The demand for public transport: a practical guide

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Executive Summary

This document reports on the outcome of a collaborative study undertaken by the Universities of Leeds, Oxford and Westminster, University College London and TRL. The objective of the study was to produce an up-to-date guidance manual for use by public transport operators and planning authorities, and for academics and other researchers. The context of the study was principally that of urban surface transport in Great Britain, but extensive use is made of international sources and examples.

The study was co-ordinated by a working group consisting of researchers from the aforementioned organisations, and officials of bodies representing the passenger transport industry. The overall direction of the project was the responsibility of a steering group which included other researchers, transport consultants, representatives from local and central government, bus and rail operators as well as members of the working group.

The overall objectives of the study were to:

- undertake analysis and research by using primary and secondary data sources on the factors influencing the demand for public transport;
- produce quantitative indications of how these factors influence the demand for public transport;
- provide accessible information on such factors for key stakeholders such as public transport operators and central and local government;
- produce a document that assists in identifying cost-effective schemes for improving services.

In 1980 the then Transport and Road Research Laboratory, now TRL Limited, published a collaborative report *The Demand for Public Transport*, which became widely known as 'The Black Book'. The report has been the seminal piece of work on demand evaluation for many years, but in the succeeding two decades a great deal of change has taken place. The values of many of the parameters under consideration have changed, new methodologies and concepts have emerged and the institutional, socio-economic, environmental and legal frameworks are substantially different.

While such changes have not invalidated the general conclusions of the Black Book, they will have reduced the relevance to modern conditions of much of the quantitative analysis. The concerns of policy makers and planners now are less with the problems of maintaining public transport, on which the mobility of a sizeable minority of people depends, but with increasing its attractiveness to car users. Effecting significant shifts from car to public transport travel would reduce congestion and improve efficiency of necessarily road-based transport operations, as well as securing important environmental benefits. An improved understanding of the determinants of public transport demand will help to inform those involved in this process and this was the aim of the new study.

The study has re-examined the evidence on the factors affecting the demand for public transport, and has extended the coverage from that of the 1980 study to reflect the changing sociological and policy background.

The most widely estimated parameters have been price elasticities of demand and, in particular, public transport fare elasticities. Evidence collected during the study suggests that short-term elasticities, relating to changes in demand measured soon after changes in fares, may be substantially different from long-term elasticities, based on measurements made several years after fare changes. Broadly speaking: bus fare elasticity averages around -0.4 in the short run, -0.56 in the medium run and -1.2 in the long run; metro fare elasticities average around -0.3 in the short run and -0.6 in the long run, and local suburban rail around -0.6 in the short run. These results appear to indicate a significant change from those reported in the 1980 study.

The examination of quality of service identifies seven categories of attributes of transport services that collectively determine quality, and examines evidence as to how these components of quality affect demand. The findings are presented either in the form of elasticities, or as weights to be given to the various quality components when incorporating them in generalised costs for purposes of modelling. There is limited evidence on elasticities with respect to in-vehicle time (IVT). The available evidence suggests that IVT elasticities for urban buses appear to be roughly in the range -0.4 to -0.6, while those for urban or regional rail range between -0.4 and -0.9.

Attribute values have been derived for various aspects of bus shelters, seats, lighting, staff presence, closed-circuit TV and bus service information. Estimates for individual attributes of the waiting environment range up to 6p per trip (subject to a limiting cap of around 26p on the total), or up to 2 minutes of in-vehicle time per trip.

Regarding the effect of income on public transport demand, the bus income elasticity, which includes the car ownership effect, appears to be quite substantial, in a range between -0.5 and -1.0 in the long run, although somewhat smaller in the short run. Evidence of the effect of another key influence on public transport demand, car ownership, indicates that in Great Britain, a person in a car-owning household is likely to make considerably fewer trips by both bus (66% fewer) and rail (25% fewer) per week than a person in a non car-owning household.

While the Guide examines the influence of fares, quality of service and income and car ownership, it also considers new transport modes such as guided busways, the relationship between land use and public transport supply and demand and the impacts of transport policies generally on public transport. It looks at the influence of developments in transport and technology over the past two decades, such as innovations in pricing, changes in vehicle size, environmental controls on emissions, and developments in ticketing and information provision facilitated by advances in computing.

The main objective of this Guide is to provide practical guidance on demand estimation for those involved in planning and operating public transport services. It is therefore written in a modular form so that readers may find the information and guidance they require without having to read the whole document. The derivation of conclusions from the large body of research and sources of data considered is presented in order to establish the reliability of the advice presented, and to serve as a source book for future research.

1 Introduction

This book is the result of a new collaborative study undertaken by the Universities of Leeds, Oxford and Westminster, University College London and TRL Limited. The objective of this study was to produce an up-to-date guidance manual for use by public transport operators, planning authorities, academics and other researchers. The context of the study is principally that of surface transport in Great Britain, but extensive use is made of international sources and examples.

The study was co-ordinated by a working group consisting of researchers from the aforementioned organisations, and officials of bodies representing the passenger transport industry. The overall direction of the project was the responsibility of a steering group which included other researchers, transport consultants, representatives from local and central government, bus and rail operators as well as members of the working group.

1.1 The need for a new report on public transport demand

In 1980 the then Transport and Road Research Laboratory, now TRL Limited, published a collaborative report: *The Demand for Public Transport* (Webster and Bly, 1980). This report, which became widely known as 'The Black Book', identified many factors which influence demand and where possible, given the limitations of the data that were available for analysis, quantified their effects. The Black Book subsequently proved to be of great value to public transport operators and transport planners and policy makers. However, in the following 20 years there has been a great deal of change in the organisation of the passenger transport industry, the legislative framework under which it operates, in technology, in the incomes, life-styles and aspirations of the travelling public, in car ownership levels, and in the attitudes of policy makers.

While these changes have not invalidated the general conclusions of the Black Book, they will have reduced the relevance to modern conditions of much of the quantitative analysis. There is therefore a need for a revised version which can take into account another 20 years' worth of public transport information, and recent advances in transport research techniques.

The Black Book was written at a time when demand for public transport was falling very rapidly (Figure 1.1), and operators' options for maintaining profitability - fare increases, reductions in service levels and network coverage - seemed counterproductive. It was predicted that ever-increasing levels of subsidy would be needed just to preserve current public services.

Some 20 years on the demand for bus travel in Great Britain appears virtually to have stabilised, arguably at a higher level than would have been predicted by extrapolation of the trend from 1970 to 1980. More vehicle km were operated in 2000/01 than at any time since 1970, following a decline of 21% between 1970 and 1985/86. Public expenditure[1] on bus services has fallen by about 16% in real terms since 1985/86, from £1637m (in 2001/02 prices) to £1367m in 2001/02. So two objectives of the Transport Act 1985, which abolished quantity control of local bus services and led to privatisation of most publicly owned bus operators, were achieved, at least in part. The failure to reverse the trend in passenger numbers was a disappointment, at least to authors of the policy.

The resurgence of rail travel since about 1995 is remarkable in view of recent financial difficulties facing the industry and (possibly exaggerated) public concern over safety and service reliability. Recent growth may be largely attributable to economic growth, constraints on car use, service improvements and the fact that rail fares (unlike bus fares) have been subject to price controls.

The concerns of policy makers and planners now are less with the problems of maintaining public transport, on which the mobility of a sizeable minority of people

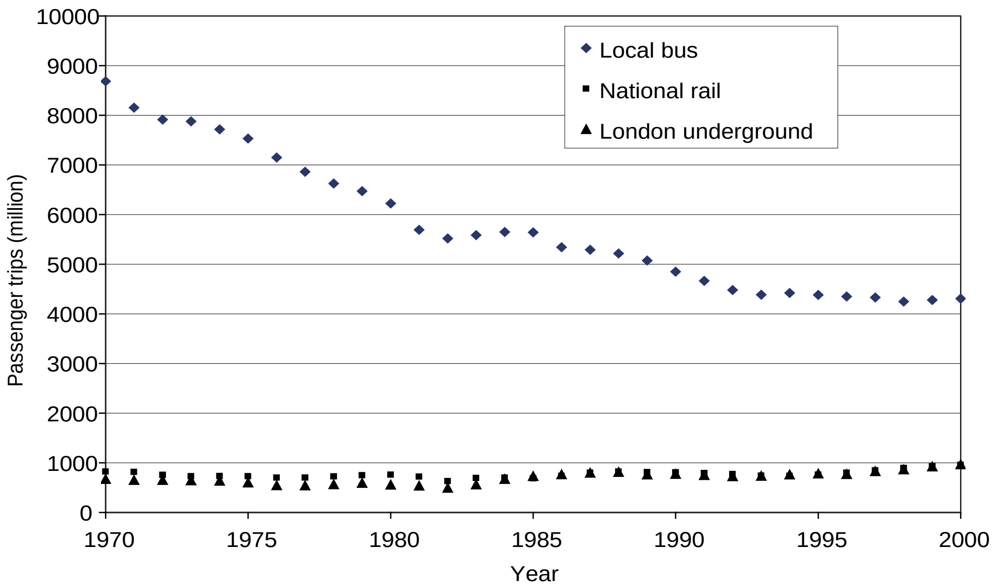

Figure 1.1 Trends in public transport demand in Great Britain 1970-2000

depends, but with increasing its attractiveness to car users. Effecting significant shifts from car to public transport travel would reduce congestion and improve efficiency of necessarily road-based transport operations, as well as securing important environmental benefits. This objective will not be achieved easily, but there appears to be a strong political will to pursue it. An improved understanding of the determinants of public transport demand will help to inform those involved in this process and this book is designed to provide it.

1.2 Scope of the report

There can be little doubt that a wide range of factors influences the demand for public transport. There is plenty of empirical evidence as to what the relevant factors are, and which of them may be more important than others, in different circumstances. But devising useful definitions and measures of these factors can be a formidable task. Even with that achieved, the remaining problems of explaining observed demand as a complex function of all the relevant factors, in order to develop models of how demand is likely to be affected by changes in any or all of them, may be even more difficult. That is not to say that imperfect models which do not entirely reflect all the complications of the real world are without value: an imperfect model may be more useful as a planning or policy-making tool than a series of well informed guesses, but it must always be recognised that the results may be subject to a considerable degree of uncertainty.

The key issues addressed in this book are the identification of factors influencing demand and assessment of their impact on trip generation and modal split. Research outputs are synthesised, including those relating to setting fare levels, devising marketing strategies, determining supply strategies, and assisting strategies to reduce car dependency culture and the associated environmental disbenefits this causes.

The overall objectives of the study are to:

- undertake analysis and research by using primary and secondary data sources on the factors influencing the demand for public transport;
- produce quantitative indications of how these factors influence the demand for public transport;
- provide accessible information on such factors for key stakeholders such as public transport operators and central and local government.
- produce a document that assists in identifying cost-effective schemes for improving services.

The new report presents evidence on factors influencing the demand for public transport drawn from three key areas:

- fundamental principles relating to transport demand;
- evidence from new factors and research carried out since publication of the 1980 report.
- empirical results for a range of modes.

The study also considers the influence of developments in transport and technology over the past two decades, such as innovations in pricing, changes in vehicle size, environmental controls on emissions, and developments in ticketing and information provision facilitated by advances in computing.

1.3 Structure of the report

The main objective of this book is to provide practical guidance on demand estimation for those involved in planning and operating public transport services. It is therefore written in a modular form so that readers may find the information and guidance they require without having to read the whole document from beginning to end. The derivation of conclusions from the large body of research and sources of data considered is presented in order to establish the reliability of the advice presented, and to serve as a source book for future research.

The arrangement of the Chapters is as follows:

Chapter 2 sets the scene for the study, discussing recent developments in public transport operation, current trends in demand, and the various factors which may influence it. Much of this material will be familiar to well informed readers, who may skip this chapter.

Chapter 3 is a summary of all the principal findings of the research. For ease of reading it is presented in as non-technical a manner as possible, without details of the evidence and argument supporting the conclusions: this is to be found in the subsequent technical chapters, to which references are made. This chapter is recommended to all readers, to gain an overall understanding of all the issues raised, and to point them towards those parts of the technical evidence and argument which they need for their own purposes.

Chapter 4 outlines the public transport data sources which are available for analysis, their strengths and weaknesses, and their use in demand modelling.

Chapter 5 is a mainly mathematical exposition of the concepts of demand functions and elasticities, which underlie the findings of subsequent chapters. It is not required reading for non-specialists.

Chapter 6 deals with the effects of pricing (public transport fares) on demand.

Chapter 7 deals with aspects of public transport services with a time dimension, principally walking times to and from stops and stations, waiting times and in-vehicle times.

Chapter 8 considers other service quality factors, including the waiting environment, comfort and safety.

Chapter 9 considers effects of changes in alternative public transport modes and in costs and times of journeys by car.

Chapter 10 discusses the influence of incomes and car ownership on public transport demand.

Chapter 11 analyses interactions between public transport demand and land use patterns.

Chapter 12 discusses the impact of new public transport systems, and methods for forecasting demand for them.

Chapter 13 examines the effects of other transport policies.

2 Setting the scene

The purpose of this chapter is to put the study into context by providing background information on public transport, its users, and non-users. In particular the following questions are raised, for more detailed quantitative discussion in the following chapters:

- What is public transport?
- How is public transport developing?
- What is the demand for public transport?
- How does demand vary between different areas, types of transport services, types of people, types of journey, journey purposes?
- How do external factors affect demand?
- How is demand changing?

2.1 Scope of the study

The main concern of this book is with the demand for public transport in Great Britain. It seems likely however that many of the findings will also be applicable to other countries in broadly similar states of socio-economic development and be of practical use there. Indeed, we have cast our net as widely as possible in a search for relevant information on public transport demand and research studies. We have concentrated mostly on high per capita income 'western' countries, primarily those in Western Europe, North America and Australasia. Conditions in lower-income developing countries are often so different, in terms of private vehicle ownership for example, that few useful generalisations can be made. Data availability also tends to inhibit the level of analysis that can be undertaken. However, major industrialised centres in Asia also display characteristics similar to those in western Europe and offer experience of intensive public transport use and provision which is relevant to this study. Examples include Japan, Singapore, and the Hong Kong region within China. In addition, the conditions faced by urban metro systems in large cities are often similar, and in this case experience from a wider range of countries may be relevant (for example, including some cities in South America).

Within countries considered of relevance, the emphasis in this study is on urban and regional markets, i.e. those dominated by short-distance travel, and fairly high frequencies of movement (such as home-to-work commuting). The long-distance, air and tourist markets are not explicitly considered, although they do form part of the national aggregate transport demand.

In terms of drawing a distinction, a useful example is that used in the British National Travel Survey (hereinafter, NTS), in which 'long distance' is defined as those trips above 50 miles (approximately 80 km) one way. This would include all intra-urban trips and the vast majority of commuting travel (apart from some long-distance commuting into very large cities such as London), together with some shorter inter-urban trips.

Sources of data, problems arising from differences in the ways in which they are collected and reported, and suggestions for resolving these problems are discussed in some detail in Chapter 3. Suffice it to say here that we have obtained and analysed data from public transport operators relating to:

- trips made on urban networks (bus, tram light rail, metro);
- trips on regional bus systems (which tend to be concentrated within the urban areas they serve, or made from surrounding rural areas).

The main ambiguity arises in respect of national rail systems which also carry substantial flows into large cities. Separate patronage statistics may not be available, and even where the administrative structure has been split up, it does not necessarily match urban hinterlands (for example, the privatised rail system in Britain includes some self-contained urban networks, such as that on Merseyside, but also companies handling a mix of interurban and long-distance work, such as South West Trains, serving the region within, and to the south-west of, London).

We have also made extensive use of NTS information collected over a number of years, and have analysed results of ad hoc surveys of passenger demand, reported in numerous research papers.

2.2 Transport modes

The main emphasis in this study is on public transport modes, but it is also vital to take into account private transport modes. These can generally be regarded as in competition with public transport (this applies especially to private cars) but may also be complementary (e.g. walking to bus stops, driving to railway stations).

The transport modes included in the broad analyses incorporated in this study are described briefly as follows.

2.2.1 Public transport modes

Buses and coaches

The largest element in public transport provision, being the most ubiquitous mode. A distinction may be drawn between 'local' and 'other' services. Local services are available to the general public on demand (generally serving all stops along a route, with cash payment on board, or at stops, permitted). Other services include longer-distance scheduled services (such as intercity express coach) which are also available to the general public. Contract school services are not open to the general public. Some buses and coaches are available for private hire by organisations or individuals.

In the British case, there is a legal distinction between registered 'local' services (eligible for Bus Service Operator Grant[2]) and 'other' (the latter comprising about one third of the operating industry turnover and vehicle-km run).

However, the 'other' category may contribute a substantial element of urban and regional public transport provision, especially where large numbers of school children are carried. Their use may be detected in household surveys such as the NTS, where sufficiently accurate definitions are applied.

In recent years there have been various developments with the aim of making bus services more attractive to passengers. These include bus priority schemes, designed to reduce bus journey times and make services more reliable by isolating buses from general traffic congestion. While some such schemes have been successful others have achieved few benefits (Daugherty *et al.*, 1999), often because of difficulties in circumventing physical obstacles where priority measures are most needed.

Guided bus schemes are a variation on conventional bus priority measures, imbuing bus services with some of the features of light rail systems (including more effective exclusion of non-priority traffic), but with the added advantage of greater flexibility at the ends of guideway sections. Low floor buses are becoming more common, enabling easier access to elderly and infirm passengers, parents with young children, as well as to wheelchair users. Off-bus ticketing systems are improving passenger convenience, and reducing boarding times, with benefits for journey times and service reliability. Bus location systems can contribute to bus priority measures, and to real time information systems for passengers.

Taxis and private hire vehicles

These are classified as public transport since they are available for public use, and may have a role complementary to, or competing with, that of buses and railways. In Great Britain their provision and use has grown rapidly since 1985, and is substantial in periods such as late evenings when conventional public transport services may be limited in scope. A 'taxi' may be defined as a vehicle available for hire on demand on street and at designated ranks. Fare scales are normally prescribed by licensing authorities, and are incorporated in the settings of taximeters. A 'private hire vehicle' (PHV) is typically a saloon car which may be hired by pre-arrangement (such as telephone booking), the fare being determined by agreement with the passenger rather than according to a fixed scale. In some large cities, such as London, the roles of taxis and PHVs may differ markedly, but in smaller centres they often perform a similar role.

Together, they account for some 10% of all public transport trips in Great Britain. The average trip length is similar to that by local bus, but less for public transport as a whole, thus comprising about 6% total of public transport passenger-km (see Table 2.1). Fares (per km) are generally higher than for other modes. Consequently taxis and PHV receive a disproportionately high share (21%) of user expenditure on public transport – almost as much as that for non-local buses and coaches (25%).

It is not the purpose of this study to examine the taxi/PHV market in detail, nor produce forecasting models. However, this mode may have a substantial role as an explanatory factor in the market for bus and rail services.

Tramways and light rail

This mode includes traditional street tramways (such as Blackpool or Amsterdam), many of which have been expanded and upgraded through reserved track extensions and priority measures (such as Gothenburg). Entirely new systems have been developed from the 1970s, either largely segregated (such as Calgary) or reintroducing the street tramway in a more modern form (such as Nantes). Average trip length is generally short, and the role filled may be similar to that of buses, but with greater potential for attracting car users due to higher speeds and service quality. Wholly automated systems often fall within this category in terms of density and trip length.

Most of the light rail systems listed in Table 2.1 have been introduced in recent years, and have achieved substantial growth, albeit from a very low base. Whether the new patronage represents mainly transfers from car use, or from other public transport modes, is a question to be discussed in Chapter 9.

Table 2.1 Demand for surface public transport in GB (2001)

	Passenger journeys (M)	*Passenger km (billions)*	*Passenger revenue (£M)*
Local bus	4310	46 (local bus and non local bus/coach combined)	2889
Non local bus/coach	200		1531
National railways	960	39.1	3548
London underground	950	7.45	1151
Glasgow underground	10	0.04	10
Light rail	130	0.8	98
Taxis/PHVs	700	5.7	2320
All public transport	7260	99	11547
Private cars	37070	500	

Most of the statistics in this table are taken from Transport Statistics Great Britain: 2002 Edition (Department for Transport, 2002c) derived from operators' reports and statistical returns.

The estimated number of passenger journeys by non-local bus and coach is very uncertain (±100M). It is based on an average annual trip rate of two per person (subject to rounding errors) derived from NTS data shown in the same publication, together with an allowance for trips for educational purposes by 'other private transport', much of which may actually be 'non-local bus/coach'.It is not possible to derive separate estimates of passenger kilometres for local buses and non-local buses and coaches.

For taxis and PHVs, estimates have been made using annual trip rates and average annual distance travelled by each mode, derived from NTS data shown in the same publication. Passenger revenue is based on an estimated average fare of £3.33 per person trip (Department of the Environment, Transport and the Regions, 2001c).

Light rail includes: Docklands Light Railway, Tyne & Wear Metro, Manchester Metrolink, Sheffield Supertram, West Midlands Metro, Croydon Tramlink.

'Heavy' urban rail

This mode comprises underground and metro systems designed for high capacity, and fully segregated from surface traffic (such as those in London, New York and Paris). Station spacing tends to be somewhat greater than for tramway/light rail, and average trip length longer. Use tends to be concentrated on radial work trips to/from city centres. The degree of short-run substitution with other modes is often less than for bus or light rail.

2.2.2 Private transport modes

Walking

This mode continues to play an important role, both in its own right, and as a feeder mode to public transport. In Britain it comprises about 25% of all trips, when short trips are included, being particularly important for shopping, personal business, and home-to-school trips by younger children (5-10 age range). Much of the apparent growth in overall trip-making in recent years is in fact a growth in *motorised* trip-making, much of which derives from a transfer from walking. In some cases this involves shifts between walking and public transport : strong substitution may exist between bus use and walking for trips around 1 to 2 km. This is reflected in higher price elasticities for example (see Chapter 6, Section 10).

Cycling (non-motorised)

This mode has generally declined in recent years, comprising only about 2% of all trips in Britain (Department for Transport, 2002b). It thus has little impact on overall demand, but may form an alternative to public transport for trips up to about 10 km. In some countries favourable climate, topography and priority measures make this mode much more important. In the Netherlands, for example, it accounts for about 29% of all trips (Central Bureau of Statistics for the Netherlands, 1995), and may take a substantial share of the short-distance market that would be handled by bus in Britain. In some instances, cycling acts a feeder to public transport, where secure racks are provided at rail stations or accompaniment on-train is encouraged (as in Copenhagen), thus enlarging the effective catchment areas of public transport networks.

Cycling (motorised)

This mode includes all powered two-wheelers (motorcycles, scooters, etc.). In most developed countries it now plays a very small role, but remains important in low-income countries as the first stage of private motorised transport, thus competing with public transport.

Private car

Within this mode, a distinction may be drawn between 'driver' and 'passenger' use. Passengers may be more inclined to switch to public transport, for example when it offers greater flexibility of trip timing than afforded by the driver. However, if reducing vehicular movement is the policy aim (as for instance in Park and Ride (P&R) schemes) it is necessary to persuade drivers to switch to public transport.

A further distinction may be drawn between 'main' and 'other' drivers (for example, in the NTS), the former being the driver undertaking the greater distance in a survey period. In many countries, the most common category of household car ownership is the one-car household (46% of all households in Britain in 2001, for example). A complementary pattern of car and public transport use may exist within such households, and the 'other' driver may make only limited use of the car. As the proportion of households with two or more cars rises (22% in Britain in 2001 - Department for Transport, 2002c) some of the driver trips made in the second car are diverted from the first car. Hence, the impact on public transport use tends to be lower than the initial shift from zero to one car ownership.

In considering competition between public transport and private car, average occupancy levels in the latter mode may be important, since direct perceived costs (such as fuel, and/or parking charges) may be divided by the number of occupants. Where public transport use involves separate tickets for each person, relative costs may appear much greater, for example where family members are travelling together. Surveys such as the NTS may be used to derive average values (which may also be assessed through specific local studies).

The overall average car occupancy level in Britain in 1999-2001 was 1.6 (for all purposes and trip lengths), but levels are often much higher for non-work purposes - in 1999-2001 averaging about 1.9 for leisure, and 1.8 for shopping, reaching 2.5 for holidays or day trips. Hence for these purposes, perceived cost per person by public transport may compare particularly unfavourably. Tickets such as the 'family railcard' or 'family travelcard' (in London) can be seen as response to this.

2.3 Demand for different forms of public transport

Current levels of demand for the public transport modes described in Section 2.2.1 are summarised in Table 2.1. Demand measures are shown in three ways: annual numbers of passenger trips (one-way); annual passenger km; and annual passenger revenue.

Two caveats should be borne in mind when considering Table 2.1. The first is that the possibility of some double counting may arise from information supplied by operators when trips necessitate interchange within or between modes (see Chapter 4 for more detailed discussion). The second is that national rail and non-local bus and coach statistics include a considerable proportion of long-distance trips which do not comply with the definition of local and regional trips adopted for this study.

Despite these minor complications Table 2.1 gives a reasonable impression of the relative sizes of the demands for different modes. In particular, it illustrates the dominance of car travel over public transport.

2.4 Variations in demand

Despite their importance national statistics give a rather superficial impression of the complex subject of demand for public transport. Public transport is used for a range of purposes by people of both sexes and of all ages, with different levels of income and car ownership, living in different types of area. In this section we briefly discuss how these factors affect demand in order to illustrate the issues to be explored in later chapters.

2.4.1 Variation by person type

The most advanced public transport ticketing systems can provide information on trip ends, trip lengths, time and day of travel. They can also provide separate information for passengers enjoying various kinds of concessions, or using season tickets or travelcards. But for a detailed analysis of person types and journey purposes and trip rates it is necessary to resort to survey data, especially those produced by the National Travel Survey (NTS). These data enable us to indicate variations in public transport use by age and sex, both in terms of absolute trip rates and market shares.

Trip rates are highest in the 'working age' groups, from 17 to 59. Bus and coach use tends to be concentrated at each end of the age spectrum, representing about 6% of all trips, but around 12% each in the age groups 17-20 and 70+. It is lowest in the age groups 30-59, at only 3 to 4%. This is associated with car availability, the youngest groups not yet being able to own cars, and many of the oldest group never having done so. Conversely, rail use shows much less variation, its highest share being in the 21-29 age group (at 4%). Taxi and private hire car use is fairly well spread over the age groups (an average share of 1%, highest at 3% in the 17-20 age group) (Table 2.2).

Females tend to make greater use of public transport than males, their average bus and coach share being 7% (compared with 5% for males), with a similar distribution by age category. Rail use is marginally lower among females than males, but taxi and private hire car use similar. A more noteworthy difference between males and females is the split between car driver and car passenger use, 48% of all trips by males are made as car drivers and 17% as car passengers. For females these proportions are 33% and 28% respectively. The differences are much less marked in the youngest groups.

For the public transport market, there are some important implications. While rail and taxi use is fairly well spread by age and sex, bus use is clearly associated with lack of access to cars. In the case of the older groups, its level of use is also associated with lower fares due to provision of concessionary travel. In future, people in older age groups are more likely to have developed habits of car use when younger and to maintain them. This may make it necessary to 'market' the concept of concessionary travel to such groups. West Yorkshire PTE for example undertook such a campaign in Summer 2002, with an introductory offer of one month's free travel (the concessionary pass in its area normally denoting eligibility for a cash flat fare).

There may, however, be some prospect of retaining and increasing public transport use among the younger age groups, provided that an acceptable quality of service and price can be offered. School and education travel may be offered at concessionary fares (or free travel in some cases), but in many instances the full adult fare may be payable from the age of about 16 (dependent upon operator policy).

2.4.2 Variation by time of day, and day of week

The internal structure of the public transport market may also be examined in terms of trip length distribution, and split by time of day and day of week. Within the Monday to Friday 'working day', work and education trips tend to be concentrated at peak periods (around 0800-0930, and 1600-1730). However, they do not usually coincide in both peaks, since the school day is generally shorter than the adult working day. Where service industry employment predominates, working hours are typically around 0900-1700, causing the morning school and work peaks to coincide, but with a spread in the late afternoon, as schools finish around 1530-1600.

In many areas, it is the school peak which causes almost the entire additional peak vehicle demand above a 'base' level from 0800 to 1800. This is evident in almost all smaller towns, and in most cities up to about 250,000 population, such as Plymouth and Southampton. Although journeys to work by public transport are substantial, they do not necessarily require more vehicular capacity (given the higher load factors accepted in the peak) than for shopping, and other trips between the peaks. Even in the largest conurbation bus networks, it is only on the radial routes to the central area that journeys to work create sharp peaks, school travel causing the peak within suburban areas.

Rail networks display a very different peaking ratio, however, being oriented almost entirely to the centres of large cities, and thus the adult work journey.

Table 2.2 Percentage of trips by age and main mode (1998-2000)

	All ages	*<17*	*17-20*	*21-29*	*30-39*	*40-49*	*50-59*	*60-69*	*70+*
Main mode									
Walk	26	37	28	26	21	19	21	28	33
Bicycle	2	2	2	1	1	1	2	1	1
Car driver	40	–	26	45	56	60	55	43	31
Car passenger	22	51	24	16	13	12	15	18	20
Other private transport	1	2	1	1	1	1	1	1	1
Bus and coach	6	7	13	6	3	4	4	7	12
Rail	2	1	2	4	3	2	2	1	1
Taxi and minicab	1	1	3	2	1	1	1	1	2
Other public transport	–	–	–	–	–	–	–	–	–
All modes	100	100	100	100	100	100	100	100	100
Total trips per person per annum	1030	898	1023	1134	1208	1219	1120	974	696

Source: Department for Transport, Local Government and the Regions (2001d).

The ratio of peak to base demand may be somewhat greater in terms of passengerkm than passenger trips, since the journeys to work are often much longer than local shopping and personal business trips within the suburban areas. The 1999-2001 NTS (Department for Transport, 2002b) shows that for all modes, work commuting trips tend to be longer (at 13.7 km average) than those for education (4.8 km) or shopping (6.7 km), with an 'all purposes' average of 10.68 km. Conversely, in smaller towns employment and shopping may show a similar degree of concentration, leading to similar trip lengths, and hence a good balance of demand during the base period.

In many areas, a greater decline than average has occurred in early morning, evening and Sunday public transport use. Car availability to the household as a whole is much greater in the latter two periods, and the first has been affected by loss of work journeys and changes in working hours (although changes in activity patterns on Sundays have led to increases in public transport use where fairly comprehensive networks are provided, as in London). Evening travel has also been affected by the long-term drop in cinema attendance (albeit recently reversed), and a reluctance among residents of some areas to go out in the dark for fear of assault. However, very late evening and allnight bus travel has grown rapidly in London following the revamped network introduced during the 1980s and subsequently expanded.

Personal security has emerged as major issue in recent years, and a number of operators have introduced measures to counteract passenger perceptions, for example in Sweden and Belgium (Warden, 2002, Detroz *et al.*, 2002).

Table 2.3 shows variation by day of week (averaged over the whole year) for selected modes. On an index of 100, distance travelled per day is typically higher on Monday to Friday, local bus use peaking on Thursdays, and rail use on Friday when commuting, business and weekend travel coincide. Saturday use is slightly below that for Monday to Friday for buses, usually due to high levels of shopping travel, but substantially lower for rail. Sunday travel is particularly low for bus (associated with low levels of service provision) but less so for rail. Taxi and minicab use peaks on Fridays and Saturdays, associated with leisure travel.

Table 2.4 shows corresponding variation by month of year. This is somewhat greater, typically lower in February (possibly due to weather conditions), June and July for local bus, with a similar variation for taxi/PHV. Rail displays a somewhat different pattern, possibly associated with long-distance travel.'

A study by one major bus operator group in Britain has suggested that weather conditions may affect ridership. Like-for-like period comparisons suggest little impact of temperature or hours of sunshine (within the range experienced prior to 2000), but heavy rainfall produced a reduction of about 3% in demand. Where demand changes have been measured through sample counts or surveys over short periods (such as one day), adjustments for day to week, month and/or weather factors, using data above may be desirable.

Table 2.3 Index of daily distance travelled by day of week and mode: 1999/2001

	Monday	*Tuesday*	*Wednesday*	*Thursday*	*Friday*	*Saturday*	*Sunday*	*All days*
Walk	101	113	110	105	110	90	73	100
Car/van driver	99	102	107	108	111	91	83	100
Car/van passenger	82	72	81	77	101	150	139	100
Local bus	105	121	119	121	114	91	32	100
Rail	111	118	110	125	130	63	46	100
Taxi/minicab	94	75	84	110	130	131	78	100
All modes	96	96	100	102	111	109	97	101

Derived from National Travel Survey (unpublished data). 'All modes' also includes cycle, motorcycle, express and tour coaches, etc. Where data are shown for a specific mode and day the sample size obtained was at least 300 in all cases.

Table 2.4 Index of annual distance travelled per person per year by selected modes and month of year: 1999/2001

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*All months*
Walk	95	91	104	100	104	97	103	96	109	103	108	87	100
Car/van driver	87	98	100	95	101	106	111	98	95	109	110	91	100
Car/van passenger	85	91	81	94	105	121	107	124	106	102	99	87	100
Local bus	117	86	110	99	102	90	91	108	102	96	101	95	100
Rail	76	125	86	94	94	117	101	89	79	124	132	87	100
Taxi/minicab	79	61	99	168	103	82	103	106	125	91	111	75	100
All Modes	85	97	94	95	103	111	111	106	98	105	107	88	100

Derived from National Travel Survey (unpublished data). 'All modes' also includes cycle, motorcycle, express and tour coaches, etc. Where data is shown for a specific mode and month the sample size obtained was at least 300 in all cases.

2.4.3 The journey to work

Table 2.5 shows the shares of the journey-to-work market by different modes, from the 1997-99 NTS (Department of the Environment, Transport and the Regions, 2000b). Note that the principal mode of transport used is shown - for example, for a journey to central London comprising a long ride by surface rail, and a shorter ride on the Underground, only surface rail will be shown as the mode used.

Overall, buses account for about 9% of all journeys to work, and rail about 5% (or, as shares of the motorised market, about 11% and 6% respectively). As one would expect, the public transport mode share is greater for central London, with 49% of journeys to work by surface rail or Underground, and 10% by bus. Note that these figures are for the whole day : during the morning peak (0700-1000), the rail share is substantially greater at about 75%. The proportions vary substantially between different parts of outer London (Croydon is well-served, for example) and between the conurbation centres. The greatest share handled by bus and coach is for conurbation centres (16%). Note that almost six times as many car commuters travelled as drivers than passengers, giving an average car occupancy for this purpose of only 1.2.

2.4.4 Other journey purposes

Although public transport's role tends to be associated mainly with the work journey, it is evident that this is not necessarily where bus takes the greatest share. In many cases, buses take a larger share of the shopping market, and this in turn forms a larger share of all bus trips than work, as Table 2.6 shows. The largest share taken by local bus is often within the education trip market. In 1999-2001, local buses (i.e. scheduled services open to the public) carried 23% of journeys between home and school by children aged 11-16, more than by car at 19%. 'Private buses' (typically, buses and coaches contracted to carry children on behalf of local education authorities) accounted for another 8%. This is also a sector in which the scheduled local bus share has been increasing, having risen from 20% in 1985/86 (Department for Transport 2002b). As many home-to-school trips lie above walking distance, a major demand for public transport is created, especially in rural areas.

Table 2.6 Composition of the market for each mode, by journey purpose 1993/95

Purpose	*Local bus (outside London)%*	*Surface rail%*
Work (commuting)	21	51
Business	1	6
Education	15	7
Shopping	34	9
Personal business	10	7
Visiting friends	13	11
Sport/Entertainment	4	5
Other	2	4
Total	100	100

Source: Department for Transport, 20 National Travel Survey 1993/95 (Department of Transport 1996).

Conversely, the role of rail is generally small for non-work purposes (1% in the case of home to school trips by 11-16 year olds, for example).

2.4.5 Variation by area type

The interaction of all the factors discussed so far and demographic factors and variations in public transport service levels from place to place results in a strong overall relationship between demand, expressed in trip rates, and settlement size. This is illustrated in Table 2.7.

Table 2.7 Frequency of local bus use by size of settlement 1997-99

	Frequency of use (percentages of respondents)		
Settlement size/type	*Once a week or more*	*Less than once a week more than twice a year*	*Once or twice a year or less*
Greater London	45%	28%	29%
Metropolitan built-up area	38%	20%	41%
Large urban area (over 250k)	33%	25%	42%
Urban area (25k to 250k)	24%	15%	61%
Small urban area (3k to 25k)	19%	19%	62%
Rural	12%	14%	74%

Source: Special tabulations from 1997/99 NTS.

