possible due to the limited data availability and the complex interactions with other economic activities of the scheme.

Accessibility impacts

In terms of community severance there seems to be no significant difference between the modes and technologies considered in this paper, although this depends obviously on the degree of segregation and provision of easy-access crossings. Underground systems seem to be ideal in terms of community severance, however they have traditionally lost out in terms of accessibility to, for example, the mobility impaired. Most new modern systems are likely to provide easy access for all as well as sufficient crossings to avoid negative accessibility impacts.

Integration with other modes and policies

Any new system is likely to have a positive impact on integration, and hopefully attract 'new customers' as a result (generated journeys). More specifically, the technology that can more easily be integrated in the current transport system will be show higher public acceptability, for example a busway scheme connecting existing interchanges with the city centre shopping area, or a light rail extension using existing or disused heavy rail corridors. In the wider transport policy context, light rail, guided bus and busway systems fit well into the current drive to provide cost-effective, reliable, clean and integrated urban public transport, showing advantages over conventional rail or bus based systems.

Identified information gaps

This review has identified a few key data gaps: the valuation of ambient noise level changes of intermediate modes; land take costs (e.g. per route-km); accident rates for systems on segregated tracks; a detailed breakdown of operating and capital costs of intermediate modes; and examples of the valuation of user and non-user benefits of existing systems. Naturally, we are lacking reliable information on performance indicators for new and proposed schemes such as ULTra.

Framework for social costing

In a second part, we propose the framework for social costing for the modelling exercise later on in the project. In a nutshell, the quantitative part involves the calculation of total social costs and benefits of a mode or technology as the sum of:

- Capital (see Working Paper 1) and operating costs,
- User costs and benefits;
- Non-user costs and benefits.

The individual cost categories are functions of intermediate variable parameters such as vehicle-km, vehicle-hours and route-km as well as semi-variable parameters such as the value of travel time, the statistical value of life and so on. All cost and benefits will be annualised and discounted using standard economic practice. This approach will be consistent with the New Approach to Appraisal and the Guidance on the Methodology for Multi-Modal Studies.

Based on these functions, the framework allows to derive further results such as cost curves (e.g. total social cost per passenger-km as a function of passenger-km) and costs and benefits as a function of intermediate outputs (e.g. number of journeys, route-km, vehicle-km).

The qualitative part will include comments on the likely impacts on land take, water pollution, integration aspects and accessibility, again consistent with the New Approach to Appraisal.

As a working paper, this document will be updated during the course of the project as new information arises.

CONTENTS

1 INTRODUCTION

1.1 Objectives

The first key objective of this paper is to review the existing evidence on the 'wider impacts' of public transport systems including:

- The benefits to users over and above those captured by the fare box, including time savings and reliability improvements;
- The benefits to non-users as a result of reduced congestion and reduced accidents;
- An assessment of the environmental impacts, including local and global air emissions and other more difficult to quantify impacts such as visual intrusion; and
- An assessment of the impacts on land-use, accessibility and integration.

Building on the earlier inventory presented in *TEST* Working Paper 1 (Brand and Preston, 2001), we will also include operating costs and revenue earning capabilities of each system.

The other key objective is to outline our approach for the remainder of the *TEST* project, consistent with current project appraisal techniques used by the Department of Transport, Local Government and the Regions (DTLR).

1.2 Background

The costs and benefits to operators, users and non-users of an urban public transport system are critical factors in the decision making process of choosing the right option for a given transport corridor or entire urban network.

This paper outlines methods for appraising public transport projects and presents values for the wider impacts of transport. The term 'wider impacts' is used interchangeably with the technical term 'externalities'.

By making a journey on public transport, users incur costs – often referred to as 'generalised cost' in cost-benefit analysis. These usually include a combination of quality of service indicators such as:

- Walking time from the origin to a stop or station (usually weighted relative to in-vehicle time by a factor of about two);
- Waiting time for the service (again, usually weighted relative to in-vehicle time by a factor of about two);
- Fare;
- In-vehicle time;
- Penalty representing the inconvenience of changing between services; and
- Walking time to the destination (again, usually weighted relative to in-vehicle time by a factor of about two).

Time units are usually converted to money costs using standard Values of Time (VOT). This is further explored in Section 3.3. For an excellent review see 'The Demand for Public Transport' by Webster and Bly (eds.) (1980) as well as the forthcoming update of this seminal book (the output of another LINK-funded project).

The journey also has an impact on the community owing to noise, exhaust emissions, emissions from power stations, risk of accident, and, for vehicles in mixed traffic, increased journey times for other transport users. These 'non-user costs' are referred to as external costs, or 'externalities'.

Sometimes passenger benefits are referred to as externalities – however this is not strictly correct. For instance, public and private transport differ in the magnitude of externalities created by additional trips. If an additional trip is made using public transport, the externalities are very small, because it is probably not necessary to run additional services. If, however, an additional trip is made by car, it is quite likely that a completely new vehicle journey will be made, generating the full set of externalities described above.

The externalities of the capital investment for a new public transport scheme may include congestion; air pollution; accidents; global-warming effect; and noise and vibration. Externalities may be valued in monetary terms so that they can be included in a project's financial appraisal. If this is to be done, it is helpful to have some understanding of the origin of the value estimates to be applied. This is done in Chapter 3.

Table 2 summarises transport costs and indicates their distribution and relevance to public transport.

Table 2: Transport cost categories – definitions and distribution

Cost	*Definition*	*Distribution*	*Borne by*
Vehicle Ownership	Fixed vehicle expenses	Internal-Fixed	Operator
Vehicle Operation	User expenses that are proportional to travel	Internal-Variable	Operator
Operating Subsidies	Vehicle expenses not paid by the user	External	Society
Fare	Public transport fare	Internal-Variable	User
User Travel Time	Time spent traveling	Internal-Variable	User
Internal Accident	Vehicle accident costs borne by users	Internal-Variable	User, society
External Accident	Vehicle accident costs not borne by users	External	Non-user, society
External Parking	Parking costs not borne by private users	External	Non-user, society
Congestion	Delay each vehicle imposes on other road users	External	Other road users, society
Severance	The disamenity roads and vehicle traffic imposes on pedestrians and cyclists. Also called "barrier effect".	External	Non-user (pedestrian and cyclist)
Infrastructure facilities	Infrastructure expenses not paid by user fees	External	Society
Municipal Services	Public services devoted to vehicle traffic	External	Society
Infrastructure Land Value	Opportunity cost of land used for roads and railway infrastructure	External	Society
Air Pollution	Costs of pollutant emissions	External	Society
Noise	Costs of noise emissions	External	Society
Resource Consumption	External costs resulting from resource consumption	External	Society
Water Pollution	Water pollution and hydrologic impacts of vehicles & infrastructure	External	Society
Waste Disposal	External costs from vehicle & infrastructure waste disposal	External	Society, operator
Land Use Impacts	Economic, environmental and social costs resulting from low density, car-oriented land-use	External	Society
Option Value	Reduced travel choices, especially for disadvantaged people	External	Society, esp. disadvantaged people

Source: adopted from Litman (1999b)

1.3 Modal coverage and definitions

We have covered the most promising public transport systems for urban and inter-urban corridors. These are either road or rail based and include:

- Light rail and dual mode rail;
- Medium capacity suburban systems;
- Buses operating in mixed traffic and in conventional bus lanes;
- Guided buses, including the new 'trams on wheels';
- Busways;
- Personal public transport, or personal rapid transit, and other unconventional public transport systems.

Local bus and coach services are labelled Public Service Vehicles (PSV), consistent with the DTLR's practice. Details on technical characteristics and investment costs for each of these can be found in Working Paper 1 (Brand and Preston, 2001).

To avoid confusion about the labelling of the 'wider impacts', or 'externalities', a few key definitions are given below. The monetary valuation of unit changes in their impact is described in Chapter 2.

Definitions of the 'wider impacts'

Noise and vibration
Noise and vibration from traffic reduce the quality of life of people exposed to them. They affect house prices, and, in the case of noise, necessitate insulation of properties. 32 million UK inhabitants are exposed to road noise in excess of 55dB (The Railway Forum, 1999).

Air pollution
Non-electric buses and rail vehicles produce direct exhaust emissions that contain dust and gases (mainly carbon dioxide, carbon monoxide, sulphur dioxide (SO_2), benzene, particulates (PM_{10}), volatile organic compounds, and nitrogen oxides). About 40% of particulates in the air come from transport. These act as a respiratory irritant, especially for those with existing respiratory conditions, so air pollution reduces the health of these sensitive groups in particular. The estimates of the effect of air pollution on health vary widely depending on the assumptions made by the researcher. The Committee on the Medical Effects of Air Pollution (COMEAP) states that, each year in Britain, air pollution may bring forward deaths from respiratory disease up to the following extents: ozone 12,500 deaths; PM_{10} 8,100 deaths; SO_2 3,500 deaths (DETR, 1998b). Note that these deaths may not be brought forward by much – possibly only a few days.

Global-warming
Most vehicles use energy that is derived from fossil fuels (mainly coal and natural gas), and some buses and light rail vehicles use electricity that is generated partly from non-fossil-fuel sources (mainly hydro and wind power). The combustion of fossil fuels releases CO_2, a gas that contributes to global warming. There are also emissions of nitrous oxide (N_2O) and methane (CH_4) from combustion of the fuel, which are minor compared to emissions of CO_2 (typically only 2% for cars after allowing for the relative global warming potentials of the two gases).[1]

Economic impacts: congestion
Congestion results from competition for road or rail space. High levels of demand relative to the capacity of the road or rail result in longer journey times, and a multiplication of other environmental costs, such as increased air pollution and noise, more crowding, and possibly more accidents. The effect of congestion is not linearly proportional to traffic – it is much greater at high levels of traffic. This can be modelled, and is usually reported as journey time lost owing to increased traffic. The other environmental costs should be inflated appropriately.

Safety impacts: accidents
Road and rail accidents cause damage to property, injury and death. The cost of damage to property is met privately through insurance, but the reduction in quality of life and loss of life resulting from injuries and fatalities is not usually compensated and therefore 'external'. The relationship between accident rates and traffic levels is disputed – some argue that the accident rate rises with increased traffic levels, others that it falls.

1.4 Methodology

As a first step we have conducted an extensive review of existing studies on the wider costs and benefits of urban public transport systems. This was essentially a desk-based study. We have structured the available information by the main economic, environmental and social assessment criteria common in this type of appraisal. This includes operating costs, user benefits and non-

[1] Methane and nitrous oxide have about 21 and 310 times the global warming potential than carbon dioxide, respectively (IPCC, 1997).

user costs and benefits. Capital investment costs (i.e. infrastructure and vehicle costs) were covered by the preceding *TEST* Working Paper 1 (Brand and Preston, 2001).

The second step involved developing the appraisal methodology to be used in the course of this project, in particular in the modelling exercise in Workpackage 4. Given the wide range of assessment criteria and associated costs and benefits, we have gone beyond the appraisal techniques used by the DTLR, however we have ensured to be consistent with these as far as possible.

Since this is a working paper we aim to update the information given here during the course of the project.

Links with other work packages in TEST

The data gathered here form the basis for further work in the TEST project:

- Cost and benefit data will feed into the social cost modelling exercise (→ Work Package 4)
- Much of the information gathered here will feed into the production of the Manual of Advice called The Supply of Public Transport, one of the two key deliverables of the TEST project (→ Work Package 6).

We intend to fill the information gaps identified during this desk study in the field study interviews with operators and local authorities (→ Work Package 3).

1.5 Structure of this paper

First we briefly give an overview of the current framework of appraisal techniques used in PT scheme assessment. We then review the wider costs and benefits in existing studies, including methodological issues and evidence of quantifiable data and qualitative statements. In a third part, we outline the methodological framework for evaluating total social costs to be applied in further Workpackages of this project, in particular in the modelling exercise.

2 APPRAISAL IN PUBLIC TRANSPORT

There is an overall approach to the assessment of transport investment supported by public funds, known as the New Approach to Transport Appraisal (NATA). This is the umbrella approach for a suite of more specific guidance:

- Guidance on Methodology for Multi-Modal Studies (GOMMMS);
- Design Manual for Roads and Bridges (DMRB);
- Guidance on the Freight Facilities Grant; and
- Planning criteria for the Rail Passenger Partnership scheme.

Most of these appraisal guidelines emphasise qualitative analysis, so there is no comprehensive guide to the quantification and valuation of impacts. Qualitative analysis is often sufficient for regulatory purposes, but when major infrastructure projects go to public inquiry, quantification of environmental and social effects might provide a more rigorous case.

2.1 New Approach to Transport Appraisal

NATA introduces five policy objectives – accessibility, safety, economy, environment and integration – and was initially applied to roads. The environmental assessment is exactly as described in DMRB (Volume 11, Section 3). NATA provides a protocol for categorising impacts into orders of magnitude, and presenting them in a standardised tabular form. It does not attempt any valuation for air pollution, although it does attach values to time and to accidents. However, it is the most holistic approach to appraisal to date.

2.2 Guidance on the Methodology for Multi-Modal Studies

The GOMMMS provides a systematic methodology for recording the wider benefits or costs of transport investments. It structures the impacts according to the five government criteria (see above), and assesses each in non-monetary and often qualitative terms, valuing only accidents and 'economy' effects such as time savings in monetary terms. The methodology requires the results to be presented on a single sheet of paper – the 'appraisal summary table' – where some impacts are reduced to descriptors such as 'slight' or 'adverse'. Partly because of this prescriptive final presentation, it is a limited approach. Unfortunately, it does not attempt to extend the boundaries of cost-benefit analysis, or to quantify the overall impact of investments in a single measure.

2.3 Common appraisal and evaluation tools

Analysis techniques such as cost-benefit analysis (CBA), cost-effectiveness analysis (CEA) and multi-criteria analysis (MCA) are common in making important investment decisions in public transport. With regards to public transport, the DTLR guidance requires to outline the steps in the CBA and clearly identify key parameters and assumptions. Broadly, the CBA involves:

- Calculating transport user and provider impacts based on model outputs and patronage forecasts; and
- Comparing benefits with costs of investment, maintenance and operation.

The CBA is based on consumer surplus theory and should be undertaken using the willingness to pay (WTP) calculus. This approach is outlined in GOMMMS (Volume 2, Appendix F) and the review by Sugden (1999) of CBA commissioned by the DTLR. It is used in valuation tools such as COBA (Cost Benefit Analysis) and TUBA (Transport User Benefit Appraisal).

TUBA assesses the user benefits (travel time and vehicle operating cost savings, accident rate changes) of multi-modal transport schemes and is capable of appraising highway and/or public transport projects with fixed or variable trip matrices.

TUBA and other appraisal methods makes use of economic valuations given in the DTLR's Transport Economics Note (DTLR, 2001a) and Highways Economics Note No1 (DTLR, 2001b), which provide the latest values of transport user time savings, vehicle operating costs and the valuation of the benefits of prevention of road accidents and casualties, for use in economic appraisals of transport projects.

3 THE WIDER COSTS AND BENEFITS

This Chapter gives an overview of the current evidence of studies assessing and valuing the wider impacts of public and, where relevant for comparison, private transport. Where available, we provide evidence of quantitative data and qualitative statements of the systems' effects with respect to impact categories common in the UK and broadly defined as environment, safety, economic, accessibility and integration (see, e.g., DETR, 1998a).

3.1 Environment

This study includes the following environmental costs:

- Effects of noise on amenity;
- Effects of atmospheric pollution on human health;
- Effects of atmospheric pollution on buildings and crops (non-health);
- Effects of greenhouse gas emissions on climate change;
- Effects of water pollution on drinking water quality;
- Effects of land use;
- Effects of biodiversity and earth heritage (qualitative).

Environmental costs are usually regarded as being 'outside' the transport sector, as the transport user does not pay the damage to the environment (e.g. noise, pollution) he or she causes by their actions (e.g. driving, using public transport). Environmental costs are therefore valued on both the marginal cost and fully allocated cost bases.

Noise and vibration

Exposure to noise is regulated by environmental standards, e.g. a level below which the noise effect was considered negligible. In 1980, the World Health Organisation (WHO) set a general environmental health goal for outdoor noise of $55L_{Aeq}$. In 1995 this was changed to a threshold below which few people are seriously annoyed, also set at $55L_{Aeq}$ (WHO, 1999). The WHO further considers noise levels over 65 decibels to be obtrusive, and estimates that 19% of the UK's population is exposed to daytime road traffic noise levels above this standard (Mumford, 2000).

In the UK, road transport noise is typically quantified using the established relationships in the Government publication "Calculation of Road Traffic Noise" (DoT, 1988), while for rail noise emissions and dispersion are often calculated based on the methods recommended in "Calculation of Rail Noise" (DoT, 1995). For instance, Sansom *et al* (2001) calculate the fully allocated costs of road transport by estimating noise levels for each road type, and attributing noise levels according to vehicle numbers. The study also assessed marginal noise costs by looking at the noise change from a 10% increase for each road type. For both the fully allocated and marginal analysis, predicted noise levels were combined with average population density data to derive the population weighted noise levels above the aforementioned 55 dB(A) threshold.

Noise emissions can then be valued. The majority of noise valuation studies in the literature are based on hedonic pricing, where noise differences reflected in the market value of housing are analysed (taking into account other variables). The information from these hedonic studies can be used to derive relationships linking average noise levels to changes in property prices –

known as a Noise Depreciation Sensitivity Index (NDSI) and usually reported as a percentage reduction in property value for a 1dB increase in noise levels. Most estimates in the literature quote a NDSI of between 0.2% and 1.5%, with most studies concentrated between 0.5 and 1%. These studies do not measure directly individual or household Willingness To Pay (WTP) to avoid noise exposure per unit time. Other studies such as Soguel (1994) that focus on monthly rent do this more explicitly. More recent work in the UK has indicated a much lower value for the NDSI. For instance, Sansom *et al* (2001) used 0.2%, 0.436%, and 0.67% for each 1dB(A) increase in noise levels as the low, central and high NDSI values – recommended for this study by the then DETR.

Air pollution

The impact of air pollution on health and has been modelled, and the consequent change in health status has been valued. The main uncertainty is the relationship between health and air pollution. The Department of Health's Committee on the Medical Effects of Air Pollution (COMEAP) recently reviewed this crucial relationship and provided relationships for use in quantification of health effects in the UK. COMEAP estimates the social cost of air pollution on human health to be around £3 billion (COMEAP, 1998). This figure is likely to fall in the future taking into account the declining emissions of air pollution from vehicle exhaust. Apart from health impacts, air pollution has adverse impacts on building materials, crops, ecosystems (terrestrial and aquatic) and on visibility.

Health costs per amount of pollutant emitted from motor vehicles have been widely reported (see e.g. McCubbin and Delucchi, 1999; ECMT, 1998; Newbery, 1995; EC, 1999b; Tinch, 1995; Litman, 1999b). Estimations depend heavily on the methodology used (usually dose-response or stated preference techniques, based on the so-called Value of Statistical Life, see below) and the types of health impacts or endpoints considered (usually including acute mortality but often ignoring chronic mortality and cancer risk).

There is widespread agreement, however, that emissions of particles smaller than 10μm (PM_{10}) are the main factor contributing to external health costs. For example, taking the NAEI (1999) tailpipe emissions factors for an average EURO2 bus on an urban driving cycle[2], and using the health impact valuation by McCubbin and Delucchi (1999) (see Table 3 below), a range between 1.58 and 23.2 pence/vehicle-km is calculated for direct and indirect PM_{10}-related health impacts. This compares to 3.02 g/vehicle-km of CO (NAEI, 1999), giving a range between 0.003 and 0.02 pence/vehicle-km – about a factor of 1000 lower than for PM_{10}! Of course there are other toxic pollutants contributing to health impacts such as 1-3-butadiene and benzene, but the majority of costs are covered by the valuation of health impacts by increased PM_{10} concentrations. Green, Khoury and Davies (2000) argue that using PM_{10} alone as an indicator in accounting for 'all the effects of the pollution soup' covers at least 80% of the total costs of emissions-related effects.

[2] PM_{10}: 0.412 g/vkm, NO_X: 10.63 g/vkm, SO_2: 0.3 g/vkm, VOC: 1.853 g/vkm (NAEI, 1999 and own calculations)

Table 3: Estimated health costs of motor vehicle emission in the USA in 1990, urban areas (converted and inflated to 1998 £ prices)

£/kg (1998)	*Pollutants*							
Tailpipe Emissions	*CO*	*NO_X*		*SO_X*	*PM_{10}*		*VOC*	*VOC+ NO_X*[1]
Ambient Pollutant	*CO*	*NO_2*	*nitrate-PM_{10}*	*sulphate-PM_{10}*	*$PM_{2.5}$ and coarse PM_{10}*	*$PM_{2.5}$ only*	*organic-PM_{10}*	*ozone*
Low	0.01	0.13	0.93	6.47	9.24	9.96	0.09	0.01
High	0.07	0.65	15.05	61.16	126.08	151.56	0.98	0.09

Source: McCubbin and Delucchi, 1999

[1] McCubbin and Delucchi also show the health costs of VOC and NO_X combined because these pollutants contribute jointly to ozone production.

Sansom *et al* (2001) recently quantified and valued in detail the health and non-health effects of atmospheric emissions in Great Britain using the impact pathway or dose-response methodology.[3] Since this is one of the most detailed and recent studies, we go in a bit more detail below. For health effects, the study's methodology involves the following four steps:

1. Assessing the atmospheric emissions of all pollutants from vehicles (based on data of the National Atmospheric Emissions Inventory (NAEI, 1999));
2. Assessing the effect of these emissions on local and regional air concentrations (using ExternE air dispersion modelling (EC, 1999b));
3. Quantifying the health and environmental impacts of pollution concentrations using dose-response functions and data on the population or stock exposed at both the local and regional level (based on the COMEAP, 1998; EC, 1999c; and EC, 2000); and
4. Valuing these health and non-health environmental impacts in monetary terms (based on values from the Ad-Hoc group on the Economic Appraisal of the Health Effects of Air Pollution (EAHEAP, 1999)).

Note that in step 4, the valuation of health impacts depends heavily on life expectancy and quality of life. The EAHEAP group therefore recommended a number of alternative values for acute mortality (deaths brought forward): a maximum value (£1.4 million) based on an adjusted value of statistical life (the VSL approach) and a range of values (from £2,600 – £110,000) based on adjusting the VSL to take account of life expectancy and quality of life (the Years of Life Lost approach) (Sansom *et al*, 2001).

Results for average fully allocated and marginal costs of air pollution by vehicle class are shown in the Section on unit values in Table 5 below. Note that since the analysis of both health and non-health impacts used linear functions, which are implemented without a threshold of effect (i.e. down to zero pollution levels), marginal and average costs are therefore reported as being equal.

[3] Details can be found in e.g. EC (1995)

Global warming

The Intergovernmental Panel on Climate Change (IPCC), an organisation of leading scientific experts, concluded, *"The balance of evidence suggests a discernible human influence on global climate"*, which could impose many costs to society (IPCC, 1997; also see websites http://gcmd.nasa.gov, www.unfccc.de and www.ipcc.ch for more information).

Climate change is predicted to alter the pattern of rainfall, raise sea levels, cause more frequent storms and increase temperatures. The consequences are changed agricultural practice, drought, flooding, damage to property, changed incidence of disease, and other large scale disruptions such as a breakdown of North Atlantic Deep Water formation or a collapse of the West-Antarctic Ice Sheet. The valuation estimates are built up from these elements and from estimates of the cost of reducing emissions. For transport, carbon dioxide is the key pollutant to consider. Damage values typically ranging between £7 and £29 per tonne of CO_2 emitted, with a central value reported for the ExternE project at £14.6[4] (see e.g. EC, 1999a; Tol and Downing, 2000; Maddison *et al*, 1996; Litman, 1999b). Given the large uncertainty associated with climate change, these values should only be considered as illustrative of possible costs.

Note that climate change is particularly a problem of the long term (20-100 years). Discounting is therefore of utter importance. Further details of damage values for CO_2 and other greenhouse gas pollutants for various scenarios and discount rates can be found in Eyre *et al* (1997, 1999) as well as in Tol and Downing (2000) and EC (2000).

Other externalities

Of course, there are a number of other environmental externalities (e.g. water and soil pollution by water runoff, severance effects, damages to natural ecosystems, visual impacts etc.). Methods to value these externalities are partly available for selected local impacts; however methods to analyse larger areas are less advanced when compared to air pollution and noise and should be further developed (Ricci and Friedrich, 1999).

Water pollution

Road motor vehicles and their facilities are major contributors to water pollution and hydrologic (water flow) impacts (Litman, 1999a). Grease spots under parking spaces and the rainbow sheens often visible on wet roadways are indications of vehicle fluid leaks. Some vehicle owners also contribute to water pollution by improperly disposing of waste fluids. Increased stormwater management costs, environmental degradation of urban streams and rivers and reduced groundwater recharge are examples of hydrologic costs resulting from motor vehicle facilities.

A few researchers have estimated the monetary cost of motor vehicle water pollutants and hydrologic impacts, although most only consider a portion of these impacts. Estimations of the impact on drinking water can be carried out, based on the estimation of the volume of drinking water that may be polluted in relation to the critical volume of pollutants. The monetary valuation is then derived by straightforward application of the (local or average) drinking water market prices. Salt damage caused by de-icing can be calculated in a similar way. Cost estimates range from about 0.08 pence per vehicle-kilometre for major spills, to approximately

[4] The ExternE value of £14.6 is based on the International Panel on Climate Change (IPCC) IS92a scenario, assuming equity weighting, a time horizon of damages to 2100, and a 3% discount rate.

0.4 pence per kilometre for the sum of oil spill, road salt, and hydrologic impacts (Litman, 1999b; converted from USD to GBP, 1999 values). These are relatively low damage costs compared to other impacts such as air quality and noise.

Land use impacts

Current methods for assessing the impact of new schemes do not incorporate a monetary value to the loss of landscape caused by a new road or track. The contingent valuation method has been used by some researchers to derive a value equal to the preservation benefits of alternative schemes that do not adversely affect the landscape. The derived benefit values were significant, however scheme-specific and therefore not directly transferable to the work carried out in this project.

The amount of land required per unit of travel varies significantly by mode, as indicated in Figure 1. Land-take efficiency (the ratio between land used and the infrastructure's traffic carrying capacity) varies strikingly from one infrastructure type to another. For example, compared to road transport, railways require the lowest land take per passenger-km and tonne-km – land take per passenger-km by rail is about 3.5 times lower than for passenger cars (EEA, 1998; Bruun and Vuchic, 1995). On the basis of land take *per passenger-km*, the difference between public transport modes depends largely on load factors: high patronage light rail services may be favourable to low patronage bus services. As private car drivers tend to travel much farther per year than non-drivers, their total per capita land requirements for transportation are much greater. In total, roads take up about 1.4% of land in the UK, rail only 0.1% (EEA, 2000).

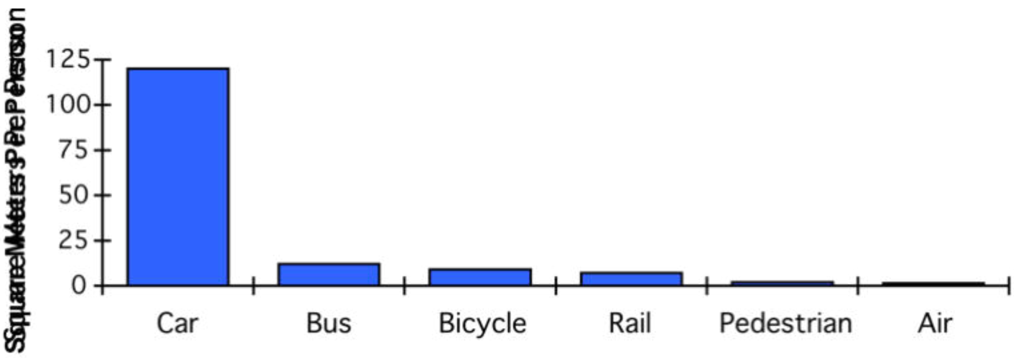


Figure 1: Land take per passenger by mode

Source: Teufel (1989)

Biodiversity and earth heritage

In GOMMMS (2000), the methodology for appraising the impact of transport schemes on biodiversity and earth heritage broadly follows a four stage general approach to appraising 'environmental capital'. Applied to biodiversity and earth heritage, the approach is:

1. to describe sequentially the characteristic biodiversity and earth heritage features;
2. to appraise environmental capital using a set of indicators; this is done by assessing the importance of these characteristic features, why they are important, and their inter-relationships;

3. to describe how proposals impact on biodiversity and earth heritage features, including effects on its distinctive quality and substantial local diversity; and
4. to produce an overall assessment score on a seven point scale.

This is mostly qualitative, with the overall assessment score given based on descriptive comments, mainly on the "magnitude of potential impact" (scale from 'positive' to 'major negative') combined with the "nature conservation value of sites damaged or improved" (scale from 'negligible' to 'very high').

For multi-modal studies, the guidance stresses that the scale of the scheme (e.g. major public transport scheme across a city), the associated infrastructure (e.g. stations for rail schemes, or tunnels) and operational impacts from use are especially relevant, and should be appraised using the qualitative method outlined above (ibid).

Bickel and Friedrich (1995) reviewed a range of externalities and their quantifiable impacts. They concluded that externalities due to water pollution, land use, use of non-renewable resources and severance effects are smaller than the costs of airborne emissions, noise and accidents.

Unit values of external costs of environmental impacts

Unit values of external costs of environmental impacts are usually expressed in £/tonne of pollutant emitted, pence/passenger-km or pence per vehicle-km.

Typical values for ***external costs per tonne of pollutant emitted*** are given in Table 3 above, based on McCubbin and Delucchi (1999). This shows a wide spread between low and high estimates and illustrates the high uncertainty attached to valuing health impacts.

In contrast, Table 4 lists ***national average unit values per passenger-km*** for passengers travelling by road and rail. This is directly taken from OXERA (2000), with an indication of the original sources.

Table 4: External costs for passenger road and rail transport in the UK (average unit values in pence per passenger-km, 1998/99 prices)

External costs		*Road*		*Rail*	
(pence/PKM)	*High*	*Central*	*Low*	*High*	*Low*
Noise & vibration	0.58 [1]	0.47 [2]	0.26 [3]	0.3 [3]	* 0.27 [7]
Air quality	1.1 [4]	0.83 [5]	0.61 [3]	0.18 [9]	* 0.13 [7]
Global warming	0.56 [5]	0.35 [1]	0.19 [5]	0.26 [3]	* 0.2 [8]
Water	0.56 [6]	0.56 [6]	0.56 [6]	n/a	n/a
TOTAL	**2.80**	**2.21**	**1.62**	**0.74**	**0.6**

Notes: 'Rail' represents heavy rail on the Railtrack network. OXERA (2000) note that Newbery's figure for water pollution represents 15% of the total cost of sewage treatment, estimated in 1995/96 as £3 billion per year. It is then divided by the total road kilometres and half is apportioned to road freight and half to road passenger.

Sources: [1] RCEP (1994, 1997), [2] Maddison *et al* (1996), [3] ECMT (1998), [4] Newbery (1995), [5] EC (1999b), [6] Newbery (1998), [7] Tinch (1995), [8] Calculated using Pearce (1994) and ECMT (1998), [9] INFRAS/IWW (1994), * additional OXERA (2000) calculations.

The above are aggregated average values and therefore of limited use for local analysis by, say, vehicle type (e.g. bus, train) and location (e.g. urban, rural). Sansom *et al* (2001) recently conducted a more disaggregated analysis based on the fully allocated cost and marginal cost approaches. The results for road and rail costs by vehicle class are shown in Table 5. Note that the results for the fully allocated cost and marginal cost approaches are equal (and therefore reported only once), except for the low estimate of noise emissions from road traffic – all other categories follow linear relationships, hence both approaches give equal results.

Table 5: Fully allocated and marginal (shaded area) environmental costs by vehicle class (in pence/vehicle-km or pence/train-km, 1998 values)

External costs	***Air pollution*** [1]		***Noise*** [2]			***Global warming*** [3]	
(pence/vehicle-km)	*low*	*high*	*low* [4]	*low*	*high*	*low*	*high*
Road							
Car	0.18	0.88	0.01	0.16	0.52	0.12	0.47
LDV	0.71	3.35	0.02	0.30	1.00	0.18	0.72
HGV-rigid	1.65	8.26	0.06	0.87	2.89	0.44	1.74
HGV-artic	1.41	7.63	0.08	1.31	4.35	0.71	2.86
PSV	3.16	15.35	0.09	1.24	4.11	0.56	2.24
Heavy rail							
InterCity	27.9	188.7	12.2	12.2	40.6	6.7	26.9
Regional	4.1	36.0	4.2	4.2	13.9	3.1	12.3
London (suburban) [5]	6.7	77.0	8.8	8.8	29.1	3.7	14.7
Passenger Sector	9.8	82.3	7.6	7.6	25.2	4.0	16.1

Source: Sansom *et al* (2001), also Quinet (1997)

Notes:
[1] Includes only tailpipe pollutant emissions. Based on values from the years of life lost approach for the low and central estimate (low £2,600), with the high value based on the full Value of Statistical Life of £1.4 million. Note the use of the full VSL for acute mortality is likely to be a significant overestimate given the evidence on the amount of life lost from air pollution related mortality.
[2] The high value is based on the fully allocated approach, and the low value based on a marginal analysis based on roads with high traffic volumes. This excludes vibration, potential night-time disturbance, perception and potential health effects.
[3] The low and high values are based on £7.3/tonne of CO_2 and £29/tonne tonne of CO_2, based on DTLR recommendations for the cited study.
[4] Marginal costs for road traffic only due to the non-linear relationship between noise level and road traffic volume. In contrast, rail traffic noise follows a linear relationship to rail traffic (in first order approximation).
[5] London (suburban) includes all suburban services going from London's railway stations, e.g. Thames Trains, Chiltern Trains, and Connex.

The authors show that although cars are responsible for a very high share of vehicle-km driven on UK roads (82.5%) they only account for around 50% (or £3.50 billion/year, 1998 values) of the total road sector environmental damages (Sansom *et al*, 2001). In contrast, PSV have a disproportionately high damage costs (7.6%, or £0.53 billion/year, 1998 values) despite a relatively low vehicle-km share (1.1%).

These traits can be seen when the *average* costs per vehicle-km are derived from *national* cost figures, shown in Figure 2. The graph indicates that PSV have higher average environmental costs than any other vehicle. This is misleading. A high proportion of PSV journeys are in urban areas, where environmental costs are higher. Therefore, in comparing the environmental costs of different vehicle types, i.e. estimating the environmental costs per passenger-km, it is essential that the costs for the same journey types are compared.

For rail, Figure 2 shows environmental costs by train type and for diesel and electric traction, suggesting interesting conclusions. Firstly, environmental costs (per km) vary more widely with diesel trains than with electric. Secondly, there are some major differences in environmental costs between diesel and electric trains of the same type. This is especially true for high speed trains, with suburban (London) and urban (PTE) services more equal. These differences occur because of air quality impacts from the two fuels and the relative balance of pollutants emitted. Diesel trains emit much higher levels of particles, the key pollutant in health impacts. For example the average emission from an InterCity diesel is around 8.5 gPM_{10}/km, whereas for the East coast line, an electric InterCity only emits around 1 gPM_{10}/km[5].

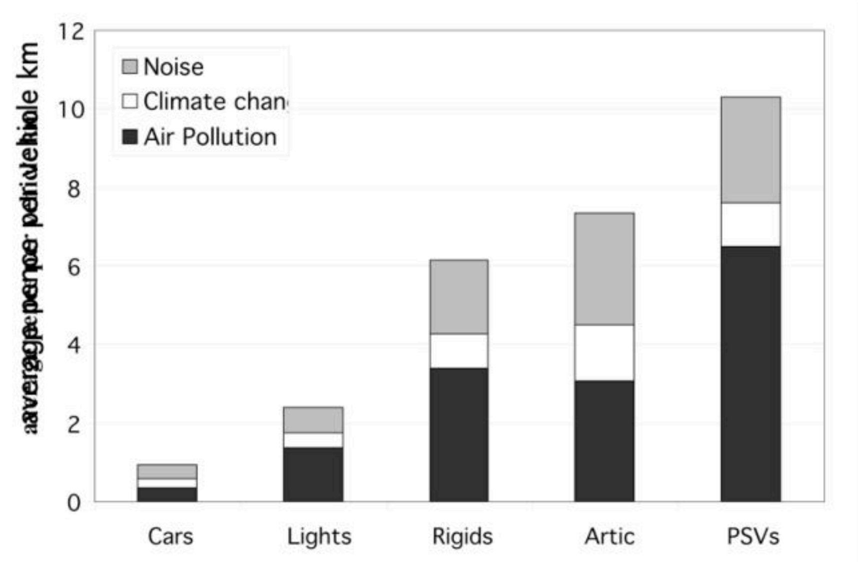


Figure 2: Average environmental costs of road vehicles (1998 fleet, central estimate)

Source: Sansom *et al*, 2001

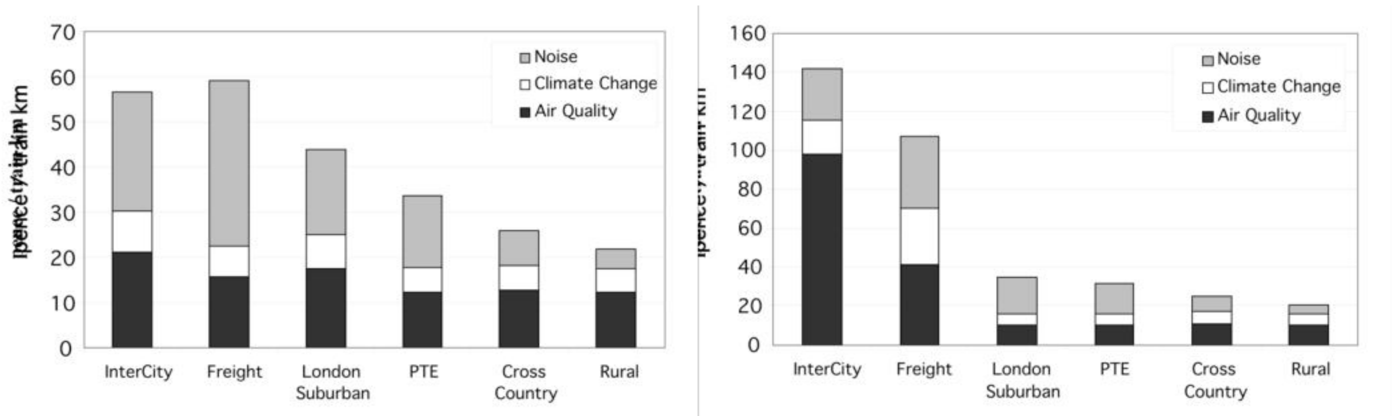


Figure 3: Average environmental costs of electric (left) and diesel (right) trains (1998 fleet, central estimate)

[5] Note the location of emissions is less important than for road. For diesel trains, most emissions are emitted along rural corridors. For electric trains, pollutants are emitted from tall power station stacks.