Table 2.5 Usual means of travel to work by usual place of work 1997/99

Area	*Walk*	*Pedal/ motor cycle*	*Car driver*	*Car passenger*	*Bus or coach*	*Surface rail*	*London Under- ground*	*Other*
Central London	7	3	26	4	10	29	20	–
Outer London	10	6	63	6	9	4	3	–
Conurbation centre	8	2	54	13	16	6	n/a	1
Other urban	11	5	61	12	10	1	n/a	–
Not urban	13	4	65	12	4	–	n/a	–
Average	10	4	60	11	9	3	2	1

Percentage (rounded to nearest whole number).

Source : National Travel Survey 1997/99, (Department of the Environment, Transport and the Regions, 2000b).

Further NTS information for 1999/2001 shows that 17% of the population travelled by local bus three or more times a week, and a further 10% once / twice a week. However, 43% reported use of local buses ‘once a year or never’ and 52% made similar use of rail (Department for Transport, 2002b).

2.4.6 Changes in individuals’ travel over time

So far, although we have disaggregated the market into certain categories of person, we have not looked at individual behaviour.

Individuals shift from one category to another, not simply as their ages change, but also their status – for example from child to student, to adult, to married person possibly with children, to pensioner. These stages in the ‘life cycle’ are associated with changes in household size and structure, car availability and in trip purpose. Thus the work journey is a major factor determining household travel behaviour for certain stages, the need to get children to school at others.

Changes in travel behaviour are often associated with critical events in the life cycle, such as setting up a new home, or changing jobs. Many people may change their mode of travel for such reasons, at least in the short run, rather than because of differences in modal characteristics. This leads to a high turnover in the market, such that net changes between one year and the next are often small compared with the gross changes that produce them. For example, panel surveys in Tyne and Wear revealed a net reduction in the public transport share for the journey to work of 2 percentage points between 1982 and 1983. This proved to be the net result of 7% of respondents ceasing to be public transport users, while 5% became new users in that period. A net change of 2% thus involved about 12% of the sample in changing modes (Smart, 1984)

These changes are likely to be particularly noticeable if individual services are examined, since people may change routes used when changing homes or jobs, while remaining in the public transport market. Even in a zone of apparently stable land use and total population, such as a well established residential area, constant change is occurring. On a typical urban bus or rail route, as many as 20% of users may have begun to use that specific service within the last 12 months. Hence, if examining the impact of a recent change (such as introduction of a ‘Quality Partnership’ upgraded bus service) it is important to distinguish users who have switched to a route for such personal reasons, as distinct from those attracted by service characteristics.

A case where a high level of turnover was found arose in evaluation of the Manchester Metrolink light rail system: data from a set of ’control’ stations which continued to be served by conventional rail services, shows that about 50% of the users were replaced by new individuals over a 3-year monitoring period, even where little change took place in service offered (Knowles, 1996).

Patterns of individual behaviour may influence trip frequencies over a very long period. For example, based on work in South Yorkshire and elsewhere, Goodwin and others have suggested that trip rates developed in early adult life may strongly influence subsequent modal use.

This ‘turnover’ effect, also known as ‘churn’ has been investigated by several researchers. A review by Chatterjee (2002) identifies ‘asymmetric churn’ in which the numbers of new and lost users over a given period are not necessarily equal. In the case of data from the Netherlands for the period 1984 to 1987, some 123 ‘high users’ of public transport in 1987 were shown to comprise only 58 who had been ’high users’ in 1984, 48 previous ‘non users’ and 17 previous ’low users’ (from Goodwin, 1989). Work by Dargay and Hanly on the British Household Panel Survey (2003) indicates that over a nine-year period, over 50% of commuters change their main mode at least once. Of those who both move house and change employer during two consecutive years, 45% also change mode. Exceptionally high rates may be found in areas such as central London, a recent survey in July 2002 of office workers showing that nearly half had changed their place of work, home or means of transport since October 2000 (Brook, 2002).

The implications of this for transport operators and planners is that responses to changes in fares and service quality should be assessed not only in the short run, but over long periods. Much short run change is caused primarily by non-transport factors, but in the long run transport characteristics will affect other choices. For example, individuals may be firmly committed to a specific mode of travel for their existing home to work trips, which may not be affected even by large changes in price or service quality, but when relocating, will have to reconsider the routing, and perhaps mode, of those trips.

2.5 Trends in public transport demand and provision

In this section, trends in Britain are considered in more detail and compared with those in other European countries.

2.5.1 Overall trends by mode and region

Local buses

Table 2.8 shows the aggregate trends in the local bus market for the period 1985/86 to 2001/02. The number of passenger journeys fell by 23% over this period. However, there were marked regional variations. In Greater London, in which Transport for London (TfL) now has major responsibility for public transport provision, bus use increased substantially. Elsewhere bus use declined, most severely in the English metropolitan areas (the six areas in England comprising the major conurbations outside Greater London where Passenger Transport Executives (PTEs) are responsible for planning and procuring services). A lesser decline occurred in the rest of England, and Wales and Scotland as a whole.

The marked differences shown are influenced by the following factors:

- The increase in average fare per trip (which covers all passengers, i.e.including concessionary travel). On a basis of the long-run elasticities (discussed further in Chapter 6) applicable over such a period, one would expect a decline in travel of similar magnitude to the percentage fare increase shown, attributable to this

Table 2.8 Changes in local bus demand, service level and fare levels

	England						
	Greater London	*Metro-politan areas*	*Non-metro-politan areas*	*All England*	*Scotland*	*Wales*	*Great Britain*
Change 1985/86 to 2001/02 (%)							
Passenger trips	24.5	-44.8	-23.2	-21.1	-34.3	-36.2	-23.1
Bus km	39.2	12.7	30.7	26.1	30.9	31.6	26.9
Passenger receipts per trip	10.9	69.4	23.6	31.0	21.7	23.4	28.7

Note: Passenger receipts at 2001/02 prices; concessionary fare reimbursement excluded.
Source: Department for Transport 2002d.

cause. However, it should be noted that the fare increase in the metropolitan areas was from a low absolute base, and hence a lower elasticity may be applicable there.

- The increase in bus-km run, generally a proxy for service frequency. Again, long-run elasticities would imply an expected growth of similar magnitude to the percentage shown, attributable to this cause.
- Exogenous factors, including trends in total population, its composition, and car ownership growth.

A major part of the differences between London and the metropolitan areas may be attributed to these factors. For example the increase in bus-km in London has offset the effect of higher real fares, combined with population growth. In the metropolitan areas, the large increase in real fares appears to be the dominant factor. However, the decline in the rest of Britain (primarily in urban areas, with populations up to around 500,000) is striking, given that the growth in bus-km exceeded that in real fares.

Rail

Table 2.9 shows trends for rail systems from 1991/92 to 2000/01. 'National rail' corresponds to the surface network formerly operated by British Rail and now by 25 privatised Train Operating Companies (TOCs). There has been substantial growth both in passenger journeys and passenger km for both national rail and the London underground system. Demand for rail travel appears to be strongly correlated with employment. Thus both underground and national rail use peaked in the late 1980s, declined during the following economic recession, then grew rapidly from the mid 1990s along with employment growth (especially in central London).

Table 2.9 Changes in demand for rail, and fare levels

	National rail	*London Underground*	*Other rail systems*
Change 1991/92 to 2001/02 (%)			
Passenger journeys	21.2	26.9	127.2
Passenger km	20.3	26.4	140.3
Passenger receipts/km	6.5	26.3	33.1

Source: Department for Transport 2002d.

'Other rail systems' comprise the Glasgow Underground and the light rail systems listed in Table 2.1. The large growth in their number in recent years produces correspondingly large percentage increases. A consistent data series for train-km run equivalent to that for buses is not available.

Further consideration of light rail developments is given in Chapter 12.

Taxis and private hire vehicles

A notable feature of trends revealed in the NTS data is the rapid growth in use of taxis and PHVs, despite the labour-intensive nature of this mode. The total number of taxis and private hire cars has grown rapidly in recent years, following legislative changes, which have partially removed restrictions on the taxi trade. Further, increasing unemployment (until the mid 1990s) stimulated entry into the trade. The number of licensed taxis in Great Britain grew from about 39,100 in 1985 to 69,000 in 1999, or by 76% (Department of the Environment Transport and the Regions, 2000a) Use of taxis and private hire vehicles (miles per person per year) grew by about 125% between 1985/6 and 1999/2001 (Department for Transport, 2002b).

In some respects, the roles of taxis/private hire vehicles and other public transport could be seen as complementary: they are used particularly for late-night travel. Some of the growth since 1985/86 may have been associated with reduced quality of bus services since deregulation. However, in London a high level of conventional (bus and rail) public transport use, is combined with the highest taxi and private hire mileage per person per year within Britain.

2.5.2 Public transport and car use

As car ownership has grown, it has had a direct effect on public transport use. Firstly, the individual having first choice in use of a newly acquired car (usually corresponding to the 'main driver' in the NTS, and typically the working head of household) will tend to use it. His or her trips will then be lost to public transport, except for occasional journeys. In addition, other members of the household may also transfer some of their trips to the car as passengers, for example a child being given a lift to school, or the family travelling together at weekends.

The loss of trips to public transport will thus be greater than those of one person alone, although this could depend upon price and quality of the service offered: if it is good, then other members of the household may be less inclined to arrange their trips so as to travel as passengers in the household car.

Cross-sectional data from the NTS may be used to indicate the principal impacts of changes in car ownership. For example, as shown in Table 2.10, persons in no-car households made 156 local bus trips per person in 1995/97, falling to 43 in one-car households. At an average household size of approximately 2.4, the drop in bus trips per annum as a result of a household shifting from the 0 to 1 car category would thus be about 270.

Table 2.10 Effect of car ownership on public transport use

Number of household cars	*Local bus trips/person/a*	*Bus km/person/a*	*Rail trips/person/a*	*Rail km/person/a*
0	156	875	22	540
1	43	311	17	541
2+	22	200	13	589
All	62	252	17	345

Source: National Travel Survey 1995/97 (Department of the Environment Transport and the Regions 1998a).

As noted earlier, the effect is greater for the first car than the second, since the latter will be used in part to take trips that were being made as car passengers in the first (the children acquiring their first cars, for example).

The public transport trips made by the members of one-car households tend to be concentrated into categories such as school and Monday-Friday shopping trips, with much less evening and weekend public transport use. Two-car households tend to make very little use of public transport. There may be exceptions for households of above-average size, or where some journeys to work are made by public transport.

It should be noted that in practice car ownership depends particularly on household size and composition. Non-car-owning households, whose members are often elderly, tend to be smaller, and contain only about 20% of the population. Rail trip rates are also affected by car ownership, but to a lesser degree, and rail distance travelled rises with car ownership. The majority of rail users, especially those using commuter services is the south east and elsewhere, come from car-owning households.

In 1999, 22.8 million private cars were licensed in Britain, corresponding to about 0.39 per head, or 1.02 per household. The most common category was the one car household, some 44% of the total. Another 27% of households had two or more cars, thus leaving 28% without a car. The proportion of households with one or more cars has grown less rapidly than car ownership in total, as average household size has fallen. Its rate of growth has also declined.

Marked variations occur by area. In 1997/99, about 38% of households in London and the metropolitan areas did not have a car, but this fell to 29% in urban areas of 25,000 to 250,000, and to 29% in rural areas (Department for Transport, 2002).

2.5.3 International comparisons

Trends in passenger kilometres over all 15 European Union countries over the last decade are shown in Table 2.11.

Table 2.11 Growth in public transport use: European Union countries 1990-1999

Mode	*Growth in passenger km*
Passenger cars	18%
Buses and coaches	9%
Tram and metro	5%
Railway	8%
Air	65%
All	19%

Source: European Commission, 2002.

Total person-km (motorised modes only) rose by 19%. By mode, the fastest growth was in air travel, at 65% (typically, this mode has grown by about 5-6% per annum in most industrialised countries). This was followed by private car at 18%. However, in aggregate, public transport modes also showed growth of 9% in bus and coach modes, 5% in tram and metro modes, and 8% in rail.

Such growth in motorised travel does not necessarily represent growth in trips. As an example, estimates of growth based on data from the British NTS are shown in Table 2.12 In this case, a more comprehensive record is made possible through the inclusion of non-motorised trips. Between 1990 and 2001 the average annual distance travelled per person increased by about 4%. However, numbers of trips made fell slightly possibly due to an ageing population (Table 2.2). Time spent in travel per person per day (averaged over the whole population) has remained remarkably stable at about 60 minutes since the mid 1970s although it may have grown from a slightly lower figure in the previous two decades. There are of course major variations by individual and person type.

Table 2.12 Trip rates and time budgets (GB – all modes, trip lengths)

	1990	*2001*
Hours travelled per person per annum	369	360
Journeys per person per annum	1090	1018
Distance travelled per person per annum	10545 km	10964 km
Average trip length	9.7 km	10.8 km
Average speed	28.7 km/hour	30.5 km/hour

Source: Department for Transport, 2002b.

The growth in person-kilometres corresponded to an increase in average speed of 10.1%. Hence, a similar number of trips (and thus, by implication, out-of-home activities) were made, but of increasing average length and speed. If the pattern of land uses were fixed, then a wider range of opportunities (for example, in terms of shopping facilities, or employment) could be accessed within the same time budget. There may also be negative outcomes - the greater distance travelled could indicate that facilities have become less accessible than before (for example, due to greater centralisation of health services).

This concept is supported by evidence from other countries, notably work by Brög (1993) in Germany, a study in Norway , and a recent survey in Lyon (Nicolas and Pochet, 2001), all consistent with an average time budget very close to 60 minutes. For example, the work by Brög in German cities indicates that for intra-urban travel the average time spent per person per day is very stable (at about 60 minutes), as is the number of activities outside the home. In comparing surveys carried out in Essen and Hanover in 1976 and 1990 it was found that average travel time per person in Essen had changed from 60 minutes to 59 minutes, and in Hanover from 61 to 62. Activities per person per day likewise changed very little (stable at 2.7, and from 2.9 to 2.8 respectively). One could see thus the urban transport market as a whole as a 'saturated' market, with little scope for dramatic expansion. More substantial changes were seen in the mix of modes used, and total travel distance (a shift from non-motorised modes to car driver and public transport). However, in Hanover in particular, public transport did not decline as a share of total trips, but rose from 16 to 22% over this period (Brög,1993).

Such time budget constraints are less likely to apply to weekend, leisure and long-distance travel.

Despite growing traffic congestion, average door-to-door speed has risen, for several reasons:

- A shift from non-motorised to motorised modes for short trips, e.g. from walk to bus; from walk to car.
- A shift from slower public transport modes (primarily bus) to car, as car availability has risen: in most cases, except where extensive priority is given, car will be substantially faster than bus for door-to-door journeys.
- An increase in trip length, reducing the proportion of walk and wait time within public transport trips. The aggregate totals shown in Table 2.12 include inter-city travel, which has grown rapidly.
- Primarily within the car mode, a reassignment and/or redistribution of trips so that relatively more travel is now made where congestion is (or was) less severe, such as suburban and rural areas.

The overall stability in the average travel time budget could also serve as a means of checking plausibility of forecasts - growth in travel which implies increased total travel time would be questionable. The stability also implies an inverse relationship between distance travelled and average speed. For example, if within a 60-minute travel time budget door-to-door average speed were 10 kph, then 10 km would be covered. An increase to 15 kph, would imply an reduction in travel time of 33%, to 40 minutes. In practice, with a constant travel time budget, distance travelled would increase by 50%, to 15 km. This overall relationship would not necessarily apply equally to each mode. For example, a greatly accelerated service (such as rail rapid transit replacing bus) would not only enable and stimulate more travel within the existing public transport user market, but also divert car trips.

There are of course wide variations by person type and individual in travel time budgets.

2.5.4 Trends within the public transport market

Table 2.13 shows some selected examples of trends for EU countries in terms of three major public transport modes (bus and coach, metro and tram, rail). An increase is evident in most cases, the noteworthy exceptions being bus and coach travel in Great Britain and also in Germany - the decline in Germany is largely or wholly associated with a sharp drop in public transport use in eastern regions after reunification. Even in the USA, growth is evident, albeit from a low absolute base.

Table 2.13 Growth in passenger km 1990-1998

	Passenger km (billions)		
	1990	*1998*	*Change*
Denmark			
Bus and coach	9.3	11.1	19.4%
Tram and metro	0.0	0.0	
Railways	5.1	5.6	9.8%
All modes	14.4	16.7	16.0%
Germany			
Bus and coach	73.1	68.2	-6.7%
Tram and metro	15.1	14.4	-4.6%
Railways	62.1	66.5	7.1%
All modes	150.3	149.1	-0.8%
Netherlands			
Bus and coach	13.0	15.0	15.4%
Tram and metro	1.3	1.4	11.1%
Railways	11.1	14.8	33.3%
All modes	25.4	31.2	23.0%
Great Britain			
Bus and coach	46	45	-2%
Tram and metro	6.5	7.3	12.3%
Railways	33.4	35.4	6.0%
All modes	86	88	2%
All EU countries			
Bus and coach	370.0	402.5	8.8%
Tram and metro	48.6	50.1	3.1%
Railways	270.4	280.8	3.8%
All modes	689.0	733.4	6.4%
USA			
Bus and coach	196.0	239.0	21.9%
Tram and metro	19.0	22.0	15.8%
Railways	21.0	23.0	9.5%
All modes	236.0	284.0	20.3%

Source: Department for Transport 2002b.

2.6 Concluding observations

By segmenting the market for public transport a better understanding may be obtained than simply using total volumes of travel. This is made possible partly through existing operator-based ticket data, but also through sources such as the National Travel Survey in Britain. In future, smartcards may enable a more reliable segmentation to be attained.

Overall trends indicate that the absolute volume of public transport demand, in terms of passenger-km, is still growing in western Europe and North America, albeit falling as a share of all motorised travel.

It remains to be determined to what extent these international differences may be explained in two main ways:

- The same elasticities and exogenous factors may apply, but marked differences in funding produce, for example, much lower fare levels. Given long-run elasticity values now known to apply in Great Britain, these would produce correspondingly large differences in overall demand.
- More fundamental differences may exist. These are likely to apply to factors other than those such as real fares and service levels, for which international comparisons (see Chapters 6 and 7) suggest broadly similar elasticity values. The income elasticity for local public transport use may be positive, and differences exist in the overall perception of public transport, affecting modal choice between it and the car.

3 Summary of findings

This chapter summarises the principal findings of all the studies considered and the additional research undertaken in the course of compiling this guide. Its purpose is to provide an overview of the topic, helping readers to gain an overall understanding of the major issues and to learn how to use some of the forecasting techniques presented.

The results are presented in as non-technical a manner as practicable, with a minimum of tables and figures and no direct references to sources in the literature and elsewhere. No details are given of the evidence considered, or the analysis of it which leads to the conclusions: that is to be found in the more technical chapters, at locations indicated by the marginal references.

The subjects addressed in this chapter are the effects of fares and service quality on public transport demand, the influence of income and car ownership, interactions between land-use and transport, the demand generated by new modes and services, and other transport policies.

3.1 Effects of fares

3.1.1 introduction

Fares are probably the most intensively studied transport demand factor, for two reasons: fares and changes in fares are relatively easy to identify and quantify, and they are the most readily, and probably the most frequently, adjusted factor.

3.1.2 Fare elasticities

Fares are fundamental to the operation of public transport since they form a major source of income to operators. In general, if fares are increased, patronage will decrease. Whether revenue increases or decreases as a result of a fare increase depends on the functional relationship between fares and patronage as represented by the demand curve. Usually this is expressed through the concept of 'elasticity'. In its simplest form the value of the fares elasticity is the ratio of the proportional change in patronage to the proportional change in fares[3]. It has a negative value when, as is usually the case, fares and patronage are inversely related: an increase in fares leads to a decrease in patronage and *vice versa*. If the value of the elasticity is in the range zero to -1, then a fares increase will lead to increased revenue. If the value exceeds -1, then a fare increase will lead to a decrease in revenue[4].

Fare elasticities are dynamic, varying over time for a considerable period following fare changes. Therefore it is increasingly common for analysts to distinguish between short-run, long-run and sometimes medium-run elasticity values. There are various definitions of short-, medium- 5.5.4 and long-run, but most authors take short-run to be 1 or 2 years, and long-run to be around 12 to 15 (although sometimes as many as 20) years, while medium run is usually around 5 to 7 years.

As well as considering the direct effects of a change in fares, it is often important to consider the effects of fare changes on other modes. The usual method to take into account the effect that other modes have on the demand for a particular mode of public transport is to use cross- 5.5.5 elasticities. These estimate the demand elasticity for a competing mode with respect to the change in the given mode, e.g. the demand elasticity of bus travel with respect to rail fares.

In this study elasticity values from many sources have been examined to provide an up-to-date overview of fares elasticities and the effects of various factors on the values. The principal results of this analysis are shown in Figure 3.1.

Fare elasticity varies significantly depending not only on the mode, and the time period over which it is being examined, but also on the specific circumstances in which a mode is operating. Broadly speaking: bus fare elasticity averages around -0.4 in the short run, -0.56 in the medium run and -1.0 in the long run; metro fare elasticities average around -0.3 in the short run and -0.6 in the long run, and local suburban rail around -0.6 in the short run.

These results appear to indicate a significant change from those reported by Webster and Bly (1980) which were based on international aggregate measures of fares elasticity for all journey purposes and passenger types across all trip lengths and fares. This analysis led to the conclusion that overall fares elasticities are low, so that increases in fare levels will almost always lead to increases in revenue. The analysis resulted in then accepted 'standard' public transport fares elasticity value of -0.3. Given the dominance of before-and-after studies in the 1980 report, it is likely this value is what would now be called a short-run elasticity. In the current work the short run elasticity has been found to be about -0.4.

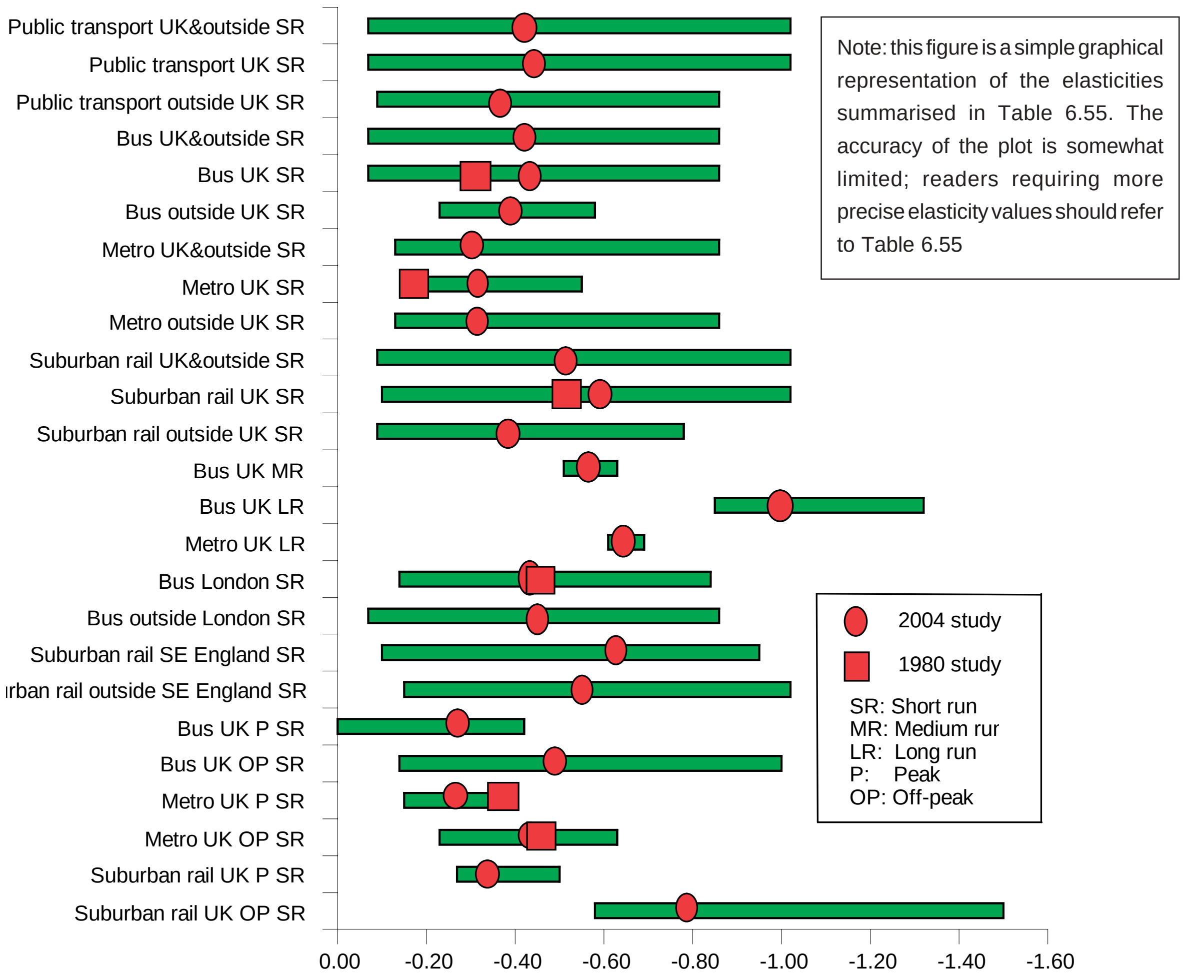

Figure 3.1 Summary of mean values and ranges of fare elasticities
(The bars indicate the range of elasticity values found)

Two of the main reasons for this difference are as follows. Firstly, given that fare elasticity is different for different journey purposes, there may have been a shift in the types of journeys for which people are using public transport (for example, more leisure travel). Secondly, for the same journey purpose the elasticity may actually have changed. This could be due a variety of factors, some of which will interact with each other: one of these is market turnover because different generations and social groups of people will have different perceptions of using public transport. Other factors include: rising incomes and car ownership and the varying quality of public transport service over the last 20 years. Suburban rail short run fare elasticity has increased slightly from about -0.5 to -0.6 in the UK.

The 1980 report did not cover medium or long run elasticities at all. Therefore the likely value of medium run bus fare elasticity of around -0.56 cannot be compared with earlier estimates.

The realisation that long-term elasticities can exceed -1 has serious implications for the public transport industry. While the immediate effect of a fare rise might be a temporary increase in revenue, the long-term effect is likely to be a decrease, although if future cash flows are discounted operators may benefit from fare increases. Nevertheless, attempts to counter falling revenue with fare increases alone will eventually fail. Reversal of negative trends in public transport patronage requires service improvements, and possibly fare reductions.

The relatively wide ranges of elasticity values about the means shown in Figure 3.1 reflect variation in methods of estimation, as well as variation between studies in a number of other factors influencing demand and elasticity. Some of these factors, and their likely effects, are discussed in the following sections.

Some travellers will have a choice between the three public transport modes included in Figure 3.1. This means that if the fare on one of them is increased, but the fares on the others are kept constant, some travellers will switch to the alternative public transport modes. However, if the fares on all public transport modes are changed simultaneously, there will be less incentive for travellers to switch. Hence one would expect elasticity values based on a fare change by just one public transport mode to be larger than those based on data from a common fare change by all public transport modes. The former are sometimes known as 'Own elasticities' and the latter as 'Conditional elasticities' (see Section 5.3 for more detailed explanation).

3.1.3 Types of fares

Fare systems can have various forms; for example, they can be flat, zonal or graduated. Each of these has its 6.2

particular characteristics. Passengers may be offered single or return cash fares, season tickets, travelcards or concessionary fares.

While there are many types of fare it is often necessary, for the purposes of analysis, to define a single value, which will often be the average amount paid for a single trip. This can be calculated by summing all the passenger receipts in the market segment of interest and dividing by the equivalent number of passengers. Alternatively, the total revenue might include funding received to compensate for concessionary fares that the operator offers as part of a policy agreement. Other studies may define fares differently.

3.1.4 Effect of types of fare change

The magnitude of the fare change

Fare elasticities may be affected by the magnitude of the fare change. In general greater fare increases produce 6.6.1
higher values of elasticity than lower increases. The differences are greatest for long-run elasticities.

The direction of the fare change

The response to a fare increase may not be equal and opposite to the response to a fare decrease. In other words, the elasticities may not be symmetrical. However, there 6.6.2
have been few opportunities for studies of the effects of fare reductions, so that there is little convincing evidence of this possible asymmetry.

The level of the fare

Fare elasticity is also affected by the current level of the fare relative to people's income. This can be illustrated by the results for London buses When fares were 6.6.3
particularly low, from October 1981 to March 1982, the elasticity was around -0.30 to -0.33, but at the higher relative fare levels in 1983, it was over -0.40.

Elasticity values have also been found to increase with fare levels for short distance (£ 32km) rail journeys outside London.

3.1.5 Variation of elasticity with type of area

There is enormous variation between different types of area in the pattern, type and level of public transport 6.7
services, and the demand for them. Generally speaking, people in areas with low population densities tend to rely more on cars and less on public transport than their more urban counterparts, and are therefore more likely to have the option of switching to car travel if fares rise.

Urban and rural areas

Elasticity values are much higher in the shire counties than in metropolitan areas, probably reflecting lower levels of captivity to bus and the greater feasibility of using car as an alternative. The greater difference between the long and short runs in the metropolitan counties may reflect a 6.7.1
greater turnover of population in such areas, allowing a wider range of responses in the long run relative to the short run compared with more rural areas.

Effect of city size

The same type of argument might lead to the expectation that residents of large cities are likely to be more 6.7.2
dependent on public transport than those in smaller cities, with corresponding differences in fare elasticities. However, the evidence is less clear cut.

London as a special case for bus travel

London bus services may be regarded as a special case within Great Britain, not least because of the size of the 6.7.3
conurbation, levels of congestion and the extent of public transport networks, but also because of the degree of regulation that still obtains in London.

In the short run, at least, bus fare elasticity is marginally higher outside London (around -0.43) than inside London (around -0.42). One might expect a higher elasticity value for buses in London because of the availability of the Underground as an alternative. On the other hand the deregulation of buses and the greater ease of use of cars outside London mean that the elasticity might be expected to be higher there. It looks as if these factors counterbalance one another.

Rail in the south east and elsewhere

Fare elasticities in the south east are slightly higher than in the rest of the UK, possibly because of the greater availability of alternative public transport in London and higher car ownership in other parts of the south east than elsewhere in Britain.

3.1.6 Fare elasticities for different trip purposes

Peak and off-peak demand

Trips made in the peak tend to be for work and education purposes, and so tend to be relatively fixed in time and space. Off-peak trips tend to include leisure, shopping and personal business trips for which there is often greater 6.8.1
flexibility in terms of destination and time. Hence one would expect off-peak elasticities to be higher.

In the UK off-peak elasticity values are about twice the peak values, with slightly greater variation for suburban rail than the other modes. This may reflect the greater use of off-peak fare discounts on rail than on bus or metro. Outside the UK, the mean peak elasticity for buses is calculated to be -0.24, while the equivalent off-peak value is -0.51 suggesting a slightly higher differential between the peak and off-peak. Insufficient numbers of values were available for metros and suburban rail systems outside the UK to allow similar calculations to be made.

The division between peak and off-peak elasticities may be an over simplification. There may be several groups of elasticities: peaks, inter-peaks, evenings, Saturdays, and Sundays. A split into seven groups is shown, for a non-London UK metro, in Table 6.30.

Trip purpose

People travelling to work or to school generally have little choice of trip ends or timing of journeys. Such trips are 6.8.2
largely the cause of the peak, which is when congestion

tends to be at its greatest, making car journeys slower. Hence one would expect trips to work and education to have lower elasticity values than other trip purposes. Elasticities for travel in London are broadly consistent with this expectation, save for anomalously low off-peak values for buses.

Price elasticities for rail services in the south east are lower for commuting journeys than for leisure and shopping. Business trips paid by employers have very low elasticity values, because an employer is likely to regard a fare increase as largely irrelevant if a local business journey needs to be made.

3.1.7 Elasticities for different types of traveller

Access to a car

Travellers with access to cars have an alternative mode of
transport and are more responsive to fare changes than 6.9.1
others.

In the long run the public transport elasticity of those with a car available is substantially greater for those without a car. Similarly the public transport elasticity of driving licence holders is much higher than for non licence holders.

Gender

Evidence from two studies suggests that males are more
likely than females to have access to a car and are 6.9.2
therefore more sensitive to public transport fares

Age

Evidence on the dependence of elasticities with age is not clear cut.

Many of the trips by the elderly and disabled will be discretionary, and so one would expect high elasticity values for these types of trips. On the other hand, many of them will have low incomes and low car ownership, and
some may have difficulty walking, so that for trips that 6.9.3
have to be made, public transport may be the only option, and low elasticity values would be expected. Variations in the mix of these factors may explain the differences between the elasticity values for the elderly and disabled relative to the whole adult population.

Income

Travellers with higher incomes are more likely to have cars available as an alternative to public transport. Hence under some circumstances they are more likely to be sensitive to
fare changes. On the other hand they have more money 6.9.4
available to absorb the effects of a fare increase.

Those on low incomes may be more prepared to walk than those with high incomes and higher values of time. Thus, one might expect low-income travellers to have higher elasticities for short trips, and high-income travellers to be more sensitive for longer trips. Where the values are not differentiated by trip length, one would expect the greater the mean trip length the greater the likelihood of high-income travellers having a higher elasticity value.

In practice it has been found that the fare elasticities are greater for travellers with higher incomes. This seems to be the case for both bus and rail. Similar trends are followed for all three modes and for trips to work and elsewhere.

3.1.8 Elasticity by distance travelled

Bus fare elasticities

Two conflicting factors seem to influence the dependence of bus fare elasticities on trip length. For very short trips, many people have the option of walking, and elasticities tend to be high. However, for long trips fares are higher and represent a greater proportion of incomes, leading to
higher elasticities. Falling between these conditions, 6.10.1
medium-length trips tend to be less elastic. Further, very long trips may also be less elastic, as a result of tapered fare scales.

The results of a number of studies support this generalisation.

Rail fare elasticities

In general, it seems that in the rail industry, fare elasticity decreases with distance. This may be because rail fares are often subject to a taper, that is, the fare per unit distance decreases with increasing distance, so one would expect a
lower elasticity value with increasing distance. This 6.10.2
argument for lower elasticities with increasing distance has to be set against the argument put forward above about fares for longer journeys being a greater proportion of income. The relationship between distance travelled and fares elasticity will depend on the relative strength of these factors in a particular situation.

3.1.9 Effect of ticket types and fare systems

Results of studies of the effects of pre-paid ticketing systems (travelcards or season tickets) show no consistent
pattern: in some cases elasticities are greater for pre-paid 6.11
tickets than for cash fares, but in other cases the opposite is found.

3.1.10 Zero fares

Zero-fare public transport trials are relatively rare. Some of these schemes have been limited to short journeys within central business districts. Their principal effect is to attract people who would otherwise walk or cycle. Otherwise, 6.12
demand increases due to the introduction of free travel seem to be consistent with normal elasticity values. There is no convincing evidence that free travel diverts journeys from cars to public transport.

3.1.11 Concessionary fares

Introduction

Since June 2001 public transport authorities in England
and Wales have been required to provide elderly and 6.13.1
disabled passengers with a minimum concession of a free bus pass entitling the holder to fares half the standard adult fares or lower. Authorities may continue to provide tokens in addition to meeting the minimum statutory requirements. Similarly, they can continue using flat rate

fares provided either that the flat rate is fixed at a level such that the concessionary passenger pays half price for even the shortest/cheapest journey or this is offered in addition to the statutory minimum. As a result many flat fare schemes are now offered as maximum fare schemes.

In Scotland, since September 2001, elderly and disabled people benefit, as a minimum, from free local bus travel within scheme boundaries for journeys outside the morning peak. In Wales, concessionary travellers are entitled to free bus travel throughout the country, funded by the Welsh Assembly.

Some authorities also offer concessions to other groups (eg school children, students, job seekers). There is very little evidence of effect of concessionary fares on transport demand in these social groups, or for other modes. The main focus of the following paragraph is therefore on local bus service concessionary fares for the elderly.