The highest environmental costs expectedly occur in congested urban locations (e.g. London), as shown for PSV in Figure 4 below. (Note these are marginal costs for one additional vehicle and assume no changes in overall vehicle speeds.[6]) This is due to mainly two factors:

1. Variations in the environmental costs (per tonne/dB(A) emitted) due to the local population density;
2. The speed-emissions relationships, which basically says that emissions are relatively higher at low (congested) and high (motorway, InterCity) speeds.

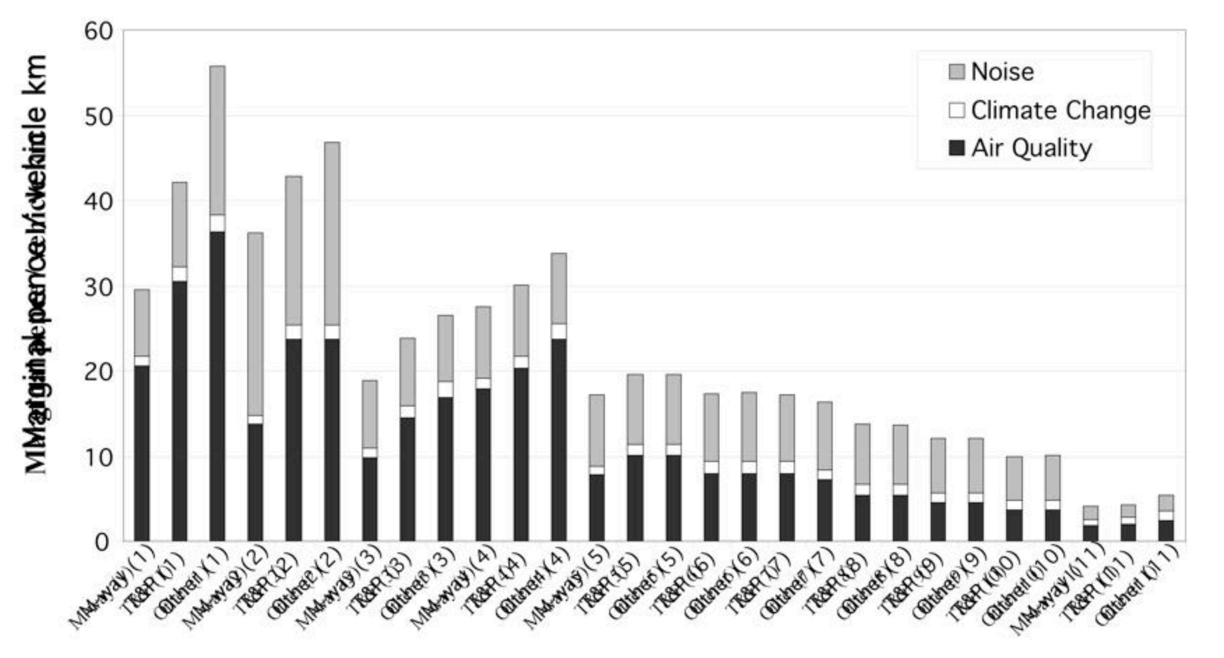


Figure 4: Marginal Environmental Costs for the Average Public Service Vehicle (1998)

Key:
1 = Central London, 2 = Inner London, 3 = Outer London, 4 = Central Conurbations, 5 = Outer Conurbations, 6 = Area>25 sq kms, 7 = Area 15-25 sq kms, 8 = Area 10-15 sq kms, 9 = Area 5-10 sq kms, 10 = Area 0.01-5 sq kms, 11 = Rural.

Source: Sansom *et al*, 2001

To compare the full external environmental costs of different modes it is, of course, necessary to look at local conditions (ambient air quality, population density, etc.) as well as upstream and downstream processes relevant to the town or city. The following example of estimated air pollution costs in Stuttgart, Germany, describes published results of marginal air pollution costs of different urban transport modes (EC, 2000).

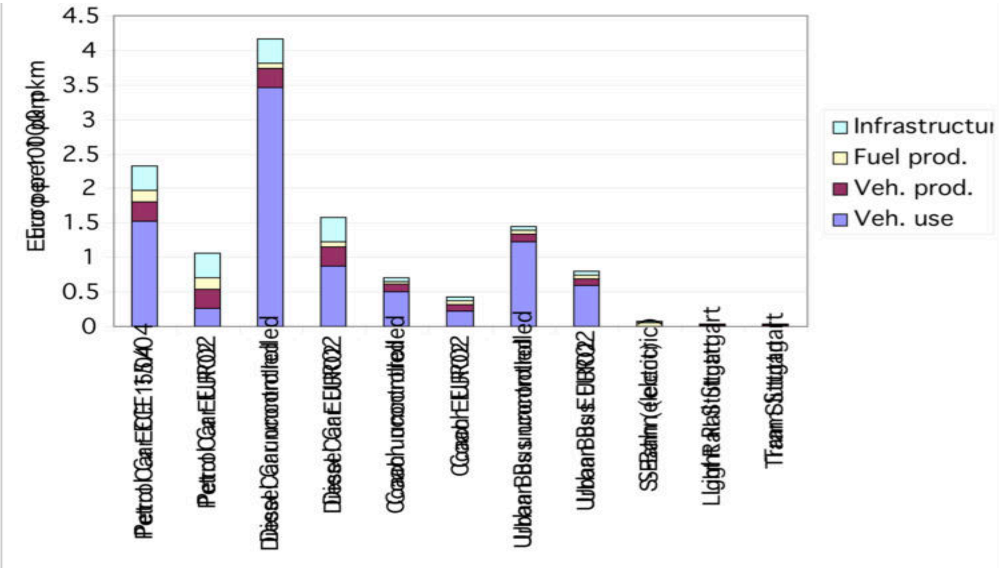
➲ *Cost of air pollution in Stuttgart, Germany*

An ExternE-Transport (EC, 2000) case study on Stuttgart illustrates the point that for comparisons between vehicle types and modes it is important to include up- and downstream processes. Figure 5 below shows marginal transport costs (in Euro per 100 passenger-km) for

[6] More significant marginal increases (e.g. 10%+ changes in vehicles numbers) will change speeds and therefore slightly change the marginal environmental costs.

private and public transport modes. In terms of total costs per passenger-km, electric rail vehicles produce the lowest damage costs due to air pollution by far. This is because in Stuttgart, rail vehicles for passenger transport are operated electrically only, with no direct emissions from vehicle use. Of the remaining processes, fuel (electricity) production causes the highest share of costs. For vehicles with diesel (mainly buses and coaches) or internal combustion engines (mainly cars), vehicle operation plays a very important role in the urban environment.

However, a direct transfer of these average costs to the UK is not possible, mainly due to different ambient pollutant background concentrations, electricity generation fuel mixes, vehicle load factors and population densities.



Source: EC, 2000

Figure 5: Comparison of marginal air pollution costs due to urban passenger transport in Stuttgart (Euro per 100 passenger-km)

3.2 Safety

Medical treatment, time off work, reduced quality of life following permanent injury, and fatality – these are just some of the likely outcomes of an accident involving road and rail vehicles. The cost of medical treatment is well known because it is recorded in health service statistics. The value of time off work is usually equated to the wage cost, and again, statistics of time off work are collected nationally.

The human costs of injury and death are much more difficult to value. Nevertheless, many people make decisions about their exposure to risk of injury or death involving an implicit valuation through their choice of occupation and pay, and other aspects of lifestyle or the products they buy. Some studies have examined these choices for statistical links between cost and risk of injury or death; other studies have asked people for their own valuations. The values range fairly widely. For example, the Highways Economics Note No1 (DTLR, 2001b) suggests a value for preventing a statistical road fatality at £0.75m - £1.25m (1997 prices). Values in this range are often used in policy analysis. The DTLR guidance further suggests adopting the mid-point of the range as the basis for the value of prevention of a fatality, i.e. £1m. Updated to 2000 values, this mid-point is £1.14m (ibid).

Table 6: Average values of prevention per road casualty, by severity and element of cost (£ 2000)

	Element of cost			
Injury severity	***Lost output***	***Medical and ambulance***	***Human costs***	***Total***
Fatal	393,580	670	750,640	**1,144,890**
Serious	15,150	9,190	104,300	**128,650**
Slight	1,600	680	7,640	**9,920**
Average, all casualties	*7,390*	*1,690*	*27,060*	***36,140***

Source: DTLR, 2001b

In the NATA, the DTLR recommends data on the reduction in numbers of (a) accidents involving personal injuries, (b) deaths, (c) serious injuries and (d) slight injuries, over a 30 year period starting from the scheme opening year, due to the scheme, compared with a scenario without the scheme. Table 6 above shows average values of prevention per road casualty, by severity and element of cost.

The values above act as a starting point for valuing external accident costs. Both the fully allocated cost and the marginal cost approaches are relevant for valuing external accident costs. This means:

- For the **fully allocated cost approach**, the starting point is the calculation of accident rates per vehicle kilometre. This can be based on actual accident rates or be based on average rates taken from the Road Accident Statistics, Great Britain (DETR, 1999b). The standard evaluation values per casualty (Table 6) can then be used to derive monetary values (DTLR, 2001b).
- In the case of **marginal cost analysis**, when an additional road user raises the accident rate per vehicle-km for all existing transport users, the full value per accident is relevant because this additional risk is external to the additional road user. The full value is also applicable when the costs are imposed on vulnerable road users.

Note that empirical evidence cited in, for example, Sansom *et al* (2001) suggests adjusting the values in the fully allocated cost approach by:

- Reducing material damages by 40% to reflect the fact that a proportion of these will be reflected in insurance payments; and,
- Adding an additional component, 40% of the individual's willingness to pay for risk reduction, as an estimate of the value that friends and family place on reduced risks. This component is not included in the standard UK appraisal values, and it is conventional to use this in a high sensitivity test because there are mixed views on whether friends and family are indifferent or not between individual's risk reduction and money payments.

For the average accident costs, the external component of the unit value comprises these net material costs plus the values held by friends and family.

The impact of additional traffic on accident risk rates is known as the risk elasticity. Elasticities are typically (taken here from the European PETS project; Jansson and Lindberg, 1998):

- For cars, light vehicles 0.25 in urban areas, zero for inter-urban contexts; and,
- For HGVs, PSVs 0.25 in urban areas, 0.5 for inter-urban contexts.

It is important to note that the use of risk elasticities, as opposed to the commonplace assumption of constant risk rates, strongly influences marginal cost estimates. This is reflected in the high/low estimates in Table 7, summarising fully allocated and marginal accident costs by road vehicle class reported in Sansom *et al* (2001).

Table 7: Fully allocated and marginal accident costs by road vehicle class, net of insurance payments (in pence/vehicle-km, 1998 values)

External costs of accidents [1]	*Fully allocated costs* [2]		*Marginal costs* [3]	
(pence/vehicle-km)	*low*	*high*	*low*	*high*
Car	0.07	0.82	0.79	1.38
LGV	0.04	0.46	0.53	0.89
HGV-rigid	0.04	0.61	1.39	1.96
HGV-artic	0.03	0.50	0.99	1.40
Public Service Vehicle	0.18	2.33	3.74	6.58

Source: Sansom *et al* (2001)

[1] Accident costs are net of insurance payments.
[2] The high and low values represent the analysis with and without the value held by friends and relatives.
[3] The high and low values represent the analysis with and without the value held by friends and relatives plus the sensitivity of risk elasticity.

The figures in Table 7 are lower than figures published in earlier papers. For example, Green, Khoury and Davies (2000) calculate average urban accident costs for buses and coaches to be about 17.7 pence per vehicle-km (thus figure is based on earlier estimations by Newbery, 1992). (Note that these should be compared with the marginal costs in the above Table, as both values are based on the full value per accident.) The differences can be explained. As Green, Khoury and Davies note, Newbery's figures are based on a somewhat out-of-date VoSL figure (£2million). Also, the figures in Table 7 are national average figures, whereas Newbery calculated urban figures.

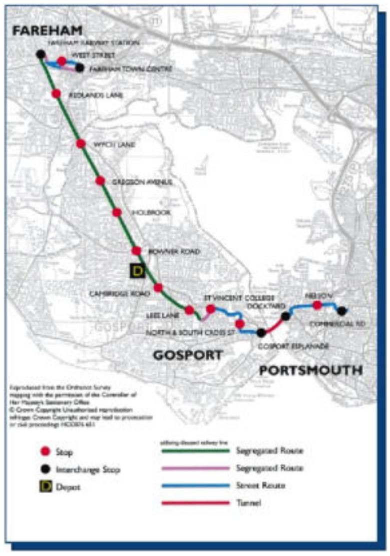
Sansom *et al* (2001) also give cost figures by area type, road type and time of day. For example, the low estimate of marginal external accident costs for cars in urban areas are higher (1.68 pence per vehicle-km for cars) than the national figures above. Similarly, the low estimate of marginal external accident costs for PSV is slightly higher at peak times (Monday-Friday, 07:00-10:00 and 16:00-19:00) than at off-peak times (other times).

External rail accident costs are often not estimated, since the *external* element is believed to be small once the level of liability placed on train operators is taken into consideration.

In general, however, the primary issue for a light rail system is the extent to which it comes into conflict with other vehicles and road users. A Transport Research Laboratory study into light rail safety (Walmsley, 1992) made the following conclusions:

- The accident rate per passenger kilometre is lower than for buses;

- A passenger making a journey by light rail has a less chance of being in an accident than if the same journey was made by bus;
- There is no evidence that bus accident rates are any higher after the introduction of light rail;
- There is a similar proportion of light rail-pedestrian accidents (7%) for both bus and light rail;
- There is a higher proportion of serious accidents per vehicle kilometre than for bus, but no more than for road traffic accidents as a whole in the UK.



For example, the South Hampshire Rapid Transit (SHRT) appraisal study concluded that the introduction of phase 1 of the system will have overall large positive effects, mainly a result of a transfer of a number of car trips to light rail. As light rail is an inherently safer mode than car this results in accident benefits in the form of reduced road accidents worth £12.5m (present value of accidents saved over project life of 30 years, 6% discount rate, 1999 prices) (SHRT, 2000). These savings are considerable compared to the planned capital costs of £110.7m, operating costs of £43.3m and total revenue of £101.7m (all present values over project life of 30 years, 6% discount rate, 1999 prices) (ibid).[7] Given the route length of 13.3km, and projected vehicle-km of 1.214 million per year, the accident cost savings amount to about £0.1m per year per route-km, or £1.1 per vehicle-km (ibid).

We have not found any reliable data on average external accident costs for intermediate bus modes (guided buses and busways). However, it is generally accepted that segregated track systems (guided bus, busways, segregated bus lanes) are inherently safer, therefore reducing unit accident costs considerably. For example, a 30% saving in injury accidents has been reported following the introduction of the Wilmslow corridor bus lane in Manchester (Manchester City Council, 1995), therefore reducing marginal external accident costs per kilometre driven to about 2.6 pence (low) to 4.6 pence (high).

3.3 Economic

Operating costs

The major elements of system operating costs are staff-related costs (mainly driver and maintenance personnel wages), vehicle operating costs (fuel, tyres, wear and tear, etc.) and vehicle and infrastructure maintenance costs. Average operating costs are usually presented as costs per vehicle-kilometre and less commonly as costs per passenger-kilometre. This aims to avoid the uncertainty inherent in average load factors. Other common indicators include fully accounted costs by distance (vehicle-kilometres), number of vehicles in service, time (vehicle hours) and/or network size (route-kilometres).

[7] Demand is forecast to be 11.7m single trips per annum. The total capital cost of the scheme is estimated to be £152m. The annual operating costs for the scheme are forecast to be £4.31m in 1999 prices, or 37 pence per single trip. Annual revenue is forecast to be £10.21m, or 87 pence per single trip, before allowing for the build-up of demand (SHRT, 2000).

Operating costs can be classified in many ways: by input, operational activity or basis of variation (see White, 1995 for a more detailed description). Table 8 shows an example of a bus cost structure according to operating activities, also indicating the basis of variation.

Table 8: An example of a bus cost structure according to operating activities

Category	Main components	Basis of variation
Variable costs	Staff wages, vehicle servicing	Time (VH)
	Fuel, tyres, third-party insurance	Distance (VKM)
Semi-variable costs	Bus maintenance	Time (VH)
	Depreciation and leasing	Peak vehicle
Fixed costs	Administration staff and welfare	Time (VH)
	Buildings and general	Peak vehicle
Interest on capital debt		Peak vehicle

Note: VH = vehicle hours; VKM = vehicle-kilometres
Source: White, 1995; Cole,

Interest, taxes and depreciation are often treated separately from the categories of operating cost described above.

- **Capital depreciation:** For example, it is common in the bus industry to use the straight line method, i.e. divide capital costs by expected service life to provide a sum set aside each year. This omits inflation and may therefore present a serious danger of failing to make necessary replacement investment. Vehicles are usually depreciated, infrastructure often not.
- **Interest on capital debt:** Mainly fixed-interest loans, in particular in the public sector. Private companies financed entirely through equity (or dividend) capital would not incur such a “cost”.

Cost figures based on operating experience are notoriously hard to obtain. They are typically of different systems and are therefore difficult to compare directly. Also, they are often subject to commercial confidentiality. To deal with this uncertainty, we have attempted to highlight any assumptions and, where appropriate, judge the quality of the data.

Light rail

A recent review on light rail by the ECMT (1994) gives financial performance data for eight selected cities (see Table 9 below). Although the data was collected in 1989 and is therefore somewhat out-of-date, it can be seen that there is a large variation in operating costs. The major differences reflect whether capital costs are low, reflecting a system built some years ago (e.g. Bern) and nearly fully depreciated, and relatively new systems with recent capital costs currently being depreciated (e.g. San Diego).

Unit operating costs of current systems operating in the UK are listed in the *Modal comparison* Section below.

Table 9: Financial performance of selected light rail systems (annual, 1992 £ Sterling)

System	Operating costs (£'000)	Capital costs (£'000)	RVH [1] ('000)	RVKM [2] ('000)	Passenger trips ('000)	Passenger revenue-km ('000)	Revenue (£'000)	Operating costs per RVKM, £
Bern	15,028	12,097	-	2,491 [4]	16,500	158,600	9,815	3.0 [5]
Grenoble	2,822	19,123	-	1,910	16,500	-	12,698	1.5
Hanover	40,042	-	752	18,336	96,501	-	33,366	2.2
Manchester	-	10,667	-	-	-	-	-	
Nantes	3,355	6,244	-	826	14,500	-	12,497	4.1
Nieuwegen	2,340	5,922	45	1,746	8,685	59,053	-	1.3
San Diego	5,037	16,675	126	3,808	11,217	122,182	4,803	1.3
Stuttgart	54,049	-	727	18,363	94,383	-	40,452	2.9

Source: ECMT, 1994 and own calculations

Notes:
1. RVH = revenue earning vehicle hours
2. RVKM = revenue earning vehicle kilometres
3. To convert $ to £ the 1992 exchange rate of 0.55 £/$ was used.
4. Bern revenue vehicle-km data is for the whole train and not for a single vehicle.
5. Assuming that the Bern system runs two vehicles per train on average.