Trip generation

Offering concessionary fares to certain groups of passengers is likely to result in additional trips being made. Fare elasticities for concessionary fares may not be the same as those for changes in full fares for a number of reasons. Concessionary fares are typically aimed at alleviating social exclusion and thus target low-income groups. The age and mobility of concession holders may also affect trip 6.13.5
generation rates, as will the way in which the scheme is run. For example token holders may use the tokens to reduce fares for essential journeys to an affordable level, or may view the tokens as a bonus to be used for additional trips. Most of the studies reviewed break down trip generation rates by type of concessions scheme.

The 'Trip Generation Factor' is normally defined as the ratio of numbers of trips made at concessionary fares, to the number which would be *made by the same people* if they were charged full adult fares. Generation factors for bus travel were found to vary between 1.5 and 2.2 for free travel schemes, 1.2 to 1.9 for flat fare schemes and 1.2 to 1.5 for half fare schemes. Rates were higher still if the pass had to be paid for. There was greater uncertainty as to the effects of tokens with trip generation rates ranging from 0.85 to 1.30.

Estimates of demand on the London Underground generated by free travel concessions lead to corresponding generation factors of 1.50 for non-economically active males, 1.60 for non-economically active females, and 1.33 for economically active people of either sex.

3.1.12 Application of fare elasticities

Fares elasticity is not simply a theoretical concept: it is an important tool in planning and management of public transport. Its principal use is in estimating changes in patronage and revenue that are likely to result from a proposed fare change.

Advice on the selection of elasticities for specific applications and incorporating them in appropriate models (with the option of using the software available with this guide) is given at the end of this chapter.

3.2 Effects of quality of service

3.2.1 introduction

Quality of service may be defined by a wide range of attributes which can be influenced by planning authorities and transport operators.

Some of these attributes (access and egress time, service intervals and in-vehicle time) directly involve time, and can be quantified with relative ease and incorporated in appropriate demand forecasting models, using relevant elasticities.

Others (vehicle or rolling stock characteristics, interchanges between modes, service reliability, information provision, marketing and promotion, and 8.1
various bus specific factors) are more problematical, and need to be treated indirectly. The relative importance of quality of service characteristics is often expressed in terms of an attribute weighting relative to another journey component. This weighting may be in terms of equivalent in-vehicle time. For example, a real time information system may equate to a 3 minute reduction of in-vehicle time per trip. Alternatively, service attributes may be expressed in money terms, such as a minute of wait time being worth the equivalent of 10 pence in fare.

Where attribute weightings are determined as monetary equivalents these may be added to actual fares and used, together with an appropriate fares elasticity, to estimate effects on demand. Where attribute weightings are derived as journey time equivalents, they may be added to generalised costs for use in forecasting.

3.2.2 Access time to boarding point and egress time from alighting point

The evidence for the impact of access and egress time is dominated by attribute valuation studies. The majority of 7.3
these studies were based on use of stated preference, rather than revealed preference, techniques.

Weightings for walking times to and from bus stops and stations range between about 1.4 and 2.0 units of in-vehicle time, with no obvious dependence on trip type and main mode. The corresponding range for access and egress journeys by all means (including driving and cycling to stations etc) is similar (1.3 to 2.1).

3.2.3 Service intervals

The effect of service intervals can be measured in a number of ways: total vehicle kilometres or hours, frequency, headway/service interval, wait time and schedule delay. The dominant indicator is the number vehicle kilometres 7.4
operated. This has an inverse but generally inexact relationship with service headways.

The elasticity of bus demand with respect to vehicle km is approximately 0.4 in the short run, and 0.7 in the long run. For rail services the short-run elasticity (based on only three measurements) is somewhat greater (about 0.75); no long-run elasticity appears to have been estimated. 7.4.1

Service elasticities for buses are found to be considerably greater on Sundays and in the evenings, when service levels are generally lower.

Similarly, elasticities tend to be higher in rural than in metropolitan areas, where service levels are higher. There is some evidence, however, that demand is shown to be more service elastic in big cities (with populations of over 50000) than small because of the competition from other public transport modes. It is also suggested that service is valued more highly in large cities due to higher income levels.

Elasticities for bus demand have also been estimated with respect to passenger waiting times. The average value appears to be -0.64, but values for off-peak journeys, and journeys to non-central destinations, tend to be higher.

Service levels may also be expressed in terms of vehicle hours operated. Elasticities estimated from increases in bus hours operated were found (in four studies) to be of the order of +1.0.

It is also possible to consider the effects of service levels by estimating attribute value of waiting time in terms of in-vehicle times. For buses wait time appears to be valued at about 1.6 times in-vehicle time, while the 7.3.2 corresponding value for rail is 1.2.

3.2.4 Time spent on board the vehicle

There is limited evidence on elasticities with respect to in-vehicle time (IVT), possibly because the options for 7.5 improving public transport speeds are somewhat limited, especially in urban areas. For short journeys, IVT may be only a relatively small part of the total journey time, and one would therefore expect greater elasticities for long-distance journeys.

Few studies have been made of IVT elasticities. Those for urban buses appear to be roughly in the range -0.4 to -0.6, while those for urban or regional rail range between 7.5.1 -0.4 and -0.9. Greater values are suggested for longer interurban journeys (-2.1 for bus, -1.6 for rail).

There is more coherent evidence on elasticities with respect to generalised cost (GC) which brings together fare, in-vehicle time, walk and wait times. Generalised costs elasticities lie in the range -0.4 to -1.7 for buses, -0.4 to - 1.85 for London Underground, and -0.6 to -2.0 for national railways. These ranges incorporate variations with journey purposes and income.

In order to estimate generalised costs it is necessary first to adopt appropriate values of journey attributes, in particular, values of time.

Estimates have been made of average values of time segmented by the key variables of user type, journey 7.5.2 purpose and whether the context is one of urban or inter-urban journeys. Key features of these estimates are:

- the value of IVT increases with distance, with a larger increase for the car mode. Walk and wait time values do not increase as strongly with distance whilst headway becomes less important as distance increases;
- rail users have higher values of IVT than car users, with bus users having the lowest values;
- the values of walk, wait and headway also vary with user type. Car users are particularly averse to walking and waiting whilst bus users have the lowest values of these attributes;
- the values of walk and wait time vary with the levels they take. The variation seems plausible. For walk time the values seem to centre around twice in-vehicle time but they are higher for wait time.

Inter-urban trips have generally somewhat higher values of time than urban trips and employer's business trips have higher values than trips for other purposes. For urban trips, commuting journeys have higher values than leisure trips 7.3.2 for all modes other than car. For inter-urban trips, there is little difference between the values of time for commuting and leisure.

The values of time vary quite appreciably according to the mode used. For urban journeys, underground (UG) users appear to have the highest values whilst bus users have the lowest values. The figures seem to indicate that rail users have higher values than car users, particularly for inter-urban trips, although there may be a distance effect at work here since inter-urban rail trips tend to be longer than inter-urban car trips.

3.2.5 The waiting environment

Passengers who have to wait for buses or trains prefer to do so in conditions of comfort, cleanliness, safety and 8.2 protection from the weather. Attribute values have been derived for various aspects of bus shelters, seats, lighting, staff presence, closed-circuit TV and bus service information.

Estimates for individual attributes of the waiting environment range up to 6p per trip (subject to a limiting cap of around 26p on the total), or up to 2 minutes of in-vehicle time per trip.

3.2.6 Effect of vehicle or rolling stock characteristics

The attributes of public transport vehicles are largely unquantifiable and they are too many and various for 8.4 direct analysis of their effects on demand. It is almost axiomatic that passengers will prefer clean, comfortable vehicles which are easy to get on and off, but the relative importance of such factors is difficult to determine.

This problem has been addressed for buses using stated preference (SP) techniques, which involve asking interviewees to trade off various groups of attributes, fare levels, journey time etc. The results may be expressed in monetary terms – for example, a trip in a low-floor bus may be perceived as being worth 5-14 pence more than a trip in a conventional bus with high steps. Unfortunately, there are wide variations between (and within) studies, but it seems clear that perceived values of vehicle attributes are much smaller than the value of in-vehicle time for a typical bus ride.

Similar research on demand for rail, using both SP and revealed preference techniques, has estimated the effects of replacing old with new rolling stock. The resulting demand increases indicate that rolling stock improvements are typically valued at around 1-2% of in-vehicle time.

SP methods have also been used to estimate the separate values associated with ride quality, seating layout, seating comfort, noise, ventilation and ambience. This was done by reference to the levels existing on different types of train with which the respondent would be familiar. As in a number of other studies, a package effect was present in that the sum of the values of individual attributes exceeded the estimated value of the overall package by a factor of two.

It was found that refurbishment which changes seating layout and levels of ride quality, ventilation, ambience, noise and seating comfort from levels associated with old south east slam door stock to new air conditioned south east stock was worth around 2.5% of the fare. However, most refurbishments would be worth somewhat less than this, with 1.5% being a representative figure.

Attitudes to overcrowding have also been studied using SP methods. The results indicate that the effect of different degrees of overcrowding is to increase values of in-vehicle time for the more unpleasant or uncomfortable conditions. The results are not entirely consistent, but on the whole they are plausible, and suggest that overcrowding can have a significant impact on demand.

3.2.7 Public transport interchange

The ideal public transport service would carry the passenger directly between origin and destination. In practice, given the diversity of travel patterns, this is not an option for many passengers who have to make 8.5
interchanges between or within modes. Studies in Great Britain have found that passengers dislike interchange. The average equivalent penalty, including walking and waiting times necessary to effect an interchange, is 21 minutes IVT on a bus trip, and to 37 minutes IVT on a rail trip. There is however considerable variation between journey purposes and from place to place. For example, interchange penalties may be much smaller in urban environments with high-frequency public transport services.

3.2.8 Reliability

The main manifestations of public transport reliability are excessive waiting times due to late arrival of buses or trains, and excessive in-vehicle times, due to traffic or 8.6
system problems. It is common to express these forms of unreliability in terms of standard deviations in waiting or in-vehicle times. The limited available evidence suggests that the perceived penalties are equivalent to the standard deviation multiplied by the corresponding value of waiting or in-vehicle time. For example if the mean waiting time is 5 minutes, with a standard deviation of 2.5 minutes, then the effective waiting time is 7.5 minutes.

3.2.9 Information provision

Some basic level of information about public transport services is necessary for those who use or plan to use them. In practice, regular travellers rarely make use of formal information systems, and many occasional 8.7
travellers rely on informal sources such as advice from family and friends. While it is relatively easy to discover who makes use of various different information systems, there is little direct evidence of their effect on demand.

The vast majority of evidence on information provision takes the form of attribute valuation, using stated preference and other attitudinal survey methods. There is considerable variation between the results from different studies, partly because of methodological differences, and partly because the resulting attribute weightings are generally small compared with other factors which vary between studies.

Most recent research has been on the effect of real time public transport information systems, with digital displays at bus stops or Underground stations displaying the predicted arrival times of relevant buses or trains. Such systems seem to be valued somewhere between 4 and 20p per trip.

Service information available at home, through printed timetables, bus maps, telephone enquiry services etc seem to be valued at between 2 and 6p per trip, and similar information at bus stops at between about 4 and 10p per trip.

3.2.10 Marketing and promotion

Marketing campaigns are generally undertaken in conjunction with other quality and price initiatives, rather than in isolation. However, this has the disadvantage from the analytical viewpoint that separating different causal 8.8
factors becomes difficult. One approach is to use a simple time-series model for factors such as known changes in real fares and service levels, and then estimate the difference between observed and expected outcomes

In some cases, however, efforts have been largely devoted to improved information and awareness of existing services, with little change in other quality factors – for example, some direct marketing campaigns. This makes identification of effects somewhat more explicit.

Traditionally, public transport operators have relied on conventional forms of communication, such as printed timetables, adverts in vehicles, and a limited amount of 8.8.3
poster and newspaper/other media advertising. Apart from household distribution of timetables, little effort may have been made to communicate directly with non-users.

In recent initiatives substantial numbers of potential bus users have been contacted by telephone and offered various incentives to try local services. Even though take – up levels are small, the additional revenue generated can exceed the costs of the campaign. Such outcomes also have implications for use of public funding to initiate service improvements which may subsequently become commercially viable, although not so in the very short run.

3.2.11 Bus specific factors

Boarding and alighting

Getting on and off vehicles is an integral part of public transport journeys. The time taken to board and alight is not normally a significant fraction of an overall journey time, but the individual passenger may be adversely 8.9.1
affected by the cumulative boarding and alighting times of other passengers. This is more likely to hold for bus rather than rail services, since bus stops are more closely spaced, and bus fares are more commonly collected by bus drivers as passengers board.

Longer boarding and alighting times lead to:

- Greater average journey times.
- Greater variability in journey times.

- Increased in dwell time at stops causing additional delays under high-density operating conditions, since following buses are unable to enter the stop area. This may also affect the potential peak flows that can be accommodated.

There are few studies available which document the ridership impacts of different fare collection systems. Experience in London in the early 1970s indicated losses of about 10% on individual routes converted from conductor-operated Routemasters (with open rear platforms) to one-person-operated buses (with front entrance doors). However, a substantial part of this represented a diversion to other parallel routes, the net loss of passengers being 3% to 4%. In this case the convenience of boarding and alighting at points other than official stops may also have been an element. Similar conversions were made in most other British cities (often of all services) in the 1970s and early 1980s. Hence, such conversion, which generally retained a high proportion of cash fare payment, was probably an element in the decline in bus usage. If not made explicit, it would aggravate 'trend' decline factors, or, where correlated with changes in vehicle-kilometres and/or real fares, the elasticities associated with them.

It also follows that a shift to simplified off-vehicle ticketing such as Travelcards may cause a growth in demand not only due to the convenience element and financial savings to individual users, but also through reducing total boarding times. This will affect journey times of all users (i.e. including those still paying in cash).

Alighting time will also have some effect on total journey time, but displays much less variation with ticketing type, typically averaging around 1.0 - 1.5 seconds per passenger. Total dwell time at stops may be reduced by separating boarding and alighting movements, for example through a separate doorway for alighting, but the benefits of this will only be evident at stops where there are substantial numbers of both boarders and alighters.

The question of access to vehicles is one that has been addressed over the last ten years by the introduction of 8.9.2
low-floor buses. Once regarded as a novelty, such vehicle are now becoming the norm, with all buses licensed since 2000 being required to meet the new standards (although it will take over ten years for all the older vehicles not complying with the new regulations to be phased out).

Low-floor buses have been proved to enhance accessibility for wheelchair users, elderly passengers in general and particularly those with walking difficulties) and parents with young children (toddlers or pushchair riders). This has led to significant increases in demand for some services (typically 5 to 10%), although the results vary considerably from place to place.

Low-floor buses also have the advantage of shorter boarding and alighting times.

Simplified networks

Where headways of around 10-12 minutes or less are offered, passengers tend to arrive randomly at stops. The effort needed to consult a timetable is greater than the time savings it would produce, and in many cases service 8.9.4
reliability is such that passengers may allow a margin of about 5 minutes or more to ensure catching a specific journey. Bus networks typically provide a much greater density than rail systems, such that the greater majority of the population is within 500 metres (around 6 minutes' walk) of the nearest bus stop. However this can result in very complex networks, with low frequencies on each route.

Concentrating provision on fewer high-frequency routes, while retaining lower-frequency services to provide local access, enables a more attractive service to be offered overall.

Accessible services

The question of access to bus services can be most problematical in rural areas where demand density tends to be lowest. Over the last twenty years there has been considerable experimentation with various forms of community bus 8.9.5
services, designed to provide journeys appropriate urban areas at times suitable for shopping and some personal business. Where the rural population is clustered into compact villages fixed route services may be appropriate; where the population is more dispersed accessibility may be improved by demand responsive operation.

Service frequencies tend to be limited because of low overall demand levels, and this in turn can limit usefulness of services for schoolchildren and adults needing to get to and from work.

Other experimental rural transport schemes have involved subsidised taxis or postbuses. The economics of such services are strongly dependent on local circumstances.

3.3 Demand interactions

3.3.1 Effects of fare changes on competing modes

The main way that the demand impact of the competition between modes is measured is through the use of cross- 9.2
elasticities. These are defined in much the same way as the elasticities already discussed in this chapter: the value of the fares cross-elasticity is the ratio of the proportional change in patronage on one mode to the proportional change in fares on the other mode. These cross-elasticities are normally positive. Where there are inadequate data to determine all the relevant elasticities and cross-elasticities directly, it may be possible to infer some of them using mathematical relationships between them. In practice cross-elasticities are highly dependent on relative market share and are therefore not readily transferable across time and space.

The most evidence on public transport cross-elasticities in Great Britain has been collected in London, usually in 9.2.1
research undertaken by, or sponsored by Transport for London and its predecessors.

In London the relatively high sensitivity of Underground use to bus fares (cross-elasticity = 0.13) may reflect the overlap of Underground and bus networks which provide a choice of public transport mode for many travellers. However, the smaller sensitivity of bus use to Underground fares conforms less well with this observation, possibly because many suburban areas served by bus are not accessible by the Underground. The relationships between rail and bus show a similar asymmetry. The least interaction seems to be between rail and Underground, possibly reflecting the complementary, rather than competitive roles of these modes. Car use is almost independent of bus and Underground fares.

In other urban areas, public transport use is remarkably sensitive to car costs, but car use is much less dependent on public transport costs. This reflects differences in market shares of public and private transport: a small 9.2.2
percentage shift from car travel can amount to a large percentage increase in public transport use. This observation also applies to inter-urban travel.

The relatively high cross elasticities for inter-urban coach travel with respect to rail fares (0.32), and *vice versa* (0.17), suggest a higher level of interchangeability between these modes.

3.3.2 Competition within modes

So far there has been limited evidence of the demand effects of competition within modes. However, some insights may be provided by a range of theoretical models, covering bus and rail service competition. These models take several factors into account, including service levels provided by competing operators, quality of service and fare levels. They give an indication of the scope for 9.3
resulting increases in overall demand, and of the likely market shares, in a variety of scenarios. It appears that competition is more effective at generating demand where original service levels are relatively low, and can be substantially improved through competition.

3.4 Effects of income and car ownership

3.4.1 Introduction

This section deals with the effects of income and car ownership upon the demand for public transport. 10.1
Traditionally these variables have been deemed 'background factors', as compared to attributes of public transport such as fares, service levels, journey times and vehicle quality, which are directly under the control of the operator. The broad relationships between income, car ownership and the demand for public transport are well documented. Despite this the exact relationships and the correlation between all three factors, and in particular between income and car ownership, would appear to be only marginally clearer 23 years on from the original Demand for Public Transport publication.

The last 23 years have seen marked increases in real income and car ownership levels in the UK and across Europe. For example, in this period GDP increased by around 68% in Great Britain whilst the number of cars per household has increased from 0.76 to 1.11. In that time, local bus journeys have fallen by around a third. The position for rail is more mixed. The performance of rail at a local level depends on congestion levels and, because of the perceived higher quality of rail, is less sensitive to increases in car ownership than bus. Indeed, central London rail commuter traffic has increased by 13% since 1980.

Income is expected to increase the number of trips and their average length. It is likely that this additional travel will be split between increased public transport trips and increased car trips, depending upon the level of car availability and assuming that public transport is a normal good. Income is also a key determinant of car ownership and hence there will be a secondary and negative impact on the demand for public transport via car ownership.

Rising car and driving licence ownership, income growth and the declining real cost of car ownership have been identified as the key factors that have shaped 10.2
personal travel patterns in the last twenty years. Whilst a host of other background factors can be cited, four key relationships are outlined below:

- An increase in income will, depending upon the level of income, lead to an increase in car ownership and so car availability, or to an increase in public transport use.
- An increase in car ownership/availability will, other things being equal, lead to a reduction in the demand for public transport modes.
- The sign and magnitude of demand elasticities for public transport with respect to car availability and income will vary depending upon the income levels.
- Income growth can be expected to increase average trip length.

Because of these relationships considerable care must be taken when interpreting public transport demand elasticities that have been estimated with respect to income and car ownership. Income elasticities estimated using demand models that do not have car ownership amongst their explanatory variables will pick up the negative effect that car ownership has on public transport. This could lead to results which contradict the 'accepted thinking' that public transport is not an inferior good. The problem with estimating models that include both variables is the collinearity that exists between them. The first Demand for Public Transport book noted this in detail and twenty years on the problem of collinearity still exists and is particularly noticeable for models that have been calibrated using time series data.

3.4.2 Effect of income on travel expenditure and distance travelled

In almost all Western European countries total person-km has risen at around 1 to 2% per annum, a little less than the growth in real GDP. Table 2.9 illustrates the growth 10.3
experienced within Western Europe between 1990 and 1998, with total person-km for motorised modes rising by 19%. The greatest growth was experienced in air travel (65%), followed by car (18%), bus and coach (9%), rail (8%), and tram and metro (5%).

There can be no doubt that income has a positive impact upon the total amount of travel. Further, the figures from the Family Expenditure Survey for Great Britain show that the percentage of household expenditure on transport and travel has slowly increased over time, rising from 14.8% in 1981 to 16.9% in 1999/00. These figures exclude expenditure on air travel which has seen significant growth (nearly 50% more passenger kms between 1989 and 1999) during the last twenty years.

Given little change in the population, traffic growth comes from two sources: people making additional trips and people making longer journeys. There is clear evidence that trip lengths are increasing with income, although the effects are not particularly strong. In general, the elasticities lie in the range 0.09 to 0.21 but with noticeably stronger growth for car commuting, business trips by rail and business trips by bus. The latter is not a particularly significant category, whilst the figures for train business trips will include longer distance journeys.

3.4.3 Effect of income on public transport demand

The empirical evidence clearly indicates that the bus income elasticity which includes the car ownership effect is negative. It appears to be quite substantial, in a range between -0.5 and -1.0 in the long run although somewhat smaller in the short run. This would explain the sustained reductions in bus demand over time. However, as car 10.4
ownership approaches saturation, the income elasticity can be expected to become less negative.

In studies based on the volume of demand, there is strong correlation between income and car ownership which means that it is difficult to disentangle the separate effects of each. In some instances, it has even resulted in coefficients of wrong sign. Various studies have attempted to overcome this problem using outside evidence and constrained estimates, whilst analysis of trip patterns at the individual level, as is possible with NTS data, does not face serious correlation problems.

There is some evidence to suggest that variations in the demand for bus purely as a result of income growth are negative, but in any event the overall effect after the introduction of car ownership is negative.

Although car ownership has a negative impact on rail demand, it is less than for bus and, although there are quite large variations between market segments and across distance bands, the overall effect of income on rail demand is quite strongly positive. Rail income elasticities are generally found to be positive, and as high as 2 in some cases. As with the bus income elasticity, the rail elasticity can also be expected to increase over time.

3.4.4 Effect of car ownership on public transport demand

There is some empirical evidence relating to the effect of car ownership on public transport demand where income is not entered into the model. However, there are fewer 10.5
instances where car ownership is the sole variable representing external factors

The evidence from studies which have concentrated solely on car ownership as a predictor of the effects of 10.5.3
external factors on public transport demand indicate that the impact is negative. In Great Britain, a person in a car owning household is likely to make considerably fewer trips by both bus (66% less) and rail (25% less) per week than a person in a non-car owning household.

3.4.5 Possible variations in income elasticity over time

As incomes rise and car ownership approaches saturation levels it is to be expected that the negative effects of 10.7
income on bus patronage will diminish, and that rail income elasticities will increase. These effects have been modelled using analyses of NTS data and the Department for Transport's car ownership forecasting model, on the assumption that incomes grow by 2% per annum.

The model results indicate rail elasticities (for commuting, business and leisure) increasing over time. For bus travel, commuting elasticities become more negative, business elasticities become more positive, and leisure elasticities remain broadly constant.

These findings are broadly consistent with the results of other studies, and it is recommended that they be used as long run elasticities for medium to long run forecasting.

3.5 Relationships between land-use and public transport

3.5.1 Introduction

The relationships between land-use and transport are complex, as each is directly dependent on the other. The difficulty is compounded by interactions with other 11.1
factors, such as age distribution, employment categories, income levels and car ownership, which may both depend on and be influenced by land-use and transport characteristics. It is therefore difficult to establish the precise relationships between public transport demand and land-use patterns.

3.5.2 Effects of land-use on public transport demand

Density and settlement size

In general higher population densities tend to widen the range of opportunities for consumers and employees, and also for commercial enterprises provided these are not in isolated locations. In consequence, journey lengths tend to be shorter, which can influence both numbers of trips 11.2
made and mode choice. Use of public transport tends to be greater in more densely populated areas, while there is an inverse relationship between car use and density. This may be explained in part by lower levels of income and car ownership in more densely populated areas combined in some cases with a scarcity of parking provision.

Settlement size can also influence transport by affecting, the choice of facilities available to meet particular activity needs. Settlement size also affects the distances that need to be travelled to reach particular services and facilities. Finally, settlement size will affect the modes of transport that can be supported by the urban area.

Public transport ridership tends to increase with increasing settlement size, as does the distance travelled on public transport per person per annum. However, the mean trip distance tends to decrease with increasing settlement size.

Population location

Combining housing, employment, shopping and other facilities in mixed-use developments provides residents with the opportunity to work and carry out other activities 11.2.3
locally, without having to drive. Mixed land use, especially where there is good local provision of 'everyday' facilities such as food stores, newsagents, open spaces, post offices, primary schools, pubs, supermarkets and secondary schools,

appears to reduce journey lengths and dependence on cars, but does not always result in more public transport use.

Proximity to major public transport routes (especially rail) is often associated with higher levels of long-distance commuting, but lower proportions of car travel. However, it can be difficult to identify cause and effect: people wishing to commute by public transport may have explicitly chosen to live near to public transport interchanges.

Employment provision

The degree of centralisation of employment and facilities also influences travel behaviour - a greater degree of centralisation encourages public transport use and reduces car use; peripheral locations tend to be much more car 11.2.4 dependent. However, this can be distorted by a number of other partially related variables such as occupational structure and the availability of parking spaces.

Urban form

A number of studies have attempted to compare the effects of urban form on transport. Some of these have shown surprisingly little dependence of modal split on different 11.2.5 urban forms. Others suggest that compact forms generate least car use (although car is always the majority mode) and most travel by public transport, cycling or walking.

The compact city is typically of the traditional mono-centric urban form, with a high-density central business district surrounded by residential areas which decrease in density with increasing distance from the centre. This is frequently associated with a radial transport network. The compact form tends to minimise the distances required to reach services and facilities thus creating favourable conditions for non-motorised forms of transport. However, settlements over a certain size or with particularly high densities suffer congestion in the central areas; this leads to long journey times. Further, flows will be predominantly towards the city centre in the morning and out from the centre in the evening. This heavy demand during peak hours in a single direction puts strain on the transport system. The effect of the compact city on public transport demand thus depends on the size of the settlement.

It has been suggested that alternatives to the mono-centric compact city (such as polycentric cities, decentralised concentration and urban villages) may have many of the transport advantages and fewer of the disadvantages.

3.5.3 Use of land-use policy to increase the demand for public transport

Land use policies that can affect transport use include the location of new residential developments, the location of 11.3 commercial and industrial zones, mixed-use developments, the design of locations, car-free development and transit-orientated development.

Density

Increasing density can increase the population within the catchment area for public transport nodes. However, the 11.3.1 existing relationship between density and mode split may not be static or reflect what happens if the density changes. Car ownership, public transport accessibility and income patterns all affect the demand for public transport but may remain unaffected by the density changes.

Mixed-use development and urban villages

The small amount of evidence on the effectiveness of this type of policy suggests that while it can be successful (especially when linked with new public transport 11.3.3 developments) it may have limitations. Moving origins and destinations closer together only work where the quality of the destination is less important, such as with food stores. Mixed-use development is unlikely to bring about significant reductions in travel for employment, as factors such as job type, pay and conditions are more important than convenience.

Zoning and development restrictions

A key UK planning objective is to ensure that jobs, shopping, leisure facilities and services are accessible by public transport, walking and cycling and local authorities are encouraged to identify preferred sites and areas where land uses can be located with a particular emphasis on 11.3.2 accessibility. The sites most accessible by public transport should be allocated for travel intensive uses such as offices, retail, and commercial leisure. Sites that are unlikely to be well served by public transport should be allocated for uses that are less travel intensive.

Transit-orientated development

Intense, comprehensive development around transit stations, can engender synergy between the transit system and major urban development schemes. The development will be mixed use for local services with the transport node providing access to a wider range of goods and services. 11.3.4 Typically transit-orientated development is based around light rail or urban rail services but could also be based on bus services, particularly rapid or guided bus systems.

Policies, which include offering incentives for transit-oriented development, have been successfully implemented in several North American cities. So far they have not been used much in British cities but Transport Development Areas are now being proposed in the UK.

Car-free zones, pedestrian zones etc.

The final complementary policy to be considered here is the improvement of pedestrian access to shops and 11.3.5 enhancement of the urban environment. This can be achieved through the creation of pedestrian zones, which may be served by public transport (including park-and-ride) or traffic calming.

3.5.4 Effects of public transport on economic growth and development

There is a reasonable amount of evidence of the links between light rail and economic growth and development, but virtually none on the links between bus and economic growth.

Contribution of light rail to economic growth

The stimulation of development is a key objective for the building of many light rail systems. A new light rail system will not, on its own, induce development, but it can form part of a package to facilitate development requiring investment in housing, jobs, shops and leisure facilities. 11.4.1 Most of this will be by the private sector. In order to start the development process off, incentives of various sorts may have to be offered, such as tax reductions or reductions in planning restrictions.

In general it is difficult to distinguish between the effects of new light rail systems and the economic climate in which they are introduced. There is some evidence of development impact in Tyne and Wear, Rouen and a number of North American cities. However, the Manchester Metrolink, the South Yorkshire Supertram and new systems in several North American Cities seem to have had little impact so far.

Effects of public transport on land use

The small amount of evidence on this subject suggests that the time scale for effects of new public transport systems on land-use may be of the order of 20 years. It may 11.4.2 therefore be too early properly to evaluate the impact of some of the more recent schemes.

It has been suggested that land-use impacts are greatest when transit developments occur just prior to an upswing in regional growth. However, transit tends to redistribute rather than create growth.

3.5.5 Public transport as an instrument of planning policy

The most common reason for developing, or planning, light rail systems in recent years was to stimulate development. 11.5 The influence of new bus schemes on development appears to be small: such schemes are unlikely to be high profile so 11.5.1 as to attract additional investment.

In some cases, the light rail system was an integral part of the redevelopment of a large area. Elsewhere the objective was to help stimulate development in the city centre by providing easier access to the economic activities there. General promotion of economic development in the urban area was the main objective in some cases.

While there is a strong belief that light rail systems can help to stimulate development. it is not clear what the mechanism is that underlies this process. The concepts of ‘image’, ‘confidence’ and so on are often cited and there is little evidence to support quantitative analysis.

3.6 New public transport modes and services

This section discusses consider how public transport demand might be affected by the introduction of new modes of public transport, or new ways of operating existing modes, which may replace or supplement more conventional public transport networks. The modes 12.1 considered are light rail, guided busways, and park-and-ride services, of which several examples have been established over the last two decades, but are currently being proposed as an important ingredient of modern public transport strategies.

Much of the discussion so far has been focussed on how public transport demand might be affected by ‘incremental’ changes in fares and services. The standard analytical technique is to derive elasticity values from demand data, and to apply these, using appropriate models, to the changes under consideration.

However, this method is inapplicable when planning new modes of transport, or radical developments to existing modes: there is no base level of demand, and there are no historical data, on which to base any model. It is therefore necessary to rely on informed assessments of the effects of similar developments elsewhere, making whatever allowances as may be possible for factors which vary between areas. Discussion of the effectiveness of various recent forms of transport is followed by a presentation of methods currently in use for forecasting demand for new rail services.

3.6.1 Light rail

The nature of light rail

Light rail is a modern form of public transport that runs on rails. It shares many characteristics with heavy rail system such as metros and suburban rail, but has lower capacity. Its main advantage over these other systems is that it is 12.2.1 cheaper and more flexible since it can be operated on the road in mixed traffic, and it can also be run at the margin or along the median of highways. Usually it has a much simpler signalling than heavier rail systems, often relying on the driver’s judgement in a similar manner to the driver of a bus, particularly in mixed traffic conditions. When it is running along a highway it can be given priority at signalised junctions. Light rail can be elevated or built in tunnel. Often a combination of these is used to match local circumstances, for example by using disused railway alignments to provide a fast interurban route with street running in town centres.

The growth of light rail

Light rail has grown in popularity in recent years. Since 1970, 61 metros and 76 light rail systems have opened, about a 12.2.2 quarter in North America and a quarter in Europe. Over the same period some sixty metro systems have opened, about two-thirds of which are in the rest of the world.

Effects of light rail systems on demand

A new light rail scheme will have both direct impacts as a new mode, and indirect impacts as an alternative to 12.2.4 existing modes, particularly the car. The provision of a new light rail system will meet the travel demand for many trips by increasing the range of modes available. Some trips will transfer from existing modes, including car, bus, and walking. Other trips will be generated: a new fast public transport mode is likely to create trip opportunities that were not possible previously by opening up new trip attractions within a reasonable travel time. However, the limited spatial coverage of a new system may mean that such opportunities tend to be focused in a limited number of corridors.

Because light rail tends to be faster than other modes it will probably lead to a net increase in trip lengths. It will enable some of those without access to a car to reach work, shopping and leisure facilities that they could not reach within the time that they were prepared to spend. A modern low-floor light rail vehicle may mean that some people with disabilities are able to make journeys of a type that were previously almost impossible. There may also be considerable novelty value which generates trips for their own sake, with the new system becoming a tourist attraction in its own right. A new light rail system is not likely to have much impact on the time of travel unless an explicit decision is taken to operate for longer hours than buses.

Some of these effects have been demonstrated in two relatively new British light rail systems: the Manchester Metrolink and the Sheffield Supertram. These systems were installed in the early-mid 1990s, and demand has been growing steadily since then, in a period when total public transport demand, and particularly demand for buses, has been shrinking.

Over half (about 60%) of the demand for Metrolink consists of journeys previously made by rail, largely on rail services which were replaced by Metrolink. In Sheffield, most Supertram demand (around 55%) is diverted from bus travel, but some 12% of trips are new. Metrolink journeys amount to about 5% of public transport demand in Greater Manchester, while Supertram (which operates on more routes) carries about 7% of public transport demand in South Yorkshire.

The use of transport planning policies to increase demand

The most promising policy to promote the use of light rail seems to be integration of bus services with new systems. Buses can serve a complementary role to a light rail system by acting as feeder services. This approach takes 12.2.8
advantage of the bus's ability to go on any road, to collect passengers to take to the light rail system which can then take them into the city centre at high speed on a segregated track. Buses can also be used as distributors if appropriate. This method is used for the North American systems. In the UK this has tended not to occur possibly because passengers prefer direct bus trips to their destinations rather than trips that require bus/rail interchanges.

The policy of provision of car parks at stations allowing light rail systems to be used for park and ride has achieved fairly widespread success in North America, but less in Great Britain. There appear to be few examples of city centre parking restriction being effective in increasing light rail use.

3.6.2 Guided busways

Automatic steering systems (mechanical or electronic) allow buses to operate in narrow, segregated busways, 12.3.1
bypassing congested sections of the network, or taking more direct routes. This can result in both reduced journey times and substantially improved reliability.

Guided buses can also use standard busways and bus lanes. Thus, at the end of the guideway, buses can go in different directions on the normal road network, thus allowing a greater number of destinations to be served without the need for interchange. Buses may also be able to leave the guideway part way along its length. Therefore a wide catchment area can make use of the improvements. This flexibility also allows the service network to adapt to changes in demand over time.

The Leeds *superbus* scheme provided service time improvements of between 3 and 5 minutes during the 12.3.2
morning and evening peaks, as well as improvements in the reliability and punctuality of the services using the route. The Ipswich scheme provided time savings of 3-4 minutes and again produced significant improvements in punctuality.

Substantial increases in patronage have been reported on both the Leeds Superbus route and the Ipswich Superoute 66. However, it is impossible to determine how much of the new demand was due to the advantages of the guideways per se (faster, more reliable journeys) and how much to other features of the packages (new buses, higher service frequencies, improved shelters etc).

3.6.3 Park-and-Ride

The most common aims of bus-based park-and-ride schemes are to stimulate economic activity in urban 12.4
centres, to make better use than parking of valuable land in town centres, and to reduce congestion, noise and pollution. The first of these aims may be achieved in some cases, with people who would not otherwise have travelled to town centres using P&R services so to do. However there is little evidence of reduction in traffic or demand for town centre parking as a result of P&R schemes.

P&R fares and charges need to be pitched at a level which will be attractive compared with the alternatives of driving to town centres and parking there, or travelling to competing urban areas. On the other hand it may be necessary to avoid undercutting fares on other bus services operating in the area.

Patronage of P&R services is mixed, with considerable variation from place to place. In some schemes substantial numbers of passengers are diverted from other bus services, as well as from cars. Some of these passengers travel to P&R sites by bicycle or on foot. This can have negative effects on the overall viability of public transport systems. On the other hand, some trips, which would not otherwise be made, appear to be generated by P&R schemes.

This raises the question of whether P&R services should be designed for use exclusively by motorists (for example non-stop services between car parks and town centres) or open to all passengers. The first of these strategies may be perceived as a form of public subsidy to motorists, while the second may make P&R services unattractive to motorists. Timetabling is another design issue. Services exclusively for commuters may only need to be operated at peak hours, whereas those designed for shoppers etc need to be provided throughout the day, and possibly in the evening.

The relationship between costs and benefits of P&R schemes depends strongly on local circumstances and varies from place to place. P&R may not, on its own, contribute much to the success of local transport policies, but it can be valuable in combination with other measures like traffic restraint and bus priority.

3.6.4 Forecasting demand for new rail services

Demand modelling

The methodology used for forecasting the impact of new services or new stations is very different to that used in for forecasting the affect of changes in fares or service 12.5
frequency. The framework for the latter is incremental, whilst for the former an approach that forecasts the absolute number of trips is required. The key parameters to be identified in forecasting demand for new rail services are the generating potential of the origin station and the attracting potential of the destination station, in addition to the generalised costs of travel between stations.

Four modelling approaches are put forward in the Passenger Demand Forecasting Handbook (PDFH) (ATOC, 2002):

- Trip rate models.
- Trip end models.
- Direct demand models.
- Mode choice models.

Trip rate models

These models are mainly used to forecast the demand associated with a new rail station. The models assume that rail demand is a function of the local population surrounding the new station and the forecasts are based on patronage at stations in ‘similar’ areas to the proposed new station. The methodology is simple but takes no account of the attractiveness of the destinations to be served. It is crucial therefore that the stations used to estimate trip rates are as similar as possible to the planned station.

Trip end models

These models represent an improvement in the trip rate models with the consideration of other key explanatory variables, including the socio-economic composition of the local population, the rail service frequency, and the frequencies of buses serving the area.

Gravity or direct demand models

These models combine the observed aspects of travel decision making (generation, distribution and mode choice) into a single direct model. The variables included are: resident population in the station catchment area, the socio-economic composition of the local population, the number of workplaces in the area surrounding the destination station, and journey times by rail, car and bus.

Mode choice models

Most of these analyse separately choices between rail and bus and between rail and car. Others models examine the three modes simultaneously using hierarchical methods. The variables used within the modes typically consist of in-vehicle time, cost, access and egress time and service headway for each mode being examined. The main weaknesses of these models is their inability to account for newly generated trips (principally in the leisure market) and the necessity to possess estimates of demand levels by other modes on the flows for which rail forecasts are required.

Car parking

The growth in car ownership has led to an increase in the number of rail passengers (or would be rail passengers) wishing to access the rail station by car. Where a station has a car park which is at least 90% full then additional parking would be expected to bring in extra revenue via car parking receipts and generated rail travel. The exact increase in revenue will vary according to local circumstances. Three potential scenarios are noted by the PDFH:

i Stations with obvious existing alternative parking facilities

Alternative parking facilities will tend to be further away from the train station and as such an increase in capacity at the train station will reduce the access/egress time for those who currently use the alternative facilities. The increase in spaces will also improve the access time for current users of the car park who are obliged to include an extra time allowance in their journeys to the station to locate a parking space. Once the overall time savings have been calculated, appropriate elasticities can be used to calculate the affect on rail demand and car parking revenues.

ii Stations where another nearby station has a large car park

In situations were there is a nearby station with plenty of parking available the provision of more parking spaces will attract passengers from the alternative station (given relative access), so altering the proportions of people choosing each of the stations

iii Stations with no single obvious alternative parking facility

In most cases, potential park and ride passengers at a particular rail station with inadequate parking facilities have a range of choices open to them,

- Parking away from the station.
- Using an alternative access mode, e.g. bus or ‘kiss and ride’.
- Using another station.
- Choosing not to travel by rail.

In such cases determining the impact of the provision of new car parking spaces requires as assessment of the level of ‘frustrated demand’ for car parking facilities at the station and the proportion of this demand that represents potential rail travellers who currently choose not to travel by rail. Generally local surveys will be required to produce reliable estimates of these quantities.

Valuation of integration with other modes

The effect of integration in relation to rail demand can be measured if improvements in integration are thought of as being equivalent to reductions in journey time.

If integration between rail and other modes changes for any reason, then the change is converted into an equivalent journey time change, as opposed to the fare change for the above attributes, and the generalised journey time elasticity is used.

3.7 Effects of other transport policies

The aim of this section is to assess the impact of a range of transport policies not covered elsewhere in this chapter. 13.1

The policies considered have broader objectives than straightforward demand issues

Five major policy objectives are listed in Figure 3.2, together with the policy instruments which might be employed in order to achieve them, and the constraints under which policies may have to operate.

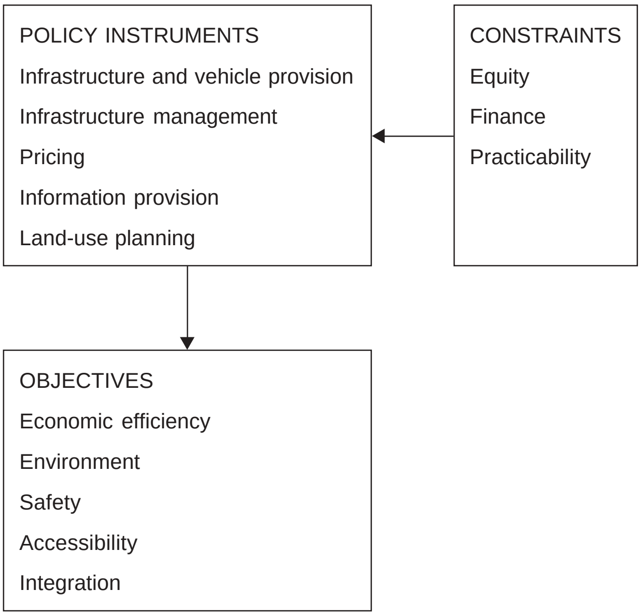

Figure 3.2 The role of policy instruments

3.7.1 Infrastructure management

Partnership between transport operators and public authorities

Over the last ten years the concept of the 'Quality Bus Partnership' has been developed in order to enhance bus 13.2.1 services using means which are not under the exclusive control of any one party. A Quality Bus Partnership (QBP) may be defined as an agreement between one or more local authorities and one or more bus operators for measures, to be taken up by more than one party to enhance bus services in a defined area.

Typically, the local authority provides traffic management schemes, which assist bus services, while the bus operator offers better quality services and vehicles.in various dimensions.

QBPs need to strike a balance between the aims of provision of better bus services, and compliance with legislation on anti-competitive agreements. Since the Transport Act 2000 it has been possible to establish statutory partnerships, legally binding all parties to an agreement. At the time of writing only one QBP is statutory; all the rest have been informal.

The growth in patronage (on average in the range 20 to 30%) resulting from QBPs seems to be encouraging operators to target their investment strategies. It is difficult to identify reasons for growth, which is enormously variable from place to place.

Allocation of road space

Allocation of road space can take several forms, the most extreme being complete prohibition of motorised traffic 13.2.3 over central city zones, on a full or part time basis. There have been several examples of this type of measure in various European cities, but there is no discernible pattern in their effects on traffic and public transport use.

The use of High Occupancy Vehicle (HOV) lanes is restricted to vehicles carrying at least the specified 13.2.4 minimum number of passengers. UK experience of HOV lanes is limited. Evidence from the introduction of a HOV lane during peak hours on a section of the A647 in Leeds suggests a slight increase in bus patronage 5 months after the scheme was introduced. The number of scheduled buses running in the morning peak has also increased.

The bus lane is in effect an extreme example of an 13.2.5 HOV. Many bus priority schemes incorporate bus lane (with- or contra-flow) but for these to be effective it is also necessary to help buses to bypass traffic queues at junctions using a variety of techniques.

In general there appears to be no correlation between the bus priority scheme length and bus journey time savings. The savings were more likely to depend on the number and severity of the bottlenecks along the length of the scheme, rather than the overall scheme length. For most schemes journey time improvements achieved are less than 5 minutes, which is small compared with overall journey times. As far as can be determined from the limited patronage data available, bus priority schemes have limited impact on bus patronage levels.

3.7.2 Pricing policies

Employer subsidies

In the US there is a growing trend to try and persuade employers to subsidise their employees' use of public transport, just as they do private transport, and in both 13.3 Britain and the US there have been moves to try and restrict employer subsidisation of private transport.

Various schemes have been established under which employers purchase public transport travelcards or vouchers for their employees. So far these schemes have been too small to have had a major impact on public transport use, or to provide evidence for generalised conclusions, but in some cases there have been encouraging shifts from car to public transport for journeys to work.

Congestion charging

The concept of congestion charging as a means of reducing congestion and its adverse environmental effects has been the subject of increasingly serious consideration over the past decade. New technologies have been 13.4 developed enabling such schemes to be implemented efficiently and effectively.

The recent Transport Acts for England and Wales and for Scotland give local authorities the power to introduce congestion charging, while the Greater London Authority Act 1999 grants similar powers to the Mayor.

There are two basic variations of road user charging: route-based schemes – charging for use of individual stretches of road; and zone-base schemes – charging users to enter a bounded zone.

Route based schemes

Route-based schemes involve charging tolls for the use of individual stretches of road and have already been 13.4.1 implemented in the UK as a way of recouping construction costs for some bridges and tunnels. So far tolls have only been set for short stretches of the network and where alternative no-pay routes are available. However, longer toll-routes are in construction. The West Midlands' Northern Relief Road will be a toll-route, with charges aimed at both recouping construction costs and ensuring a free flowing route around the West Midlands. The M1-M6 route around the conurbation will remain free of charge.

UK empirical evidence on the effects of road tolls on travel behaviour is limited to two pilot studies aimed at reducing congestion and improving the environmental quality of the cities involved. Notional tolls of up to £10 appeared sufficient to affect travel behaviour, with substantial numbers of motorists changing routes or Journey timings to avoid tolls, and others switching to Park-and-Ride or other buses.

Trials in Stuttgart and Florence resulted in up to 5% of motorists switching to public transport.

Zone based schemes

There are two main variants of zone-based schemes – (1) cordon toll schemes where road users are charged to cross the zone boundary, in either one or both directions; and (2) area licensing schemes, where users purchase a licence to move within the zone. Zone based schemes can be implemented 13.4.2 either through the display of a disc in the car window to show eligibility to enter a zone or through smart cards activated every time the car crosses the zone boundary. The London area licensing scheme implemented in February 2003 works by comparing licence plates of vehicles photographed inside the zone with a registry of vehicles that have either paid to enter the zone or are exempt from the charges.

The Oslo cordon toll scheme came into effect at a time of steeply falling demand for public transport, but seemed to have prevented so large a decline within the cordon.

The Singapore scheme achieved a substantial shift (about 10% of travellers) from car to public transport for commuter trips.

Initial indications are that the London scheme has caused substantial reductions in traffic in central London, but more time is needed to collect data for evaluation of all the traffic effects and the impact on public transport use.

Parking policy

There are a number of ways in which parking policy could be used as a traffic demand management tool. These 13.5 include limiting the number of available spaces, increasing the price paid for parking and changing the mix of short and long term parking spaces available.

However, parking policies are not always effective traffic demand management tools. Strict enforcement is required as the tendency for evasion is high.

There are numerous examples of the effects of restricting parking space availability or increasing charges. Both tend to have a positive effect on public transport demand, but there is no clear pattern in the cross elasticities derived from this evidence.

The Transport Act 2000 has enabled local authorities in England and Wales to impose levies on work place parking spaces provided by employers. It appears that such levies could cause significant reductions in parking space availability, and result in employees being charged more for remaining spaces. Both would tend to encourage switching from car to public transport. To date no local authority has made use of these new powers.

3.7.3 Transport policy integration

An important issue is how packages of policy instruments might be put together in a complementary manner. For example, increasing parking controls and charges will 13.7 increase the demand for public transport and hence the case for public transport infrastructure. Conversely, provision of additional public transport infrastructure is likely to increase public acceptability of parking control and charges, particularly where the two policies are linked financially through hypothecation.

Considerable empirical modelling work has been undertaken in order to quantify these synergistic effects. The optimal transport strategy for any area depends strongly on local characteristics, eg size, demographics, economic activity, road and public transport networks, and current traffic and fare levels. The results are too specific for application elsewhere without further modelling.

3.8 Application of elasticity measures and modelling

The key forecasting parameters reported in this document are elasticities which indicate the proportionate change in demand after a proportionate change in some variable. These are relevant to variables that are continuous in nature, such as time and cost, where proportionate changes can be specified. However, there are other attributes which are categorical or discrete in nature where proportionate changes cannot be specified or would make little sense.

The demand framework therefore contains three components:

- Continuous variables (X_1, X_2, … X_n) where elasticity evidence is available, such as for fare and income, and others where there is little or no evidence, such as with journey time or access time, where the elasticities have to be deduced using the 'ratio of elasticities' approach (see Section 5.6).
- Variables which control for any dynamic effect. Much of the empirical evidence relates to models that specified lagged dependent variables (see Section 5.4) and hence this form of lagged behavioural response is used here.
- Variables which are categorical or discrete (Z_1, Z_2, …. Z_k) for which there is evidence of the proportionate change in demand that results from a change in that variable or where there is no direct evidence of the demand impact and it must be deduced from some reference elasticity.

The change in demand (V) between two time periods (t and t+1) is forecast as:

$$\frac{V_{t+1}}{V_t} = \left(\frac{X_{1t+1}}{X_{1t}}\right)^{\beta_1} \left(\frac{X_{2t+1}}{X_{2t}}\right)^{\beta_2} \ldots\ldots \left(\frac{X_{nt+1}}{X_{nt}}\right)^{\beta_n} \left(\frac{V_t}{V_{t-1}}\right)^{\theta} \bullet$$

$$e^{\lambda_1(Z_{1t+1}-Z_{1t})+\lambda_2(Z_{2t+1}-Z_{2t})+\ldots+\lambda_k(Z_{kt+1}-Z_{kt})}$$

β_1, β_2 and β_n are the elasticities to the variables X_1, X_2 and X_n and represent short term effects.

θ determines the long run effect (see Section 5.4). For the short run forecast, V_t/V_{t-1} is assumed to be one. For the bus industry in Britain, most studies have been based on annual data and hence *t* equals one year. For the rail industry, studies have been based on four weekly or annual ticket sales data and, in the absence of any distinction between the results for the two time periods, a representative value for *t* would be quarterly.

The exponential (*e*) of λ_1, λ_2, and λ_k denotes the proportionate effect on demand of a change in Z_1, Z_2 and Z_k.

Where direct evidence on an elasticity is unavailable, it is deduced using the formula:

$$\beta_2 = \beta_1 \frac{v_{X2} X_2}{X_1}$$

Here the elasticity for variable X_2 (β_2) is deduced from the elasticity to variable X_1 (β_1), which is known, given the levels of X_1, X_2 and the value of X_2 in equivalent units of X_1 (v_{X2}). If X_1 is price, then v_{X2} denotes the money value of X_2.

Where direct evidence on a parameter associated with the discrete variables (Z) is unavailable, it is deduced using a slightly modified variant of the ratio of elasticities approach:

$$\lambda_2 = \beta_1 \frac{v_{z2}}{X_1}$$

Here the parameter associated with variable Z_2 (λ_2) is deduced from the elasticity to variable X_1 (β_1), which is known, given the level of X_1 and the value of Z_2 in equivalent units of X_1 (v_{Z2}). If X_1 is price, then v_{Z2} denotes the money value of Z_2.

As an example, suppose we wish to forecast the demand response after one time period of:

- A 5% fare reduction, where the elasticity evidence indicates a short run value of –0.3.
- A 10% journey time increase, where the journey time elasticity is deduced from the fare elasticity using the ratio of elasticities approach.
- A need to interchange, which evidence indicates reduces demand by 20%.
- The introduction of new vehicles where the impact on demand is not known but must be deduced from the fare elasticity given that the new vehicles are valued at 5% of the fare paid.

The journey time elasticity is deduced, given a fare elasticity of –0.3, from a value of time of 8 pence per minute, a journey time of 30 minutes and a fare of 150 pence, as:

$$-0.3\frac{8\times 30}{150} = -0.48$$

The variables must be specified in consistent units. Thus if the money value of time is specified as pence per minute, the fare is specified in pence and journey time in minutes.

Given that the introduction of interchange reduces demand by 20%, the relevant λ parameter is –0.223 (equals ln 0.8).

The λ coefficient for the new vehicles, given that they are valued at 5% of the fare, is deduced as:

$$-0.30\times 0.05 = -0.015$$

Given that this is an improvement in vehicles (the change in Z in the above equation is negative), the value entered into the equation is 0.015.

Using these parameters, the change in demand would be forecast as:

$$\frac{V_2}{V_1} = 0.95^{-0.3} 1.10^{-0.48} e^{-0.223} e^{0.015} = 0.788$$

$$= 21.2\% \text{ demand reduction}$$

This forecast represents a first period (year) effect. Even without any further changes, the forecasting equation allows for subsequent dynamic effects. If the value of θ in the bus market is 0.49, so that the long run elasticities are 96% larger than the first period (year for bus) elasticities, then the change in demand in the second period would be:

$$\frac{V_3}{V_2} = 0.788^{0.49} = 0.890 = 11.0\% \text{ demand reduction}$$

In the third period the change in demand would be:

$$\frac{V_4}{V_3} = 0.890^{0.49} = 0.944 - 5.6\% \text{ demand reduction}$$

Note that the money values should be converted into the prices relevant for the forecasting period. Strictly speaking, the deduced elasticities would vary as the valuations of the variables vary over time, as well as with variations in the levels of the relevant variables.

The forecasting equation can be extended to any number of relevant variables. A software package has been developed and is available for more complex forecasting applications, including forecasting over a number of time periods and the possibility of different changes in variables in different time periods as well as accounting for dynamic effects.

4 Data sources and methodology

4.1 Principal data sources on public transport ridership

4.1.1 Introduction

Reference has already been made in Chapter 2 to principal data sources such as operator ticket sales, and surveys such as the National Travel Survey (NTS), with examples from both used to illustrate the structure of the British market. There are a number of additional aspects of such data to be borne in mind prior to their use in estimating ridership, and hence as an input to demand models.

4.1.2 Activities, journeys and interchange

While it may seem obvious, the concept of a 'journey' or 'trip' requires definition. Data collected by operators often differ from that derived from other surveys.

In terms of activities, most transport demand can be seen as a 'derived demand', i.e. there is little (if any) utility from the consumption of transport itself, but it is used as a means to an end, to get from one activity to another (the tourist market would be in part an exception to this, but largely falls outside the scope of this study). A 'trip' thus comprises movement from one activity to another, for example from home to work. This may be divided into 'stages' each comprising use of a different mode - for example, walk, bus, metro, walk. This terminology corresponds to that used in the NTS. Where more than one ride is made on the same mode in the course of the same journey (e.g. use of two successive buses), these may be described as 'boardings'. Note that even within the NTS definitions, some double-counting may take place, since a 'stage' is defined as commencing when a change of mode occurs, or a separate ticket is used. Thus, where through ticketing is not found (e.g. on most bus systems in Britain for single journeys) two bus 'stages' will be recorded as part of one journey.

Ideally, an activity diary provides the most comprehensive record of trips, by prompting the respondent to consider explicitly each time activities change whether a trip between them was involved (e.g. a shift from eating to sleeping within the home would not involve a trip outside the house, but eating in a restaurant then returning home to sleep would do so). In practice, most data are derived from travel diaries rather than activity diaries as such, and may thus tend to understate short non-motorised trips between activities.

Operator data, in contrast, tend to be derived from ticketing systems, and thus to define a 'trip' as a ride in a vehicle. This is particularly so where a change of mode is involved, in which each operator will make a separate record - thus, in the home to work example above the bus and metro operators would each record a 'trip' as having been made. Even within the same mode this may occur where traditional ticketing systems have involved selling a ticket for each ride on a vehicle. This is typically the case for bus systems, but less so for metros or urban railways. Thus, in large cities where more interchanges occur within a one-way trip, a greater degree of overstatement of the public transport trip rate will occur than in smaller centres where almost all trips involve only one motorised stage.

Some simple examples illustrate these effects.

Using unpublished British NTS data, it is possible to distinguish 'boardings' from 'stages', and calculate the ratio between them. For the bus mode, 1999-2001 data indicates ratios of 1.08 for all areas outside London, and 1.16 in London, the latter being subject to greater bus-to-bus interchange associated with use of Travelcards, bus passes and pensioner concessionary passes, which eliminate the financial penalty associated with interchange when traditional cash fares are used.

In the case of London Underground, NTS data (Department for Transport, 2002b) indicate that for each 100 stages by underground, there are 19 bus stages and two by surface rail within the same trip, indicating significant bus feeder/distributor traffic.

One may also use operator-derived data for 'trips' and compare them with sources such as the NTS. As part of this study, such comparisons have been made for recent data in Britain. Outside London, the ratio between operator-recorded bus 'trips' and NTS bus stages is similar to that shown above, implying about 5 to 10% of trips involving bus/bus interchange. However, much greater differences are found within London, due in part to problems of securing a representative sample for the NTS, as well as the greater element of bus/bus interchange. Further detail at national level for Britain is given in the Appendix to Chapter 4.

Throughout this study, the term 'trip' or 'journey' refers only to one-way movements (hence, someone travelling from home to work, then returning home, makes two trips).

4.2 Measures of aggregate demand

4.2.1 Trips

Subject to qualifications expressed above, the total number of 'trips' recorded is the most common measure of aggregate demand. Ideally, this would be the measure of 'linked' trips to overcome the bias noted above. In practice, the definition used may vary substantially between studies, and some overstatement is likely to have occurred where operator-based data are used.

4.2.2 Distance travelled

This is usually expressed in passenger-kilometres. It may be derived by multiplying the number of 'trips' (howsoever defined) by an average length estimated from surveys, either on-vehicle or through household surveys. This measure thus avoids the double-counting problem associated with some definitions of 'trip' discussed above. It is unwise, however, to derive such data from distances *paid for*, since these will generally exceed the distance actually travelled, especially where zonal or flat fares apply. Simple on-board surveys may be used to determine stops/stations at which passengers alight and board, or more detailed origin and destination data used to infer total trip length.

Average vehicle load may be estimated by dividing total passenger-kilometres by vehicle-kilometres.

4.2.3 User expenditure

This may be used as an indicator of importance of public transport modes in relation to one another, to other modes, and within total expenditure. Such data may be derived from direct household surveys (such as the Family Expenditure Survey in Britain) or operator-derived totals. This forms a means of distinguishing cases where much higher expenditure per kilometre is incurred for higher quality services (for example, a taxi instead of local bus, or first class instead of standard class rail travel). However, particular care must be taken in assessing changes over time within the same mode where elasticities are low. For example, a 10% real fare increase on an urban network with a short-term price elasticity of -0.4 would produce a drop in demand of 4% and revenue growth of about 6%, but the growth in revenue simply reflects a transfer of consumer surplus from the remaining users to the operator (in addition to the loss of consumer surplus of those no longer travelling).

4.3 Issues in the use of operator-based data

4.3.1 Data from electronic ticket machines (ETMs)

Traditionally, single tickets have been sold for each journey transaction, either on-vehicle (as for most bus services) or at stations (most rail systems). Trips made may thus be equated with such sales, although as discussed above this may introduce an element of double-counting where multi-modal journeys are made, or within the bus mode for journeys involving more than one bus (where a separate ticket is sold for each ride on a vehicle), although less common on rail systems (except where more than one operator is involved). Where electronic ticket machines (ETMs) are in use, data may be downloaded showing for each ticket sale items such as:

Ticket type (single, return, pensioner concession, etc.).

Route number.

Time of issue.

Stage boarded (where, on graduated fare scales, a route is divided into a number of 'stages' typically about 1 km long, covering several stops, or in the case of rail systems, a named station).

Stage alighted (or destination station).

Such data may then be aggregated to give a distribution of trips by time of day, route, stage/station boarded, etc. A crude origin-destination matrix may be constructed, based on the stages or inter-station journeys paid for (however, this will not give the exact stop used on bus systems, nor ultimate origin or destination for which a direct user survey is needed). However, a number of limitations exist with such data, notably lack of information of the timing of return journeys.

In the case of flat fare or zonal fare systems information may be obtained on station/stage boarded but not destination or trip length paid for, except to zonal level, apart from systems with exit gates (see below).

4.3.2 Trip rates for pass and card holders

A growing proportion of public transport trips may be made by holders of tickets or passes not involving cash transactions at the time of travel. These in turn often form a core market, representing a high proportion of all trips made. Clearly, assumptions which may be made regarding use of travelcards or season tickets have a major impact on estimated total volume. Traditionally, operators have assumed a certain number of trips per holder per period, which may be used to gross-up to periodic totals. In some cases, however, these estimates may be relatively crude, and require updating periodically (for example, to allow for changes in the number of days worked per year).

London offers a good example in which a large proportion of travel is through such ticket types, but also where sample user diary surveys are undertaken to establish trip rates per card holder, from which a grossed-up estimate of total market size may be made. Examples of trip rates thus derived are shown in Table 4.1.

Table 4.1 Trip rates for different types of pass and travelcard in London

Trip rate per card 2001	
Bus pass	
Season*	24.2 per week
One day	4.7 per day
Travelcards (all modes)	
Season*	9.4 Underground/DLR/tram per week
	4.4 bus per week
	4.8 National Rail** per week
One day	2.4 Underground/DLR/tram per day
	0.8 bus per day
	0.9 National Rail** per day

* *Periods of one week upward.*
** *Surface rail services, provided by privatised companies.*
(One day cards are used mostly for off-peak travel).
Source: Transport for London, 2002.

The London rate should not necessarily be taken as a guide elsewhere, especially in respect of bus trips per day, due to the higher element of bus/bus interchange noted above.

Use of such tickets may also be detected on board vehicles or at stops, but data currently obtained (for example, by a bus driver pressing a button on an ETM when such a passenger boards) are currently fairly crude. The development of smartcard technology (see below) enables not only more reliable estimates of the trip rate per cardholder, but also attribution by route, operator, time period, etc.

The trip rates for travelcards will depend in part on the price ratio *vis a vis* single tickets. Where the ratio is high (i.e a large number of single trips needs to be made within each time period to make travelcard purchase financially worthwhile), overall travelcard sales will be lower, but the trip rate per card issued will be high. The opposite applies for a low price ratio.

4.3.3 Use of continuous monitoring surveys

Another aspect of such travel is the use of passes by pensioners and other categories eligible for concessionary travel. Especially where free off-peak travel is permitted, little data is obtained directly, but large sums may be involved in compensating operators for revenue foregone. This has stimulated the use of continuous monitoring by organisations such as Passenger Transport Executives (PTEs) in Britain, as an alternative method of assessing ridership. In this method, on-vehicle surveyors sample a selection of journeys from the duty schedules, and then interview all passengers on board to determine stages boarded and alighted, classifying the data by ticket type and time period. This produces estimates of total trips (including non-concessionary travel), and also for passenger-km.

The accuracy of such methods is of course influenced by sample size and the extent to which it is representative of the total market served. As part of this study, comparisons have been made of such data gathered by the Greater Manchester and West Midlands Passenger Transport Executives with that published by the central government Department for Transport from bus operators' statistical returns. This generally reveals similar estimates of total passenger trips: while noteworthy differences may be found within the same year (in the order to 3 to 5%), long-term trends from both data sources are very similar.

The largest example of such continuous monitoring is probably the Greater London Bus Passenger Survey (GLBPS), used for apportioning concessionary fare compensation.

It should be borne in mind neither source is perfectly accurate. The operator returns, for example, depend on the accuracy of ticket issue data and assumptions regarding use of passes (see above). In addition, a question of sampling of smaller operators arises, which can also influence short term variations for small areas. Current practice in Britain, for example, is to take a 100% sample each year of all operators with 30 or more vehicles, but smaller sampling rates for smaller fleets (for example 50% of operators with 15 to 19 vehicles) (Department of Transport, Local Government and the Regions, 2001c).

A further review of operator data collection methods and issues arising has been completed recently in Britain (DfT, 2003c).

4.3.4 Potential data from 'smart card' systems

Where smart card systems have been introduced, data are then available for each individual card issued (either to a unique holder, or in some cases inter-available), enabling a profile of use for that card to be established – for example, showing not only average trip rates over a period but a rate for each card in use. Data may also be derived for boardings by time of day, service used, etc. This is equivalent to the data obtainable from cash-paid systems, but with the additional benefit of identifying individual user patterns. As in the case of cash fares, 'boardings' rather than linked trips are recorded in the case of bus systems. In future, such data may be combined with that from traditional user surveys to establish a much larger sample of trips made. However, traditional surveys such as NTS will continue to provide source data for variables such as journey purpose.

Recent work on derivation of data from smartcards has indicated they that may be most useful in the following respects (Bagchi and White, 2003):

i Trip rates per person (or card issued). These may be estimated over much longer periods than the NTS 7-day diary, for example.

ii Timing of individual trips by time of day/day of week.

iii Inferring interchange (where both services and/or modes employ the same smartcard system) by assuming a given time range within which a second boarding may be assumed to comprise interchange within a one-way trip rather than a new trip.

iv Identifying linking of return trips and more complex trip chains.

v Identifying 'active' users of cards (e.g. a pensioner concession card) by applying a defined time period within which use has not been recorded.

These are subject to some limitations, notably good passenger and staff discipline to ensure that cards are validated for each boarding of a system.

In principle, data on trip length could also be obtained. However, while this is readily possible in fully 'gated' urban rail systems where exit reading takes place, it is much more difficult to apply on bus and light rail systems: exit reading may be difficult to enforce, and reliance may continue to be needed on sample surveys to estimate trip lengths.

4.3.5 Derivation of trip rates from operator data

In addition to determining total volume of travel for a named operator or area, trip rates may be derived. As a crude initial approximation, total trips reported may be divided by population served to estimate an annual trip rate per head of population. This is subject to being able to match operator areas with those defined for other purposes. For example, in the case of Greater London, local bus and Underground travel may be related closely to the area covered by the Greater London Authority, but trips made on privatised Train Operating Companies (TOCs) typically serve a radial segment covering part of Greater London but also areas much more distant, making it difficult to match operator data to the population catchment.

Such overall estimates may also be broken down by person type, notably for pensioner travel where separate ticket types (either for cash journeys, or passes) are available. This may then be related to estimates of the total number within the population eligible for such concessions to give a trip rate per person.

An important benefit of deriving even crude annual trip rates is that the effect of changes in total population on demand may be identified, rather than calibrating models simply on total demand, and thus biasing trend variables or coefficients produced. For example, in the case of Greater London, resident population rose by 7.0% between 1991 and 2000, forming a substantial element in the growth of total bus and underground trips, of 17.8% and 29.2% respectively over this period (derived from Transport for London, 2001).

4.4 Use of survey data

In addition to routine data collection based on ticket sales, operators may undertake ad hoc surveys on factors such as journey purposes, ultimate origin and destination, attitudes toward service attributes, etc. However, the value of such data for systematic demand analysis (as distinct from before and after case studies) may be limited, due to its non-continuous form, and differences in definition between operators. Where a more systematic approach has been adopted, such data may be of greater value – for example, a regular six-monthly attitudinal survey is now carried out by each Train Operating Company in Britain, on a standard scale, results of which are collected by the Strategic Rail Authority (2002a).

For a more comprehensive picture of demand, independent household surveys generally provide a much better guide, also enabling modal shares to be identified, a and relationships between transport use and factors such as car ownership, household structure, location, etc. Reference has already been made to the National Travel Survey in Britain: this provides a continuous household sample since 1989, covering the whole year with a seven-day diary for each household member.

Similar studies my be found in other European countries, but typically cover only one day (usually Monday-Friday) or at most two (UITP, 1997). The London Area Transport Survey (LATS) is also an example of the latter. In consequence, the average daily trip rate from such surveys may appear somewhat higher than in the NTS, due the latter's inclusion of Sundays and holiday periods.

All household surveys encounter problems of response rate, which affects both total sample size obtained and the extent to which is it representative of the population. For example, in the case of the NTS, the percentage of addresses contacted 'fully responding' fell from 71.1% in 1989/91 to 59.3% in 2000 [derived from NTS 1998/2000 update bulletin, pp 3,4,6]; the term 'fully responding' comprises those chosen households successfully contacted who produced complete travel diaries for all members. Particular problems are found in large cities such as London, which creates some difficulty in comparability with operator-derived data.

Household surveys may also be limited in that not the whole population is covered. In the case of NTS, for example, households are contacted via individual postal addresses. This leads to omission of some multi-occupied properties, establishments such as student halls of residence, and short-term visitors from other countries. Again, large cities such as London tend to be most affected.

4.5 Other concepts in market analysis

4.5.1 The 'market gearing' concept

A further general concept which may be introduced at this stage is that of 'market gearing', i.e. the share of demand which may be attributed to a specific category of users. In addition to calculating average trip rates, even broken down by age or sex, for example (see Chapter 2), we can show that certain categories of individuals produce a substantial part of total demand. This may be derived from operator ticket data where defined individuals hold certain types of ticket or pass (such as a pensioner concession, or working age adult travelcard) and the number of trips attributable to such users can be estimated. Surveys such as the NTS also enable such estimates to be made. For example, in Greater London, there are about 1 million holders of the pensioner pass, and about 0.86 million holders of rail/bus Travelcards valid for periods of one week or more, plus 0.32 million bus-only passes (Transport for London, 2002) each representing a substantial share of all public transport trips.

A notional example is shown in Table 4.2. In this case, pensioners comprise 15% of the population, but 26% of public transport trips. The highest ratio is found for adult travelcard users (travelling between home and work about 200-225 days per year) in which 7.5% of the population produce 30% of all trips. For the less frequent users, it may be difficult to identify them separately from 'non users' (since they do not hold separately-issued cards), and some boundary definition may need to be adopted (e.g. use less than once a month). A shift to smart card use may assist, in that they will become attractive to less frequent users who now pay in cash.

Table 4.2 A notional example of market gearing

Person type	*Number (m)*	*Trips per person per year*	*Total trips (m)*	*Percentage of total*
Pensioners	0.15	200	30	26
Adult travelcard holders	0.075	450	34	30
Child pass holders	0.05	400	20	18
Other users	0.3	100	30	26
Non-users	0.425	0	0	0
Total	1.0		114	100

Although notional, this pattern does compare fairly well with NTS data, as shown in Table 2.3. In addition to the travel diary, a question is sometimes included in the NTS on overall frequency of use of different modes. In 1999/2001 this question showed that 17% of the population travelled by local bus three or more times a week, and a further 10% once or twice a week. However, 43% reported use of local buses 'once a year or never' and 52% likewise for rail (Department for Transport, 2002b). The last category matches the 'non user' share of 42.5% assumed in the table above. Bear in mind that published NTS data give an average for the whole population, including small towns and rural areas, and hence the share of the population using public transport with high frequency would be less than assumed for a city as above.

Higher trip rates in Europe outside Britain may be reflected in a different gearing structure. For example, in the case of the Cologne (Koln) city-region, there is an overall public transport trip rate of about 158 per head per annum by all modes, and a 30% share of the total transport market (excluding walking). Given that there is an upper limit to the amount of use that an individual 'frequent' user can make of a public transport system (typically, 10 home/work or education trips per week plus some off-peak travel), a higher overall trip rate in the population is likely to be reflected in a higher proportion of residents in the higher frequency categories. For example, in the Cologne case, about 48% of the population in the core cities are classified as 'regular users' (daily or several times per week) of public transport (Leyendecker, 2002), compared with 38% travelling once or more per week in British metropolitan areas (see Table 2.7).