More recently, operating costs for the proposed South Hampshire Rapid Transit have been estimated to be £4.31m per year, or £43.3m over the project life of 30 years (all 1999 prices; SHRT, 2000). In unit costs this is £3.5 per vehicle-km, £0.32m per route-km, or £71 per vehicle-hour (average values, not allocated!).

An example of the breakdown of operating costs by staff and other expenses is shown in Table 10 below. This shows that for this particular case, nearly 40% of total operating costs are staff-related, whereas power supply (traction only) and maintenance (including cleaning and maintenance equipment) account for about 7% and 23%, respectively.

Table 10: Light rail operating cost breakdown: example South Hampshire Rapid Transit (£'000 per year, 1998 prices)

Detailed cost	Quantity	Cost/Unit	Total cost	%
Drivers	39	15,900	620,100	14.69
Senior controllers	2	20,140	40,280	.95
Controllers	5	18,020	90,100	2.13
Line supervisors	3	20,140	60,420	1.43
Rostering, train	1	20,140	20,140	.48
Senoir inspectors	1	20,140	20,140	.48
Inspectors	7	16,960	118,720	2.81
Vehicle maintenance supervisors	2	20,140	40,280	.95
Vehicle maintenance technicians	7	15,900	127,200	3.01
Managers (main, ops & mark, fin & pers)	3	31,800	95,400	2.26
Assistants (main, ops & mark, fin & pers)	3	25,970	77,910	1.85
Secretaries, clerks	4	14,310	57,240	1.36
Managing directors	1	47,700	47,700	1.13
TOTAL STAFF	**88**	**17,809**	**1567,210**	**37.12**
Power supply (traction)			300,465	7.12
Other energy (elec, gas, water, etc.)			60,093	1.42
Maintenance materials (track, equip)			526,336	12.47
Subcontracts (clean, rs, maint. Equip)			441,620	10.46
Subcontracts (bus service)			70,000	1.66
Subcontracts (surveys, marketing)			75,000	1.78
Tunnel maint.			80,000	1.89
Insurance			250,000	5.92
Depot security, vandalism			50,000	1.18
Rating			75,000	1.78
Office supply and misc.			75,000	1.78
TOTAL OTHER EXPENSES			**2003,514**	**47.45**
Tech. Assist. Managt fees, profit			357,072	8.46
Contingencies (7.5%)			294,585	6.98
TOTAL OPERATING COSTS			**4222,381**	**100**
Operating costs per veh km			3.48	

Source: SHRT, 2000

Dual-mode rail systems

The Karlsruhe experience shows that operating costs of dual mode rail systems operating on suburban heavy rail lines can be significantly lower than those of heavy (suburban) rail services (which they often replace or compete with). Average costs can be as much as 50% lower

(CrossRail, 2001). One of the reasons for this difference is that on suburban German rail lines network access charges are lower per km driven for light rail than for heavy rail.

When compared to conventional light rail services, operating costs for dual mode rail systems are about the same. This statement is, however, based on the limited experience in Karlsruhe and Saarbrücken (CrossRail, 2000).

Bus based systems

Typically, operational costs for conventional bus systems are slightly lower than for light rail systems on a per passenger-km basis; some costs are lower per unit of output (e.g. some maintenance costs, costs of amortisation) while others are higher (e.g. staff costs).

When compared to conventional busways, the operating costs of guided busways are claimed to be slightly lower (Disley, 1994; Hass-Klau *et al*, 2000). Maintenance costs have been reported to be less owing to the reduced wear-and-tear on the vehicles and track. However, there is no empirical evidence to support this. Also, since wear and tear costs represent only a relatively small proportion of total costs, the difference may be considered negligible.

An urban bus company has about 70% of its operating costs accounted for by staff-related costs (bus drivers wages, maintenance personnel wages, National Insurance, pensions etc.) (White, 1995; Lesley, 1997). These are part of the *variable costs* (about 75% of the total), which vary in direct proportion to passenger capacity output. Other variable costs relate to fuel use and wear and tear. For example, only 5-10% of the total operating costs are accounted for by energy use (White, 1995). Some maintenance, vehicle refurbishment, marketing, recruitment, training and operating supervision costs are only broadly related to the output of passenger mileage; these are about 10% of total costs (ibid). The fixed costs represent the headquarters, depot and amortisation costs, which in a typical bus company represent about 15% of annual costs (Lesley, 1997).

Table 8 above shows a typical bus cost structure, based on an activity-based classification developed in the 1970s by the Chartered Institute of Public Finance and Accountancy (CIPFA). This methodology takes account of the fact that most bus operating costs do not vary with distance but with time (White, 1995), namely crew wages, bus servicing and maintenance, administration staff and welfare payments.

Cost allocation

Cost allocation methods are similar for rail and bus operations, however allocating costs to specific traffic flows becomes difficult and often arbitrary for large networks. Cost components are slightly different to the bus industry. For instance, rail operating costs include train crew, track maintenance, signalling (bus operators usually don’t pay for road maintenance and signalling), terminals (stations and depots) and rolling stock maintenance. Also, cost variation by traffic density (VKM/RKM) is a major factor for railways.

Nash (in Dodgson and Topham, 1988) outlines a simple model of frequency and route density. They suggest calculating bus operating costs as a linear function of bus size. By appropriate substitution, the total operating cost per hour may then be calculated as:

$$TOC = c_1 \cdot VKM + \frac{c_2 \cdot TL \cdot PT}{LF}$$

where:

c_1, c_2 = parameters of the linear function in *Cost = c1 + c2 * Size*
VKM = total bus-kilometres on all routes per hour
TL = mean passenger trip length
PT = passenger trips per hour
LF = maximum load factor

TL: in 1999/00, bus journeys in the UK averaged 6.8km in length (DETR, 2000b). Of course, this figure varies heavily depending on location. Average trip lengths in urban areas are lower, and higher in rural areas.

Data

Typical bus operating costs in the 1980s were about 136 pence per kilometre for a 15-seater at average 13 kph and 233 pence per kilometre for an 86-seater at average 11 kph (Dodgson and Topham, 1988). (Note that prices have been inflated to 2000 from 1988 values.) These figures are comparable to the national US average of about £2 per vehicle-km (converted to GBP at 1999 prices) and the figures calculated by Boyd *et al* (1978) and Reilly (1977) (see Table 12 and Table 13 below).

More recent figures are 158 pence per vehicle-km for London, 93 pence/vkm for English metropolitan areas and 82 pence/vkm for all areas outside London (TSGB, 2001). Note that operating costs are higher in London and metropolitan areas than elsewhere. Greater traffic congestion, more frequent services and the need to use larger buses for busy services all contribute to higher costs. The real cost reductions in recent years reflect a number of factors: changes to the numbers and types of staff employed, more flexible wage structures and working practices, and some reduction in the range of operators' activities.

Unit operating costs of current systems operating in the UK are listed in the *Modal comparison* Section below.

Experience with systems based on alternative bus technology

When compared to conventional diesel buses, the pros and cons of alternative fuelled buses are:

- **CNG** fuel is generally significantly cheaper than diesel or LPG, due largely to the low fuel duty on natural gas in many European countries (Smith, 2001). LPG is cheaper per unit of energy than diesel, again due to lower fuel taxation. Maintenance costs may also be reduced.
- The cost of **bio-diesel** fuel is dependent on the choice of feedstock and the tax rate. Current pre-tax costs (around 40 pence/litre) are higher than mineral diesel but low taxation rates in many countries give an overall fuel cost advantage. Large-scale commercial use of bio-diesel produced using today's technology could reduce the cost of bio-diesel to 25 pence/litre, and ongoing research programmes could further reduce costs (CVTF, 2000).
- Fuel costs for **electric buses** are low, particularly using cheap tariff electricity when recharging overnight (Economy 7 or cheap commercial rates) at the operators' refuelling stations.
- **Hybrid electric buses** are said to offer higher fuel efficiencies and long battery lifetimes, which lead to lower operating costs (Smith, 2001).

- Fuel costs for **fuel cell** vehicles will vary depending on the fuel choice and prevailing tax rates. Fuel cell vehicles are generally more energy efficient than conventional combustion engine (petrol, diesel) vehicles so fuel costs will be lower. However, hydrogen is currently very expensive to produce. Other operating costs will depend on the lifetime of the catalysts used in the fuel cell stack and the fuel processor.

Operational cost examples of alternative fuelled buses

1. In **Merton**, a fleet of 25 CNG minibuses, vans and refuse trucks was purchased at an additional cost of around £17,500 per truck and £2,500 per minibus or van. Government and EU subsidies were available to cover up to 75% of the additional capital cost of purchasing the vehicles. Maintenance cost savings of £40,000 per year (on average £1,600 per vehicle per year) were achieved, and together with low natural gas prices this gave a payback time of 1.6 years. The project was so successful that the local authority now plans to convert 80% of its fleet (170 vehicles) to CNG by 2010 (Smith, 2001).
2. In the town of **Linköping, Sweden**, all 66 public transport buses and some passenger cars run on biogas produced from anaerobic digestion of the town's sewage and abattoir waste. From an initial supported demonstration phase involving just six buses, the biogas bus fleet now operates on a near-commercial basis, with costs only 5-10% above a conventional diesel fleet. However, this is heavily dependent on continuing zero taxation for the biogas fuel. In contrast, the bio-gas producer is not profitable, partly because the biogas sale price is set to be 10% below diesel prices, which were very low for most of the project period. To achieve full commercial viability in future, the biogas plant operator will need to charge producers of the organic waste feedstock for disposal of this waste via the biogas plant, and also sell by-products from the process to farmers for use as fertiliser.
3. In Stockholm, operating costs of running 250 ethanol buses are around 7-8% higher than for diesel buses (http://www.responseonline.com/etha.com).

Vehicle Operating Costs in project appraisal

The DTLR recommends a set of vehicle operating cost (VOC) values for use in economic appraisals of transport projects. These are used to assess costs and benefits to users and non-users arising from any modal shift and suppressed journeys. VOCs are separated into fuel VOCs and non-fuel VOCs. Fuel VOCs simply represent the costs incurred by consuming transport fuel (diesel, electricity, alternative fuels or whatever) whereas non-fuel VOCs include oil, tyres, maintenance, depreciation and vehicle capital saving (only for vehicles in working time). Table 11 shows the latest values for PSV (buses and coaches) set out in the DTLR's *Transport Economics Note 2000* (DTLR, 2001a).

Table 11: PSV Vehicle Operating Costs recommended by the DTLR for economic project appraisal (Source: DTLR, 2001a)

	Formula	*a*	*b*	*c*	a_1	b_2
Fuel costs	$L = a + b \cdot V + c \cdot V^2$	0.7244	-0.01135	0.00007157	-	-
Non-fuel costs	$C = a_1 + \frac{b_1}{V}$	-	-	-	18.287	306.60

Where:

L = consumption, expressed in litres per kilometre;
V = average link speed in kilometres per hour;
a, b and *c* are parameters defined for each vehicle category (in litres per km);
C = cost in pence per kilometre travelled;
a_1 is a parameter for distance related costs defined for each vehicle category (in pence per km);
b_1 is a parameter for vehicle capital saving defined for each vehicle category (in pence per km). This parameter is only relevant to working vehicles.

Fuel consumption can be converted into fuel costs (in pence per vehicle-kilometre) by multiplying by the cost of fuel. PSV are traditionally diesel powered, hence for non-working trips the market price for diesel (on average 77.8 pence in 2000) is the most relevant.

Sansom *et al* (2001) calculated VOCs on the basis of average link speeds and the information provided above. They came up with 79.61 pence per PSV-km as a national average (1998 prices), and curiously a little bit lower (78.7 pence) in peak times and a bit higher (80.1 pence) at other times. As expected, VOCs are slightly higher in urban traffic; for example, 83.9 pence per PSV-km in outer conurbations. (Note these PSV operating cost values include the taxation components mentioned above).

Modal comparison

Small (1992) compares bus, light rail and heavy rail based on three accounting cost studies (Allport, 1981; Boyd, Asher and Wetzler, 1978; and Reilly, 1977) that calculate operating costs as a function of common intermediate outputs (e.g. vehicle-hours, vehicle-kilometres). Table 12 shows the results, adjusted to 2000 GBP. Note that the data may be considered somewhat outdated and therefore treated with care.

Table 12: Operating cost (functions) for various public transport modes

	Heavy rail		*Light rail*	*Bus*		
Operating costs	Boyd et al (1978)	Allport (1981)	Allport (1981)	Allport (1981)	Boyd et al (1978)	Reilly (1977)
Per RKM (£m/year)	0	0.338	0.084	0.003	0	0
Per PV (£k/year)	0	37.70	26.72	17.28	0	8.46
Per VH (£)	4.68	24.55	32.21	30.91	17.75	18.07
Per VKM (£)	2.99	1.08	1.15	0.51	0.49	0.36

Notes:

- Prices have been adjusted to 2000 GBP by converting 1989 USD to 1989 GBP and inflating to 2000 prices.
- '*0*' means that items in this category are included under other categories. For instance, Allport assumes operating costs to vary with all four outputs, whereas Boyd *et al* assume they vary only with VH and VKM.

Allport's study is helpful because it draws from the accounts of a single operator (in Rotterdam, The Netherlands) providing all three types of transit.

Hensher and Waters (1993) report of an Australian study that suggests that busways are slightly more cost-efficient than light rail, quoting operating and maintenance costs of £2.4-2.8 per vehicle-km for a busway system and £2.4-4.0 per vehicle-km for a light rail system (excluding capital depreciation and interest, converted and inflated from 1993 USD).

Some crude comparisons between rail and bus operating costs may be made by dividing total operating costs by train/bus-kilometres, passenger-kilometres and route-kilometres. Table 13 shows US national averages (adopted from APTA, 1999 and converted to 1999 GBP) while Figure 6 illustrates the modal comparison in terms of cost per vehicle-km.

Table 13: Total operating cost performance indicators, US national averages

Total operating costs (values in 1999 GBP)	*Light Rail*	*Bus*	*Suburban rail*	*Heavy rail*	*Trolleybus*
Total (£million)	338	7261	1596	2290	103
Total/tot. vehicle-km (£)	4.31	1.98	3.73	2.46	4.52
Total/tot. passenger-km (£)	0.174	0.213	0.113	0.110	0.345
Total/tot. vehicle-hours (£)	104.9	42.7	187.8	76.6	54.4
Total/active vehicles (£'000)	260.8	97.8	326.9	222.2	120.4
Total/'000 tot. route-km (£)	262	28	191	924	149

TOC = total operating costs. Suburban rail = 'commuter rail'.

Source: adopted from APTA, 1999 with own calculations.

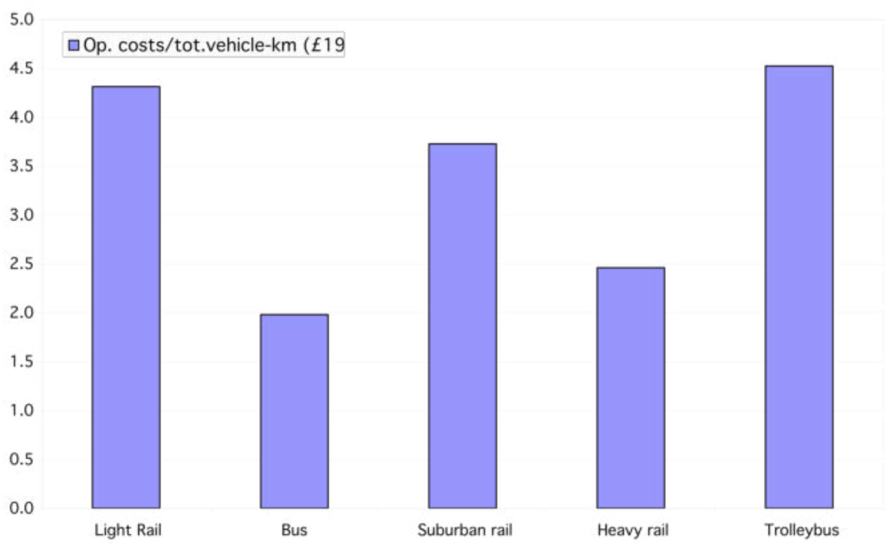


Figure 6: Modal comparison of total operating costs per vehicle-km, US national averages (1999 GBP values)

Source: APTA, 1999

For the UK, Table 14 shows unit operating costs for selected rail and bus systems, with an indication of what is and what is not included in total operating costs. For instance, capital financing (depreciation, renewal, amortisation) is often reported separately from variable and semi-variable operating costs. Operating costs for light rail systems in the UK show a wide range – about a factor of ten between the cheapest (West Midlands Metro) and most expensive (Docklands Light Railway). Unit costs for the Dockland Light Railway are much higher than for the other schemes – a surprising result given the expected lower staff-related costs of driverless transit.

Underground/metro operating costs are in the range from £15-20 per train-km. Note that although costs per train-km are higher for the London Underground, the higher load factors achieved on the London network result in lower costs per passenger-km than for the Glasgow Underground. Suburban railways are in the range from £9-11 per train-km. Although unit costs per route-km are highest for the Thameslink services, costs are relatively low at 10 pence per passenger-km due to the high load factors achieved (an average of 113 passengers per train) (Transit, 2002).

Operating costs for standard urban bus services are on average 93 pence per bus-km, with higher costs in London (158 pence/bus-km). However, similarly to what was said on rail-based systems, the higher load factors achieved in the densely populated capital bring unit costs per passenger-km down to national levels (about 9-12 pence per passenger-km) (TSGB, 2001). This is slightly lower than for light rail (5-44 pence per passenger-km).

We were unable to find appropriately disaggregate and comparative data for guided buses and bus lanes operating in the UK. However, given the limited experience abroad we can assume that operating costs for busways and bus lanes are about the same than for conventional bus services. This is further discussed in the *Cost comparison* sections below.