An important consequence of the use of travelcards and similar passes is the effect they may have on elasticity values derived. Since, within the time periods and zones for which a card is valid, each trip has a marginal money cost of zero, a price increase will not affect trips made, unless the user decides not to renew the card. The elasticity thus becomes a function of the decision to purchase the card as such. This may be very sensitive to certain threshold values (e.g. the level up to which a card is still worth purchasing to give better value than single tickets for frequent journeys between home and work). Over some price change ranges, very little effect may be found on card purchase, and hence total trips made by card holders. In other cases, demand may be highly sensitive. This may produce widely varying elasticity values for travelcard demand (see Chapter 6, Section 6.11). It should also be borne in mind that where large price changes occur *vis a vis* single cash fares, the trips rate per card holder will change. For example, if travelcard prices are raised appreciably *vis a vis* single cash fares, a drop in card sales is likely to occur, since the break-even number of trips per period increases. However, the remaining users are likely to have a higher trip rate than the average found for travelcard users when the price was lower, hence the drop in the total number of trips made by card holders will not be as great as that in card sales.

4.5.2 Trip chaining

Patterns of travel during the day may be best understood in terms of trip chains. Just as individual journeys are better analysed as linked trips from one activity to another, the day's travel can be seen as a 'chain' of such links, starting at home, then via various activities and destinations until home is reached again. The simplest consists of 'home one activity (for example, work) home', but more complex patterns may be found, such as returning home for lunch (mainly in smaller towns), or returning in the evening via the shops, or place of entertainment. Analysis of travel diaries from the 1985/86 NTS enables us to understand such chains more clearly (Dennis *et al.*, 1981).

In analysing such data, short walk links must also be considered. For example, someone working in a city centre might walk to a shopping street open in the evening, then return home by public transport: although only two public transport journeys would be recorded, the trip chain is nonetheless a 'complex' one in terms of individual behaviour.

Complex public transport-based trip chains are found mainly in larger cities, often associated with the use of tickets such as the travelcard which permit additional linking trips at zero money cost.

Trip chain analysis also enables us to understand how trips made by the same individual are linked by time of day - for example, in 1985/86 a substantial proportion (around 40%) of one-way trips made on bus services after 18.00 were in reality the return leg of trip chains which began earlier in the same day, rather than new home-based trips. Hence, cutting out a poorly-loaded evening service has implications for ridership on daytime services, should the inability to make the return leg of the trip result in the user switching to another mode for the whole trip chain. This also has implications for interpretation of fare and service elasticities, since many evening public transport trips are not components of home-based evening trip chains whose primary purpose is leisure, for example, but the final stage of trip chains commencing earlier in the day for which the primary purpose may have been work.

The more complex chains may explain why cars are used sometimes for the peak work journey into large cities even when public transport may appear more convenient, as the car is available for indirect homeward journeys in the evenings, or business trips during the day. To capture a high share of the work market, public transport may need to offer good evening services, and facilities which permit complex trip patterns without financial penalty.

4.6 Data on factors affecting demand

Detailed discussion of the influence of factors affecting demand is contained in later chapters, but it is useful at this stage to identify principal data sources and possible sources of bias which may be found.

4.6.1 Fares and fare levels

Two approaches may be adopted:

a To measure demand with respect to specific fares charged, i.e. the sum paid for particular tickets by person type, time period, etc. This requires data on the full fare scale charged in each period and sales/use of each ticket type.

b Given that such data are rarely available, an alternative approach is to measure total revenue received by operators (deducting any element of subsidy or compensation not paid by passengers themselves) to produce an estimate of average revenue per trip or per passenger-kilometre.

For example, revenue received for local bus services in Britain in 2000/01 was £2,889m, and passenger trips made 4,309m, giving an average revenue of 67.0 pence. However, this includes an operator revenue element of £468m due to concessionary fare reimbursement. Hence, revenue received from passengers themselves was £2421m, giving an average revenue per trip of 56.2 pence, (derived from Department for Transport, Local Government and the Regions, 2001c).

In many cases, this may be the only approach available, but clearly it will conceal much variation by ticket type and trip length. The average revenue received per trip will also be affected by changes over time in market composition, such as shifts between cash and off-vehicle tickets, the proportion of concessionary travel, and changes in average trip length. Some cross-elasticities between market sectors may also be obscured. For example, average local bus trip length in Britain outside London has increased from 6.3 km in 1989/91 to 7.41 km in 1999/2001 (derived from Department for Transport, 2002b), which could itself cause an increase in average revenue per trip (although not *pro rata,* due to existing flat and zonal fares, and the tapering element in graduated fare scales).

A third approach is to construct a weighted average fare index, from a sample of fares charged, weighted by relative frequency of ticket sales/trips made. This has been adopted by the Strategic Rail Authority in Britain, using the extensive CAPRI data set to derive weightings (Strategic Rail Authority, 2002b). However, this quality of data may not be available for most urban and regional bus and local rail operations.

In calibrating models over periods other than the very short run, it is usual to adjust fare changes to reflect 'real' changes, by reference to the Retail Price Index (RPI) in Britain (or equivalent indices elsewhere). This gives an indication of public transport prices *vis a vis* the general cost of living. For example, the SRA index just quoted gives a value of 108.00 (average for all ticket types) for January 2002 on a base of January 1999. The equivalent value for RPI over the same period was 106.1, giving a real average index for rail fares of 101.8.

In some cases, however, it may also be appropriate to compare public transport fares with cost of alternative modes, principally direct costs of private motoring (fuel, parking charges, etc.) which may differ substantially from the overall retail price trend.

4.6.2 Service level

A typical proxy for service level, in the sense of frequency, is vehicle-kilometres operated, although this may also change in response to network size and/or period of day and week over which service is provided (see further discussion in Chapter 5). In the case of buses, each individual vehicle is run separately, and hence change in vehicle-km reflects change in frequency provided (for a given route length). However, for rail systems, train length can vary. Since users respond to changes in waiting time and frequency, it is train-km (not vehicle-km as such) that is the relevant factor (for example, if 12m vehicle-kms are run on a rail route and average train length is 6, train-km will be 2m).

At a detailed level, timetabled changes for individual routes may be analysed, but this is usually appropriate only for localised case studies. As a more general proxy, timetabled vehicle-km for a whole area or network may be derived from operator statistics. Where this indicates a proportional change in frequency, a corresponding change in headway may also be derived (for example, an increase of 50% in vehicle-km where the initial headway is 30 minutes would correspond to a new headway of 20 minutes, i.e. a reduction in headway of 33%). Changes in waiting time may then be derived, subject to the assumption that passengers are always able to board the first vehicle to arrive (in most western countries this is true, but not in developing countries). There may also be exceptions such as conversion to minibuses, where lower vehicle capacity results in peak overcrowding).

Change in vehicle-km are not necessarily proportional to change in total capacity provided (i.e. seat-km., or person-space km.) – this is only true where average capacity per vehicle remains unchanged. In practice, large variations may occur in bus size (from minibuses of about 16 seats capacity to articulated vehicles with a total capacity of around 150), and even more so in train length and capacity.

A distinction may also be drawn between scheduled service offered, (i.e. the advertised timetable) and that actually provided, the latter generally lower due to 'lost vehicle km' associated with factors such as staff shortage or traffic congestion. Such data are produced by operators, and in some cases elasticities of demand with respect to variation in service levels may be derived. (These are generally higher than for scheduled changes, due to unpredictable waiting times, and greater probability of overcrowding)

4.6.3 Access to the network

Where data on route length are available, an estimate may be made of network density (e.g. route-km per square kilometre, or per 10,000 population). This provides a simple indicator of density, subject to allowance for duplication of route lengths in statistical returns where one or more routes serve the same section. However, while these data are readily available for rail networks, it is less commonly available for bus networks.

Vehicle-km per unit area or population may also be estimated, as a measure combining frequency and network density.

Alternatively, access to the network may be assessed more directly, through data from household surveys. For example, the National Travel Survey obtains data for each household of walking times to the nearest bus stop and nearest rail station, which are then used to classify percentages of the population within certain time bands (such data are quoted in Chapter 7). This has the advantage of allowing for the actual distribution of population around stops and stations, rather than the implicit assumption of a uniform density in simple measures such as route length per unit area.

Further indicators such as 'PTAL' (Public Transport Accessibility Level) have been developed, combining walking distances with frequency offered. These data are now available for London and some other areas.

At a more detailed level, access to the network can be considered in terms of accessibility of vehicles and stations for passenger boarding and alighting, especially in the development of low-floor vehicles in recent years, for which there is some evidence of stimulus to ridership as a result, considered later in this report.

4.6.4 Service speed and journey time

While speed has long been identified as major factor in long-distance and rail demand, little attention has been paid to it in intra-urban modelling, partly due to limited data availability – while scheduled speeds are available for urban rail systems, such data are rarely produced a in systematic form for urban bus systems. While trends in general road traffic speeds are available from sample surveys, these do not necessarily indicate trends for bus services, due to effects such as boarding times (associated with the ticketing system used) and vehicle manouverability. It is quite possible in the British case, for example, that the high proportion of cash-paid fares on buses has significantly affected average speeds, and hence service attractiveness.

A failure to allow for changes in average speed over time may cause bias in models, especially the value of any 'time trend' factor, and/or coefficients for other variables (for example, an increase in bus vehicle-km associated with an extensive bus priority network being introduced also being correlated with an increase in average speed. Were all the ridership growth attributed to the vehicle-km (frequency) effect, this would exaggerate the elasticity with respect to that variable)

Given the low average trip length for intra-urban public transport journeys, access time to the stop/station and waiting time (a function of frequency and reliability) are likely to dominate door-to-door journey time rather than in-vehicle speed. Nonetheless it may be an important factor, especially for longer commuting journeys.

Data are available in selected cases where speed and journey time variability have been changed through measures such as bus priorities and radical change in ticketing systems. However, there appears to be little evidence of systematic relationships with ridership.

4.6.5 Generalised journey time and generalised cost

As discussed further in later chapters, the cost and time element of a journey may be combined in a single measure.

Generalised Journey Time (GJT) converts elements of door-to-door journey time into a single time measure, with appropriate weighting factors for the waiting time at the stop/station, and walking time, *vis a vis* in-vehicle time. Further details and examples are provided in Chapter 7.

The concept may be further extended to that of 'generalised time' in which the monetary element of journey cost is converted to time at a appropriate value of time (VoT).

'Generalised cost' (GC) adopts a similar approach, by converting the journey time elements (after appropriate weighting of each element as described above) into a cost by using of an appropriate VoT.

Clearly, the validity of both generalised time and generalised cost measures is dependent upon the selection of suitable behavioural values of time. However, while convenient in modelling processes (for example of spatial trip distribution at one point in time), it is debatable whether users perceive such values, as distinct from trading off journey time and monetary cost.

4.6.6 Exogenous factors

In addition to changes in population total and its composition, other exogenous factors may also be critical in assessing public transport demand:

Gross Domestic Product (GDP) and real per capita income

For most countries, estimates are readily available of GDP, adjusted in real terms and per head of population. This may form a variable in aggregate time-series modelling. In some cases, sub-division by regions within a country may be available. This may affect public transport demand both directly (through increasing user income available to purchase travel) and indirectly (notably through the stimulus to higher car ownership)

Employment

Overall employment levels will tend to correlate with GDP changes. In addition, employment data may be available for specific areas. Of particular importance may be the levels in city centres served by radial public transport networks (e.g. central London). In addition to directly stimulating demand for journeys to/from work, increased employment may also result in other journeys being made as a result of increased disposable income.

Private vehicle ownership

This may be measured by relating the number of licensed vehicles to population, to estimate a vehicle ownership rate per head (assuming a high degree of compliance with the law on vehicle registration). In addition, the distribution of private vehicle ownership by household categories may be derived from direct surveys. This may be of particular importance to public transport use, given the differential impacts of shifting from 0 to 1 cars, and 1 to 2 cars per household, as discussed in Chapter 2.

Population composition

Within a given total population, change in composition will affect the structure and levels of public transport demand. For example, growth in proportions of pensiners or school-age children will stimulate off-peak and weekday peak demand.

4.7 Modelling and elasticities of demand

Concepts and data described above may be used to model demand in various ways.

4.7.1 'Revealed preference' methods

The term 'revealed preference' (RP) refers to use of observed data, such as ticket sales from operators, household surveys, etc:

- *Revealed Preference aggregate cross-section* models. Public transport trip rates estimated as a function of fare level, service level, car ownership, etc. This is usually most appropriate in modelling the effects of exogenous factors (such as car ownership, or population density).
- *Revealed Preference aggregate time-series*. Changes in total volume of travel may be expressed as function of fare level, service level, and exogenous factors (e.g. car ownership, income). Typically, annual data may be employed. Elasticity coefficients may be derived for real fare and service level changes (as discussed in further detail in Chapters 6 and 7).
- *Revealed Preference 'before and after' studies*. Typically, these may examine the effect of a specific change by measuring change in the total volume of travel. One example is the studies of conversion of full-sized bus services to high frequency minibus operation in Britain during the 1980s.

In some cases, different sources may be used to cross-check results. For example, aggregate time-series work by Dargay and Hanly (1999) indicates elasticities of approximately equal magnitude (but opposite sign) for real bus fare levels, and bus-kilometres run. Hence, where changes of the same magnitude occur, we would expect these to offset one another. This is supported by NTS data for residents in non-car-owning households, indicating an unchanged bus trip volume (in terms of passenger-km) per head between 1985/86 and 1997-99.

Note that use of aggregate RP data does not enable us to distinguish between changes in trip volumes as a result of the same group of users making more or fewer trips, and those resulting from new users joining, or existing users leaving, the system.

4.7.2 'Stated Preference' (SP) methods

A limitation of all revealed preference (RP) methods is that many factors cannot be easily disaggregated. Furthermore, user responses to proposed future changes in systems cannot be assessed (such as introduction of a new light rail system). Stated preference (SP) methods have come into extensive use since the 1980 report, overcoming this problem, which will be reviewed. However, care must be taken in comparing elasticities derived from SP models with those from RP models. The SP elasticities may be of greater use in indicating the relative importance of different factors which are not easily assessed through RP methods.

5 Demand functions and elasticities

5.1 Introduction

In this chapter we present the mathematical methods commonly used for estimating demand for public transport and how it is affected by changes in price, journey time, service quality, competition by other transport operators and external factors. We start in Sections 5.2 and 5.3 by reproducing, *in toto*, the explanations of demand functions and elasticities published in the 1980 version of the Demand for Public Transport. The concepts discussed here are still valid, provided that they are used to explain or predict changes occurring over relatively short times. However, research undertaken since 1980 suggests that the time required for demand to reach a new equilibrium state after a significant price or service change may be several years. The dynamic processes and methods of allowing for them in forecasting are discussed in Section 5.3. In the next section (5.4) we discuss methods of inferring elasticities for user groups for whom here is no direct elasticity evidence. In Section 5.5 we discuss methods of deriving cross-elasticities which may be used in predicting effects of competition. Finally we give some illustrative examples and guidance on the use of elasticity measures.

5.2 The demand function concept

The rationale behind the demand models used to analyse the travel market is in general to be found in economic theory. According to economic theory, travellers are seen as choosing among alternatives so as to maximise their 'utility', i.e. to choose that package of goods, services and trips which they consider best among all the packages available to them, bearing in mind the various constraints which might be imposed on their choice. Firstly, these constraints include the limited amounts of both time and money available to the traveller. Secondly, the travel itself imposes constraints on the travellers' choice of how much time to spend in travel, since to take part in an activity at a particular destination involves the traveller in spending a certain amount of time in travel: one cannot decide to spend less. This constraint is especially irksome when public transport is used because travel time is governed by the timetable and is almost wholly outside the traveller's choice. Moreover, if the service is infrequent, the outward and return legs of the journey can only be made at certain specified times which may seriously restrict the usefulness of the journey. Of course, the traveller may be able to select an alternative destination where the travel constraints are less irksome, but this second choice destination may be less satisfactory than the first choice. Such restrictions on the allocation of time are widespread in the travel market, as well as in some other service markets, but do not characterise all consumption activities[5]

Thus the travel choice is in reality a very complicated mechanism and in practice any explicit mathematical representation of this behaviour is bound to be grossly simplified. The relationship in question is called the demand function, which expresses the number of trips demanded during a given period of time in terms of a set of explanatory variables. When considering the demand for public transport, these explanatory variables include the monetary costs of the journey, the time spent travelling, perhaps divided into the various components such as waiting, walking and in-vehicle time, similar variables for competing modes of transport, and income. A general formulation of a demand function is:

$$y = f\left(x_1 .....x_n\right) \qquad (1)$$

where y is the dependent variable (level of demand) and x_i ($i = I, ..., n$) are the explanatory variables. The demand function reflects the behaviour of an individual, whose preferences dictate the particular functional form of the relationship, or it may be formulated to explain the behaviour of an aggregate group of individuals; in this latter case it is generally assumed that the preferences of the individuals in the group either are identical or sufficiently similar that the same type of demand function can be used to describe the behaviour of all the individuals in the group.

There is no general rule or consensus among researchers in the field as to either the functional form of the demand equation or the variables which should be used to obtain the best explanation of the demand[6]. These questions have to be resolved by empirical analysis, i.e. by testing various forms and specifications against observed behaviour using statistical techniques. Many functions used in demand analysis are based on a linear or a log-linear relationship between the dependent and independent variables. A particular specification of the demand function which is often used to analyse travel demand is expressed in terms of 'generalised costs'. This concept is an attempt to summarise the 'cost' of a journey by adding together the various components of time or money spent; it may be written:

$$GC = a_o + p + \sum_i a_i q_i \qquad (2)$$

where:

GC is the generalised cost of the journey (see above).

p is the monetary cost of the journey.

q_i is the time required to complete the journey divided into the various components i of travelling time.

a_i is the value of time associated with time component *i*.

a_o is the residual component of the 'cost' of making a journey which is not a function of the monetary cost or the time involved but is a 'cost' associated with making use of a particular mode: it is often referred to as a 'mode-specific cost' or 'residual effort' component.

The values of time in the generalised cost function represent the traveller's willingness to pay to reduce the waiting, walking or in-vehicle time by one unit of time. The residual effort component is also measured in monetary units. This cost may represent many different aspects of travel, e.g. the effort involved in taking heavy or bulky baggage on a trip or that part of the discomfort or general inconvenience which is not a function of the time duration of the journey, such as is experienced when having to transfer from one vehicle to another. In some models this component also represents the different propensities to travel of different segments of the population, grouped by income, sex, age etc and will take different average values in all these categories.

Although equation (2) is the most commonly used expression for the 'cost' of a journey, the concept of generalised time is also widely used. In this formulation, all the various costs are expressed in terms of an equivalent amount of time, i.e. the generalised time is given by:

$$GT = \frac{a_o + p}{a_i} + \sum_i \frac{a_i q_i}{a_i} \qquad (3)$$

where a_i is the appropriate value of time (usually the value of in-vehicle leisure time) and the other symbols are as defined earlier.

The idea of amalgamating time, money and effort into a single quantity is obviously a very attractive one for considering the decisions which travellers might make when confronted with a number of alternatives, and since the two equations (2) and (3) differ only by the constant and it makes no difference which of the two formulations (generalised time or cost) is used in such cases - they both give the same result. Difficulties are likely to arise, however, in situations where the value of time (a_i) is assumed to change. Since it is generally believed that people with higher incomes are more willing to pay money in order to save time than lower-income travellers, this causes problems in forecasting future travel behaviour, since incomes will change over time. If the value of time is assumed to vary with shifts in income (as seems plausible), inconsistencies are likely to occur in the theoretical underpinning of the generalised cost concept. Changes in overall travel behaviour which result from changes in income are much more likely to be connected with changes in activity patterns, rather than with changes in the perceived 'cost' of travel and must therefore be predicted by a separate process. Within this overall demand for travel, however, the generalised cost concept still offers a useful approximation of people's behaviour in choosing where to go and which mode to use.

The assumption that the 'cost' of a journey may be formulated as equation (2) (or equation (3)) means that the demand function (1) can be rewritten in the following way:

$$y_j = g\left(GC_{i,\ldots,} \; GC_{j,\ldots,} \; GC_r\right) \qquad (4)$$

i.e. that the demand for a trip of type *j* may be expressed not only in terms of the generalised cost for this trip, but also in terms of the generalised costs of alternative trips. In this context alternative trips may refer to trips by a different mode, to a different location or with a different purpose[7].

The values of the parameters of demand functions such as (1) and (4) can be estimated from statistical analysis of data concerning travel demand and the explanatory variables. These parameters determine the functional form of (1) and (4), as well as the values of time and the residual effort component a_0. When the parameters have been estimated it is then possible to use the functions to forecast the effects on demand from changes in the explanatory variables, such as prices, travel times and income (but note the words of caution given earlier).

5.3 The elasticity concept

A measure frequently used to summarise the responsiveness of demand to changes in the factors determining the level of demand is the elasticity. Elasticities are, in practice, measured in several ways, according to the size of the change in the explanatory variable. The elasticity of demand can be defined as:

$$e_{x_i} = \frac{\text{The proportional change in demand}}{\text{The proportional change in the explanatory variable}}$$

$$= \left(\frac{\Delta y}{y} / \frac{\Delta x_i}{x_i} \right) \qquad (5)$$

where Δy is the change in the demand y, and Δx is the change in the explanatory variable x_i. This may be anyone of a set of explanatory variables: for example, x_i would be the fare paid if the elasticity were being measured relative to fares (i.e. the 'fares' elasticity). The basic definition refers to a change Δx_i which is vanishingly small, however, so that it may be written mathematically as:

$$e_{x_i}^{\text{point}} = \frac{\text{Limit}}{\Delta x_i \to 0} \left(\frac{\Delta y}{y} / \frac{\Delta x_i}{x_i} \right) = \frac{x_i}{y} \left(\frac{\partial y}{\partial x_i} \right) \qquad (6)$$

where, in the limit of the changes being vanishingly small, $\partial y/\partial x_i$ is the partial derivative of the demand function with respect to the factor x_i. This is called the 'point' elasticity, and in general the size of the elasticity measured might be expected to be different for larger changes in x_i. Since in the real world the changes in the explanatory variable (e.g. the fares) may be quite large, other elasticity measures have been defined to approximate the elasticity measurement (5) above, for situations where the changes in the variable x_i are discrete and possibly quite large.

If x_i represents a cost of travel, it is to be expected that as x_i increases the demand y will fall. The relationship between these two is the *demand function*, often represented graphically by the *demand curve*. The point elasticity represents the slope of the curve ($\partial y/\partial x_i$) at the particular value of x_i multiplied by the ratio of this value x_i to the corresponding level of demand y.

Thus the point elasticity is, as its name implies, calculated at a particular point on the demand curve; in other words, it refers to particular values of the explanatory variables and to a given level of demand. Unless the shape of the demand curve is known, knowing the elasticity value at one particular point does not provide information about the elasticity at a different point. This quality of the point elasticity measure is important to bear in mind, since it implies that it cannot in general be used to forecast the effects on demand of changes in an explanatory variable which are so large that the variable takes on a very different value from that used to calculate the elasticity. As a consequence the point elasticity can in general only be used for rather limited changes in the explanatory variables, though one exception to this limitation will be considered below.

Several measures of the responsiveness of demand are used when larger changes in the explanatory variables are considered. The term 'arc elasticity' is frequently used to refer to such measures.

A particularly useful definition is the logarithmic form of elasticity. This may be derived from the differential, i.e:

$$\text{Elasticity} = \left(dy/y\right)/\left(dx/x\right) = d\left(ln\,y\right)/d\left(lnx\right) \qquad (7)$$

This has the benefits of 'reversibility', i.e. if a fare is increased by a certain amount and then reduced to its original level, then the original demand will be estimated. This also helps to make explicit whether the elasticity is, in fact, the same in the two directions.

The term 'arc elasticity' will be used here to refer to one particular measure, calculated in the following way:

$$e_{x_i}^{arc} = \frac{\log\, y_2 - \log\, y_1}{\log\, x_{i2} - \log\, x_{i1}} = \frac{\Delta\left(\log\, y\right)}{\Delta\left(\log\, x_i\right)} \qquad (8)$$

where y_1 indicates the level of demand prior to the change from x_{i1} to x_{i2} in the relevant variable and y_2 the level of demand after the change. The arc elasticity refers therefore to two points on the demand curve.

A similar measure of responsiveness for larger changes is the 'linear elasticity', which is defined as:

$$e_{x_i}^{lin} = \frac{y_2 - y_1}{\tfrac{1}{2}\left(y_2 + y_1\right)} / \frac{x_{i2} - x_{i1}}{\tfrac{1}{2}\left(x_{i2} + x_{i1}\right)}$$

$$= \frac{\left(y_2 - y_i\right)\left(x_{i2} + x_{i1}\right)}{\left(y_2 + y_1\right)\left(x_{i2} - x_{i1}\right)} \qquad (9)$$

A third elasticity measure, which is frequently used by bus operators to summarise the effects on demand caused by changes in the fare, is called the 'shrinkage ratio':

$$e_{x_i}^{s} = \left[\frac{y_2 - y_1}{x_{i2} - x_{i1}}\right] \bullet \left[\frac{x_{i1}}{y_1}\right] \qquad (10)$$

Another measure used by bus operators to measure the effect of a fare increase is the 'passenger resistance', which is defined by an equation identical to 9, except that x_{i1} is replaced by x_{i2}, ie the level of the fare after the change. This measures the proportion by which the additional revenue produced by a fares increase falls short of the revenue which would have been generated if the passenger demand had remained unchanged. (This is described more fully in Appendix III.2 of the 1980 study (Webster and Bly, 1980)).

Except for large changes in the explanatory variable the three measures 8, 9 and 10 take on broadly similar values; when the change is infinitesimal they all coincide with the point elasticity measure 6.

For larger changes, however, the difference between the measures can be substantial, in particular between the shrinkage ratio (and passenger resistance) and the two other measures. The relationships between the different elasticity concepts are discussed in more detail in Appendix III.2, where it is shown that the arc elasticity is numerically larger than the shrinkage ratio but numerically smaller than the linear elasticity for positive changes in the explanatory variable (eg an increase in fares), while the converse holds for a negative change (decrease in fares).

When using demand elasticities, a distinction has to be made between those which refer to changes in demand for a particular mode brought about by changes in the variables associated with that mode (called own-elasticities) and those which refer to changes in demand for a particular mode brought about by changes in the variables associated with other (competing) modes (called cross-elasticities). For example, the elasticity which measures the change in public transport demand with respect to a change in public transport fare is an own-elasticity, while the effect on public transport demand due to an increase in, say, the costs of using a private car is measured by a cross-elasticity.

When own-elasticities are calculated with respect to fares and travel times they can be expected to take on negative values, reflecting the condition that fewer journeys are demanded when fares go up and when travel times increase. Cross-elasticities with respect to the same variables will take on positive values when the factors changed are associated with a mode which is competing with public transport, and negative when it is complementary to public transport, as is the case when using a park-and-ride combination.

The term 'conditional elasticity' is also employed, where parallel changes take place in fares or other characteristics of alternative modes. For example, in London considerable scope exists for substitution between bus and underground modes where services are parallel. The 'own mode' elasticity is that estimated when fares for one mode change without change in those of the other public transport mode (hence its value would reflect both shifts to/from that other public transport mode, together with suppression/generation effects, and changes to/from any other modes). The 'conditional' elasticity is that when a change of the same percentage occurs in the other modes (e.g. bus and underground fares change by the same percentage at the same time). The conditional elasticity generally has the same sign as the own mode elasticity, but is of smaller size.

When reviewing the empirical results of measurements of elasticities in later chapters, use will be made of both point and arc elasticities. It is particularly advantageous to use the latter measure rather than a linear elasticity or shrinkage ratio for larger changes in the explanatory variable for the reasons given below.

Elasticities have traditionally been used as an aid in calculating the consequences for revenue of changes in the level of fares, and it may be shown that if the point fare elasticity is of greater magnitude than -1.0[8], the total revenue will decrease as a result of increasing fares. If, on the other hand, the elasticity is less than -1.0, then a (small) increase in the fare level will give rise to an increase in revenue. Fares elasticities can, in other words, be used directly to indicate the direction of the change in revenue from (small) changes in the level of fares. With regard to the other measures of elasticity (which can be used for large changes in fares), not all of them have the property that an elasticity value of one represents a dividing line between increasing and decreasing revenues. This simple interpretation does not apply to the shrinkage ratio, for example, which perhaps is one reason why it is used less widely nowadays. The two other measures, the arc elasticity and the linear elasticity, can on the other hand be shown to meet this requirement (approximately).

One of the reasons for preferring the arc elasticity to the linear-elasticity is concerned with the mathematical properties of demand functions. In principle, the arc elasticity is based on the assumption that the demand function is convex[9], while the linear elasticity presumes the demand function to be linear. There is a certain amount of empirical evidence to suggest that demand functions relevant to the types of problem discussed here are indeed convex so that, for most purposes, application of a linear elasticity over a wide range of change in the variables is likely to give unrealistic predictions. But there is also another reason why the arc elasticity is in general preferred to the linear elasticity. Consider the demand function:

$$y = k\left[x_1^{\alpha_1} \cdot x_2^{\alpha_2} \ldots . x_i^{\alpha_i} \ldots \ldots x_n^{\alpha_n}\right] = k\prod_i x_i^{\alpha_i} \qquad (11)$$

where k and α_i are constant parameters. This demand function is a convex function and hence yields convex demand curves[10]; it can be shown that both the point and arc elasticities are independent of the explanatory variables, always the same and of constant value α_i. The model (11) is therefore referred to as a constant elasticity demand function.

The use of this type of function is of course very convenient since the parameters α_i contain all the relevant information about the way demand reacts to changes in the explanatory variables. As this degree of information is embodied only in the arc elasticity and not in the linear elasticity or the shrinkage ratio, the arc elasticity has become the preferred measure for large changes. However, its validity is based on the assumption that demand functions are of the form given by (10) and it must be pointed out that there is, as yet, not much evidence to support such an assumption.

5.4 Dynamics and public transport

5.4.1 Introduction

The traditional approach to analysing public transport demand is essentially static, with the emphasis on equilibrium states. This was essentially the approach adopted in the 1980 version of the Demand for Public Transport. However, since that date greater emphasis has been placed on the dynamic processes that allow these equilibrium states to be achieved or in certain circumstances prevent equilibrium states from being achieved. Goodwin (1992) was an early attempt to summarise this work, with later work including that of Dargay and Hanly (1999, 2002). In particular, it is believed to be important to distinguish between elasticities with different time horizons. For example, with annual data:

- short-run elasticities might be based on the demand response within a year or two of a change;
- medium-run elasticities might be based on the demand response within five years or so of a change; and
- long-run elasticities might be based on the demand response within ten years or so of a change.

There are a number of inter-related reasons why we might expect dynamic processes to be important. First, it might take some time for all consumers to become aware of a new or improved public transport service. There will be lags for the information about such changes to diffuse through the entire population. Secondly, some consumers will be reluctant to change behaviour even when they are informed about service improvements. Habit is an important behavioural factor which may only be overcome gradually. Thirdly, some consumers will be constrained by various factors. For example, in the short run commuters' residential and workplace locations are relatively fixed but in the longer run they can change. Land-use responses to public transport service changes will be an important determinant of the difference between short-run and long-run elasticities. Fourthly, there is the issue of path dependency. The sequence of change will be important. A service in which fares are increased in real terms by 20% in year one and then reduced in real terms by 25% in year two, leading to an overall reduction of 10%, will have a different profile of demand over time than the same service in which fares are reduced by 10% in real terms in year two. Moreover, the end-state demand of these two changes may be different due to asymmetric response to fare increases and decreases. This phenomenon is known as hysteresis in the literature. In this case, differences in the end-state demand will be exacerbated if elasticities also vary with the magnitude of change. Fifthly, there may be cases where the rate of service and other changes is so rapid that consumer response never settles down and a permanent state of disequilibrium (or series of disequilibria) exists.

5.4.2 Mathematical background

The conventional (and simplest) way in which to model dynamic effects is through the use of lagged dependent variables. For convenience we have assumed a constant elasticity formulation but variable elasticity versions can be devised. The constant elasticity formulation involves estimation of an equation of the following form:

$$V_{it} = \alpha F_{jt}{}^{\beta} Z_{it}{}^{\gamma} V_{it-1}{}^{\delta} \quad (12)$$

where:

V_{it} = Volume of public transport travel in area *i* in time period *t*.

F_{it} = Mean public transport fare in area i in time period *t*.

Z*it* = Vector of other relevant explanatory variables.

V_{it-1} = Volume of public transport travel in area *i* in time period *t* - 1.

$\alpha, \beta, \gamma, \delta$ are parameters to be estimated.

With this formulation, the short run fares elasticity is given by the parameter β and the long run fares elasticity by β / (1 - δ). The medium run fares elasticity is more difficult to estimate. To do so, it becomes helpful to re-write the above equation in logarithms:

$$lnV_{it} = ln\ \alpha + \beta ln\ F_{it} + \gamma lnZ_{it} + \delta lnV_{it} \quad (13)$$

If we let V^*i be the equilibrium value of *Vi*, let *Xt* be the deviation of $ln\ V_{it}$ from $ln\ V^*i$ and let X_0 be the difference between $ln\ Vi_0$ (the starting value) and $ln\ V^*i$, we can determine that:

$$X_t = \delta\ tX_o$$

Suppose we have estimated a short run elasticity of -0.4 and a long run elasticity of -0.8 from annual data covering years 1 to 10 with a major fare change at the beginning of year 1, this would imply a value of δ equal to 0.5. Suppose also that the fare change at the beginning of year 1 had been a 20% increase. We would be forecasting a 13.6% decrease at the end of year 10 and a 7.0% decrease at the end of year 1. We can then calculate that:

$ln\ V_{i1}$ – *ln* (0.864) = 0.5 (*ln* (1) – *ln* (0.864)) and hence V_{i1} = 0.930. (demand down by 7.0%).

$ln\ V_{i5}$ – *ln* (0.864) = 0.5^5 (*ln* (1) – *ln* (0.864)) and hence V_{i5} = 0.868. (demand down by 13.2%).

$ln\ V_{i10}$ – *ln* (0.864) = 0.5^{10} (*ln* (1) – *ln* (0.864)) and hence V_{i5} = 0.864. (demand down by 13.6%).

In this example the change occurs relatively quickly. 51% of the change occurs by the end of year one and 97% of the change by the end of year five. The implied medium run five year elasticity is -0.78.

This is an example of a partial adjustment model. In this case, the higher the δ estimate, the slower the speed of adjustment and the greater the difference between the short run and long run elasticities. The number of periods n required to close a given proportion p of the gap between the equilibrium and starting values of *V* can be calculated as:

$$n = ln(1-p) / ln(\delta) \quad (14)$$

There are a number of different ways in which dynamics may be incorporated including specifying lags of higher order than the first order lag presented above and including lagged independent variables. Partial adjustment models of this type have been criticised for using short time-series and for ignoring the fact that data are non stationary (i.e. that variables tend to grow (or in some cases reduce) over time). There may be spurious correlations between variables exhibiting random walks. This can lead to statistical problems with goodness of fit measures meaning that incorrect inferences might be drawn. More advanced econometric techniques, such as co-integration and error correction models, have been developed to overcome some of these problems. However, error correction models can be more data intensive and hence partial adjustment models are often used where time series data sets are limited in duration.

The simplest error correction models use an Engle-Granger two-step estimation procedure. This involves estimating a long-run relationship from a static regression:

$$V_{it} = \beta\ F_{it} + \mu_{it} \quad (15)$$

where β is the long run fare parameter (if logs are taken this will be the long run elasticity) and μ is the stochastic error term. The stationarity of μ is then examined using tests such as the Durbin–Watson test of the cointegrating regression. If co-integration is indicated (that is that the variables in levels are non stationary but some linear combination – in this case first differences – is stationary), the residuals from the co-integration regression μ are used as an error correction term in a model of the following form:

$$\Delta V_{it} = \beta_o \Delta F_{it} + (\varphi - 1)\mu_{it-1} \quad (16)$$

It should be noted that in the error correction model the variables are specified in terms of differences (denoted by Δ) rather than levels. The short run fare parameter is given by β_0 (this will be the short run elasticity if logs are taken) and the feedback effect is given by (φ - 1). This indicates that (1 - φ) of the deviation between the short-run and long-run response is closed each period.

5.4.3 Examples

Bus

Dargay and Hanly (1999) provide some useful comparisons of the two approaches, at least for the English metropolitan areas (excluding London). A partial adjustment model estimates a short run fare elasticity of -0.74 and a long run elasticity of -1.09. The more appropriate error correction model (given that the data were found to be non stationary) estimates a short run fare elasticity of -0.69 and a long run elasticity of -1.06. For the error correction model (φ - 1) was estimated at -0.68 suggesting a relatively quick adjustment (68% of change occurring in the first time period). This is identical to the findings from the partial adjustment model, given a value of δ of 0.32, which implies 68% of change (1 - δ) occurs in the first time period.

This suggests that the use of the partial adjustment model, in this case, does not lead to any serious biases in estimation. However, there were larger differences between the estimated elasticities from the error correction model and the partial adjustment model when separate estimates were made for each of the six English metropolitan areas (see Table 5.1).

Table 5.1 Comparison of fare elasticities from an error correction model and a partial adjustment model for six english metropolitan areas

	Error correction model		*Partial adjustment model*	
	Short run	*Long run*	*Short run*	*Long run*
Manchester	-0.35	-0.96	-0.79	-1.09
Merseyside	n.s.	-0.70	-0.52	-0.72
South Yorks.	-1.13	-1.08	-0.82	-1.13
West Yorks.	-0.90	-1.22	-0.85	-1.17
Tyne & Wear	-0.73	-0.70	-0.59	-0.81
West Midlands	n.s.	-1.11	-0.82	-1.13

n.s. = not significant at the 10% level

This suggests that there is the need for further econometric work to test the robustness of the error correction and the partial adjustment methods. There may also be scope for investigating error correction/ cointegration models that involve higher than first order differences. Other issues include the assumption that all explanatory variables are exogenous (if this is not the case a system of equations needs to be estimated) and, where there are more than two variables, that there is only one cointegrating relationship. Both these assumptions need to be tested.

The above discussion also assumes that the demand models are fully specified. These models included service levels and income as explanatory variables in addition to fares but they do not include measures of bus speeds. It might be expected that bus speeds have decreased over time and that these decreases might be correlated with the increases in fares (estimated to have gone up by between 23% and 202% between 1985 and 1996 for the six areas studied). This might have led to biases in the estimation of the fare parameter values and, if decreases in bus speeds have become more marked over time, might have led to the erroneous detection of a long-run effect. Other explanatory variables missing from the analysis include the price (and other attributes) of rival modes, particularly rail-based public transport and the private car, and the overall composition of the market (including the importance of concessionary groups such as the elderly). It should be noted that the elasticities for the Metropolitan areas are higher (in absolute terms) than those recommended by Goodwin and Dargay (2001) for Great Britain as a whole (where motoring costs and proportions of pensioners are also included as explanatory variables). They suggested a bus fare elasticity of around -0.4 after one year, -0.6 after two years, -0.8 after five years and –0.9 after ten years. As the estimates are based on a partial adjustment model, this implies a value of δ of 0.56, with 44% of change occurring in the first period. Models of this type suggest a short and long run fare elasticity for the Shire counties of -0.49 and -0.66, with the corresponding elasticity estimates for the Metropolitan areas being -0.26 and -0.54 (Dargay and Hanly, 2002). However, it should be noted that these estimates are constrained to produce the same elasticities across areas of a similar type and are thought to be less appropriate than area specific estimates. Nonetheless, it suggests that results may be sensitive to the level of spatial aggregation.

Two other applications of error correction models to the British bus industry are the studies undertaken by Romilly (2000) and by OXERA (2003). Romilly's study was based on annual data for the British bus industry outside London 1953-1997. The OXERA study used data for the Government Office Regions (excluding London and Northern Ireland) between 1985/6 and 1999/2000.

The results are given by Table 5.2. In the Romilly model the feedback parameter (φ - 1) was estimated at -0.37, but the OXERA study did not report the feedback parameters, which, unlike Romilly vary across the attributes of interest. For comparison, the Dargay and Hanly (1999) recommended values are also given. There is some concurrence between these three studies with respect to the long-run bus fare elasticity but important differences with respect to all other estimates, particularly income. This reflects the sensitivity of error correction methods to data and model specification, as well as the sensitivity to spatial aggregation noted above which is also reflected by the instability of OXERA's results at the Government Office Region level.

Rail

An example of a partial adjustment model of rail demand is the work of Owen and Phillips (1987) whose initial work was based on four weekly ticket sales data for 20 Inter City routes from 1973 to mid 1984. There were 149 time series observations per route. Their median results suggested a short term price elasticity (i.e. after one month) of -0.69, whilst the long term elasticity was -1.08. This suggests an estimated median value of δ of 0.36. We can use this to rework our earlier analysis although we are now forecasting that a 20% fare increase at the start of the period would result in a 17.9% reduction in demand by the end of the period.

Table 5.2 Error correction model estimates of bus demand elasticities

	Bus fare elasticity		*Bus service elasticity*		*Income elasticity*		*Car price cross-elasticity*	
Study	*SR*	*LR*	*SR*	*LR*	*SR*	*LR*	*SR*	*LR*
Romilly (2000)	-0.38	-1.03	0.11	0.30	0.23	0.61	0.17	0.45
OXERA (2003	-0.63	-1.08	0.38	0.37	0.60	-0.56		
Dargay and Hanly (1999)	-0.4	-0.9	0.4	0.9	0	-0.5 to -1.0	0	0.3 to 0.4

SR – short run; LR = long run

$ln\ V_{ij2} - ln\ (0.821) = 0.36^2\ (ln\ (1) - ln\ (0.821))$ and hence $V_{ij2} = 0.842$. (demand down by 15.8%).

$ln\ V_{ij3} - ln\ (0.821) = 0.36^3\ (ln\ (1) - ln\ (0.821))$ and hence $V_{ij3} = 0.829$. (demand down by 17.1%).

$ln\ V_{ij6} - ln\ (0.821) = 0.36^6\ (ln\ (1) - ln\ (0.821))$ and hence $V_{ij6} = 0.821$. (demand down by 17.9%).

In other words, this modelled example suggests that virtually all of the change occurred within the first six months. Indeed, 66% of change occurred by the end of the first month, 88% of change by the end of the second month and 96% of change by the end of the third month. This might lead one to conclude that dynamics are not that important for long established Inter City routes.

One important point to note here is that Owen and Phillips worked with (broadly) monthly data whilst Dargay and colleagues worked with annual data. There is some scope for econometric work that tests whether different types of data with respect to time period tend to exhibit different dynamic effects.

An alternative way that long term demand increases might be forecast is through the use of models that forecast the impact transport improvements might have on land use, particularly residential and workplace location. An example of such a model is the Leeds Integrated Land Use and Transport (LILT) model developed by Mackett and Bird (1989) and applied to Network South East in the late 1980s This model worked in increments of five years from a base year of 1986. Some elasticity estimates are presented in Table 5.3.

From Table 5.3 it can be seen that the estimated short run travel time elasticities are around 90% of the long-run values. For fare, the short-run elasticities are between 60% and 90% of the long-run values. However, in the case of fare elasticities, this is not just due to land use changes but also because rail fares increase over time. LILT is underpinned by a logit model in which (absolute) elasticities increase with the value of the attribute of interest (in this case rail fares). Hence the long run impact on the elasticity value of a 5% per annum fare increase is more marked than the impact of a 1.5% per annum fare increase.

5.4.4 Conclusions

There is an increasing amount of evidence on the dynamic processes that underpin public transport demand but knowledge remains limited. In part, this is due to the limited availability of consistent data sets that cover long time periods. It is also due to problems with estimation methodologies. However, what evidence there is suggests that demand for the local bus industry which might take 10 years for demand to fully respond to fare and service changes, with long run elasticities two to three times the short run elasticities. In contrast, demand for long established Inter City rail routes seems to respond quickly to marginal changes in fares and, by inference, services. This apparent discrepancy between the dynamic properties of bus and rail demand requires explanation. There is some evidence that the long term impacts of fare and service changes may be more important for commuter rail services, where land use impacts may be more important than for inter-urban transport. This may provide a partial explanation of the discrepancy between bus and rail. There is also some evidence that the demand for new (or dramatically improved) rail products takes time to emerge (ATOC, 2002). For new high speed rail services, it may take up to four years for demand to reach an equilibrium, with demand in year one only around 50% of that in year four. For new urban rail services, it may take slightly longer (five years) for demand to reach an equilibrium, but growth will be less marked, with demand in year one being 75% of that in year five. It is important to take these demand build-ups into account when appraising new or improved public transport products.

5.5 Effects of demand interactions

Where there are competing forms of transport, a change in the price or other attributes of one may affect demand for another. Such demand interactions are known as cross effects. We distinguish between two types of cross effect: that emanating from the competition between modes and that emanating from competition within modes. The key indicator is the cross-elasticity which, for a price change, may be expressed as follows:

$$\eta_{ij} = \frac{\partial Q_i}{\partial P_j} \frac{P_j}{Q_i} \qquad (18)$$

where:

η_{ij} = the cross-elasticity of demand for service *i* with respect to the price of service *j*,

Q_i = the demand for service *i*, and

P_j = the price of service *j*.

Table 5.3 Short run, medium run and long run elasticity estimates from LILT

	All trips			*Trips to central London*		
Change modelled	*Short-run (1991)*	*Medium-run (1996)*	*Long-run (2001)*	*Short-run (1991)*	*Medium-run (1996)*	*Long-run (2001)*
Fares increased by 1.5% per annum[1]	-0.31	-0.32	-0.35	-0.15	-0.17	-0.19
Fares increased by 5.0% per annum[2]	-0.33	-0.38	-0.45	-0.17	-0.22	-0.28
Travel times reduced by 10%[3]	-0.63	-0.67	-0.69	-0.34	-0.36	-0.38

[1] *First fare increase implemented in 1991 (fares up 7.73%), subsequently fares increased by the same percentage in 1996 and 2001. (Test 1A).*

[2] *First fare increase implemented in 1991 (fares up 27.63%), subsequently fares increased by the same percentage in 1996 and 2001. (Test 1B).*

[3] *Central London rail times (including Underground) remain constant. Many rail journeys include travel within central London, so the actual average reduction was less than 10% and the travel time elasticities are slight under estimates. (Test 2C).*

In practice such effects may be difficult to measure because the direct effects (e.g. of the change in P_i on Q_i) often outweigh the cross effects (e.g. of the change in P_j on Q_i). However, we can infer cross-elasticities from direct elasticities by making use of the following formula:

$$\eta_{ij} = \left|\eta_{ii}\right| \frac{Q_i}{Q_j} \frac{\partial Q_j}{\partial Q_i} \quad (19)$$

where

η_{ii} = the direct elasticity of demand for service *i* with respect to the price of service *i* (also referred to as own price elasticity).

Q_i/Q_j = the relative market volumes of services *i* and *j*.

$\partial Q_j/\partial Q_i$ = the proportion of the change in service *i* trips as a result of a price change that are diverted from mode *j*. We refer to this as a diversion factor and will present some evidence on such factors below.

Cross-elasticities have some other theoretical properties that can be useful. We highlight briefly two. First, there is the homogeneity condition. This simply states that for any good the sum of the own-price elasticities and all cross-price elasticities equals minus the income elasticity. Secondly, there is the symmetry condition which, assuming no income effects, states that for all i not equal to *j*:

$$\frac{\partial Q_i}{\partial P_j} = \frac{\partial Q_j}{\partial P_i} \quad (20)$$

These two conditions can be used to infer a full set of cross-elasticities in situations where only a sub-set of direct and cross-elasticities are known. This assumption of there being no income effect implies that the elasticity of demand for a service with respect to income is zero and/or the proportion of income spent on a service is zero. In many circumstances in public transport markets this may be an adequate approximation of the truth.

5.6 The ratio of elasticities approach

Mode A's own fare elasticity for *user group 1* (e.g. commuters) in circumstances where multiple travel choices exist and when these choices are described by the *logit* function is given by:

$$E_{A1} = b_1 C_1 \left(1 - \text{Prob}_{A1}\right) \quad (21)$$

Where:

b_1 is the cost parameter;

C_1 is the cost;

Prob_{A1} is the probability of choosing mode A.

The *ratio of elasticities* can be used in solving the relationship between aggregate elasticities and disaggregate elasticities. The ratio between user group 1 and user group 2 elasticities is given by:

$$E_{A1} / E_{A2} = b_1 C_1 \left(1 - \text{Prob}_{A1}\right) / b_2 C_2 \left(1 - \text{Prob}_{A2}\right) \quad (22)$$

This relationship can be simplified, if:

- The relationship between C_1 and C_2 is known (e.g. the stage fare is 50% lower for one group and similar journey lengths are undertaken).
- BUT MORE IMPORTANTLY: Mode A has the same market share for user groups 1 and 2.

More generally, suppose we can write price elasticity as follows:

$$E_p = \left(\partial Q / \partial P\right) \cdot \left(P / Q\right) \quad (23)$$

where:

Q = Volume of bus travel,

P = Mean bus fare.

Suppose also we can express value of time as follows:

$$VoT = \left(\partial A / \partial T\right) / \left(\partial Q / \partial P\right) \quad (24)$$

where:

T = Mean bus in-vehicle time.

Then we can write in-vehicle time as follows:

$$\begin{aligned} E_T &= \left(\partial q / \partial T\right) \cdot \left(T / Q\right) \\ &= \left(\partial Q / \partial P\right) \cdot \left(P / Q\right) \cdot \left(\partial Q / \partial T\right) \cdot \left(\partial P / \partial Q\right) \cdot \left(T / P\right) \\ &= E_p \cdot VoT / P \end{aligned} \quad (25)$$

In other words, if we have reliable estimates of the price elasticity and the value of in-vehicle time, then we can infer the in-vehicle time elasticity for any combination of in-vehicle time *(T)* and fare *(P)*.

5.7 An example of the use of elasticities

One important use of elasticities in public transport planning is, as mentioned above, to indicate the direction and size of the change in revenues from changes in the level of fares. More recently elasticities have become important in other areas and in particular when considering the supply of public transport services. The use of elasticities for this purpose will be indicated below using a simple hypothetical example.

An average journey by bus in a particular urban area involves 8 minutes waiting time, 10 minutes walking time and 12 minutes in-vehicle time. A service increase, limited by a fixed budget, is planned for the network. Within this budget constraint the following three strategies are feasible:

a A decrease in bus headways which would reduce the average waiting time from 8 to 5 minutes.

b An increase in the number of routes which would reduce the average walking time from 10 to 6 minutes.

c An extension of reserved bus lanes and bus-only roads which would reduce the average in-vehicle time from 12 to 10 minutes.

If it is assumed that the arc elasticities with respect to waiting time (wt), walking time (st) and in-vehicle time (vt) are:

$e^{arc}_{wt} = -0.5.$
$e^{arc}_{st} = -0.6.$
$e^{arc}_{vt} = -0.4.$

then it is possible to calculate the percentage change in patronage for each of the three strategies as follows:

a 100 $[(5/8)^{-05} -1] = 26\%$.

b 100 $[(6/10)^{-0.6} -1] = 36\%$.

c 100 $[(10/12)^{-0.4} -1] = 8\%$.

If the aim is to maximise the number of passenger journeys, the strategy (b) should be chosen.

5.8 Some guidelines on the prqactical use of elasticities

Using elasticities in practice is quite simple, as has been illustrated above, and this also accounts for their popularity. It must be pointed out, however, that elasticities are not strictly a substitute for demand functions, except in some special cases, since they only convey limited information about the structure of demand. When calculating and/or using elasticities, attention should be paid to the properties of the elasticities in order to ensure that their limitations are understood and that they are applied only when it is valid to do so. Such properties include:

i The size, direction and type of change.

ii The purpose of the journey.

iii The time period over which the demand is measured.

iv The characteristics of the individuals or sections of population concerned.

v Transferability in time and space.

vi Whether the effect refers to the short or the long term.

vii The functional form of elasticity used in the original study.

Each of these aspects is considered in more detail as follows:

i Elasticities are usually calculated at only one or two values of the explanatory variables. Since the entire demand function is not known, elasticities may differ for different types of change and for different initial values of the variable being changed. There are other reasons, however, why elasticities depend on the type of change being studied; for example, it is often argued that it is easier to lose passengers than to gain them because increases in fares, or decreases in the supply, induce travellers to seek alternative means of transport, such as cars; once a car has been bought, the owner tends to become 'captive' to his vehicle. If this is so, then the fares elasticity might be expected to be larger when fares are increased than when they are decreased. It is also suggested that elasticities might be larger for large changes than for small ones, since large changes are easier to perceive than small ones and consequently induce a more active search for alternative travel modes or destinations.

ii Elasticities may also be expected to vary with journey purpose, since they are bound to be dependent to some extent on how optional the particular journey is (at least in the short term). Elasticities associated with work journeys are thus in general smaller than those associated with other types of journeys, such as shopping and socialising, since there are usually very few substitutes for work journeys (though this may not be true in the long term). Other types of journeys can often be made at different times, to different destinations or by different modes (or omitted altogether, if necessary) if travel times and costs are increased, so the response is relatively sensitive to such changes, giving rise to correspondingly larger elasticities.

iii An elasticity refers to a response averaged over a given period of time, which may be as short as the rush hour or as long as a year or more. The elasticities for different time periods will reflect the different types of journey which predominate and the alternative modes which are available.

iv As noted earlier, demand functions may refer either to individuals or to groups of individuals. Calculating elasticities from individual data may be of limited value since elasticities are mainly used to determine group behaviour. In particular, it is necessary to make sure that the values of the explanatory variables used as input to individual demand functions do represent averages for the population which the elasticity is supposed to reflect. In many instances this has not been so. The same problem applies to aggregate functions also.

v Elasticities are not necessarily transferable in time or in space. One reason for this is that preferences change over time. Furthermore, with incomes rising over time it may be expected that consumers would become more willing to pay more to avoid discomfort and to reduce travelling time (though see Section 5.2 - the demand function concept), which would mean that elasticities with respect to travelling times would be expected to rise in relation to price elasticities if the money costs involved rise less rapidly than income. Similarly, elasticities derived from data obtained in one area may not be applicable to other areas where car ownership, incomes, the level of public transport service etc may be quite different.

vi A final aspect to which attention should be paid when using elasticities is whether they reflect long-run or short-run behaviour. This is because changes in a particular aspect of public transport, such as travelling times, have both a direct and an indirect impact on demand, as has been emphasised above. The direct impact is registered shortly after the change, but the indirect impact, which may be due to changes in residential location or car ownership levels, affects demand at a much later date; thus, the full effects of, say, a fare change may not be realised for several years. Whether a demand function and the elasticities calculated from it reflect short- or long-run effects in this sense is a consequence of both the type of model used and the type of data employed to estimate the demand function. Even if it is only required to know about the short-run effects on demand from a change in an explanatory variable, it is not always possible to observe the effects until some time has elapsed; for example, it is a common experience that full adjustments to a fare change may take as long as six months, partly because it takes passengers some considerable time to find acceptable alternatives and settle into new travel habits, but also because a fare increase is often followed by a short-lived passenger 'protest' which depresses demand abnormally. As a consequence, elasticities which are calculated from observations made soon after a fare increase may be larger than those based on observations made rather later, if the 'protest' effect dominates, or the reverse may be true if demand is taking some time to settle down.

viii As indicated in earlier parts of this chapter, the functional form of the elasticity used in the original reference study may have substantial effects on the values derived. It is therefore desirable to use elasticities in the same functional form as that in which they were initially estimated, although this may not always be possible in practice where the original study specification is not readily available.

5.9 Incorporation of revealed preferences changes not reflect in 'elasticity' values

Many of the principal demand factors can be represented in numerical form, to which appropriate elasticity values may then be related (such as those for fares, and frequency). Changes in demand resulting from changes in such factors may then be estimated by inputting the appropriate changes in the causal variable (such as a fares increase). This is represented by a shift *along* a demand curve.

There may be greater difficulty in assessing discrete of 'step' changes in factors which may not be quantifiable in terms of continuous variables. For example, increased attention has been paid by operators to factors such as marketing, driver training, improved vehicle design (such as low-floor access, or air conditioning), alternative fare structures, etc. One method of analysing such changes is to view them as a demand curve shift, i.e. a shift *between* demand curves, or a shift of an existing demand curve to the left (where the net effect has been to worsen quality of service, resulting in lower demand) or the right (where an improvement has occurred, increasing demand).

For example, the severe instability in bus services following deregulation in Britain in the mid 1980s could be represented as shift of a demand curve to the left (i.e. allowing for changes in average real fare, service frequency and exogenous factors, demand was lower than would have been expected on established elasticity values). Conversely, large increases such as those due to impacts of an extensive marketing campaign would be seen as a shift of the demand curve to the right.

While less easy to quantify in terms of traditional estimation methods, such factors may well have greater impact on public transport demand than substantial changes in fare or service levels, and may be far more cost-effective, especially in the short term, in which demand with respect to fare or service level is fairly inelastic.

This may also be an appropriate method for looking at shifts occurring through travel awareness campaigns, and personalised travel marketing, which can result in substantial growth in ridership without any changes in service level or price, especially where the current market share of public transport is low, and hence even a small shift of car travel to public transport represents a large percentage growth in the public transport demand.

A good example was the pilot scheme carried out in Perth, Western Australia, in 1997, following earlier work by Socialdata in Germany, using 'soft' policies to influence modal choice (Brög and Grey-Smith, 2002). The concept of 'Individualised Marketing' was an essential component of this approach. Households were contacted to determine their existing modal choices and journeys made, and scope identified for transfer to modes such as walking, cycling and public transport from car. Trips per person per day remained the same before and after the project, at 3.4, but those made as car driver fell from 60% to 54% and bus trips rose from 6% to 7%. This was followed by a larger-scale demonstration project in South Perth, including over 13,000 households, producing similar results.

Another recent example is the direct telephone-based marketing conducted by Stagecoach in Britain, giving an estimated modal shift from car of up to 9% (Transit, 2003).

It may also be the case that changes occur simultaneously in factors which can be quantified and for which elasticity values have been established from previous studies, and those more appropriate to the demand curve shift concept. For example, a revised urban bus network may be accompanied by changes in vehicle-km operated (as a proxy for frequency) and average fare, together with simplification of routes, changes in fare structures, extensive marketing, etc.

As part of the study, a number of cases have been identified where performance has differed substantially from that generally found in Britain (for example, bus ridership in certain urban areas, outside London). As a means of identifying the effect of factors other than changes in fare level and service level, data have been provided by the operators concerned for changes in ridership, average revenue per trip and vehicle-km operated. Using representative elasticities for such variables, the 'expected' and 'observed' outcomes may be compared. The difference due to other factors may then be estimated. This has already enabled quantification of effects due to marketing and fares simplification. (Note: due to reasons of commercial confidentiality, results reported in the study will discuss overall conclusions from such analysis, rather than individual cases in detail).

In terms of converting such demand curve shifts to estimates to changes in consumer surplus, a distinction needs to be drawn between two types of shift:

a An improvement in service quality which is not necessarily reflected in variables for which conventional elasticity values can be calculated, which results in benefits both to existing and to new users. Examples might include real-time information at stops, low-floor access to vehicles, etc.

b A growth in demand due to wider awareness of existing services through personalised travel marketing, etc. In this case, while new users may be assumed to enjoy some benefits (otherwise their behaviour would not have changed), it would not be reasonable to infer similar benefits for existing users already aware of the service offered.

5.10 Concluding observations

Any modelling of public transport demand must involve a considerable degree of simplification. It is always important to bear in mind that most travel comprises trip chains made by individuals from the home. Indicators of demand need to allow for effects of definitions used, especially in respect of linked trips. Aggregate demand changes may result both from existing users changing their level of use, and others either joining or leaving the public transport market as a consequence. For many of the major demand variables, such as fares and service levels, elasticities may be derived from observed data, or stated preference responses. This may be more difficult to apply directly to factors affecting perception and awareness of services.

6 Effects of fares

6.1 Introduction

In this chapter, the effects of fares on public transport patronage are considered. Fares are fundamental to the operation of public transport since they form a major source of income to operators. In general, if fares are increased, patronage will decrease. Whether revenue increases or decreases as a result of a fare increase depends on the functional relationship between fares and patronage as represented by the demand curve. Usually this is expressed through the concept of 'elasticity' which was discussed in Chapter 5.

Recent research suggests that fare elasticities are dynamic, meaning that they vary over time since the fare change. Therefore, it is increasingly common for analysts to distinguish between short-run and long-run, and sometimes medium-run elasticity values; there are various definitions of short-run, medium-run and long-run, but most authors take short-run to be 1 or 2 years, and long-run to be around 12 to 15 (although sometimes as many as 20) years, while medium-run is usually around 5 to 7 years.

In recent years, two quite different methods have been used in econometric studies to distinguish between short-run and long-run elasticities. The first is to define, a priori, certain classes of behavioural models to be interpreted as indicating something about the time scale of the response as 'short-term' or 'long-term'. In principle, this enables such cross-section, or equilibrium, models to be interpreted as indicating something about the time scale of the response, by consideration of which responses are included. The conditions for this to be valid are stringent and rarely fulfilled, and even where they are, no statements are possible about how many years it takes for the long-term effect to be completed.

The second approach is to use a dynamic econometric model in which time series data are used with a model specification in which a gradual response over time is represented explicitly. In this case, the short-run is the interval of the data series; for example, the short-run is one year for annual data, three months for quarterly data and so on. The long-run response and its time scale are determined empirically as key results of the analysis.

There have been many papers on fare elasticities. In their day, two of the most influential, were the 1980 'Demand For Public Transport' (Webster and Bly,1980) and a report by the Commission of The European Committee (1980). More recent major reviews on the subject, include: Dargay and Hanly (1999), Goodwin (1992), Oum *et al.* (1992) and Goodwin *et al.* (1992). The latter three are interrelated. The first draws on the latter trio, but supplements it with more recent work. According to this quartet, other useful literature reviews are: Fowkes, Sherwood and Nash (1992), Oum *et al.* (1990), Goodwin (1988), and Goodwin (1991).

Elasticities can be derived in a number of ways, for example: time trends, stated and revealed preference surveys, before-and-after studies, time series analysis, cross-sectional analysis, and logit modelling. For more information on the different types of modelling see Chapter 5. All forms of modelling have their drawbacks: before-and-after studies have tended to deal with the short-run rather than the long-run, stated preference surveys may be skewed in two ways: firstly, people may react differently in the real situation to how they think they will react, and secondly, in order to obtain their desired outcome (e.g. a new bus service) they may say they will react in a particular way when they know they will not. Time trends are not always a reliable indicator, as they can be subject to policy change. For example time trend estimates, as well as including the response to fare changes, may incorporate past changes in car ownership which have been influenced by policy intervention on car use which have led to increased public transport use, so that the resulting elasticity values may appear higher than they otherwise would be.

In this study, elasticity values from many sources have been examined. Some are discussed in the text. Others are included in the Appendix to Chapter 6. This shows, for each study covered, the elasticity value, the nature of the value, the source reference and then summarises the values by means of averages and standard deviations. Generally, one value is taken from each study for the averaging process to avoid bias towards studies which have produced several values.

A traveller's response to a fare change will depend, to some extent, on how large a part the fare plays in the decision to make that journey or the choice of mode. For example, journeys to work or school are necessary, at least in the short-term. In the longer term, people may change their location, and their individual circumstances will probably change anyway, due to changes in age, income, educational status, employment situation, family situation and so on. All of these factors have an influence on whether people make a particular journey, by a particular mode. People may travel at particular times of the day to take advantage of the various fare reduction options available at that time, or use pre-paid discount cards for particular types of people or groups (such as young people or families) to obtain a reduced fare. More work is required on how this affects elasticity (Wardman, 1995). There is some evidence of passengers changing ticket type rather than mode in response to a fare increase (Steer Davies Gleave,1999a). This reflects the context-specific nature of some ticket types.

As well as considering the direct effects of a change in fares, it is important to consider the effects of fare changes on other modes. The usual method to take into account the effect that other modes have on the demand for a particular mode of public transport is to use cross-elasticities. These estimate the demand elasticity for a competing mode with respect to the change in the given mode, e.g. the demand elasticity of bus travel with respect to rail fares. They will be discussed in Chapter 9.

The rest of this chapter synthesises evidence to provide an up-to-date overview of fares elasticities and the effects of various factors on the values.

6.2 Types of fares

Fare systems can have various forms; for example, they can be flat, zonal or graduated. Each of these has its particular characteristics (White, 1995):

Flat fare - A single fare paid regardless of distance travelled.

Zonal fare - A flat fare applies for travel within a designated zone.

Graduated fare - A fare charged by distance or a fare charged which varies with costs and loadings.

Season ticket - Weekly, monthly or annual season tickets which offer discounts off individual trip tickets and can result in large savings for the passenger.

Travelcard – A card allowing unlimited use of public transport within a specified area over a fixed time period (eg one day or one week). It may apply to all public transport services, or be limited to particular modes or operators. It may be purchased at ticket offices, automatic ticket machines etc. The name 'travelcard' is used in London; others may be used elsewhere.

For more details on the various types of fares see the Appendix to Section 6.2.

As discussed above, there are many types of fare. For the purposes of analysis, it is often necessary to define a single value, which will often be the average amount paid for a single trip. This can be calculated by summing all the passenger receipts in the market segment of interest and dividing by the equivalent number of passengers. Alternatively, the total revenue might include funding received to compensate for concessionary fares that the operator offers as part of a policy agreement.

6.3 Elasticity of bus travel

In this section, the response of demand to changes in bus fares are discussed, including a discussion on short, medium-run and long-run elasticity values.

Table 6.1 shows the average value for bus fare elasticity, averaged over the 49 studies identified in the Appendix to Chapter 6. It can be seen that the overall short run bus fare elasticities average about -0.41, which is considerably higher than the -0.30 given in the 1980 report (Webster and Bly, 1980). It has been found that in the short run the UK data for bus fare elasticity averages around -0.42, however, the international data have a lower average elasticity of around -0.38. This difference may reflect higher fare levels and lower service levels in the UK than elsewhere in the world.

Table 6.1 Bus fare elasticities (short-run values)

Location	*Elasticity*	*Number of values*
UK	-0.42	33
Non-UK	-0.38	11
Overall	-0.41	44

For data and sources see appendix to Section 6.3, Tables A6.3 and A6.7.

Comparisons with earlier literature reviews, from about 1980, show that overall short run bus fare elasticity values have increased. This reflects increasing car ownership and less reliance on the bus over time. Broadly speaking, the results compare closely to those from the early 1990s (Goodwin, 1992, Goodwin *et al.*, 1992, and Oum *et al.*, 1992).

Goodwin (1992) examined the literature to see the effects of the length of time since the fare change on the elasticity value. His results are shown in Table 6.2.

Table 6.2 Bus fare elasticities related to time period

Source	*Time period*	*Average elasticity*	*Standard deviation*	*Number of cases*
Before and after studies	Around 6 months	-0.21	0.12	3
Explicit short	0-6 months	-0.28	0.13	8
Unlagged time series	0-12 months	-0.37	0.18	24
Explicit long	4+ years	-0.55	0.20	8
Equilibrium models	5-30 years	-0.65	0.18	7

Source: Goodwin (1992)

Goodwin (1992) states that the average of the values in Table 6.2 is -0.41. The mean of the elasticities for the studies that use a time period of 12 months or less is -0.34.The effect after about four years is about –0.55, which increases over time to about -0.65. More recent work by Dargay and Hanly (1999) using estimates from dynamic models produces the figures shown in Table 6.3. These are market elasticities, that is, they reflect the effect on bus patronage of average fare changes of all services in a given area. The long-run values are clearly higher than the short-run values.

Table 6.3 Bus fare elasticities for full-fare paying passengers

	Short run	*Long run*
Great Britain	-0.2 to –0.3	-0.7 to –0.9

Source: Dargay and Hanly (1999).

An interesting result was produced by Gilbert and Jalilian (1991) using complex econometric models on data for London. They obtained a value of -0.839 for the short run and -1.318 for the long run. (Imposing long-run symmetry reduced the values to -0.788 and -1.185 respectively). The long-run value of greater than unity implies that revenue would decrease when fares were increased. Thus, these suggests that in the short-run, a fare increase would lead to an increase in revenue, but with the passing of time, the loss of passengers would be so great that this effect would outweigh the increase in the mean fare paid by those still travelling.

Table 6.4 shows the mean elasticity values for the short, medium and long runs, based on UK data. The short-run value of -0.42 is the mean of 33 UK studies, as discussed above. Medium-run bus fare elasticities appear to average somewhere between -0.5 and -0.6, which are very similar to those found by Goodwin (1992) and Halcrow Fox *et al.* (1993). However, this is based on the results of only two studies, namely: McKenzie and Goodwin (1986) and Preston (1998), and so caution is required when using this figure.

Table 6.4 Bus fare elasticities (UK values)

Length of forecast period	*Elasticity*	*Number of values*
Short run	-0.42	33
Medium run	-0.56	2
Long run	-1.01	3

For data and sources see appendix to Section 6.3, Tables A6.3, A6.10 and A6.13.

Lon-run bus fare elasticities seem to average around -1, which is noticeably higher than those found in previous literature reviews, most of which produced values in the range of -0.57 to -0.80. This may be partly due to the current results being dominated by cross-sectional modelling, which tends to produce higher values than other methods (see Section 6.5), whereas the earlier literature reviews appear to be dominated by conditional elasticities.

It has been shown that the longer the period over which the elasticity values have been calculated, the greater the magnitude of the value. Two reasons can be identified for this effect. Firstly, it reflects the fact that the longer the elapsed time after a fare increase, the greater the range of responses open to those who have been directly affected by the fare increase. In the short run, bus passengers can, in many cases, switch modes or cease making trips. In the long run, they can change homes, change jobs, buy cars, and so on. It should be noted that these long-run effects are not necessarily caused directly by the bus fare increase: these types of decisions are made, typically, every few years, and the resultant outcome (where to live, where to work, and so on), will reflect the conditions at the time, including bus fares for those who travel by bus. With higher fares, more people are likely to choose locations which do not require use of the bus. The second reason that long-run values are higher is that, in the long run, there is market turnover: the group of people who use public transport in a given area will change as some people leave the market (due to changes in their circumstances) and new people enter it. These new people will have different characteristics from the users they replace. They may have grown up in a generation, or with a lifestyle, which makes them perceive using public transport as more or less desirable than the users they replace.

The long-run elasticity is around three times that of the short run elasticity. This is supported by evidence by Dargay and Hanly (1999) who found results for British systems of long-run elasticities for British systems of between 1.5 to 3 times the short-run values.

Dargay and Hanly (1999) asked various bus operators if they thought their elasticity estimates were accurate. They found that 77% of those surveyed thought their short-run elasticities were about right, but only 41% thought that the long-run elasticity was about right; 28% felt it was too high, the remainder felt it was too low. 53% of those surveyed felt that the elasticity values represented the effects of fare-change on the market over time accurately, and 39% felt the effects of fare change on individual operators was represented accurately. Of those surveyed 44% made use of elasticity estimates and 52% did not (the remaining 4% did not respond).

6.4 Elasticity of rail travel

6.4.1 Rail elasticities overall

In this section, elasticities for rail travel are considered. Table 6.5 shows that the overall average value is -0.41. This is similar to the value for buses, shown in Table 6.1. As with buses, the UK value is greater than that for the rest of the world, but the differential is greater than for buses.

Table 6.5 Rail fare elasticities (short-run values)

Location	*Elasticity*	*Number of values*
UK	-0.46	35
Non-UK	-0.33	20
Overall	-0.41	55

For data and sources see appendix to Section 6.4, Tables A6.16, A6.19, A6.25 and A6.28.

The fare elasticity for rail travel as a whole has a wide range, as shown in the Appendix. This is due in part to the wide variation in the effect of competing modes. Oum *et al.,* (1992) note that intracity rail travel is likely to be significantly affected by competing modes, such as bus; therefore cross-elasticities tend to be significant in this context. A considerable amount of work has been done on cross-elasticities, involving rail demand. Of particular note are Wardman (1997a) and Wardman (1997b) cited in Steer Davies Gleave (1999a), which review choice models and applications of cross-elasticities for both price and service, between one mode and another, for urban and inter-urban travel in Great Britain, but acknowledge that results are not necessarily transferable from area to area. Cross elasticities will be discussed in more detail in Chapter 9.

Owen and Phillips (1987), in their work on inter-city rail fares, mention how, while in the short run revenue might be increased by increasing the price of tickets, in the long term this benefit is quickly eroded by a decrease in patronage. Wardman (1995), also found that if car costs increased, then people would be more likely to switch to the train than the bus, while if car costs decreased more people would switch from the train than the bus.

As Table 6.6 shows, there is an increase in the elasticity value with time since the fare increase. The differential appears not to be as great as that for buses, but there are only two values for the long run (and none for the medium run).