Table 14: Modal comparison of unit operating costs, selected UK systems

Mode (Year)	Total loaded train/bus-km	Costs per vehicle-km	Costs per passenger-km	Costs per route-km	Source
Light rail	(millions)	(£)	(£)	(£million)	
Docklands Light Railway '00 [3]	2.64	25	0.44	2.4	TSfL, 2000
NEXUS (Tyne & Wear Metro) '01	4.7	5.64	0.12	0.45	NEXUS, 2000/1 TSGB, 2001
Manchester Metrolink '93	2.0	4.0	0.15	0.26	Transland, 1999 TSGB, 2001
Sheffield Supertram '00	2.4	2.8 [4]	0.18	0.23	TSGB, 2001
Centro (West Midlands Metro) '01	1.9	1.6 [4]	0.05	0.14	Centro, 2002 TSGB, 2001
Croydon Tramlink '01	2.1	5.6 [4,5]	0.12	0.42	FirstGroup, 2001 TSGB, 2001
South Hampshire Rapid Transit '99	1.214	3.5	0.08	0.32	SHRT, 2000
Average *Standard deviation*		*6.9* *8.1*	*0.16* *0.13*	*0.6* *0.8*	
Metro					
London '00 [3]	63.1	21.5	0.19	3.33	TSGB, 2001
London '00 [6]	63.1	15.2	0.13	2.36	TSGB, 2001
Glasgow '99 [3]	1.13	14.5	0.35	1.5	SPTE, 1999
Average *Standard deviation*		*18.0* *4.9*	*0.27* *0.11*	*2.4* *1.3*	
Suburban railways					
London suburban		10.2			White, 1995;
- c2c [2]	6.1	(avg.)	0.08	0.48	SRA, 2001
- Connex SC [2]	27.7		0.11	0.40	
- Connex SE [2]	28.2		0.09	0.38	
- Silverlink [2]	10.1		0.10	0.32	
- Thames Trains [2]	13.8		0.14	0.25	
- Thameslink	11.36	11.1	0.10	0.57	Transit, 2002
Average *Standard deviation*		*10.7* *0.6*	*0.10* *0.02*	*0.40* *0.11*	
Urban bus services					
London '00 [3,7]	365	1.58	0.12 (est.)	-	TSGB, 2001
English Metropolitan areas '00 [3,7]	656	0.93	0.10 (est.)	-	TSGB, 2001
All outside London '00 [3,7]	2,234	0.82	0.09 (est.)	-	TSGB, 2001

[1] Prices inflated from 1992/3 accounts.
[2] Cost data based on the average of two figures: Thameslink and previous Network Southeast operations. This excludes the infrastructure charge imposed by Railtrack of about £7 per vehicle-kilometre. These are argued to be clearly much greater than the sum of infrastructure-related costs or staff-related costs (White, 1995; Transit, 2001).
[3] Includes renewal, depreciation and, where applicable, PFI charges.
[4] Assuming receipts (fare box income) equal operating costs, i.e. £6.8m for Sheffield, £3.0m for Centro, and £11.8m for Croydon.
[5] Takes account of that Tram Operations Ltd (100% FirstGroup subsidiary that has the operating contract for the Croydon system) made an operating profit of £0.7m in '00/01. FirstGroup's share of operating loss of Tramtrack Croydon (joint venture that owns the track) was £0.3m in '00/01.
[6] Excludes renewal, depreciation and severance costs.
[7] Net of fuel duty rebate.

Cost comparison 1: Pittsburgh and Ottawa

Kain (1998) and Hass-Klau *et al* (2000) report of operating costs for different systems operating in two North American cities, Pittsburgh and Ottawa.

- **Pittsburgh**. Pittsburgh operates buses, busways and light rail. The relative output (in passenger miles) of buses operating on busways is less than one third of buses in mixed traffic. There is close similarity between the operating costs per passenger kilometre of the two types of bus (about 24 pence), whereas the corresponding figure for Pittsburgh's light rail is about 16% higher than this (about 29 pence). This is shown in Table 15. Note that these costs are sensitive to the city authority's assumptions on average load factors (about 10 passengers/bus and 20 passengers/tram).

Table 15: Operating costs in Pittsburgh (1997/8 £/$ prices)

Mode	*Operating costs ($Million)*	*Passenger miles (Million)*	*Operating costs per pass-km (£/pkm)* [1]
Bus in mixed traffic	129.0	203.3	0.247
Bus on busways	38.5	62.3	0.24
Light rail	26.5	35.8	0.288

Source: Hass-Klau *et al*, 2000 and own calculations. [1] The average 1998 exchange rate of £0.627 per $1 was used here for conversion.

- **Ottawa**. Ottawa operates buses and busways (*Transitway*). The latter account for about 75% of bus passenger trips – a relatively high number for a capital city. When converted into £, the operating cost per passenger kilometre of all Ottawa buses (note: mainly *Transitway*) is much less than is reported for Pittsburgh (8 pence compared to 24 pence). The authors explain the gap with significantly different wage rates (roughly £7.9/h in Ottawa compared to about £18.2 in Pittsburgh!) and higher load factors assumed for the Canadian city.

In sum, the data for the two cities highlight the problems of comparing operating costs of different locations. While the infrastructure and vehicle market is more or less international, local differences in e.g. wage rates, load factors and fuel costs result in sometimes hugely different operating costs. In a single location such as Pittsburgh, with different systems in joint operation, operating costs for buses, busways and light rail are at least comparable. This compares with Kain (1998) who claims that on a per passenger trip basis, light rail in Pittsburgh has been at least twice as expensive to operate as busways. Typically, light rail trips are longer than bus trips, hence the difference is somewhat less in terms of costs per passenger-km, and therefore consistent with Hass-Klau's analysis.

Cost comparison 2: San Diego and Houston

As a further example, Kain and Liu (1999) reviewed the experience of two American cities: San Diego and Houston. San Diego operates both buses and light rail (the so-called *Trolley*), Houston only buses. In terms of operating cost per passenger boarding the *Trolley* was less expensive than the two bus systems. In 1997 its operating cost per passenger boarding was about three-quarters the figure for San Diego's buses and almost half of the figure for Houston's buses (£0.92 against £1.21 and £1.72, respectively; converted from 1993 USD and inflated to 2000 GBP).

Since the average length of San Diego *Trolley* trips exceeds bus trips, a comparison in terms of operating cost per passenger-km favours the *Trolley* even more. The 1997 level was about 10 pence per passenger-km for the San Diego *Trolley*, compared to about 16 pence for San Diego buses and 22 pence for Houston buses (converted from 1993 USD and inflated to 2000 GBP).

Revenue-earning capabilities

The major financial 'benefits' for operators are the income via the fare box and other income from marketing-related activities (e.g. advertisement on buses, trams). The former is mainly determined by the fare structure and the patronage achieved on the network.

Actual revenue income and patronage figures for selected UK systems are listed in Table 16 below. (Refer to Table 14 for total vehicle-km by mode.) Some revenue earning capability indicators were already shown for light rail in Table 9 above. The information collected and calculated here goes a bit further and includes revenue forecasts for one of the planned new light rail systems in the UK.

Table 16 shows that the revenue earning capability of underground systems is slightly higher (68-114 pence per journey) than for light rail (57-105 pence per journey) and conventional buses (50-69 pence per journey), whereas the example of Thameslink suggests that suburban rail revenue is substantially higher (355 pence per journey).

In contrast, all systems listed in the Table are comparable in terms of revenue per passenger-km: light rail revenues range from about 6 to 18 pence per passenger-km; underground 15-21 pence per passenger-km; Thameslink suburban rail 11 pence per passenger-km; and urban bus services 11-14 pence per passenger-km. The new West Midlands Metro light rail system (run by Centro) is clearly the least capable of bringing in revenue on a per passenger-km basis. However, the system is still in its infant stage and the data obtained represent the results of the first year in operation, so things might change over the coming years.

Note that on a per vehicle-km basis, the high capacity modes underground and suburban rail come out top, light rail middle, and bus bottom of the list. This makes sense and roughly corresponds to the systems' passenger capacities.

The data and analysis presented here are roughly in line with a recent study on urban transport operations carried out for the European Commission (ISOTOPE, 1997). The study was based on previous work of Mackie and Nash (1982), which developed a series of economic performance indicators. In a nutshell, the economic research gives the following results for the UK (prices converted from 1997 ECU and inflated to 2000 GBP):

- The average revenue per bus passenger-km was about 8 pence, compared to about 18 pence for rail-based modes (though based on only one observation);
- Revenue per bus-km was on average £1.2, compared to about £3 for rail-based modes (again, only one observation).

Table 16: Modal comparison of patronage and revenue earning capabilities of selected UK systems

Mode (Year)	Total journeys (million)	Total journeys per route-km	Average journey length	Revenue per journey made	Revenue per vehicle-km [2]	Revenue per passenger -km
Light rail	(million)	(million/km)	(km)	(£)	(£)	(pence)
Docklands Light Railway (00)	31.3	1.16	5.5	0.71	7.66	12.9
NEXUS (Tyne & Wear Metro) (01)	32.5	0.55	7.05	0.74	5.13	10.5
Manchester Metrolink (01)	17.2	0.44	8.85	1.05	4.11	11.9
Sheffield Supertram (00)	10.9	0.38	3.4	0.62	2.83	18.4
Centro (West Midlands Metro) (01)	5.4	0.27	10.3	0.57	1.63	5.6
Croydon Tramlink (00/01)	15.0	0.54	6.4	0.81	5.8	12.7
South Hampshire Rapid Transit (forecast) (99)	11.7	0.82	3.3 [1]	0.87	8.4	38.6 [1]
Average	-	*0.59*	*6.92*	*0.77*	*5.1*	*12.0*
Std. deviation	-	*0.30*	*2.44*	*0.16*	*2.5*	*4.1*
Metro						
London (99/00)	927	2.27	7.74	1.14	16.77	15.0
Glasgow (99/00)	14.7	1.34	3.20	0.68	8.33	21.0
Average	-	*1.81*	*5.47*	*0.91*	*12.6*	*18.0*
Std. deviation	-	*0.66*	*3.21*	*0.33*	*6.0*	*4.2*
Suburban rail						
London (00/01)						
- c2c	26.6	0.21	29.4	-	-	-
- Connex SC	110.4	0.15	23.5	-	-	-
- Connex SE	132.2	0.17	24.3	-	-	-
- Silverlink	36.1	0.11	28.3	-	-	-
- Thames Trains	36.4	0.06	27.8	-	-	-
- Thameslink	40.2	0.20	32.1	3.55	12.57	11.1
Average	-	*0.15*	*27.6*	*3.6*	*12.6*	*11.1*
Std. deviation	-	*0.06*	*3.2*	-	-	-
Urban bus						
London (99/00)	1,307	-	3.6 [3]	0.50	1.78	13.7 [3]
English Metropolitan areas (99/00)	1,160	-	5.6 [3]	0.61	1.07	10.7 [3]
All outside London (99/00)	2,972	-	6.8 [3]	0.69	0.92	10.2 [3]
Chester Guided Busway (forecast) (00)	0.56	0.11	2.6 [4]	-	-	-
Oxford Guided Transit Express (forecast) (01)	2.69	-	-	0.69	-	-
Average [5]	-	*0.11*	*3.93*	*0.60*	*1.43*	*12.2*
Std. deviation	-	-	*1.53*	*0.10*	*0.50*	*2.1*

Sources: TSGB, 2001; SHRT, 2001; SPTE, 1999; SRA, 2001; Gennard *et al*, 2000; TAS, 2001.

[1] We have assumed figures proportional to the Croydon Tramlink figures (route length, average trip length). The total passenger-km are the product of average trip length and the number of total journeys.
[2] Vehicle means a single or articulated bus, a whole train (e.g. an underground train has 6-8 carriages) etc.
[3] Estimated assuming average bus loading factors of 13 for London, 10 for English Metropolitan areas, and 9 for 'All outside London'.
[4] The figure given here represents the length of the guided track.
[5] Excluding 'All outside London' values.

Journey times

Public transport journey times[8] are usually broken down into:

- Walking time;
- Waiting time;
- In-vehicle time (including boarding time).

The valuation of travel time may include estimations of route length, passenger trip numbers, total vehicle-km, mean passenger trip length, the mean width of the PT system's catchment area and, most importantly, the values of time for different journey time 'slices'. (The different values of time are listed in Table 17 below.)

Value of time

The standard practice is to differentiate only between working and non-working time. However, survey work has shown that passengers' stated valuation of journey time varies geographically, and between bus, rail, light rail, car and air journeys. It can be politically sensitive to differentiate rates regionally or between modes, although there are also pragmatic reasons for using a standard value to make the analysis easier. For the purpose of project appraisal, a standard value of time is often applied (DTLR, 2001), for instance the *'Average of all workers'* value shown in Table 17. In general, the working time rates are valued at the employer's labour cost (gross wage rate plus non-wage labour costs), and non-working time is valued using figures obtained from surveys of people's preferences (Table 17). Values of working time apply only to journeys made in the course of work. This explicitly excludes commuting journeys. In contrast, the value for non-working time applies to all non-work journey purposes, including travel to and from work, by all modes. The value of non-working time spent waiting for public transport, walking and cycling is usually double the standard appraisal value (DTLR, 2001).

Table 17: Selected Values of Time per person (£/hour, average 1998 prices and values)

Traveller	**Perceived Cost (£/hour)**
Working Time	
PSV driver	6.7
PSV passenger	11.1
Taxi passenger	23.7
Rail passenger	25.2
Underground passenger	21.2
Train Driver (including underground)	15.0
Walker	24.0
Average of all workers (including car, taxi and bike driver not shown)	***11.6***
Non-working time	
All non-work journey purposes (in-vehicle time for public transport)	4.5
Waiting for public transport, walking and cycling	9.0

Source: DTLR (2001)

[8] In UK transport appraisal, travel time means *expected* travel time (that is, the statistical mean taken from the range of actual or predicted travel times). Changes in the variability of travel time are dealt with separately under journey-time reliability.

Calculation of time-related user benefits

There are different methodologies how to calculate these user benefits. In PT scheme appraisal, user benefits are estimated using the DTLR's cost-benefit computer program TUBA (Transport Users Benefit Appraisal). TUBA is a matrix based computer program capable of appraising highway and/or public transport projects with fixed or variable trip matrices. It is based on the conventional consumer surplus theory, with a disaggregation of user benefits by mode and by the components of perceived cost. The key input parameters are:

- Total vehicle-hours saved by the new scheme;
- Peak journey time change (min);
- Off-peak journey time change (min).

Key outputs are valuations of travel-time reductions resulting from the time advantage of the new scheme over previous/competing modes and reductions in travel time for people who continue to travel by car and benefit from a less congested road network.

Annex 1 details a similar journey time costing methodology for bus operations based on Dodgson and Topham (1988), applying the generalised (or perceived) cost approach.

Data

Working paper 1 (Brand and Preston, 2001) discussed the effects of different intermediate technologies on speeds and journey times. This showed, not surprisingly, that track segregation improves overall speeds and therefore journey times. For example, bus lanes are claimed to improve average journey times by anything between –10% to +30%. For example, the experience with the Edinburgh Greenways bus lanes suggests that these schemes have "improved levels of service, reducing bus journey times and improving reliability. Bus patronage on these routes has increased, reversing a long term decline" (Edinburgh LTS, 2001).

A simple example illustrates this further. Say a new scheme along an existing corridor operates at average speeds of 25km/h compared to the previous mode at 20km/h. The average trip length shall be 5km, and the walking and waiting time shall be equal for both modes. Taking standard values of time the time benefit is 3 minutes per journey, valued at 22.5 pence per journey. The scheme may show additional patronage of 3 million journeys per year, giving £675,000 in travel-time user benefits.

Let us look at two recent examples of scheme appraisal and the valuation of travel time. First, the travel time benefits due to the introduction of a new light rail scheme in the Portsmouth area have been estimated to be £250m to light rail users (resulting from time advantage of light rail over previous mode: bus, rail, ferry, and car) and £105.5m to car users (people who continue to travel by car and benefit from a less congested road network). This is significant when compared with the estimated capital cost of £152m and net operating costs of £31m (SHRT, 2002; 1999 present values, 6% discount rate, 30 year horizon).

The second example regards the proposed *Chester Deeside Transport System Phase 1*, a 2.6 km long, two-way guided-busway linking the city centre to a new P&R site. The Chester Local Transport Plan (2001) predicts total

Transport System Phase 1

economic efficiency benefits of £13.6 million against the 'Do Nothing' scenario (present value, 6% discount rate, 30 year time horizon, 1994 prices) (Chester LTP, 2000). (This is based on the outputs from the SATURN model for Chester.) This compares favourably to forecasts of fare-box revenues of £4.8 million and operating costs of £3.5 million (all PV, 1994 prices). Overall, this option showed more economic benefits than a comparative option involving a bus lane (not guided or physically separated) parallel to the guided busway (ibid).

Vehicle operating cost savings

In addition to travel time benefits, public transport schemes usually claim to deliver vehicle operating cost savings (i.e. benefits) to public (i.e. PT users) and private (i.e. car) users. Often, the main element of the vehicle operating cost savings to, say, light rail users arises to people who previously drove. They therefore save fuel and maintenance costs which they previously incurred.

The valuation follows the appraisal technique outlined in the previous Section on *Vehicle Operating Costs in project appraisal* (see above).

Note that for most PT schemes the value of VOC savings tends to be relatively small when compared to the value of travel time savings. For example, the appraisal of the SHRT (2002) claims VOC benefits to light rail users who previously travelled by car of £52.3m (PV) and VOC benefits to car users (basically for people who continue to travel by car and benefit from a less congested road network) of £6.2m (all present values, discounted at 6% to 1999). When compared to travel time savings (£250m to light rail users, £105.5 to car users who remain on the network), however, the reductions in vehicle operating costs are relatively small (ibid).

Journey time reliability

Journey time reliability is an important aspect of making public transport more attractive, especially to car users. This is because users have to make an additional time allowance in order to militate against their service either arriving early or arriving or running late. There are four key aspects to this:

1. Unreliability due to multiple interchanges;
2. Unreliability due to mixed traffic situations, especially when congested;
3. Reliability in terms of fast boarding/regress time;
4. Unreliability due to on-vehicle ticket sales.

Multiple public transport interchanges add considerable uncertainty to the reliable timing of journeys. In practice passengers are unwilling to make journeys that involve more than one interchange by public transport. Hence the more a new scheme covers corridors where before implementation the user had to change more than once the better the improvement in journey time reliability. In general, the more congested a road or rail track is the higher the unreliability impact. For roads, journey time reliability is linked to traffic flow and flow capacity (often referred to as the Congestion Reference Flow). The ratio of actual flow and capacity is called the stress level of a road and has been used as a proxy for journey time reliability (DETR, 1998a). Furthermore, if new public transport schemes achieve a shift of travel from other modes (mainly conventional bus, car), then reliability on the existing roads will improve.

Modern light rail systems are claimed to have an advantage over bus-based systems in terms of boarding/regress time as they are designed to provide level boarding, providing easy access for all users without hindering dwell time at stops and reliability (see e.g. SHRT, 2002). In addition, modes that are given priority in mixed traffic situations improve reliability considerably – busway, guided bus and the rail-based systems show obvious benefits. A further reliability benefit for light rail over bus arises from its off-vehicle ticket sales. A frequent cause of delay on buses results from the vehicle having to remain at the stop while passengers stop to pay. The off-vehicle ticket machines, which will be installed at every station, mean that this delay is eradicated for light rail. The advantages of light rail in terms of reliability are more manifest in the peak due to the level of congestion on the road network. This therefore benefits travellers-to-work disproportionately as they comprise the majority of peak travel.

Little data could be obtained regarding existing guided bus schemes. In terms of future systems, the Chester LTP claims that the proposed Chester Deeside Transport System Phase 1 guided busway scheme (see above) will provide moderate reliability benefits as the route has 65% of its length along the guideway and a further 14% along bus priority routes in the City Centre (Chester LTP, 2000). The reasoning is similar to other modes running at least partially on segregated track.

Congestion

As the bulk of congestion costs are internal to the transport system, external congestion costs are usually valued on the marginal cost basis (e.g. congestion cost of one additional vehicle on the road or rail network). As it is the external cost that is of interest, the marginal external cost of congestion does not include the additional vehicle's private travel time. The key concepts involve assessing external congestion costs as a function of marginal increases of traffic volume and the 'value of time' for different journey segments.