Table 6.6 Rail fare elasticities (UK values)

Length of forecast period	*Elasticity*	*Number of values*
Short run	-0.46	35
Long run	-0.65	2

For data and sources see appendix to Section 6.4, Tables A6.16, A6.21 and A6.25.

Further information on rail elasticities can be found, according to Goodwin (1992), in Fowkes *et al.* (1985), Glaister (1983), Hughes (1980), Jones and Nichols (1983), Kroes and Sheldon (1985), Mackett (1985), and Oldfield and Tyler (1981). Of particular note are Godward (1984) and Bamford (1984) which deal with the West Midlands, and, Hensher and Bullock (1979) and Hensher and Smith (1986) which refer to Australia.

The results in Tables 6.5 and 6.6 include studies of both metros and suburban rail. There may be differences in the response to changes in fare levels for the two types of system reflecting differences in the length and type of trip served and the competitive modes. Generally, metro trips will be shorter with bus or walk as competitors, while suburban rail trips will tend to be longer often with car as a competitor. Given that many of the trips will be to work, there may be a lower degree of captivity to suburban rail, with some commuters choosing alternative job locations away from the city centre and travelling by car after a fare increase (Mackett and Nash, 1991). Metros are considered in Section 6.4.2 and suburban rail in Section 6.4.3.

6.4.2 Metros

As Table 6.7 shows, the metro elasticity values tend to be lower than the overall rail values, with slightly higher values from the UK than from the rest of the world. The overall value of about -0.29 is considerably higher than the value of about -0.15 given in Webster and Bly (1980), although within their range of -0.08 to -0.31.

Table 6.7 Metro fare elasticities (short-run values)

Location	*Elasticity*	*Number of values*
UK	-0.30	15
Non-UK	-0.29	9
Overall	-0.29	24

For data and sources see appendix to Section 6.4, Tables A6.16 and A6.19.

In the long run, metro fare elasticities tend to be higher than in the short run, as shown in Table 6.8. It should be noted that all the UK results are from the London Underground.

Table 6.8 Metro fare elasticities (UK values)

Length of forecast period	*Elasticity*	*Number of values*
Short run	-0.30	15
Long run	-0.65	2

For data and sources see appendix to Section 6.4, Tables A6.16 and A6.21.

Goulcher (1990) estimated a short-run elasticity for the London Underground of -0.43, and a long-run value of -0.61. Gilbert and Jalilian (1991) estimated equivalent values of -0.355 and -0.688 respectively for the same system (-0.396 and -0.983 respectively with long-run symmetry imposed in the model). Slightly earlier work by Fairhurst *et al.* (1987) using time series analysis data from 1970 to 1985 produced a short run value, after one year, of -0.2 and a longer term effect of -0.4. This all implies that the long run elasticity for the London Underground is between 1.5 and 2 times the short run value, possibly higher. In general the long run fare elasticity appears to be around twice that of the short run.

Comparisons with other literature reviews are complicated by the fact that few of them list metro as a separate entity. Halcrow Fox *et al.* (1993) did cover metro separately and concluded with a short run fare elasticity of -0.40, and a long run value of -0.69.

There appear to be very little data on medium run metro fare elasticities, although Halcrow Fox *et al.* (1993) literature review gives a value of -0.45 for London Underground.

6.4.3 Suburban rail

The suburban rail fare elasticities are shown in Table 6.9. These are equivalent to those for overall rail fare elasticities in Table 6.5.

Table 6.9 Suburban rail fare elasticities (short-run values)

Location	*Elasticity*	*Number of values*
UK	-0.58	20
Non-UK	-0.37	11
Overall	-0.50	31

For data and sources see appendix to Section 6.4,Tables A6.25 and A6.28.

As Table 6.9 shows, overall, suburban rail has a fare elasticity of around -0.50. This is identical to the value established by Webster and Bly (1980). There is a noticeable difference between the UK and the non-UK results, with the latter having an average value of -0.37, a little less than two-thirds of the UK average value of -0.58. Most of the international results come from the US and Australia, so the difference could be a result of different urban morphology. A result from Arsenio (2000) from Spain also yielded a low elasticity, of -0.33. In contrast, Goodwin (1992) shows a higher mean value of -0.79 which is an average over 92 studies, but this included a wide variety of different types of rail service, not just suburban rail.

It can be seen that suburban rail has a higher elasticity than metro and bus, possibly reflecting the longer average trip length with car as a competitor.

6.4.4 Comparing bus, metro and suburban rail

Table 6.10 compares short run bus, metro and suburban rail fare elasticities, and shows the overall mean, averaged across all modes.

Table 6.10 Public transport elasticities (short run)

Mode	*UK*	*Non-UK*	*Overall*
Bus	-0.42	-0.38	-0.42
Metro	-0.30	-0.29	-0.29
Suburban rail	-0.58	-0.37	-0.50
Overall public transport	-0.44	-0.35	-0.41

Data from Tables 6.1, 6.7 and 6.9.

Metro appears to have a lower elasticity than bus (-0.30 compared with -0.42 for bus). This reflects metro's main advantage for many trips: it offers a rapid method of travel from outer urban areas to the centre for many commuters. Both bus and car suffer from congestion and so cannot compete for many such trips, and they are too long to be walked, so many travellers are largely captive unless they choose to change employment location. That option is not open to many workers who work in occupations which are centrally-located and cannot afford to (or choose not to) live close to the city centre. Suburban rail has higher average than either bus or metro. This may reflect the fact that many of these trips are commuting trips from outside urban areas to the city centre and some commuters have the option of employment outside the main urban area, travelling by car, as discussed above. It should be noted that in all cases the averages reflect a wide range of values which show considerable overlap.

Pratt *et al.* (2000) compared bus and rail rapid transit (metro) elasticities for Chicago, New York, San Francisco, London and Paris and found that bus fare elasticities were about twice the magnitude of rail rapid transit fare elasticities.

Table 6.10 also shows that elasticity values tend to be higher in the UK than the rest of the world on average. This may reflect higher fare levels and poorer service quality in Britain than some other parts of the world.

It can also be seen that the overall public transport elasticity appears to be about -0.4, an increase from the value of -0.3 identified in the 1980 Demand for Public Transport Study. This increase reflects the increase in car ownership and decrease in dependence on public transport for many people over the twenty or so years since that report was published.

6.5 Effect of methodology

The results here have been estimated using a variety of methods. It is possible that elasticity values are a function of the methodology used to derive them. This issue is considered here for the three modes of bus, metro and suburban rail.

Much analytical work on public transport demand is based upon the analysis of observed behaviour by travellers, for example by examining the numbers travelling on a mode before and after a fare change. This method uses 'revealed preference' (RP) data.

An alternative approach is to use 'stated preference' (SP) techniques. These have been developed to help overcome the problems in forecasting the potential use of a alternative that does not exist yet. The method involves the presentation of a series of hypothetical questions to a sample of potential users. In the questions, the respondents are asked to trade-off between pairs of attributes that might influence their demand for public transport.

Elasticity values for three public transport modes have been discussed. Some travellers will have a choice between these modes: this means that if the fare on one of them is increased, but the fares on the others are kept constant, some travellers will switch to the alternative public transport modes. However, if the fares on all public transport modes are changed simultaneously, there will be less scope for travellers to switch modes. Hence one would expect elasticity values based on a fare change by just one public transport mode to be larger than those based on data from a fare change by all public transport modes. The former are sometimes known as 'Own elasticities' and the latter are sometimes known as 'Conditional elasticities'.

A different approach is to use some form of spatial transport model to make forecasts of travel demand under different circumstances, for example with and without a fare increase and to use the different levels of public transport demand forecast as the basis of the calculation of elasticity values. Since the comparisons are made for the same point in time, under the two assumptions about fare levels, results from this approach are labelled 'Cross-sectional modelling'.

There is very little published evidence from stated preference (SP) studies, so most of the results are RP own elasticities, RP conditional elasticities, and from cross-sectional modelling. Table 6.11 shows mean elasticity values for bus, metro and suburban rail for the UK, and Table 6.12 shows the equivalent for outside the UK. Insufficient values based on stated preference research were available to be included. It can be seen that lower elasticity values are, in general, obtained for the conditional elasticities, when the fares on all public transport modes are changed, than when the fares on only one public transport sub-mode are changed because, in the former case, travellers can switch to or from another public transport sub-mode. Cross-sectional modelling tends to produce larger elasticity values than the other methods shown for the studies from outside the UK, but between the two other methods for UK suburban rail. The small number of studies makes it difficult to form a definite conclusion.

As discussed above, the conditional elasticities, when fares on all public transport modes are changed, are considerably lower than the own elasticities, where passengers on the mode with the fare change can switch to or from other public transport modes thereby reducing the impact of the change. The cross-sectional modelling produces the largest values for bus and for metro, and a value which is lower than that for own elasticities for suburban rail. The own elasticity values are usually based on before-and-after studies and so include an element of time trend. Assuming that the majority of values are based on fare increases rather than fare decreases, because that is

Table 6.11 Short-run fare elasticities for the UK by methodology

	Bus		*Metro*		*Suburban rail*	
Methodology	*Elasticity*	*No of values*	*Elasticity*	*No of values*	*Elasticity*	*No of values*
Own elasticities	-0.46	15	-0.35	6	-0.69	7
Conditional elasticities	-0.39	18	-0.26	10	-0.49	10
Cross-sectional modelling	–	–	–	–	-0.61	3
Average	-0.42	33	-0.30	15	-0.58	20

For data and sources see appendix to Section 6.5 Tables A6.3, A6.16, and A 6.25.

Table 6.12 Short-run fare elasticities for outside the UK by methodology

	Bus		*Metro*		*Suburban rail*	
Methodology	*Elasticity*	*No of values*	*Elasticity*	*No of values*	*Elasticity*	*No of values*
Own elasticities	-0.29	1	–	–	-0.63	2
Conditional elasticities	-0.36	9	-0.21	8	-0.31	9
Cross-sectional modelling	-0.58	1	-0.86	1	–	–
Average	-0.38	11	-0.29	9	-0.37	12

For data and sources see appendix to Section 6.5, Tables A6.7, A6.19, and A 6.28

the more usual situation, then it may be that the own elasticities incorporate an element of secular trend which in the UK has, historically tended to be a decrease in patronage. The cross-sectional modelling is based on consideration of two different scenarios at the same point in time and so do not include this secular element.

There have been some studies in which the results from stated preference work has been compared with those from revealed preference analysis. Cummings *et al.* (1989) carried out research in Chicago using both revealed and stated preference techniques. The revealed preference work was based on a comparison of patronage before and after three fare increases in the 1980s, which produced fare elasticities for bus and metro combined of -0.17, -0.59 and -0.27, which have an arithmetic average of -0.34. In 1987 Cummings *et al.* (1989) carried out a stated preference survey in which 6000 questionnaires were distributed at 25 employment centres to obtain information about the journey to work; 1100 were returned. For non-work trips an interview survey was carried out at activity centres such as shopping malls that attract non-work journeys. The size of this survey is not stated. They obtained an average public transport fares elasticity value of -0.62 for the whole day, which disaggregated into -0.38 for the peak and -0.82 for the off-peak. However, they felt that these were too high, and so, when aggregating the individual results, they made corrections to the car availability classification, and established values of -0.19 for the peak and -0.44 for the off-peak, giving an overall mean of -0.33. This can be compared with the overall elasticity from the revealed preference work for February 1986 of -0.27, which is the date nearest the stated preference survey. The wide variation in the revealed preference results should be noted.

Preston (1991) used an aggregate simultaneous model to examine the effects of opening new railway stations in West Yorkshire. From this he estimated rail fare elasticities of -0.83 from the log-linear version and -0.65 from the semi-log version. They had similar levels of goodness-of-fit (R2 of 0.539 for the former and 0.532 for the latter). He then went on to estimate a disaggregate model in which a hierarchical logit model was used for work trips only. It gave an elasticity of -0.34. He then went on to estimate some elasticity values from stated preference data by examining the effects of small changes in fares on the forecasts that had been made. The overall mean elasticity value produced for rail travellers was -1.75, which is much higher than that produced using the revealed preference data. Preston (1991) argues that this difference is related to the low values of time used and the fact that users had an alternative to rail which they were already using. Also, he argued, stated preference techniques do not take into account fully the effects of habit and inertia.

Kroes *et al*. (1990) used stated preference techniques in a study on Intercity Cross-Country rail services in Britain in 1987. The main objective of the study was to examine the potential for increasing net revenue through the introduction of restrictions on the use of ‘Saver’ tickets (reduced price tickets with restrictions on the times and days on which they can be used). Whilst this is not local public transport, it is useful to see the comparison between the values estimated and the then currently accepted values from more conventional techniques, as shown in Table 6.13. It can be seen that there is close agreement between the two sets of values.

Table 6.13 Peak period rail fare elasticities for Intercity Cross-Country rail services

	Estimated from the stated preference model	*The then currently adopted Intercity values*
Employers’ business	-0.4	-0.5
Personal business	-1.0	-1.0
Leisure	-1.6	-1.5

Source: Kroes et al. (1990).

There is some debate as to how accurate elasticities derived from stated preference data are. In general, it is thought that SP gives quite accurate figures for the relative values, or ratios between elasticity values, but is not very accurate at giving absolute values (Jones, 2001).

An example of the cross-sectional approach is the use of the LTS model to look at the effects of a 20% increase in public transport fares in London, amongst other things (MVA (1992) cited in Halcrow Fox *et al.* (1993)). The LTS model is a conventional four-stage travel demand model that includes congested assignment. Peak-hour elasticities were calculated both with and without feedback to the travel costs from the effects of congestion. The former implies that congestion and crowding effects are included and that equilibrium between the trip pattern and the costs has been reached, while the latter implies that such feedback can be ignored. The values for the morning peak are shown in Table 6.14. It can be seen that the feedback to the costs produces smaller elasticity values because the extra road congestion caused by the initial switching to car would cause some public transport users not to change mode.

Table 6.14 Public transport elasticities calculated from a 20% fare increase estimated from the LTS model

	Bus	*Metro*	*Suburban rail*	*All public transport*
Without feedback	-0.24	-0.29	-0.33	-0.27
With feedback	-0.18	-0.22	-0.20	-0.19

Source: Halcrow Fox et al. (1993) citing MVA (1992).

An alternative approach to understanding the influence of the methodology used on the results is to use meta-analysis on a set of studies. Nijkamp and Pepping (1998) used this approach to try to explain the variance in public transport demand elasticities in Europe. They examined twelve studies, some of which were undertaken as part of the EXTRA project carried out in 1996-97 under the Transport Research Programme of the EU. Three of the studies were in Finland, six in the Netherlands, two in Norway and one in the UK. They concluded that there were three core variables which formed part of all the theories to explain the variation: the country, the number of competitive modes (from one to four or more) and the type of data (time series, cross-sectional survey and panel survey). Three types of model were covered by the survey: basic OLS (linear demand models), discrete choice models (logit or probit) and other types (the translog utility function, used by Oum (1992)). The type of model used was one of four variables that could explain the variation in the dependent variables, in one of two theories. (The other theory used the indicator of travel demand which was either the number of trips or the number of person-km, in place of the type of model). In both cases the other variables were the three core variables mentioned above.

6.6 Effect of types of fare change

6.6.1 The magnitude of the fare change

Fare elasticities may be affected by the magnitude of the fare change. There has been some cross-sectional modelling work on rail fares (Mackett and Bird, 1989), and the overall results from these are given in Table 6.15. In the model forecasts were made over a period of ten years with fares increased in real terms each year by a given percentage (small increases being 1.5% per year and large increases 5% per year). Linear elasticities were calculated by using the change in the number of rail trips in year ten from the forecast with the fare increase imposed compared with the situation when the fares were assumed constant in real terms. It can be seen that for fare increases of greater magnitude, the elasticity was higher than for increases of a lower magnitude. In the long run the elasticity is larger at a higher magnitude than at a lower magnitude. The model took into account the choice of location of homes and jobs, so that the higher the fare increase, the greater the number of people who made different locational choices.

Table 6.15 Effect of magnitude of fare change on fare for peak rail journey to work

	Low magnitude fare increase		*High magnitude fare increase*	
Run	*All rail trips*	*Trips to central London*	*All rail trips*	*Trips to central London*
Short	-0.31	-0.15	-0.33	-0.17
Medium	-0.32	-0.17	-0.38	-0.22
Long	-0.35	-0.19	-0.45	-0.28

Source: Mackett and Bird (1989).

6.6.2 The direction of the fare change

The response to a fare increase may not be equal and opposite to the response to a fare decrease. In other words, the elasticities may not be symmetrical. One example of this is the rail fare elasticity work in Australia, carried out by Hensher and Bullock (1979), where it was found that for the railway system in Sydney as a whole, the fare elasticity was -0.21 when the fares were increased and -0.19 when the fares were decreased. An analysis of stated preference studies in Wardman (2000) found no evidence of elasticity asymmetry; however, that study did not include very many cases where the prices fell.

6.6.3 The level of the fare

Fare elasticity is also affected by the current level of the fare relative to people's income. As Halcrow Fox *et al.* (1993) put it:

Elasticities will be higher for goods which consume a large proportion of income than for goods which consume a small proportion of income.

This statement can be illustrated by the results for London buses (Collins, 1982). When fares were particularly low, from October 1981 to March 1982, the arc elasticity was around -0.30 to -0.33, but at the higher relative fare levels in 1983, it was over -0.40.

Dargay and Hanly (1999) estimated fare elasticities for buses at different levels of fare, as shown in Table 6.16. It can be seen that much higher elasticities were obtained for the high fares (£1 in 1995 prices) compared with those for the low fares (27p in 1995 prices).

Table 6.16 Bus fare elasticities at different fare levels

	Low fares	*High fares*
Short run	-0.13	-0.77
Long run	-0.27	-1.60

Source: Dargay and Hanly (1999).

The Passenger Demand Forecasting Handbook (Association of Train Operating Companies, 2002) shows the variation in elasticity values for non-London short distance rail flows for daily tickets in its recommended values, as shown in Table 6.17. It can be seen that elasticity values increase with fare levels for all three types of area. It should be noted that the values were estimated from formulae, but the differences by area and fare level reflect observed differences.

Table 6.17 Rail fare elasticity values for non-London short distance flows (32 km and less)

	£ per mile		
	0.08	*0.10*	*0.12*
PTE	-0.36	-0.44	-0.51
Cross boundary	-0.90	-0.98	-1.05
Non-PTE	-0.65	-0.73	-0.80

Source: Association of Train Operating Companies (2002).

PTE = Passenger Transport Executive, and refers to the large urban areas in Britain outside London.

Stated preference surveys analysed by Wardman (2000) also found that elasticity values were influenced by the respondents' incomes. In the US it was found by Zahavi and McLynn (1983), cited in Goodwin *et al.* (1992), that at low fares, the fare elasticity was -0.21; this was almost double for high fares at -0.38. Therefore, it does seem that the higher the fare relative to income level the greater the elasticity value.

6.7 Variation of elasticity with type of area

6.7.1 Bus fare elasticities for urban and rural areas

Urban and rural areas differ in terms of population density, land use pattern, car ownership, and public transport service patterns. It seems likely that fare elasticities will also differ.

Table 6.18 shows elasticities for urban and rural areas in the Netherlands (Meurs *et al.*, 1990). The rural values are generally higher than the urban values. The longer-run elasticities are, as would be expected, larger than the short-run elasticities.

Table 6.18 Public transport fare elasticities from the Netherlands

	Rotterdam	*Small towns*	*Rural and villages*
Immediate	-0.29	-0.32	-0.36
After four years	-0.39	-0.35	-0.45

Source: Meurs et al. (1990).

Dargay and Hanly (1999) used county-level data to estimate elasticities for bus travel. They produced the values shown in Table 6.19 for metropolitan counties which are predominantly urban, and shire counties which contain rural areas, although many bus trips would be within urban areas. It can be seen that the values are much higher in the shire counties, probably reflecting lower levels of captivity to bus and the greater feasibility of using car as an alternative. The greater difference between the long and short runs in the metropolitan counties may reflect a greater turnover of population in such areas, allowing a wider range of responses in the long run relative to the short run compared with more rural areas.

Table 6.19 Bus fare elasticity values for English counties

	Metropolitan counties	*Shire counties*
Short run	-0.21	-0.51
Long run	-0.43	-0.70

Source: Dargay and Hanly (1999).

From the above work it appears that elasticity values are larger in rural areas than urban areas.

Dargay and Hanly (1999) produced a set of recommended values which are shown in Table 6.20 from their analysis. It can be seen that they are suggesting that in the short run, they recommend the use of similar values for urban and non-urban areas, but in the long run, higher values apply in non-urban area. This is illustrated further by the difference between the values for England and those for Great Britain, because the latter also includes Scotland and Wales, and they tend to be more rural than England.

Table 6.20 Bus fare elasticities for full fare-paying patrons

	Short run	*Long run*
Urban	-0.2 to –0.3	-0.4 to –0.6
Non-urban	-0.2 to –0.3	-0.8 to –1.0
England	-0.2 to –0.3	-0.6 to –0.8
Great Britain	-0.2 to –0.3	-0.7 to –0.9

Source: Dargay and Hanly (1999).

In general, it has been found that the less urban an area is, the more sensitive travellers are to fare changes. This may be partly due non-fare issues, such as more people having the option of travelling by car in more rural areas (due to higher car ownership, less road congestion, and fewer parking restrictions). The short run price elasticity may be highest in suburban areas (White, 2002). This is not really surprising, since it is the area where the greatest modal choice exists. Suburban areas often have good public transport infrastructure (sometimes lacking in rural areas), but they do not have as much congestion as urban areas, thus making both private and public modes of transport a realistic possibility

6.7.2 Effect of city size

In the UK, work has been carried out by Higginson (1987) who found that large conurbations have a much higher level of bus use than small towns and cities. This is partly due to parking being available in the small towns and cities, but more restricted and expensive in big cities. By contrast, large urban areas are more likely to have bus priority measures, and they have a higher number of users warranting a more frequent public transport service. In more remote areas not only is the service, if it exists, infrequent, but also passengers tend to be making longer trips, so the fare will usually be greater. However, even for journeys of the same length, the larger towns and cities tend to have lower fares than the smaller ones. Higginson (1987) also found that towns and cities with an industrial focus made greater use of public transport in general, and buses in particular, than those with a commercial focus, which were, by contrast, much more car oriented. This was due to differences in income (see Section 6.9.4) with those resident in the industrial towns and cities being more likely to belong to lower income groups, and therefore be captive to public transport, than those in the commercial towns and cities who were more likely to have a higher income and own a car.

Internationally, Mayworm *et al.* (1980), cited in Pratt *et al.* (2000), reported mean arc elasticities for public transport (including both bus and rail) varying from -0.35 in areas with city populations of less than 500,000 to -0.24 in areas with central populations of greater than 1 million, as shown in Table 6.21.

Table 6.21 Transit fare elasticities by city size

Central city population	*Greater than 1 million*	*500,000 to 1 million*	Less than 500,000
Mean	-0.24	-0.30	-0.35
Cases	19	11	14

Source: Mayworm et al. (1980) cited in Pratt et al. (2000).

Pratt *et al.* (2000) reported that bus fare elasticities from 32 urbanised areas with population under one million averaged -0.43 compared with -0.36 for 20 larger urban areas.

The ISOTOPE research project, (ISOTOPE, 1997), reported price elasticities for urban transit operations in a number of European countries. The findings were segmented into small cities (population below 500,000) and large cities (population above 500,000) as shown in Table 6.22.

Table 6.22 Price elasticities

Elasticity	*Large city*	*Small city*
Price	-0.34	-0.50

Source: ISOTOPE (1997).

According to ISOTOPE (1997):

> *The lower fare elasticity in large cities reflects the greater degree of captivity to public transport due to longer journey distances (making walking less attractive) and greater congestion and parking problems (making car less attractive).*

In Arsenio's (2000) study of rail in Spain, a price elasticity of -0.30 in large cities and -0.32 in small cities was reported.

Webster and Bly (1980) and Hamberger and Chatterjee (1987) found that in North American cities, the reverse is the case; that is, the larger cities have a higher fare elasticity than the smaller ones. According to Dargay and Hanly (1999), this is likely to be because European cities are physically smaller and are therefore both more congested than North American cities, and parking is less prevalent and therefore more expensive than in North American cities (Hamberger and Chatterjee, 1987).

6.7.3 London as a special case for bus travel

In the early 1980s a new fare structure was introduced in London, with a concentric zonal system replacing the previous distance-based fare structure, and travelcards were introduced. In 1986 bus services outside London were deregulated, while in London, competitive tendering for routes was introduced, with integrated fares and travelcards retained. Outside London deregulation had a number of effects including introducing some uncertainty about the availability of services and fare levels. There has been a significant loss of patronage in the conurbations while patronage in London has remained much more buoyant (see Chapter 5). The loss in the conurbations was due in part to the huge relative increases in fare levels following new limitations on subsidies before deregulation. For these reasons, it is worth examining bus fare elasticities for London and other parts of the UK separately. These are summarised in Tables 6.23.

Table 6.23 Bus fare elasticities for London and areas outside London

	London		*Outside London*	
Run	*Elasticity*	*Number of values*	*Elasticity*	*Number of values*
Short run	-0.42	15	-0.43	14

For data and sources see appendix to Section 6.7.3, Tables A6.31 and A6.34.

It can be seen that in the short run, at least, bus fare elasticity is higher outside London than in London, at around -0.42 in London and -0.43 outside London. One might expect a higher elasticity value for buses in London because of the availability of the Underground as an alternative. On the other hand the deregulation of buses and the greater ease of use of cars outside London mean that the elasticity might be expected to be higher there. It looks as if these factors counterbalance one another.

6.7.4 Rail in the south east and elsewhere

Table 6.24 shows the differences between elasticities in the south-east compared with outside the south-east for suburban rail. The value for south-east England is higher than elsewhere, possibly because of the greater availability of alternative public transport in London and higher car ownership in other parts of the south-east than elsewhere in Britain.

Table 6.24 Average rail fare elasticities for south-east England and areas outside south-east England

South-east England		*Outside south-east England*	
Elasticity	*Number of values*	*Elasticity*	*Number of values*
-0.61	13	-0.55	11

For data and sources see appendix to Section 6.7.4, Tables A6.38 and A6.42.

The Passenger Demand Forecasting Handbook (Association of Train Operating Companies, 2002) shows that the differences may be between trips into London and other trips for season tickets, as shown in Table 6.25, with higher values with increasing distance from London for other types of ticket.

Table 6.25 Rail fare elasticities

	Trips to London	*Other trips within the London Travelcard area*	*Outside south-east England*
Season tickets	-0.3	-0.6	-0.6
Other tickets	-0.66	-0.72	-0.9

Source: Association of Train Operating Companies (2002)

6.8 Fare elasticities for different trip purposes

6.8.1 Peak and off-peak demand

Trips made in the peak tend to be for work and education purposes, and so tend to be relatively fixed in time and space. Off-peak trips tend to include leisure, shopping and personal business trips for which there is often greater flexibility in terms of destination and time. Hence one would expect off-peak elasticities to be higher than peak ones. Table 6.26 shows elasticity values for bus, metro and suburban rail for the peak and off-peak.

Table 6.26 UK short-run fare elasticities by time of day

	Bus		*Metro*		*Suburban rail*	
Time of day	*Elasticity*	*No of values*	*Elasticity*	*No of values*	*Elasticity*	*No of values*
Peak	-0.26	9	-0.26	6	-0.34	4
Off-peak	-0.48	10	-0.42	5	-0.79	5

For data and sources see appendix to Section 6.8, Tables A6.43, A6.44, A6.45, A6.47, A6.48, and A6.49.

It can be seen that in the UK, off-peak elasticity values are about twice the value of peak ones, with slightly greater variation for suburban rail than the other modes, which may reflect the greater use of off-peak fare discounts on this mode than bus or metro. Outside the UK, the mean peak elasticity for buses is calculated to be -0.24 (based on 8 values in Table A6.46 of the Appendix to Chapter 6), while the equivalent off-peak value is -0.51 (based on 8 values in Table A6.50), suggesting a slightly higher differential between the peak and off-peak outside the UK. Insufficient numbers of values were available for metros and suburban rail systems outside the UK to allow similar calculations to be made.

Pratt *et al.* (2000) cite Linsalata and Pham (1991) who examined fare elasticities in five US cities and found the values shown in Table 6.27. It can be seen that the off-peak values are all greater than the equivalent peak values, despite the wide range in values.

Table 6.27 Peak and off-peak bus fare elasticities in the US

	Peak	*Off-peak*
Spokane, Washington	-0.32	-0.73
Grand Rapids, Michigan	-0.29	-0.49
Portland, Oregon	-0.20	-0.58
San Francisco, California	-0.14	-0.31
Los Angeles, California	-0.21	-0.29

Source: Linsalata and Pham (1991) cited in Pratt et al. (2000)

This view is further supported by Pratt *et al.* (2000) observing that:

This relationship, of off-peak ridership being roughly twice as sensitive to fare changes as peak ridership, is consistent with the findings from older studies made in London, New York and Stevenage, England.

Another US example, which supports this finding is shown in Table 6.28, from Cummings *et al.* (1989), for Chicago rail and bus excluding travel within the central area.

Table 6.28 Value of fares elasticity derived from a stated preference survey of rail and bus in Chicago

Market segment	*Peak*	*Off-peak*
Central area	-0.26	-0.39
Radial	-0.11 to -0.13	-0.36 to -0.39
Local	-0.19 to -0.24	-0.41 to -0.44
Less than 2 miles	-0.29	-0.49
Overall	-0.19	-0.44
Average all day	-0.33	

Source: Cummings et al. (1989).

O'Mahony *et al.* (1995) calculated elasticity values for public transport in Dublin and Brussels in estimating parameters for the TRENEN urban optimising model. The values obtained are shown in Table 6.29. It can be seen that the off-peak elasticities are about 2.5 times the peak values.

It may not be as straightforward as a simple division between peak and off-peak. Preston (1998) recommends that there should be several groups of elasticities: peaks,

Table 6.29 Fare elasticities in Dublin and Brussels

	Peak	*Off-peak*
Dublin	-0.267	-0.724
Brussels	-0.563	-1.261

Source: O'Mahony et al. (1995).

inter-peaks, evenings, Saturdays, and Sundays. A split into seven groups, is shown, for a non-London UK metro, in Table 6.30.

Table 6.30 Fare elasticity for adult bus users by time of day and day of week

Period	*Short run*	*Long run*
Early morning	-0.16	-0.24
Morning peak	-0.20	-0.31
Interpeak	-0.31	-0.55
Afternoon peak	-0.21	-0.27
Late evening	-0.19	-1.06
Saturday	-0.20	-0.27
Sunday	-0.69	-1.06

Source: Preston (1998).

When divided into the six groups, there are far more variations than just peak and off-peak. It can be seen that travel on a Sunday is far more elastic than at any other time in the week, reflecting the fact that Sunday journeys are more likely to be for leisure purposes than those at any other time in the week. The least elastic is the early morning, reflecting the fact that journeys at this hour are likely to be to work. Late evenings, Saturdays and the two peaks all seem to have quite similar short run elasticities, of around -0.2, although rather different long run elasticities. The fare elasticity for the peaks and Saturdays in the long run is about 1.5 times that of the short run. This is similar to long run elasticity in general, an indication of the proportion of the market that is taken up with peak travel. However, evening travel has a long run elasticity of five times its short run fare elasticity. New potential users coming into a market may have a different perception of evening travel by public transport, while for existing users, their individual circumstances may change, due to such factors as age, employment, and family situation, and this is likely to have a greater impact on their demand for evening travel than anything else.

6.8.2 Trip purpose

Trips to work and to school tend to be relatively fixed in time and space and made during peak times. Indeed they are largely the cause of the peak, which is when congestion tends to be at its greatest, making car journeys slower. Hence one expect trips to work and education to have lower elasticity values than other trip purposes. Table 6.31 shows elasticity values for London deduced from a literature review carried out as part of the London Congestion Charging Study (Halcrow Fox *et al.*, 1993). The most surprising figure is the low value for off-peak bus travel. Otherwise, work has the lowest value, particularly by metro.

Table 6.31 Short run elasticity values for London estimated from a literature review

	Bus	*Metro*	*Suburban rail*
Home-based work	-0.28	-0.15	–
Peak	-0.20 to –0.30	-0.20 to –0.29	-0.20 to –0.33
Home-based other	-0.38	-0.26	-0.45 to –0.55
Employers' business	–	-0.23	-0.50
Off-peak	-0.14	–	-0.58

Source: Halcrow Fox et al. (1993).

Gunn *et al.* (1998) examined the fares elasticity for journeys by purpose for public transport trips in Paris, as shown in Table 6.32. It can be seen in Table 6.32 that the least price-sensitive trip purposes are home-to-work and business trips. The surprising value is the very high one for education, which may reflect the specific nature of such trips in the study: for example, they may be short enough to walk in many cases.

Table 6.32 Elasticity by specific trip purpose

Purpose of trip	*Public transport fare elasticity*
Work – white collar	-0.23
Work – blue collar	-0.24
Business	-0.26
Education	-0.84
University	-0.29
Regular shop	-0.80
Other shop	-0.30
Other	-0.45
Non home-based work	-0.55
Non home based other	-0.42
Total	-0.34

Source: Gunn et al. (1998).

For off-peak travel Pratt *et al.* (2000) suggests the fare elasticities for different trip purposes shown in Table 6.33. It is noticeable that in the off-peak, the smallest price elasticities are mostly for purposes that also dominate the peak that is getting to work and school. The largest price elasticity is for recreation trips.

Table 6.33 Off-peak fare elasticity values by trip purpose

Trip purpose	*Arc elasticity*
Work	-0.11
School	-0.19
Shop	-0.25
Medical	-0.32
Recreation	-0.37
Social	-0.25
Other	-0.19

Source: Pratt et al. (2000).

When comparing Tables 6.32 and 6.33, it should be borne in mind that Table 6.32 shows elasticities by trip purposes at all times, whereas Table 6.33 shows only values for off-peak times; it can be seen that in both cases, trips for work purposes are the least price-sensitive.

Steer Davies Gleave (1993) reports price elasticities derived from stated preference analysis, segmented by trip purpose. These are shown in Table 6.34. This shows a lower value for commuting journeys than for leisure and shopping. The business trips paid by the employers have very low elasticity values, because an employer is likely to be less sensitive to a fare increase than a passenger paying his or her own fare.

Table 6.34 Rail fare elasticities in south east England

Market segment	*Elasticity*
Commuting	
London destination, up to 15 miles	-0.35
Non-London, up to 15 miles	-0.51
Business (all distances)	
Fare paid by employer	-0.05
Fare paid by passenger	-0.43
Leisure and shopping	
Railcard, up to 60 miles	-0.60
Non-Railcard	-0.58

Source: Steer Davies Gleave (1993).

These values follow the same pattern as the recommended values for the London Travelcard area the Passenger Demand Forecasting Handbook (Association of Train Operating Companies, 2002), which are shown in Table 6.35.

Table 6.35 Rail fare elasticity values by trip purpose for the London Travelcard area

Commuting	*Business*	*Leisure*
-0.3	-0.2	-1.0

Source: Association of Train Operating Companies (2002).

6.9 Elasticities for different types of traveller

6.9.1 Access to a car

Cross-sectional microsimulation modelling work carried out by Mackett (1990), simulating the behaviour of a sample of the population in Leeds at a micro scale, showed that in the long run the public transport elasticity of those with a car available was -0.75 compared to -0.48 for those without a car. The same modelling also found the public transport elasticity of those who held a driving licence was -0.80, compared to -0.32 for those who did not hold a licence. The main point is that car owners often have an alternative to public transport, because as Hamberger and Chatterjee (1987) say:

> Passengers who have an alternative mode of transportation are more responsive to fare changes than others and, therefore, have a more elastic response to a fare change.

The effect of car ownership will be discussed in much greater detail in Chapter 10.

6.9.2 Gender

The microsimulation modelling work carried out by Mackett (1990) found that in the long run the public transport elasticity of males was -0.59 compared to -0.39 for females. This implies that males are more sensitive to public transport fares than females, probably because they are more likely to have access to a car. This view, that females have a lower price-elasticity than males, is supported by Wardman (2000).

6.9.3 Age group

A study by Goodwin (1987) observed that bus fare elasticity decreased with age, and produced a 'generating model' which showed that the short run elasticity which averaged -0.49, was -0.87 for the youngest age group and -0.25 for the oldest age group. There is further evidence that elasticity decreases with age in Goodwin and Layzell (1983).