Calculation of marginal external costs of congestion

Given what was said above, the marginal external cost of congestion (MECC) is derived by differentiating total time cost (TTC) by traffic volume (Q), and subtracting the average time cost (the value of time, VOT, multiplied by the average time, AT). The average time cost is subtracted in order to remove the additional vehicle's private travel time cost. Sansom *et al* (2001) calculate the MECC this way and give as the result:

$$MECC = \frac{\beta \cdot VOT \cdot Q}{S^2}$$

where:

β = slope of the linear speed-flow curve
VOT = value of in-vehicle time
Q = traffic volume
S = speed

In practice, speed and flow values for a given corridor may have to measured/assigned, or alternatively, default values can be taken from sources such as TSGB (2001) and the National Road Traffic Forecast's speed-flow curves (DETR, 1999c).

Sansom *et al* (2001) have calculated marginal cost figures for road travel using the method outlined above. Table 18 summarises *national weighted average costs* (low and high estimates) as well as *outer conurbation average costs* (low estimate) for *weekday peak and 'other time'* travel. As expected, the latter figures indicate that the marginal external cost of weekday peak travel is often 3 times that in the other-time period. *National average congestion* costs for bus and coach (PSV) *weekday peak* travel were estimated as 20.31 pence per vehicle-km for peak – still almost double the figure for 'other time' travel (12.31 pence per vehicle-km; all 1998 prices, low cost estimates).

Table 18: External marginal cost of congestion (1998 prices)

External cost of congestion	***National weighted average***		***Outer conurbation (low est.)***	
(pence/vehicle-km)	*low*	*high*	*weekday peak*	*other time*
Car	8.98	10.44	23.01	7.73
LDV	9.26	10.61	23.01	7.73
HGV-rigid	16.78	18.45	38.72	13.01
HGV-artic	24.15	24.89	56.69	19.05
Public Service Vehicle	15.22	18.19	34.52	11.60

Source: Sansom *et al* (2001)

For rail-based modes, external congestion costs relate to the likely delays to other trains or trams as a result of an additional vehicle being added to the network. These costs are only relevant for the marginal cost analysis. Sansom *et al* (2001) give congestion costs (provided by Railtrack from their simulation model) for national, regional and London services – only the London services are relevant here. The low and high cost estimate for external marginal congestion costs of adding another train service to the London network is 0.28 pence per train-km (ibid).

The marginal external congestion costs shown in Table 18 may also be compared with the decongestion benefits per car-kilometre used in the appraisal of public transport initiatives such as light rail and guided bus schemes. It should be noted that the above estimates are at the current level of demand, whilst the estimates used in appraisal are obtained from transport models in which new demand equilibriums have been reached. A range of 12.7 to 50.8 pence per PCU-km (in 1998 prices and values, PCU = passenger car unit) has been identified for assessing the decongestion benefits of "major rail-based urban public transport" (DoT, 1994, inflated using the average earnings index).

Wider economic impacts

Wider economic impacts are those regeneration impacts that can be attributed to the introduction on new transport infrastructure. New transport services often have a catalytic effect on the economy, reducing the cost of travel. This improves access to labour and to product markets. Economic regeneration is often included in the description of the benefits of a project by its sponsors, but is rarely quantified and proven. The UK Government therefore asked the Standing Advisory Committee on Trunk Road Assessment (SACTRA) to consider the relationship between investment in transport infrastructure and economic growth. SACTRA concluded that better methods of assessment are needed to measure local and regional economic impact (SACTRA, 1999). The balance between new growth and displacement is critical. Economic growth resulting from reduced costs in the economy creates a real increase in wealth; the displacement of employment and employees from one area to another may not.

In conducting an appraisal, it is therefore not sufficient to assume that economic regeneration benefits will occur. Two types of model may be used: one models the cost relationship between travel and land use, the other models the generalised cost of travel in a model of the economy. Their merits are discussed in SACTRA's report. According to the Guidance on the Methodology for Multi-Modal Studies (GOMMMS; DETR, 2000a), consideration should be given as to whether:

- A proposal is significantly beneficial for designated regeneration areas (such as Assisted Area, Single Regeneration Budget, European Structural Fund); and
- There are significant developments within, or adjacent to, the regeneration area that are likely to be dependent upon the proposal being approved. These development sites must form a key part of the pre-existing regeneration strategy.

Where significant regeneration benefits have been identified, they should be described. Although these benefits may also be quantified, they should not be included in the Cost Benefit Analysis.

Two examples of post-investment appraisal of economic regeneration are the London Underground Jubilee Line Extension study, conducted by the University of Westminster, and the University of Salford's work on the Manchester Metrolink.

A supporting report to the aforementioned SACTRA report by the DETR (1999a) use the term "economic impacts" to include all effects of a transport change outside the transport system itself. Money savings to transport users, while clearly economic impacts, are not included as an economic impact in the DETR report, but any action taken in response to such money savings are included. Economic impacts can take various forms and be measured in various ways, including changes in employment, output, income and construction.

- Direct economic impacts are the immediate economic impacts of the capital and operational expenditure required to build, operate and maintain a scheme.
- Indirect economic impacts include all other economic impacts that stem from the scheme. These include multiplier effects of direct economic impacts as well as induced impacts, which are all impacts resulting directly or indirectly from the use (or possible use) of the scheme. Induced impacts may have multiplier effects, which are themselves included under induced impacts. Induced impacts may also include additional construction to accommodate increased demand.

While the existence and the methods required to estimate direct impacts and their multipliers are relatively uncontroversial, induced impacts, in contrast, are more difficult to identify and to predict. Examples of each type of impact are given in Table 19 below.

Table 19: Summary of economic impact categories

Main category	*Sub-category*	*Examples of impact*
Direct	Direct economic impacts	Additional employment for transport systems (e.g. light rail staff)
Indirect	Multiplier effects of direct impacts	Retail sales migrate to new light rail lines
	Induced effects	Firms move location to London Regional Transport line taking advantages of greater accessibility
		Retail and service multipliers from these relocations
		Additional development to accommodate changed demands

Source: DETR, 1999a

In a nutshell, the wider economic impacts can be assessed qualitatively, however quantification is often not possible due to the limited data availability and the complex interactions with other economic activities of the scheme.

To illustrate this point, the NATA appraisal of the South Hampshire Rapid Transit claims that the new light rail scheme would "play an important role in stimulating economic growth along the A32 corridor and in Portsmouth. In so doing, the scheme will alleviate the historical problems, such as relatively high unemployment and deprivation, associated with the decline of defence and naval functions." Furthermore, it is claimed that the scheme would "enhance access to [existing] development sites and therefore increase their longer-term viability, even though the developments themselves are not dependent on the scheme. [The scheme] would also be likely to have the following regeneration benefits:

- To bring planned or proposed developments forward helping to ensure that they meet requirements to have a certain proportion of employees or visitors travelling by public transport.
- To deliver regeneration benefits in a sustainable manner, therefore ensuring long term benefits to the area." (SHRT, 2002)

In this particular case, quantification of the described impacts would be difficult to quantify.

3.4 Accessibility

Option values

Option values reflect benefits to people who will not use a given PT scheme/mode regularly (and whose benefits are reflected by the demand modelling) but who benefit from the *option to use it at some particular time*. It has been shown that option values are more pertinent to the removal of an existing service or station rather than the provision of a new scheme (SHRT, 2002).

For major urban PT schemes, the qualitative procedure defined in GOMMMS (Volume 2 section 7.3) is a satisfactory alternative to the more detailed approach, using guidance from the then shadow Strategic Rail Authority (sSRA, 1999). Any adverse effects of the scheme should be included, such as withdrawal of through-services onto the national rail network following conversion of heavy rail routes to light rail. The latter point is particularly relevant for dual mode rail schemes such as the existing Karlsruhe and Saarbrücken schemes as well as the planned dual mode extension of the existing Nexus (Tyne & Wear Metro) light rail network.

The impacts can only sensibly be assessed on a scheme-to-scheme basis. The GOMMMS asks for an indication of the size of populations affected and the nature of analysis used to generate any monetary measures of total value. To illustrate the former criterion, the NATA appraisal of the South Hampshire Rapid Transit light rail scheme has assessed the number of people for whom option value benefits are likely to accrue. This has been estimated by examining the number of people within 800m of the route and the additional number within a ten minute bus feeder catchment. According to 1991 census data, a total of 27,141 households, representing a population of 67,064, live within 800m of the planned light rail stops (ibid). The *average option value* for each of these residents is likely to be high due to the high level of accessibility they have to light rail. The nature of the light rail scheme, offering a unique seamless journey across the harbour, will also contribute to a high option value for non-regular users. A further 200,000 (again based on 1991 census data) people have been estimated to fall within a ten minute bus feeder catchment of the proposed light rail route. The appraisal concludes that the scale of option value benefits for each of these people will be significantly lower than for those within the immediate catchment of the route, but are nevertheless of relevance.

Community severance

Severance impacts usually occur when transport infrastructure makes pedestrian or cycle movements difficult by creating real physical barriers. This can have consequences for the community, for instance, by separating a school from a residential area. The impact of a new scheme may be negative compared to do-nothing where, for example, a new segregated track is built for busway, light rail or guided bus systems.

Essentially, there is no significant difference between the intermediate modes considered in this paper. One would expect no significant severance impact where the new track is running on existing alignment on segregated sections and on-street, i.e. where no additional physical barriers would be built. With regard to the segregated section pedestrian crossing points would ideally be required to either be reinstated or new crossing facilities be introduced to offset any loss of an existing facility. Where new segregated tracks are built without the necessary amount of pedestrian/cycle crossings, the overall impact would obviously be negative. This is true for all at-grade guided bus, light rail and busway systems. Suburban/heavy rail is usually fenced off for safety reasons, with less crossings per km of track built, so an overall negative impact in this category.

Elevated/underground tracks of metro systems or the proposed ULTra system have no added severance impact. ULTra makes use of automatic vehicles, therefore street running is not feasible. In an implementation study of the ULTra system for a PT corridor in Bristol, Medus and Lowson (1999) suggest that a optimised system would consist of approximately 54% of the track be placed at grade, 44% elevated and 2% underground, with little added severance.

A suggested methodology for valuating severance impacts is to assess the number and types of population affected and then conduct a SP survey to value the willingness to pay for avoiding a possible new physical barrier. Another method could involve costing an appropriate amount of easy-access crossings to sufficiently mitigate the problem. However, we have not found any reliable data in existing appraisal studies.

Access to the transport system

Accessible public transport is a key determinant of their quality of life for a range of users, namely non-car available households, the mobility impaired and the retired.

Access to the public transport system is evidently most important for those people who do not have a car available. This includes both members of households with no car and individuals in households with a car, but without access to it for particular journeys.

For instance, the South Hampshire Rapid Transit appraisal claims that there are 27,141 households (population of 67,064) within an 800m catchment of light rail stops. 36.7 per cent of these households do not have a car available to them. Across Hampshire the proportion of non-car households is considerably lower at 24.0 per cent (SHRT, 2002, based on 1991 census data). This indicates that the distributional impacts of the light rail scheme are positive in terms of their social inclusiveness in targeting and area with greater need for public transport accessibility improvements.

Lack of accessible public transport can be a major hindrance to the job opportunities and general quality of life of the mobility impaired. Ideally new schemes, and in particular schemes involving elevated section of track (e.g. ULTra), should address the following:

- Level, low gradient ramp or lift access, with railings, to all stops;
- Tactile surfaces and information at all platforms;
- Ticket machines and help points located at a height that can be used by wheelchair users;
- Level boarding of vehicles.

Many of the new at-grade systems fulfil these criteria, however some of the older systems compromise on ramp access and level boarding. New modern systems are likely to fulfil these criteria – not least to attract a greater patronage.

Obviously, where a new scheme reduces the number of interchanges needed to get from A to B, the accessibility benefits will be greater for the mobility impaired. The other factor to keep in mind is the distance between stops. The shorter the distance between stops the higher the accessibility for the mobility impaired. For example, on the Karlsruhe dual mode network new stations were added on the heavy rail lines (with distances of about 500 metres) to improve accessibility for suburban dwellers, with particular benefits for the mobility impaired (CrossRail, 2000, Annex 6).

Retirees are often disproportionately reliant on public transport compared to other groups in society. This reflects lower levels of car ownership among this group and a lower propensity to have passed the driving test. In addition, some retirees may not be able to drive due to physical impairment.

There are about 15% of retirees across the UK (1991 census data), slightly increasing since then. A reasonable indicator would be the percentage of retirees living less than 800 metres (1/2 mile) from public transport stops. If the percentage were greater than the average UK rate of 15%, the scheme would have a positive impact. This assessment, of course, needs to be done on a scheme-to-scheme basis. We hope to obtain more information in the field studies (→ Workpackage 3).

3.5 Integration

The need for an integrated approach to transport planning and provision is a central theme of the Government's White Paper 'A New Deal for transport: Better for Everyone ' (DETR, 1998b). The White Paper, and subsequent Guidance (e.g. GOMMMS), has focussed on the need to promote Integration in the following ways:

- Integration within and between different modes of transport, so that each contributes its full potential and people can interchange easily between them;
- Integration with land use planning at national, regional and local level, so that transport and planning work together to support more sustainable travel choices and reduce the need to travel; and
- Integration with policies for education, health and wealth creation, so that transport helps to make a fairer more inclusive society.

Integration with other modes

The need to interchange between modes, and the poor quality of interchange facilities in terms of poor onward connections, information and waiting environment can be a major deterrent to public transport use for car drivers, and can impact adversely on the journey quality of 'captive' public transport users. Clearly public transport journeys are easiest and more convenient if they avoid the need to interchange. Hence the better the provision of intermodal change and information systems, the better the overall integration impact compared to a 'do-nothing' scenario. For example, a new scheme along a corridor that was previously served by various different modes (bus, rail, ferry etc.) should improve the operation and ease of use of the transport system both by creating new direct journey opportunities and improving interchange between modes, facilitating a range of other movements.

Further interchange improvements include:
- Integrated ticketing and information;
- Secure cycle parking at most stops;
- Reduced walking/interchange distances to other modes (taxi, cycles, car, bus, rail, etc.).

'Policy fit'

In terms of the 'general policy fit', the potential role of intermediate modes in meeting urban transport, environmental and land use objectives is being increasingly recognised. The 10-year transport plan, for example, makes it clear from the beginning that one of its key purposes is to "put our new integrated approach into practice" (DETR, 2000c). More specifically, the plan aims at introducing a number of light rail schemes to meet its target of doubling light rail use in England (measured by the number of passenger journeys) by 2010 from 2000 levels. Another main emphasis of the emerging transport policy environment is the need to make 'best use' of existing infrastructure. This would be an advantage for schemes that utilise existing rail alignments.

Land use policy

The interaction between land use and transport is increasingly recognised as central to achieving more sustainable patterns of movement, both through reducing trip volumes and trip lengths and by encouraging journeys to be made by less polluting forms of transport, such as cycling, walking and public transport. Recent Government planning guidance has therefore sought to encourage sustainable travel by encouraging denser forms of development, for instance by focussing on town centres as the centre of retail and commerce and brownfield sites as desirable locations for housing and industrial or business development.

Obviously, integration with national, regional and local land use policies need to be assessed on a scheme-to-scheme basis. The relevant policy guidance are:

- **National policies**: PPG1 (General Policy & Principles), PPG2 (Green Belts), PPG4 (Industrial and Commercial Development and Small Firms), PPG6 (Town Centres and Retail Developments), Draft PPG11 (Regional Planning), PPG12 (Development Plans and Regional Planning Guidance), PPG13 (Transport), Vital and Viable Town Centres – Meeting The Challenge (1994), Royal Commission on Environmental Pollution report (1994).
- **Regional policies**: relevant Regional Planning Guidance (RPG) documents, documents identifying Priority Areas for Economic Regeneration (PAERs), LTPs with regional elements (LTPs should include transport proposals that support delivery of urban renaissance, regeneration and concentrated development).
- **Local policies**: LTPs, County Structure Plans, Transportation Strategy documents, Local Plans.
- **Other Government policy aims**: healthier lifestyles, welfare to work, access to education, social inclusion.

We do not aim at valuing these impacts in the modelling exercise (→ Workpackage 4) but hope to get insight in the qualitative impacts of the 10 field study schemes in Workpackage 3.

4 THE VALUATION FRAMEWORK FOR *TEST*

Further to the more specific assessment and valuation methods described in the previous Chapters, we outline the proposed methodology for total social costing in this project below. Building on this approach we can derive a variety of transport and economic indicators to aide any public transport investment decision process. These will form part of the output from the modelling exercise in Workpackage 4.

4.1 Total social costs and benefits

As the basis for valuation we envisage to use the accounting costing approach following earlier work by, amongst others, Meyer, Kain and Wohl (1965), Allport (1981), Small (1992) and Kain (1998). The pioneering study is by Meyer, Kain and Wohl whose study excludes user costs (e.g. fare, time), but they compensate for this by constraining the various modes to provide comparable levels of service. Several later studies incorporate user costs explicitly, and this is now common practice in cost-benefit analysis of major public transport schemes (see e.g. DTLR, 2000a; DTLR, 2001a). More recent studies such as Sansom *et al* (2001) have incorporated and others such as Tinch (1995) and Sudgen (1999) have focussed on external costs, although there is still some uncertainty as to what externalities should be included, and to what extent.

Despite the controversy of whether or not to include external costs, we intend to include them here as much as possible. We therefore envisage to calculate the total social cost (*TSC*) for each public transport technology *i* as the sum of total operating costs (*TOC*), total user costs (*TUC*) and total external costs (*TEC*), or:

$$TSC_i = TOC_i + TUC_i + TEC_i \qquad \text{for each technology } i.$$

On the benefits side, we intend to estimate user benefits such as reduced travel time, vehicle operating costs, accident rate changes and increased reliability for public transport passengers and (fare box) revenue for operators. Since other elements such as comfort and convenience have not been valued in any study we found (which would be extremely difficult to do anyway), they are not considered in the quantitative costing framework here. Also, we aim to incorporate benefits to non-users such as reduced travel time on, say, decongested roads and overall increased road safety due to lower traffic volume on roads (note that lower volume may increase speeds which in turn may increase accident rates). Note that this will have to be modelled in conjunction with network models such as VIPS/3 and SATURN. Note that alternatively we could treat benefits as negative costs, although it could be argued that policy makers might prefer to speak of benefits (what matters to voters) rather than of reduced costs (what matters to them).

Total social benefits (*TSB*) will therefore be estimated as the sum of total user benefits (*TUB*) and total non-user benefits (*TNUB*) for each public transport technology *i*, or:

$$TSB_i = TUB_i + TNUB_i \qquad \text{for each technology } i.$$

Each of these terms is described below.

Operating costs

Total operating costs include:
- Annualised vehicle & infrastructure ownership costs;
- Infrastructure access charges;
- Fuel, wear & tear costs;
- Vehicle & infrastructure maintenance costs;
- Staff wages and employment-related costs;
- Fare collection costs.

These costs are borne by the operator and can be calculated as a function of intermediate system parameters such as vehicle-kilometres (*VKM*), the number of peak vehicles in service (*PV*), vehicle-hours (*VH*), route-kilometres (*RKM*) and, to some extent, passenger-kilometres (*PKM*). (Note that for clarity we have omitted the *i* index in the following equations.)

$$TOC = a \cdot VKM + b \cdot PV + c \cdot VH + d \cdot RKM + e \cdot PKM$$

Where *a* to *e* represent the unit costs for each operating cost category, namely:

a = cost per vehicle-kilometre (e.g. fuel costs)
b = cost per peak vehicle (e.g. fixed vehicle maintenance costs)
c = cost per vehicle-hour (e.g. driver wages, variable vehicle maintenance costs)
d = cost per route-kilometre (e.g. infrastructure maintenance costs)
e = cost per passenger-kilometre (e.g. fare collection, vehicle wear & tear)

Where unit costs (*a* … *e*) are not available default values may be used as described in Chapter 3.

User costs

Total user costs usually include fares, travel time costs and internal accident costs.

TUC can be calculated as a function of intermediate system parameters such as operating speed, frequency, network density and passenger-kilometres. Frequency is represented by the ratio of vehicle-kilometres and route-kilometres, or *VKM/RKM*, whereas network density corresponds to the ratio of route-kilometres and area, *RKM/A*. Hence:

$$TUC = f(Speed, \frac{VKM}{RKM}, \frac{RKM}{A}, VOT) \cdot PKM$$

Note that passenger-kilometres may in turn be a function of fare price, operating speed, frequency (*VKM/RKM*) and network density (*RKM/A*), hence:

$$PKM = f(Fare, Speed, \frac{VKM}{RKM}, \frac{RKM}{A})$$

Alternatively, we propose to calculate user costs according to the fully allocated costing approach. This will be used when data are limited and econometric analysis using the functions above may not be feasible.

External costs

As noted above, total external costs (TEC) are the sum of all valuations of impacts on the community owing to noise, exhaust emissions, emissions from power stations, risk of accident (as opposed to internal accident costs borne by the user), and, for vehicles in mixed traffic, increased journey times for other transport users. These 'non-user' costs are mainly a function of traffic volume (vehicle-kilometres) and demand (passenger-kilometres):

$$TEC = f(VKM, PKM, S) = \sum_i a_i(S) \cdot VKM + \sum_j b_j(S) \cdot PKM \,.$$

Where:

a_i = average unit cost per vehicle-km for externality *i* (e.g. air pollution and noise costs);
b_j = average unit cost per passenger-km for externality *j* (e.g. external congestion costs);
v = operational or average speed.

Externalities such as air pollution, noise and congestion depend on operational speeds, indicated by the term *S* in the above equation. Where possible, we will incorporate this important dependency. For instance, for congestion we will use the equation shown in Chapter 3 giving marginal external congestion costs as a function of the variable parameters speed and traffic volume, with the slope of the linear speed-flow curve and the value of in-vehicle time as fixed parameters. However, where this proves impossible, we will use the unit cost data presented in Chapter 3.

User benefits

Following the approach of TUBA, the total value of reduced travel time will be estimated as a function of the expected change in peak and off-peak journey times (in minutes). Other input parameters include the value of travel time for different time slices and user groups (see DTLR, 2001 for the latest values).

Vehicle operating cost savings to public transport users will be estimated as function of the total vehicle-hours and vehicle-km saved by a new scheme (e.g. car-km saved for people who previously drove). Again, this follows the TUBA approach (see the *Vehicle operating cost savings* Section above).

Journey time reliability is a function of the stress level of a road or rail corridor, or in other words, a function of the ratio of actual flow and capacity of the corridor.

We will further use actual revenue forecasts or the average revenue to estimate the main financial benefits to operators. These are a function of the number of journeys made and, depending on the fare structure, the total vehicle-km.

In sum, the total user benefit can be written as:

$$TUB = f(\Delta JT_U, \Delta VH_U, \Delta VKM_U, CFL, CC, NT)$$

Where:

ΔJT_U = change in peak and off-peak journey times (in minutes);
ΔVH_U = change in total vehicle-hours of previously used mode;
ΔVKM_U = change in vehicle-km of previously used mode;
CFL = corridor flow;
CC = corridor capacity;
NT = number of trips (patronage).

Non-user benefits

As said before, total non-user benefits (TNUB) include travel time and VOC savings for car users not switching to a new public transport service due to 'decongested' roads as well as overall increased road safety due to lower traffic volume on roads. The method for calculating travel time and VOC savings follows the calculation for user benefits (based on TUBA and DTLR guidance). Accident rate changes will be modelled according to flow and speed changes (see Section on external accident costs above).

$$TNUB = f(\Delta JT_{NU}, \Delta VH_{NU}, \Delta VKMN_{NU}, \Delta AR_{NU})$$

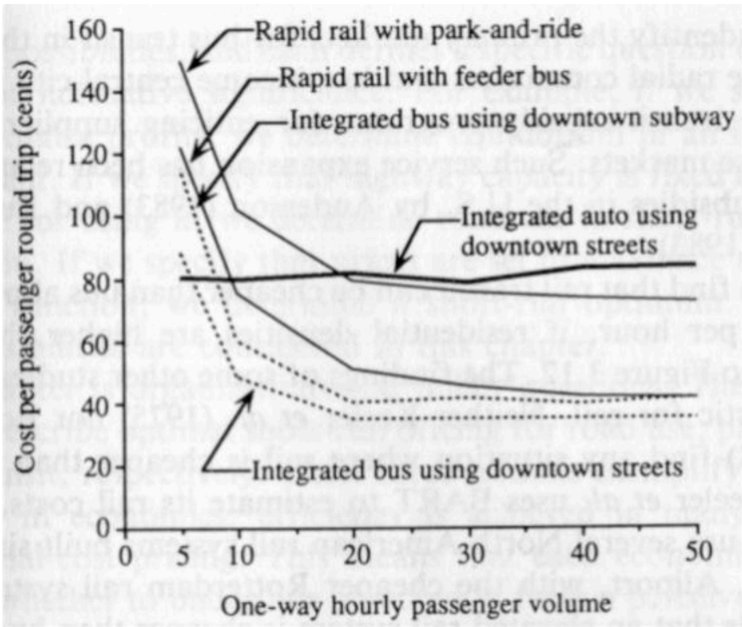
Where:

ΔJT_{NU} = change in non-user peak and off-peak journey times due to 'decongested' roads;
ΔVH_{NU} = change in non-user total vehicle-hours of other modes affected by new mode;
ΔVKM_{NU} = change in vehicle-km of other modes affected by new mode;
ΔAR_{NU} = change in accident rate of other modes.

4.2 Additional outputs and indicators

From the total cost and benefit calculations we can derive the following indicators:

- *TSC/PKM* [and *(TSC-TSB)/PKM*] as a function of *PKM* (→ graph), based on Meyer, Kain and Wohl (1965) and Small (1992) (see also the illustration below, taken from Small, 1992);
- $\partial TSC/\partial PKM$ [and $(\partial TSC-\partial TSB)/\partial PKM$] as a function of *PKM* (→ graph);
- CBA outputs such as (*TSB–TSC*), *TSB/TSC* and *(TSB-TSC)/TSC* indicating if a scheme is worth pursuing from a societal point of view;
- *TSC* and *TSB* per demand (number of trips, *PKM*);
- *TSC* and *TSB* per *RKM*, per *VKM*, per *VH*, etc.



Example of internal cost comparison (Source: Small, 1992

Impacts that are notoriously difficult to value in such economic analysis will not be included in the quantitative modelling exercise. These relate mainly to accessibility and integration (see above) and include:

- **Land take**. Based on Figure 1 above and the land take characteristics of urban public transport systems identified in Working Paper 1 (Brand and Preston, 2001), we can estimate the likely land take impacts of introducing a new system and compare it to a, say, 'do-nothing' scenario.
- **Integration with other modes**. We suggest checking a series of indicators such as integrated ticketing & information and reduced walking/interchange distances to other modes.
- **Access to the transport system**. To estimate distributional impacts, we suggest assessing the number of households (population) within an 800 metre catchment area of PT stops. The proportion of these without access to a car, or of retirees living there, can then be compared to national/regional averages. The impact is positive if the proportion is bigger than the national average.

- **Wider economic impacts**. Only qualitative impacts will be assessed, e.g. whether or not any benefits occur for designated regeneration areas and proximity to development sites that are part of that regeneration strategy.

5 CONCLUSIONS

This paper has reviewed the current evidence of the wider costs and benefits of urban public transport schemes, based on common assessment and valuation methods supported by data of existing (and planned) urban public transport schemes. We conclude by addressing each of the identified impact categories in turn.

Environmental costs

The studies reviewed here confirm the common view that there is a wide spread of unit costs of noise, air quality, global warming and other impacts (typically a factor of 5 between high and low estimates of damage values). However, we argue that this uncertainty is only marginally higher than the uncertainty of, say, valuing accident casualties and travel time in traditional transport economic analysis. We therefore believe that it is better to include environmental externalities rather than not and deal with uncertainty with appropriate sensitivity analysis whenever possible.

According to the studies reviewed, air pollution costs turn out to be highest – about a factor of two higher than noise or climate change impacts. For instance, the UK national average environmental costs of driving a PSV for one kilometre are in the range of 3-15 pence for air pollution, 0.1-4.1 pence for noise and 0.6-2.2 pence for climate change. As expected, the highest environmental costs occur in congested urban locations (up to 56 pence per bus-km in Central London). However, these are notably lower than congestion externalities.

Safety

Two methods of valuing external elements of safety impacts have been found useful: the fully allocated and marginal accident cost approach. Fully allocated costs for PSV are in the range from about 0.2-2.3 pence per vehicle-km whereas marginal costs are in the range from 3.7-6.6 pence. Marginal costs are higher per vehicle-km because when an additional road user raises the accident rate per vehicle-km for all existing transport users, the full value per accident is relevant (this additional risk is external to the additional road user).

External rail accident costs of suburban heavy rail services are often not estimated, since the *external* element is believed to be small once the level of liability placed on train operators is taken into consideration. Light rail accident rates per passenger-km (and therefore fully allocated accident costs) are said to be lower than for buses, of course depending on the load factors.

Since operation in mixed traffic results in accidents we argue that external costs of light rail, busway and guided bus safety impacts are negligible when operated on segregated tracks.

Economic

In the UK, average bus operating costs are about 160 pence per vehicle-km in congested urban locations and about half of that for English metropolitan areas. This compares to light rail operating costs of about 160-560 pence per train-km (excluding the Docklands Light Railway where accounts show a somewhat high 2,500 pence per train-km for 1999/00). Suburban rail and underground have higher costs per vehicle-km, about £10-11 and £15-22 per train-km. As mentioned above, higher load factors of high-capacity modes bring costs per passenger-km on almost equal footing: 5-18 pence for light rail (excluding DLR), 13-35 pence for underground, 8-14 pence for suburban rail, and roughly 10 pence for urban bus services. Note that bus (incl. busway and guided bus) and light rail seem to be cheaper to operate than in the US and Canada where rail-based systems show lower national unit costs than road-based bus systems (Table 13).

The examples from Pittsburgh, Ottawa and others basically mirror the evidence found in the UK: operating costs per passenger-km are comparable for buses and light rail, even if the rather modest average loading factor for Pittsburgh is used – in the North American cities is slightly higher, in the Australian city it's slightly lower. This shows that the actual patronage (loading factor) is decisive and that light rail could only be cheaper than buses if it is running at or near full capacity. Also, the dominance of staff-related costs of bus operations (about 70-80%) can be equally crucial. Staff-related and maintenance costs for light rail are more modest (about 40% and 20% of total operating costs, respectively).

One overseas study compared operating costs of different modes as a function of intermediate outputs and concluded that the cost element per vehicle-km (mainly fuel, wear-and-tear and variable maintenance costs) is about twice as high for light rail than for buses, and the cost element per vehicle-hour (mainly wage-related) is comparable between intermediate modes (for a single operator in the city of Rotterdam). Although the data are somewhat out-of-date this confirms what was said above.

The evidence found also shows that while the infrastructure and vehicle market is more or less international, local differences in e.g. wage rates, load factors and fuel costs can result in a wide range of operating costs on a scheme-to-scheme basis.

In terms of revenue-earning capabilities, light rail operations in the UK earn about 60-100 pence per journey or £2-8 per vehicle-km, which is higher than for buses at 50-70 pence per journey and £0.9-1.80 per vehicle-km. Metro and suburban rail tend to achieve a lot more – about £8-16 and £13 per train-km, respectively. In terms of revenue per passenger-km, however, most systems in the UK are comparable (a range from 6-18 pence per passenger-km for light rail, 15-21 pence for metros, about 11 pence for suburban rail, and 11-14 pence for urban buses). These data lie in the range found by previous studies such as ISOTOPE.

Beyond the fare costs (what are of course benefits to operators), transport users incur time costs (walking, waiting, in-vehicle time). In current UK appraisal, the costs and benefits to users (public *and* private transport) of different options are compared using standard Values of Time, currently about £4.5 per hour for all non-work journey purposes (in-vehicle time) and double that for waiting for and walking to/from public transport. Travel time benefits of new systems over previous modes can be substantial and represent the main element of user benefits. Time benefits to users that do not switch modes to the new system can also be substantial and result mainly from less congested roads. Other user benefits include vehicle operating cost savings to public and private transport users; these are, however, generally a lot smaller than the value of time benefits. This is certainly true if a new PT scheme such as a light rail or busway line runs parallel to a previously heavily congested road. Note that the total value of time and VOC savings depend heavily on the predicted (or actually achieved) patronage of the new line and the proportion that previously used other modes (mainly car travel).

In terms of journey time reliability, the evidence confirms the common view that the modes that run mostly on segregated track (e.g. metro, suburban rail, light rail) are more reliable than modes operating primarily in mixed-traffic conditions (e.g. bus lanes and guided bus corridors in traditional bus network, hence with low shares of segregation). Also, bus based systems in the UK have the disadvantage of delays from on-vehicle ticket sales.

Congestion costs to the user are internalised in increased travel time costs. There has been a debate about which Value of Time is relevant here: the value for in-vehicle time, or the value for waiting time, which is double the former value. *External* congestion costs represent the costs to non-users (as mentioned before other non-user costs are costs to society due to air, noise and water pollution etc.) and are usually valued on the marginal cost basis. Typical external unit congestion costs for buses and coaches are 15-18 pence per vehicle-km (national average), increasing to about 35 pence per vehicle-km in outer conurbations in weekday peak conditions. For rail, the value per train-km is obviously much lower, with an estimated 0.28 pence per train-km for the London suburban rail network.

Accessibility

This paper briefly looked at three accessibility criteria: option values, community severance and equitable access to the system. Option values have shown to be more important to the removal of an existing service or station rather than the provision of a new scheme. However, current UK appraisal guidance requires some sort of semi-quantitative assessment taking into account demographic and geographic data. The valuation of the benefits or disbenefits of any new scheme is therefore very localised and this therefore not considered further.

In terms of community severance there seems to be no significant difference between the modes and technologies considered in this paper. It’s the degree of segregation and provision of easy-access crossings over tracks and roads that’s important here, not the actual mode or technology. Generally, the higher the share of segregated route-km the more negative the severance impact on the community living/working in the corridor. The valuation of these impacts has not been established yet, which is reflected in that GOMMMS requires only a quantitative assessment.

Equitable access to the transport system (mainly for people who do not have a car available) is not a comparative issue between intermediate modes either. It may be an issue for metro and suburban systems, where station spacings are higher and underground operation may restrict access to job opportunities and general quality of life for e.g. the mobility impaired. However, most new systems (Croydon Tramlink) or system extensions (e.g. Jubilee Line in London) provide easy access for all transport users.

Integration

There seems to be little between the intermediate modes in terms of integration into the transport system. Obviously this depends heavily on local conditions, in particular the local transport and land use planning policies. In the current planning climate, however, it can be expected that any new major guided bus or light rail scheme will be well connected to existing PT stations (rail, regional bus, underground) as well as major private/public transport hubs (pedestrian zones, P&R sites, car parks, major employment developments etc.). Any new system is therefore likely to have a positive impact on integration, and hopefully attract 'new customers' as a result (suppressed journeys). More specifically, the technology that can more easily be integrated in the current transport system will be show higher public acceptability, for example a busway scheme connecting existing interchanges with the city centre shopping area, or a light rail extension using existing or disused heavy rail corridors. In the wider transport policy context, light rail, guided bus and busway systems fit well into the current drive to provide cost-effective, reliable, clean and integrated urban public transport, showing advantages over conventional rail or bus based systems.

Valuation framework

The proposed valuation framework is based on the total social costing approach, including all the quantifiable costs (and benefits) to operators, users and non-users. It goes beyond the traditional assessment based on economic efficiency. However, it incorporates many of the methodologies and data outlined in this document. Where local data are not available we envisage to use regional or national averages, e.g. unit values for external costs of congestion, accidents and air pollution.

This approach specifically includes benefits to transport users and non-users, and we intend to value these wherever a method has been established (e.g. travel time savings). Where data are available but uncertainty is high, benefits will be included with an option to conduct sensitivity analysis. In addition, where data and methods are not reliable we intend to make qualitative comments explaining the likely type and scale of positive or negative impacts.

Data gaps

In a review covering such a wide range of impacts it is inevitable that the data set underlying the economic analysis is not complete. In particular, we have found the following gaps:

- Noise emissions data by mode, and how these affect ambient noise levels along a corridor. (Most likely these are difficult to obtain.) The noise cost valuation also requires population and property value statistics that can be obtained locally. Alternatively, average noise costs per dB(A) emitted may be used.
- Electricity sources/companies used for electric systems such as light rail and underground (needed for better assessment of valuation of regional and global impacts of air pollution).
- Any data on water pollution (e.g. from road run-off or electricity production) and the resulting damage values.
- Land take costs per, say, route-km. Any data will be very localised depending on land prices etc.
- Accident rates (or accident costs per km driven) for modes on segregated tracks vs. mixed traffic.
- Detailed breakdown of capital and operating costs (ideally in the form represented in Table 8, or even better, in Table 10), in particular for intermediate modes. This will enable us to derive operating cost functions for each mode and technology (including alternative technologies).
- Examples of the valuation of journey time in the assessment of existing systems.
- Examples of non-user benefits of existing systems.

We envisage to fill some of these data gaps in the *TEST* project field studies.

ANNEX 1 JOURNEY-TIME COSTING FOR BUSES

Public transport journey times are usually broken down into:
1. Waiting time;
2. Walking time;
3. In-vehicle time (including boarding time).

Nash (in Dodgson and Topham, 1988) derives costs for buses for each of these as a function of intermediate parameters such as bus-kilometres and bus route length. Note that this methodology can also be applied to other intermediate modes.

Waiting time costs

Assuming high frequency services, mean waiting time will be simply half the headway, therefore total waiting time costs may be calculated as (Dodgson and Topham, 1988):

$$TWC = \frac{60}{2} \cdot \frac{v_1 \cdot R \cdot N \cdot PT}{VKM}$$

where:

v_1 = mean value of waiting time (pence per minute)
R = route length
N = number of routes operated
PT = number of passenger trips per hour
VKM = total bus kilometres per hour

Walking time costs

Assuming the mean width of the bus service catchment area is inversely proportional to the number of routes, and the mean walking distance, in turn, is one half of this width, total walking time costs per hour are (Nash in Dodgson and Topham, 1988):

$$TPC = \frac{0.5 \cdot v_2 \cdot W \cdot PT}{N}$$

where:

v_2 = mean value of walking time (pence per minute)
W = parameter governing the mean width of catchment area in terms of mean walking time
N = number of routes operated
PT = number of passenger trips per hour

In-vehicle time costs

It has been argued that in-vehicle time per passenger consists of a constant plus a boarding time for each passenger joining the bus in the course of the journey. Nash (ibid) gives the total cost of in-vehicle time per hour (TIC) as:

$$TIC = v_3 \cdot \left(t1 + \frac{t2 \cdot PT \cdot TL}{VKM} \right) \cdot PT$$

where:

v_3 = mean value of in-vehicle time (pence per minute)
t_1 = mean in-vehicle time per trip *excluding boarding time* (minutes)
t_2 = mean boarding time per passenger (minutes)
TL = mean trip length
VKM = total bus-kilometres on all routes
PT = number of passenger trips per hour

Nash (in Dodgson and Topham, 1988) quotes (inflated from 1988 to 2000 values):

- Mean value of waiting and walking time $v_1 = v_2$ = 6 pence per minute, or £3.60 per hour;
- Mean value of in-vehicle time v_3 = 3 pence per minute, or £1.80 per hour.

Although these prices have been inflated, the values differ by a factor 0f 2.5. The time spent on public transport has obviously gone up considerably over the last 12 years.

REFERENCES

1. Allport, R.J. (1981) "The Costing of Bus, Light Rail Transit and Metro Public Transport Systems". Traffic Engineering and Control, 22, 633-639.
2. APTA (1999) "APTA Public Transportation Fact Book 1999". American Public Transportation Association, Washington DC. www.apta.com.
3. Bamber and Khoury (1999)
4. Bickel, P. and Friedrich, R. (1995) "Was kostet uns die Mobilität? Externe Kosten des Verkehrs." Springer Verlag, Berlin.
5. Boyd, J.H., Asher, N.J. and Wetzler, E.S. (1978) "Non-Technological Innovation in Urban Transit: A Comparison of Some Alternatives". Journal of Urban Economics, 5, 1-20.
6. Brand, C. and Preston, J. (2001) "Technical and Financial Characteristics of Public Transport Systems". TSU Working Paper No. 906 (??), Transport Studies Unit, University of Oxford.
7. Bruun, E. and Vuchic, V. (1995) "Time-Area Concept: Development, Meaning, and Applications". Transportation Research Record 1499, pp. 95-100.
8. Centro (2002) "Centro Annual Report 2001". Taken from Centro website: www.centro.org.uk.
9. Chester LTP (2000) "Local Transport Plan 2001/02 - 2005/06", Cheshire County Council, Chester.
10. COMEAP (1998) "Quantification of the Effects of Air Pollution on Health in the UK". Department of Health, London, The Stationery Office.
11. CrossRail (2000) "CrossRail – Integrating local and regional rail including cross-border aspects: Identification Report." European Commission, Brussels. http://www.tramtrain.com.
12. CVTF (2000) "An Assessment of the Emissions Performance of Alternative and Conventional Fuels", The Report of the Alternative Fuels Group of the UK Government's Cleaner Vehicles Task Force. The Stationary Office, London. http://www.road.detr.gov.uk/cvtf/index.htm.
13. DETR (1998a) "A New Deal for Trunk Roads in England: Understanding the New Approach to Appraisal". DETR, London.
14. DETR (1998b) "A New Deal for transport: Better for Everyone", Government White Paper on Integrated Transport. The Stationary Office, London.
15. DETR (1999a) "Analysis of Transport Schemes: Economic Impact Studies". David Simmonds Consultancy for the Standing Advisory Committee on Trunk Road Assessment (SACTRA), DETR. ISBN: 1-851123-51-6, The Stationary Office, London.
16. DETR (1999b) "Road Accidents Great Britain 1998 – the casualty report". Department of the Environment, Transport and the Regions. The Stationery Office, London.
17. DETR (1999c) "Constraining forecast traffic growth to the road network: the fitting on process". Working paper No.4. National Road Traffic Forecasts 1997. DETR, London.
18. DETR (2000a) "Guidance on the Methodology for Multi-Modal Studies. Volumes 1 and 2". DETR, Wetherby.
19. DETR (2000b) "Transport Statistics Bulletin. A Bulletin of Public Transport Statistics: Great Britain 2000 edition".
20. DETR (2000c) "Transport 2010: The 10 Year Plan". Department of the Environment, Transport and the Regions. The Stationary Office, London
21. DTLR (2001a) "Transport Economics Note 2000". Department of Transport, Local Government and the Regions, March. http://www.roads.dtlr.gov.uk/roadnetwork/heta/ten00/index.htm.

22. DTLR (2001b) "Highways Economics Note No1: 2000". Department of Transport, Local Government and the Regions, October.
23. Dodgson, J.S. and Topham, N. *ed.* (1988) "Bus Deregulation and Privatisation". Avebury, Gower Publishing Company Ltd., Aldershot.
24. DoT (1988) "Calculation of Road Traffic Noise". Department of Transport/Welsh Office. The Stationery Office, London.
25. DoT (1994) "Transport Policies and Programme Submissions for 1995/96". Supplementary guidance notes on the package approach. Annex B. DoT, London.
26. DoT (1995) "Calculation of Railway Noise". Department of Transport. The Stationery Office, London.
27. EAHEAP (1999) "Economic Appraisal of the Health Effects of Air Pollution". Department of Health, London. The Stationery Office.
28. Edinburgh LTS (2001) "Local Transport Strategy". City of Edinburgh Council, Edinburgh.
29. EEA (1998) "Spatial and Ecological Assessment of the Trans European Network (TEN) – demonstration of indicators and GIS methods". European Environment Agency, Copenhagen, Denmark.
30. EEA (2000) "Are we moving in the right direction? – Indicators on transport and environment integration in the EU", Transport and Environment Reporting Mechanism (TERM) 2000. European Environment Agency. Copenhagen, Denmark.
31. European Conference of Ministers of Transport (1998) "Efficient Transport for Europe: Policies for Internalisation of External Costs". ECMT, Paris.
32. EC (1995) "Externalities of Energy, *ExternE* Project: Volume 2, Methodology". European Commission, DGXII – Science, Research and Development, JOULE Programme (EUR 16521 EN).
33. EC (1999a) "Externalities of Energy, ExternE Project: Volume 8, Global Warming". European Commission, Brussels.
34. EC (1999b) "Externalities of Energy, ExternE Project: Volume 9, Fuel Cycles for Emerging and End-Use Technologies, Transport and Waste". European Commission, Brussels.
35. EC (1999c) "Externalities of Energy, ExternE Project: Volume 7, Methodology 1998 Update". European Commission, Brussels.
36. EC (2000) "External Costs of Energy Conversion – Improvement of the ExternE Methodology and Assessment of Energy-related Transport Externalities. Final Publishable report of the ExternE Core/Transport Project. Published by EC-DG Research. 2000. Full report published Summer 2001.
37. Eyre, N., Downing, T.E., Hoekstra, R. and Rennings, K. (1997) "Global Warming Damages". ExternE project, EC-DG XII, Brussels.
38. Eyre, N., Downing, T.E., Hoekstra, R. and Rennings, K. (1999) "Update: Global Warming Damages". ExternE project, EC-DG XII, Brussels.
39. FirstGroup (2001) "Annual Report 2001, Transport solutions for the 21st century". FirstGroup plc, Aberdeen.
40. Gennard, D., Smithard, M. and Roberts-James, C. (2000) "Chester Deeside Transport System – Towards Implementation". Cheshire County Council, Chester.
41. Glaister, S., Graham, D., and Hoskins, E. (1999), 'Transport and Health in London: A Report for
42. the NHS Executive, London'.
43. Green, J.P., Khoury, G.A., Davies, R.F. (2000) "External Costs of Road Transport in London". Proceedings of the Institution of Civil Engineers: Transport.
44. Hass-Klau, C., Crampton, G., Weidauer, M. and Deutsch, V. (2000) "Bus or Light Rail: Making the Right Choice". Environmental and Transport Planning, Brighton.

45. Hensher, D.A. and Waters, W.G. (1993) "Light Rail and Bus Priority Systems: Choice or Blind Commitment?"" Working Paper ITS-WP-93-4. Institute for Transport Studies, University of Sydney.
46. HM Treasury (1991) "Economic Appraisal in Central Government: A Technical Guide for Government Departments", April.
47. INFRAS/IWW (1994) "External Effects of Transport". Final report to the UIC, Paris.
48. IPCC (1997) "IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual", IEA/OECD, 1996 revisions.
49. ISOTOPE (1997) "Improved structure and organisation for urban transport operations of passengers in Europe (ISOTOPE) – Final Report". EC-DGVII-51, European Commission, Brussels.
50. Jansson, J.O. and Lindberg, G. (1998) "Transport pricing principles". Pricing European Transport Systems (PETS), Deliverable 2. Institute for Transport Studies, Leeds.
51. Kain, J.F. (1998) "The Urban Transportation Problem: A Re-examination and Update". Mimeo. The University of Texas at Dallas.
52. Kain, J.F. and Liu, Z. (1999) "Secrets of success: assessing the large increases in transit ridership achieved by Houston and San Diego". Transportation Research A, 33, pp601-624.
53. Litman, T. (1999a) "Evaluating Public Transit Benefits and Costs". Victoria Transport Policy Institute, Victoria, British Columbia, Canada.
54. Litman, T. (1999b) "Transportation Cost Analysis". Victoria Transport Policy Institute, Victoria, British Columbia, Canada.
55. Mackie, P.J. and Nash, C.A. (1982) "Efficiency and Performance Indicators: the case of the bus industry". Public Money, 2, 3.
56. Maddison, D. (1995) "The True Costs of Road Transport in the United Kingdom", Centre for Social and Economic Research on the Global Environment.
57. Maddison D. *et al* (1996) "Blueprint 5: The True Costs of Road Transport". Earthscan Publications, Oxford.
58. Manchester City Council (1995) "Wilmslow Road Corridor – Review Update". Report for the acting City Engineer and Surveyor and the Chief Executive, Policy and Resources Committee. Manchester City Council, Manchester.
59. McCubbin, D. and Delucchi, M. (1999) "The Health Costs of Motor Vehicle Related Air Pollution". Journal of Transport Economics and Policy, Vol. 33, Part 3, pp. 253-86.
60. Medus, C.E. and Lowson, M.V. (1999) "Planning PRT Networks: The Case of ULTra". Paper at ASCE APM Conference, Copenhagen.
61. Meyer, J.R. Kain, J.F. and Wohl, M. (1965) "The Urban Transportation Problem". Harvard University Press.
62. Mumford, P. (2000) "The Road from Inequity: Fairer Ways of Paying the True Costs of Road Transport". Adam Smith Institute, London.
63. NAEI (1999) "UK Emissions of Air Pollutants 1970-1998", Report of the National Atmospheric Emissions Inventory. AEA Technology Environment for the (then) DETR, AEAT-3092, January.
64. Nash, C.A. (1997) "Economic and environmental appraisal of transport improvement projects". In O'Flaherty, C. (Ed) "Transport Planning and Traffic Engineering". Arnold, London.
65. Newbery, D.M. (1995) "Reforming Road Taxation". Commissioned by the Automobile Association, September.
66. Newbery, D.M. (1998) "Fair Payment from Road-Users: A Review of the Evidence on Social and Environmental Costs", commissioned by the Automobile Association, February.
67. NEXUS (2000) "Annual Report 2000". NEXUS, the Tyne and Wear PTE. http://www.tyneandwearmetro.co.uk/pdf/Annual%20Rep&Ac_complete.pdf

68. NEXUS (2001) Personal communication with Mr Maurice Brown, Financial Director of Nexus.
69. OXERA (2000) "The Wider Impacts of Road and Rail Investment". OXERA Environmental for The Railway Forum.
70. Pearce, D. (1994) "Costing the Environmental Damage from Energy Production", paper to the Royal Society Discussion Meeting, March 1994, CSERGE.
71. Pearce, D. *et al* (1995) "The True Cost of Road Transport", Earthscan, London.
72. Peirson, J. and Vickerman, R. (1996) "Environmental Effects and Scale Economies in Transport Modelling: Some Results for the UK", Fondazione Eni Enrico Mattei, Working paper 78.96.
73. Quinet, E. (1997) "Full Social Cost of Transportation in Europe", in *The Full Costs and Benefits of Transportation*, Greene, D., Jones, D. and Delucchi, M. *eds*, pp. 69-111, Table A1. Springer (Berlin).
74. RCEP (1994) "Transport and the Environment, 18th Report". Royal Commission on Environmental Pollution, Cm 2674. The Stationery Office, London. (Also published by the Oxford University Press in 1995).
75. RCEP (1997) "Transport and the Environment, Developments since 1994, 20th Report". Royal Commission on Environmental Pollution, Cm 3752. The Stationery Office, London.
76. Reilly, J.M. (1977) "Transit Costs During Peak and Off-Peak Hours". Transportation Research Record, 625, 22-26.
77. Ricci, A. and Friedrich, R. (1999) "Calculating Transport Environmental Costs", Final Report of The Expert Advisors to the High Level Group on Infrastructure Charging (Working Group 2). CUPID project.
78. SACTRA (1999) "Transport and the Economy". Standing Advisory Committee on Trunk Road Assessment (SACTRA), DETR. ISBN 0-117535-07-9, The Stationery Office, London.
79. Sansom, T., Nash C.A., Mackie P.J., Shires J. and Watkiss P. (2001) "Surface Transport Costs and Charges: Great Britain 1998". Final report for the (then) DETR. ITS, University of Leeds, Leeds, July 2001.
80. SHRT (2000) "South Hampshire Rapid Transit: Fareham-Gosport-Portsmouth Investment Appraisal". Hampshire County Council, Portsmouth City Council and Steer Davies Gleave. ISBN 1 85975 405 8.
81. Small K.A. (1992) "Urban Transportation Economics", Fundamentals of Pure and Applied Economics 51. Harwood academic publishers, Chur, Switzerland.
82. Smith, A. (2001) "Cleaner Vehicles in Cities: Guidelines for Local Governments", UTOPIA project deliverable 19. European Commission, DG-TREN, Brussels.
83. Soguel, N. (1994) "Evaluation Monetaire des Atteintes a l'Environment: Une Etude Hedoniste et Contingente sur l'Impact des Transportes". Imprimerie de l'Evole SA, Neuchatel.
84. SPTE (1999) "Annual Report 1999". Strathclyde Passenger Transport Executive, Glasgow. http://www.spt.co.uk/Publications/index.html
85. sSRA (1999) "Planning Criteria: A Guide to Appraisal of Support for Passenger Rail Services". Shadow Strategic Rail Authority. http://www.sra.gov.uk/sra/Publications/Default.htm
86. SRA (2001) "Towards a Safer Better Bigger Railway, Annual Report 2000/1". Strategic Rail Authority. http://www.sra.gov.uk/sra/annual_report/Annual_Report_Default.htm.
87. Sudgen, R. (1999) "Developing a Consistent Cost-Benefit Framework for Multi-Modal Transport Appraisal", Economics Research Centre, University of East Anglia.
88. TAS (2001) "Task Note 4: Updated Revenue and Patronage Forecasts". The TAS Partnership Ltd, Preston for GTE for Oxford Ltd.

89. Teufel, D. *et al* (1989) "Die Zukunft des Autoverkehrs (The Future of Motorised Transport)". Umwelt- und Prognose-Institut Heidelberg e.V., Heidelberg, Germany.
90. The Railway Forum (1999) "Rail Strategy and Sustainable Development: Securing Rail's
91. Environmental Advantages". The Railway Forum, February.
92. Tinch, R. (1995) "On the valuation of environmental externalities". Department of Transport. HMSO, London.
93. Tol, R.S.J. and Downing, T.E. (2000) "The Marginal Costs of Climate Changing Emissions". Environmental Change Institute, University of Oxford, United Kingdom.
94. Transit (2002) "Thameslink margins hit 12% as profits up by 31% and patronage keeps on growing". In Transit, p.16, 11 January 2002.
95. Transland (1999) "Manchester Metrolink – Not In-Depth Case Studies", Transland Consortium for the European Commission, DG Transport. http://www.inro.tno.nl/transland/
96. TSfL (2000) "Transport Statistics for London 2000". Transport for London, UK.
97. TSGB (2001) "Transport Statistics Great Britain 2001 Edition". The Stationary Office, London.
98. Walmsley, D.A. (1992) "Light rail accidents in Europe and North America". TRL report 335. Transport Research Laboratory, Crowthorne.
99. Webster, F.V and Bly, P. H. (eds) (1980), "The Demand for Public Transport", Report of an international collaborative study, Transport and Road Research Laboratory, Crowthorne, Berks.
100. White P. (1995) "Public Transport". Third Edition. UCL Press, London.

GLOSSARY

Term/acronym	Explanation
CBA	Cost Benefit Analysis
CEA	Cost Effectiveness Analysis
CIPFA	Chartered Institute of Public Finance and Accountancy
COBA	Cost Benefit Analysis computer program used in current project appraisal
COMEAP	The Department of Health's Committee on the Medical Effects of Air Pollution
dB(A)	decibel (A), a unit for measuring ambient (A) noise levels
Depreciation	The process of setting aside funds during the life of an asset, such that an equivalent asset can replace it without additional capital being required.
DMRB	Design Manual for Roads and Bridges
DR	Discount Rate, usually 6% in public transport appraisal
EAHEAP	Economic Appraisal of the Health Effects of Air Pollution
EURO2	European exhaust emissions standard for road vehicles, here stage 2 for buses.
GOMMMS	Guidance on the Methodology of Multi-Modal Studies
IPCC	Intergovernmental Panel on Climate Change
LTP	Local Transport Plan
MCA	Multi Criteria Analysis
NAEI	The National Atmospheric Emissions Inventory
NATA	The New Approach to Appraisal
NDSI	Noise Depreciation Sensitivity Index
PAER	Priority Areas for Economic Regeneration
PCU	A Passenger Car Unit, indicating the relative road space taken up by road vehicles; mainly used in congestion modelling and allocation of road damage costs to vehicle types.
PKM, pkm, passenger-km	Passenger-kilometres
PPG	Planning and Policy Guidance
PSV	Public Service Vehicle, here buses and coaches
PT	Public Transport
PTE	Passenger Transport Executive
PV	The Present Value of investment or revenue, with future payments/income discounted to the stated year
PV	Peak Vehicle
RKM, route-km	Length of a public transport route or entire network, in kilometres
SACTRA	Standing Advisory Committee on Trunk Road Assessment
TUBA	Transport User Benefit Appraisal computer program used in current project appraisal
VH	Vehicle-hours, the time a vehicle is in operation
VKM, vkm, vehicle-km	Vehicle-kilometres
VOC	Vehicle Operating Costs
VSL, VoSL	Refers to the 'Value of Statistical Life' in environmental costing, typically a value between £1-2 million for the UK.
WTP	Refers to the 'Willingness To Pay' approach in the valuation of impacts.
YOLL	Refers to the 'Year of Life Lost' (or life expectancy) approach to calculate air pollution mortality (deaths brought forward). The full Value of Statistical Life (VSL) is adjusted to take account of life expectancy (→ *Years of Life Lost*) and quality of life (from WTP valuation). Adjusted values based on this approach are significantly lower (typically £2,600 – 110,000) than typical Values of Statistical Life (£1-2 million).