Studies, segmenting public transport users into the user groups of children, adults, and elderly and disabled, have been carried out in the UK on bus and rail travel by Preston (1998), bus in the UK by Goodwin *et al.* (1988), and internationally in Australia for public transport in general by Luk and Hepburn (1993). These are given in Table 6.36.

The elasticities for children given by Preston (1998) are of much greater magnitude than the other two cases. A possible explanation for this may be that in Preston's (1998) work, specific school buses were not included, but in the other cases they probably were. The children will be largely captive to buses put on especially to take them to school, and so they would be expected to have low elasticity values. Combining these with the other values from Preston's (1998) work would reduce the average values. Neither Goodwin *et al.* (1988) or Luk and Hepburn (1993) make it clear whether specific school travel was included. Luk and Hepburn (1993) commented that fare elasticities for school children were likely to be low because they have very limited travel options.

Many of the trips by the elderly and disabled will be discretionary, assuming that most of them are not in employment and so one would expect high elasticity values for these types of trips. On the other hand, many of

Table 6.36 Fare elasticities segmented by age group

Study	*Source*	*Adults*	*Children*	*Elderly and disabled*
UK, bus	Preston (1998)	-0.28	-0.40	-0.29
UK, rail	Preston (1998)	-0.59	-0.47	-0.77
UK, bus	Goodwin *et al.* (1988)	-0.3	-0.2 to -0.15	0 to -0.7
Australia, general	Luk and Hepburn (1993)	-0.28	-0.11	-0.19

Sources: Preston (1998), Goodwin et al, 1988), and Luk and Hepburn (1993).

them will have low incomes and low car ownership, and some may have difficulty walking, so that for trips that have to be made, public transport may be the only option, and so low elasticity values would be expected. Variations in the mix of these factors may explain the differences between the elasticity values for the elderly and disabled relative to the whole adult population.

6.9.4 Income

Those with higher incomes are more likely to have a car available as an alternative to public transport. Hence under some circumstances they are more likely to be sensitive to fare changes. On the other hand, by definition, they have more money available to absorb the effects of a fare increase. Those on low incomes may be more prepared to walk than those with high incomes and higher values of time. Thus, one might expect low income travellers to have higher elasticities for short trips, and high income travellers to be more sensitive for longer trips. Where the values are not differentiated by trip length, one would expect the greater the mean trip length, the greater the likelihood of high income travellers having a higher elasticity value.

Table 6.37, based on work by Halcrow Fox *et al.* (1993), shows that the greater a traveller's income the more elastic the response to a fare increase. This seems to be the case for both bus and rail according to these figures. Similar trends are followed for all three modes and for trips to work and to elsewhere. Similar evidence is put forward by Hamberger and Chatterjee (1987).

Table 6.37 Elasticities by mode and journey type

Trip purpose	*Income*	*Bus*	*Metro*	*Suburban rail*
Home-work	Low	-0.30	-0.20	-0.40
	Medium	-0.33	-0.30	-0.50
	High	-0.45	-0.50	-0.60
Home-other	Low	-0.50	-0.60	-0.45
	Medium	-0.60	-0.65	-0.55
	High	-0.70	-0.75	-0.70

Source: Halcrow Fox et al. (1993).

The values shown here are the mid-points of the ranges quoted by Halcrow Fox et al. (1993).

6.10 Elasticity by distance travelled

6.10.1 Bus fare elasticities

The longer a journey, the greater the total fare paid, and so the greater its proportion of income. Hence one expects elasticities to increase with journey length.

White (1981) found an elasticity for medium distance bus journeys -0.4 which doubled for long distance journeys to -0.8.

This relationship is reflected in demand elasticities for bus trips in Melbourne, estimated by Luk and Hepburn (1993), shown in Table 6.38. The distance increases as the number of sections increases, and with it the elasticity increases. A possible explanation for the particularly high

Table 6.38 Estimated demand elasticities for bus trips by section

Trip length	*Elasticity*
City section	-1.39
One section	-0.28
Ten or more sections	-0.85

Source: Luk and Hepburn (1993).

elasticity in the city section is that people may substitute transport trips by walking here.

The increase of elasticity with distance may not necessarily continue unabated. A time series study of bus fare elasticity in the Greater Manchester areas, (Grimshaw, 1984) found that, at peak times, elasticity did indeed increase with distance, from -0.13 to -0.22 for adults and children, and from -0.34 to -0.56 for the elderly. In off-peak times the elasticity increased with distance from -0.53 to a maximum of -0.67 (for trips of 1.5 miles or 2.4km), and then dropped down to -0.40 for longer distance trips (up to 13 miles or 20.8km). Furthermore, for very short trips, the elasticity may be much higher. Another bus fare study, also in the Greater Manchester area (Tyson, 1984), found that while bus fare elasticities for adult fares in general were -0.5, they increased to between -0.55 to -0.75 for very short distance journeys, which were presumably ones which might be replaced by walking.

It therefore looks as though fare elasticities are initially high for very short journeys, dropping sharply to a low, and then increasing gradually with distance, until a peak point after which they decrease to a lower level for very long distances (White, 2002).

6.10.2 Rail fare elasticities

Work by Preston (1998) has produced the rail fare elasticity results given in Table 6.39, for adult single fares in a British PTE (Passenger Transport Executive) area with 8 distance based fare bands. The pattern is not very clear, but there seems to be a decrease with increasing distance in both the short and long run.

Table 6.39 Adult single rail fare elasticities by distance based bands

Fare band	*Short run*	*Long run*
1	-0.76	-0.83
2	-0.53	-0.65
3	-0.53	-0.62
4	-0.51	-0.61
5	-0.60	-0.66
6	-0.38	-0.52
7	-0.48	-0.56
8	-0.48	-0.55

Source: Preston (1998).

O'Fallon and Sullivan (2000) cited a study by Transmark/SDG (1993), of rail fare elasticities in Sydney, which investigated the effect of both distance and peak/off-peak travel. In this case, long distance was defined as being journeys over 20 minutes. It was found that for short distances, the elasticity was -0.59 in the peak and -0.98 off peak, while for long distances the elasticity was noticeably lower at -0.26 in the peak and -0.50 off-peak.

The Independent Pricing and Regulatory Tribunal of New South Wales (1996) in Australia, cited by the Australian Bureau of Transport Economics (2003), has produced elasticity values for Cityrail services in Sydney, as shown in Table 6.40. It can be seen that all the values, peak and off-peak, CBD (central business district) and non-CBD, decrease with increasing trip length.

Table 6.40 Elasticity values for Cityrail services, Sydney Australia

	Peak		*Off-peak*	
Trip length	*CBD*	*Non-CBD*	*CBD*	*Non-CBD*
Short	-0.29	-0.78	-0.62	-0.66
Medium	-0.19	-0.28	-0.25	-0.36
Long	-0.08	-0.18	-0.12	-0.21

Source: Independent Pricing and Regulatory Tribunal of New South Wales (1996) cited by the Australian Bureau of Transport Economics (2003).

In general, it seems that in the rail industry, fare elasticity decreases with distance. This may be because rail fares are often subject to a taper, that is, the fare per unit distance decreases with increasing distance, so one would expect a lower elasticity value with increasing distance. Also, many longer rail journeys may have car as a viable alternative, whereas shorter rail journeys may be within urban areas where congestion makes use of the alternatives of car and bus less attractive. These arguments for lower elasticities with increasing distance have to be set against the argument put forward above about fares for longer journeys being a greater proportion of income. The relationship between distance travelled and fares elasticity will depend on the relative strength of these factors in a particular situation.

6.11 Effect of ticket types and fare systems

The effects of ticket types depend on their market shares. If the ticket is a very common one (such as London's Travelcard) then there is a very different response compared to that for a very specialist type of ticket catering for a niche market.

The various types of fares have been outlined in Section 6.2. The most common types of tickets to have been analysed in Britain are zonal travelcards and season tickets. A study by Gilbert and Jalilian (1991), found that the introduction of travelcards in London increased the number of Underground trips by 10% and bus trips by 16%. For Underground users, a travelcard offered more travel opportunities to users than the Underground season tickets which they replaced. Bus revenues were boosted by 14% with Underground revenue down by almost the same amount. This difference was partly due to the method used to allocate the revenue from travelcards. Previously, the Underground had kept 100% of the revenue from season tickets, but with travelcards, London Underground only received 70% of the revenue with the rest going to London Buses.

York (1995) found lower elasticities for travelcard prices for both bus and rail users. This may be because when travelcard prices are raised in comparison to cash fares, people switch to paying cash, but still make 10 journeys a week to and from work. A study by McKenzie and Goodwin (1986), cited in Goodwin *et al.* (1992), on bus patronage in the Midlands found the elasticity for travelcard holders to be significantly lower in both the short and medium run than for those paying in cash fares. Part of the reason for this may be that users who actually purchase a travelcard may be more likely to use public transport than those who do not. However, it has often been found that patronage increases following the introduction of the travelcard, suggesting that it does stimulate demand. This view is supported by Fowkes and Nash (1991), who analysed the introduction of the London Travelcard, which slowed the decline in bus use. Employment growth may also have been influential, as might have been road congestion which was not modelled explicitly.

Preston (1998) found that the medium run price elasticity for adults using pre-paid tickets for bus travel in English metropolitan areas was -0.74 compared to -0.28 for those paying cash fares Similarly for adults using a pre-paid ticket for rail travel, the elasticity was -1.02 compared with -0.59 for those paying in cash fares, while for children using a pre-paid ticket for rail travel the elasticity was -1.18 compared to -0.47 for those paying cash fares. All this suggests that pre-paid ticket holders are more sensitive than those who pay cash fares. However there was much wider variation among the results for pre-paid ticket holders, and, in general, users of pre-paid tickets are often less price sensitive, in the short run. For season ticket holders, this is partly because they do not pay the new fare until they renew their season ticket. For both season ticket holders and those whose pre-paid tickets are of shorter duration there is also a significant convenience factor.

Another type of fare change is from gradual fares to zonal or flat fares. An example of this has been in the Brighton area (Langridge, 2001). In January 2001, for a four month trial period, the Brighton and Hove Bus Company, part of the Go-Ahead Group, switched from a distance-based graduated fare scale to a widely-advertised single flat fare of £1 in the Brighton and Hove conurbation. Overall, this meant there would be an increase in the average fare, which might be expected to lead to a decrease in patronage. The scheme was introduced for a trial period so that if it were unsuccessful, it could be withdrawn easily. However, the scheme has proved to be popular with passengers, because they now know exactly how much it will cost to board the bus, producing rising revenues and a year on year patronage growth of 8.5% (Transit, 2002). The scheme has also been popular with bus drivers, because it makes their job easier, and boarding times are quicker, which means that bus reliability is increased. Therefore, the scheme will be continued for the foreseeable future. There may be problems when the fares are increased in line with inflation, as the simplicity of having a round-figure fare will be removed (Transit, 2002).

The Independent Pricing and Regulatory Tribunal of New South Wales in Australia (1996), cited by the Australian Bureau of Transport Economics (2003) examined fare elasticities for the Sydney region and found, for buses, a value of -0.078 for single tickets and -0.383 for TravelTen, a multi-journey ticket. For rail, the values shown in Table 6.41 were obtained. It can be seen that travellers are more sensitive to fare increases in more expensive longer-term tickets. Non-commuters are least sensitive to increases in off-peak individual tickets, reflecting the irregularity of such trips, and the price sensitivity and greater flexibility in terms of time of such travellers.

Table 6.41 Fare elasticities for rail in the Sydney region

Ticket type	*Commuters*	*Non-commuters*
Train single	-0.08	-0.093
Train off-peak	-0.123	-0.043
Train weekly	-0.25	-0.691
Train TravelPass	-0.529	-1.103

Source: Independent Pricing and Regulatory Tribunal of New South Wales (1996), cited by the Australian Bureau of Transport Economics (2003).

In the rail sector, Hensher (1998) noted that previous studies had usually ignored the possibility that passengers might switch ticket-types within a mode. On carrying out modelling, based on revealed and stated preference surveys, Hensher (1998) found that if the price of a particular type of ticket increases, then passengers are more likely to change to another mode than to change their type of ticket. This may be partly explained by the fact that the fare-elasticity for particular types of rail tickets is context-specific; that is, it will be higher if there are a lot of reasonably similar alternatives than if there are not. Indeed, one of the difficulties in measuring the effect on patronage following a change in types of fares, such as the introduction of a travelcard, is that in some cities there is a lot of switching to or from cash fares, so there are significant cross-effects which have to be taken into account.

In addition, there is also a problem of fare elasticity not being symmetric which means that the direction of the fare change has to be considered. Often, when travelcards have been introduced, they have been priced lower than cash fares. In some cases they were subsequently increased by a larger proportion than the cash fare (White, 2002).

Changing level of discounts for the prepayment of fares is one form of alteration in fare structure pricing relationships. Prepayment may involve purchase of multiple-ride tickets, tokens, stored fare or unlimited-ride passes. Three US examples, from Denver, Philadelphia and Virginia, of the effect of introducing various fare initiatives can be found in Trommer *et al.* (1995).

In a low-income area in Philadelphia, it was found that offering packs of discounted tokens, and reorganising the size of the token packs to reflect the needs of different types of travellers, helped to retain patronage in spite of recession in the early 1990s, with many cash payers continuing to travel, because they could use the discounted tokens.

Similar initiatives in another low income area in Richmond, Virginia, failed to reduce the decline in patronage. It is thought that the main reason for this is that in May 1990, following a survey, Southeastern Pennsylvania Transportation Authority (SEPTA), operating in Philadelphia, reorganised the size of their token packs to reflect the needs of different types of travellers. When first introduced, the tokens were sold in packs of 7, which was soon increased to 10. Following the survey, tokens were made available in packs of 2, 5 and 10.

By contrast Greater Richmond Transit Company (GRTC) operating in Virginia, introduced their Supersaver Ten, a deeply discounted book of ten tickets, in February 1992, accompanied by a large advertising campaign. Trommer *et al.* (1995) suggest a ten ticket book was not really suitable for the majority of GRTC's market, who are doing part time or casual work, and it so failed to prevent large drops in patronage during the recession. The advertising campaign did increase patronage, but most of the new riders paid in cash. Revenues continued to decline, but rather than reorganise their ticketing, GRTC increased the price of the Supersaver Ten, by around 33%, thus eliminating the deep discount.

In Denver, the introduction by Regional Transportation District (RTD) of a discount ten-trip ticket called 'FareSaver' in 1989 has been largely responsible for RTD's 4% annual growth. In 1991, RTD also introduced an environmental travelcard called Eco Pass, which has had less of an impact than 'FareSaver', because only 4% of RTD's riders use it, compared to the 14% who use 'FareSaver'. The Eco Pass is purchased by employers, in a similar manner to medical insurance, as a tax-free benefit to their employees (the employer may pass none, part or all of the full cost of the pass on to the employee), and allows unlimited travel on all RTD routes. It is designed to encourage employers to provide these instead of company cars or parking spaces.

The Eco Pass is an example of an 'environmental travelcard'; another particularly successful example of such a ticket type has been described by Fitzroy and Smith (1998b). Since the early 1980s, the German city of Freiburg experienced an enormous and unprecedented rise in the demand for local public transport. The authors state that the main explanation for this increase in demand is the introduction of low cost 'environmental' travelcards with the key characteristics of transferability across friends and family and wide regional validity across operators; these seem to indicate that season tickets have considerably augmented transit demand without seriously exacerbating the operating deficit. Similar types of travelcards have been introduced in some parts of the UK, for example the 'Megarider' in the East Midlands.

Simple fare reduction schemes can have an adverse effect on revenue. A variety of fare experiments have been carried out, especially in Norway (Norwegian Trial Scheme for Public Transport, 1993), where it was found that successful initiatives to persuade people to make greater use of buses, required rather more than just fare reductions. Increasing service levels, making bus routes more easily accessible for mobility-impaired persons, and marketing campaigns to make people more aware of what is available to them, have a combined positive effect on patronage. If the combination works well it can also increase both patronage by users who would not previously have considered the service, and increase revenue.

Cervero (1990) studied the impacts of time-of-day fare programmes on patronage on a number of transit systems in the US. The study findings are summarised in Table 6.42. This shows that there is a significant difference between the peak and off-peak elasticity (see Section 6.8.1), but also that users are far less sensitive to peak surcharges than off-peak discounts and that differential increases may cause less loss of patronage than a blanket increase, since the value for differential increases is rather lower than the mean values identified in Sections 6.3 and 6.4.

Table 6.42 Effect of ticket types on US transit systems

Type of fare change	*Mean estimated fare elasticity*	*Number of transit systems*
Off-peak discount	-0.67	6
Differential increases	-0.30	5
Peak surcharges	-0.27	6

Source: Cervero (1990).

6.12 Zero fares

It has been suggested by Daly and Zachery (1977), that free public transport would reduce car ownership by 3% and car availability by 10%, resulting in a total reduction in car use of 22%. Very little work seems to have been carried out on the issue directly since then.

Sometimes, particular groups of users have zero fares. During the time-period of the investigation by Preston (1998) (see Section 6.9.3) elderly and disabled people initially had zero fares in off-peak periods on buses, but this was changed to a flat fare, and the overall elasticity for cash fares for them was found to be -0.29.

As well as zero fares for certain groups of people, it is also possible to have zero fares in particular areas. For example, on the light rail systems in Calgary and St Louis, travel is free in the city centre. Internationally, work has been carried out by Berechman (1992) who states that intra-urban transit demand is more time-elastic than fare-elastic by a factor of approximately 2 to 3. It is reported by Berechman (1992) that:

> *...several experiments with free transit have corroborated this general contention by showing that the effect of zero fares on travel demand was mainly to divert walking and cycling trips, but not car trips, to transit.*

Pratt *et al*. (2000), reports that a majority of free transit services involve bus operators in central business districts and universities. An example from Richmond Virginia was cited where a fare was introduced on a previously free transport service. This was found to have an elasticity of -0.33 overall, and -0.32 for trips not from the CBD (Central Business District). Results reported by Mayworm *et al.* (1980) cited in Pratt *et al.* (2000) is shown in Table 6.43.

Table 6.43 Free public transport fare elasticities

Service restriction	*Off peak elasticity*	*All hours elasticity*
CBD (Central Business Districts)	-0.61	-0.52
Senior Citizens	-0.33	
Students		-0.38
No restrictions	-0.28	-0.36

Source: Mayworm et al. (1980) cited in Pratt et al. (2000).

Pratt *et al.* (2000) concluded that:

> *On balance, it seems likely that CBD free fare programs do attract more ridership than average bus fare elasticity values would predict, but that other applications fall within normal ranges of ridership response to lowered or otherwise altered fare levels, particularly when city size is taken into account.*

Besides instances where there is actually a zero fare, either in a particular area (such as a city centre) or for a particular group of people (such as the elderly), there are also many instances where users with some form of travelcard may make an additional journey because the marginal fare is zero. These users, such as regular commuters, who find it convenient, and possibly cost-saving to purchase a season ticket for their journey to work or school, then find they can make use of it for additional trips, at zero marginal cost, for non-essential purposes (White, 2002).

It has been found, from stated preference surveys (Wardman, 2000), that users who pay zero fare appear to have a very low sensitivity to fare change. It is thought that this is because they tend to disregard fares in a stated preference exercise.

6.13 Effect of concessionary fares

6.13.1 Introduction

The Transport Act 2000 requires public transport authorities in England and Wales to provide elderly and disabled passengers with a minimum concession of a free bus pass entitling the holder to fares half the standard adult fares or lower. This came into force in April 2001. The Transport Act 2000 does not preclude authorities from continuing to provide tokens in addition to meeting the minimum statutory requirements. Similarly, they can continue using flat rate fares provided either that the flat rate is fixed at a level such that the passengers with concessions pay half price for even the cheapest journey or this is offered in addition to the statutory minimum. As a result many flat fare schemes are now offered as maximum fare schemes (Dillon, 2001).

In Scotland, elderly and disabled people benefit, as a minimum, from free local bus travel within scheme boundaries for journeys outside the morning peak. This came into force in September 2001. In Wales, elderly and disabled concessionary travellers are entitled to free bus travel throughout the country, funded by the Welsh Assembly.

In addition to the concessions offered to elderly and disabled passengers, some authorities offer concessions to other groups such as school children (in addition to assistance for transport to school provided by the local authority under the provisions of the Education Acts) and students. At least 23 local authorities in England had a concessionary fare scheme for school children. 26 local authorities provided a concessionary fare scheme for further education students (Department for Transport, Local Government and the Regions, 2001a).

The main focus of the following sections is on local bus service concessionary fares for the elderly. There is very little evidence of effect of concessionary fares on transport demand in other social groups, or for other modes.

6.13.2 Types of concessionary fares available

There are a variety of different types of concessionary fare on offer. Broadly, they can be split into two categories – pass-based systems and token-based systems. With the former system, the pass, which may be provided free or at cost to the user, entitles the bearer to reduced-cost travel. Over 94% of local authorities offer a half fare concessionary scheme for the elderly, 90% for the disabled and 60% for blind people (Department for Transport, Local Government and the Regions, 2001a). The remaining local authorities offer either a flat-fare or free-travel scheme. A small number of local authorities offer a token system as an alternative to the main pass-based system. With a token system, the user purchases at a reduced rate (or is given) tokens in advance, which can then be used towards the travel costs. Some schemes have upper limits on the value of tokens that are distributed to each eligible person.

6.13.3 Concessionary schemes currently in operation

In 2001 there were over 400 different concessionary fare schemes for the elderly in operation, with many authorities running a new half-fare pass scheme in response to the statutory requirements alongside existing programmes (Dillon, 2001) as Table 6.44 shows. Over 40 percent of local authorities offered an alternative to their half fare scheme (Department for Transport, Local Government and the Regions, 2001a). Most local authorities offered the same scheme for the elderly as for disabled people (Department for Transport, Local Government and the Regions, 2001a).

Schemes differ in detail, such as the modes included in the scheme: the most basic schemes restrict travel to local bus services, whilst others include rail, ferries, community transport or taxis. Similarly, some schemes only cover travel within the District whilst others include travel in neighbouring areas. Many of the concessionary fare schemes on offer to students were limited to journeys to and from their place of education (Department for Transport, Local Government and the Regions, 2001a). Some schemes also place time restrictions on pass and token use, for example concessions are often only available after the morning peak.

Table 6.44 A summary of concession schemes for the elderly, 2001

	Pass based scheme					
	Free fare	*Flat/Max fare*	*Half fare*	*Other fare*	*Total*	*Offering alternative schemes*
London	1	0	0	0	1	0
English PTAs	2	3	0	1	6	2
English counties	0	0	19	0	19	6
English unitaries	1	2	40	2	45	20
English districts	2	2	233	1	238	104
Strathclyde	0	1	0	0	1	0
Scottish unitaries*	1	7	8	4	20	1
Welsh unitaries	1	0	21	0	22	0
Total	8	15	321	8	352	106

**Includes pass-based schemes with a charge for issuing the pass.*

Sources: Department for Transport, Local Government and the Regions (2001a), Dillon (2001).

6.13.4 Demand for concessions

Uptake of concession schemes will vary depending on the area and type of scheme on offer. For example, Rye *et al.* (2002) estimate that the uptake of half-fare passes in Scotland ranges from 24% in the Western Isles to 72% in Perth and Kinross. The National Travel Survey (NTS) 1999/2001 Update, (which must understate the current take-up), gives an average take-up of 49% in Great Britain as a whole, and 79% in the London Boroughs (Department for Transport, 2002b). However, quality data on the uptake of concessionary schemes is hard to come by as many local authorities do not keep accurate, up-to-date records of pass holders. For example Fife estimate that 65,000 passes have been issued for their concessionary fare scheme whilst the elderly population of Fife in 1997 was only 64,125 giving an uptake rate of 101% (Rye *et al.,* 2002).

The numbers of trips made per pass holder also varies by scheme. Schemes which charge for a pass are likely to have higher trip rates per pass holder than those which provide a free pass, as travellers are unlikely to be willing to pay for a pass unless they can recoup the full cost of the pass through the travel reductions provided.

6.13.5 Trip generation

Offering concessionary fares to certain groups of passengers is likely to result in additional trips being made. Fare elasticities for concessionary fares may not be the same as those for changes in full fares for a number of reasons. Concessionary fares are typically aimed at alleviating social exclusion and thus target low-income groups. The age and mobility of concession holders may also affect trip generation rates, as will the way in which the scheme is run. For example token holders may use the tokens to reduce fares for essential journeys to an affordable level, or may view the tokens as a bonus to be used for additional trips. Most of the studies reviewed break down trip generation rates by the type of concessions scheme. Research by Balcombe and Astrop (1995) suggest that fare elasticities for concessionary travel may also vary with trip length and fare level.

Hopkin (1986) compared travel patterns of pensioners with concessions with the travel patterns of three different groups to estimate the trip generation factors given in Table 6.45. Hopkin's analysis is based on National Travel Survey (NTS) data for 1978/9. The three comparison groups – pensioners without concessions, economically-inactive people aged 50 up to pension age, and economically-inactive people aged 18 up to pension age – were normalised for type of area (settlement population size), household car ownership and SEG/ employment status. The pensioners without concessions group includes both those living in areas where no concessions are provided and those choosing not to take up a concession scheme on offer. The trip generation rates based on comparisons with this group are likely to be an overestimate

Table 6.45 The percentage difference between bus use by concession holders and the non-concession holders weighted groups

	Pass provided free				
	Free fare	*Reduced fare*	*All*	*Pass paid for*	*Tokens*
Bus stages 'generated'					
Pensioners without concessions	83	93	81	88	30
Economically inactive, 50-pension age	42	39	39	32	-12
Economically inactive,18-pension age	39	40	37	33	-15
Bus mileage 'generated'					
Pensioners without concessions	71	78	69	100	44
Economically inactive, 50-pension age	50	43	45	30	7
Economically inactive, 18-pension age	47	41	42	31	-4

Source: Hopkin (1986).

Hopkin (1986) does not explain why the provision of a token scheme seems to suppress travel. It could be that the comparison group choice of economically inactive adults was incorrect. Alternatively, it may be that the difference in fare paid when the pensioner has tokens to use and when the tokens have run out is perceived as too great. Thus the pensioner desists from using the bus when the token supply has been depleted.

O'Reilly (1990) attempted to update Hopkin's figures using National Travel Survey data for 1985/6. Unfortunately the results are not directly comparable as O'Reilly grouped concession types differently, and used a different measure of settlement type (density rather than population) to weight the comparison groups. O'Reilly's results seem to show similar rates of trip generation, to those produced by Hopkin (1986) (Table 6.46).

A major weakness of the above results is that neither set include the effect of the fare paid, once the pass or tokens are purchased, on the trip generation rates.

Balcombe *et al.* (1998) also based their analysis on National Travel Survey data. Using data from surveys conducted between 1989 and 1994, Balcombe *et al.* (1998) applied regression analysis to bus travel data for people living in 1 or 2 person households aged 50 plus. Differences

Table 6.46 The percentage difference between the number of bus trips made by concession holders and non-concession holders

	Pass provided			
	Free	*Paid for*	*Tokens*	*Other concessions*
Pensioners without concessions*	42	54	18	46
Economically inactive, aged 18 to pension age*	25	47	-7	17

**Weighted groups.*
Source: O'Reilly (1990).

in car ownership, bus service level and employment were taken into account through inclusion as explanatory variables in the analysis. Gender was also included but found to be an insignificant determinant of bus travel. Concessionary fares were included by calculating the effective fare paid based on average adult fares. Two models were produced using different service level variables. They had similar explanatory powers (R2 = 0.79 and 0.78). Trip generation rates were then estimated by feeding different fare values into the resulting models, whilst keeping other variables constant. The ratios of the trip generation rates of those with various concessions to those of similar people without concessions are shown in Table 6.47.

Table 6.47 Ratio of trip generation rates of those with concessions to those of similar people without concessions based on regression analysis of National Travel Survey data 1989/94

	Free travel	*Half fare*	*Flat fare*
Trip generation rate	1.59-1.62	1.35	1.32-1.35

Source: Balcombe et al. (1998).

Balcombe *et al.* (1998) collected data on nine different locations that had introduced a change in concessionary fares and commissioned surveys. In addition, data were used for four areas where no changes to the concessionary fare schemes on offer had been implemented. Using these data, the underlying trends in demand were identified and demand models were then fitted to the data for each area. Both constant elasticity and exponential elasticity models were tested. Weather and bus mileage (representing service levels) were also included in the models where possible. Fare elasticities inferred at the concessionary fare ranged from -0.04 to -0.27, compared with those predicted at full fare, which ranged from -0.27 to -1.03.

Balcombe *et al.* (1998) also estimated fare elasticities and generalised cost elasticities for concessionary fares by comparing four areas (2 in Berkshire and 2 in Avon) with different concessionary fare schemes in place (free fare pass, reduced fare pass, and tokens). A demand curve was derived by plotting mean weekly trips against the effective fare paid by concessionary pass holders. Elasticities were calculated separately for households with cars and without cars (Table 6.48).

Table 6.48 Generalised cost and fare elasticities for concessionary fares by car ownership

	Fare elasticity @ 50p full fare	*Fare elasticity @ 75p full fare*	*Generalised cost elasticity*
Non car owners	-0.35	-0.38	-0.46
Car owners	-0.50	-0.53	-0.60

Source: Balcombe et al. (1998)

Goodwin *et al.* (1988) went a step further and calculated fare elasticities separately for different types of area (low, medium and high density) as well as for car owning and non-car owning households. The estimates (Table 4.49) are based on data from one-day diaries sampled from homes in six towns with different types of scheme (two each of no concessions, half fare and free travel). Elasticities range from 0 to -0.7. Goodwin *et al.* (1988) also calculated elasticities using fare per minute as a proxy for cost per mile. This yielded very similar results to those presented in Table 6.49.

Table 6.49 Fare elasticities for concessionary fares by car ownership and area type

	Low density	*Medium density*	*High density*	*All*
Non car owners	-0.51	-0.40	-0.23	-0.38
Car owners	-0.40	-0.69	-0.01	-0.35
All	-0.39	-0.45	-0.19	-0.35

Source: Goodwin et al. (1988)

Fairhurst (1996) calculated trip generation rates as a result of the London-wide free fare concessionary scheme based on data from the LATS (London Area Transport Survey) household survey data for 1991/2. Fairhurst (1996) found increases in the daily trip generation rates of between 10% and 50% depending on economic status and sex (Table 6.50). The increases in the trip generation rates were higher for non-economically active adults aged 50+ than for economically active adults of the same age group and slightly higher for females than for males.

Table 6.50 Estimates of the percentage increase in the number of trips as a result of the free scheme in London for buses

	Male	*Female*
Non-economically active	45	50
Economically active	10	10

Source: Fairhurst (1996).

Other studies include a before and after study carried out by Steer Davies Gleave (1991) for South Yorkshire PTE, examining the effect of an increase in the concessionary flat fare rate from 10p to 20p. The study found a 13% reduction in trips made by pass holders. The biggest reduction was in the number of shopping trips undertaken, with a reduction of 21%.

Balcombe and Astrop (1995) estimated a generation factor of 2.04 ±20% based on responses to 'reconstructive interviews' taken before and after a change to the concessionary fare scheme in Tyne and Wear. The 'reconstructive interviews' involved asking concessionary pass holders how they would change their travel behaviour in response to hypothetical concessionary fare increases. Travel diaries and PTE continuous monitoring survey data were used to aid robustness of the technique.

6.13.6 The effect of time restrictions

Balcombe and Astrop (1995) found in Tyne and Wear that increasing the concessionary fare time restrictions to include the evening peak resulted in a redistribution of journeys, with the proportion of journeys being made in the evening peak doubling under the new regime. This increase was accompanied by a corresponding decrease in the proportion of journeys being made after the evening peak. This suggests that, as a result of abolishing the evening peak restriction on the use of concessionary fares, people were able to go home when they had finished their activities rather than delaying their returns until after 1800.

6.13.7 Other modes

As well as calculating trip generation rates for buses in London as a result of the London-wide free fare concessionary scheme, Fairhurst (1996) also calculated trip generation rates for Underground concessionary travel. Fairhurst found the increases in the daily trip generation rates of between 33% and 60% depending on economic status and sex (Table 6.51). As with the rates for buses (Table 6.50), the increases in the trip generation rates were higher for non-economically active adults than for economically active adults, and slightly higher for females than for males.

Table 6.51 Estimates of the percentage increase in the number of trips as a result of the free scheme in London for the Underground

	Male	*Female*
Non-economically active	50	60
Economically active	33	33

Source: Fairhurst (1996).

6.13.8 Students

Very few studies have calculated trip generation rates or fare elasticities for student concessions. One exception is the Goodwin *et al.* (1988) study of six towns. The study uses three different methodologies to estimate fare elasticities for secondary school pupils, based on data from three wards in each of the towns. Overall elasticities range from -0.34 to -0.44. The study also gives a break down by density, with elasticities of -0.8 to -1.45 for low and medium densities. However, elasticities for high density areas were found to be positive, suggesting other influences at play.

6.13.9 Conclusions

Trip generation factors were found to vary between 1.5 and 2.2 for free travel schemes, 1.2 to 1.9 for flat fare schemes and 1.2 to 1.5 for half fare schemes. Rates were higher still if the pass had to be paid for. Only two studies considered tokens explicitly. There was much greater uncertainty as to the effects of tokens with trip generation rates ranging from 0.85 to 1.30. Variations in trip generation rates depend on the level of service, the initial cost of the pass or tokens, and full adult fare rates. The methodology was also important with higher trip generation rates being produced when the data were restricted to frequent bus users rather than the full cohort of those entitled to concessionary fares. This suggests that there are two elements to trip generation – new users and increased trips by those already using the bus.

6.14 Meta-analysis of British fare elasticities

Meta-analysis involves pooling together the results from different empirical studies and developing a quantitative model which explains variations in results across studies. There is a vast amount of British evidence on fare elasticities and a meta-analysis of it was conducted as part of this project. The aim of the research was to corroborate the findings of the more conventional review and to obtain insights into issues that would not otherwise be possible.

The analysis takes the form of a regression model, estimated to 902 public transport fare elasticities obtained from 104 studies conducted in Britain between 1951 and 2002. The markets covered are inter-urban rail travel, suburban rail travel, urban bus travel and London underground. A number of interesting findings have emerged and the models can be used to 'predict' fare elasticities for a range of situations.

The methodology and the results obtained are discussed in more detail in the Appendix to 6.14. The elasticities predicted by the resulting model, for various types of modes, journeys and travellers are compared with those deduced here from individual studies in Table 6.55. There is a good degree of consistency between these results, suggesting that the model derived from the meta-analysis might prove a useful tool for estimation of fare elasticities where it is not possible to establish them by more direct methods.

6.15 Comparison with the analysis in the 1980 version of the Demand for Public Transport and other major studies

The 1980 edition of 'The Demand for Public Transport' (Webster and Bly, 1980) examined international aggregate measures of fares elasticity for all journey purposes and passenger types across all trip lengths and fares. This analysis led to the conclusion that overall fares elasticities are low, so that increases in fare levels will almost always lead to increases in revenue. The analysis resulted in then accepted 'standard' public transport fares elasticity value of -0.3. Given the dominance of before-and-after studies in the 1980 report, it is likely this value is what would now be called a short-run elasticity. In the current work the short run elasticity has been found to be about -0.4. This is broadly in line with the results found in Goodwin (1992) and Dargay and Hanly (1999).

The 1980 report shows metro fare elasticities to be about -0.15: in this work they have been found to be around -0.30. Although this is significantly higher than that in the 1980 report, it is lower than the value of -0.4 found in Halcrow Fox *et al.* (1993). There may be various reasons for this difference. Two of the main reasons are as follows. Firstly, given that fare elasticity is different for different journey purposes, there may have been a shift in the types of journeys for which people are using public transport. Secondly, for the same journey purpose the elasticity may actually have changed. This could be due a variety of factors, some of which will interact with each other: one of these is market turnover, because different generations and social groups will have different perceptions of using public transport. Other factors include: rising car ownership and the varying quality of public transport service over the last 20 years. Suburban rail short-run fare elasticity has increased slightly from about -0.5 to -0.6 in the UK.

The 1980 report did not cover medium or long run elasticities at all. Therefore the likely value of medium run bus fare elasticity of around -0.56 cannot be compared with the 1980 report. The value compares well with those in Goodwin (1992) and Halcrow Fox *et al.* (1993).

Halcrow Fox *et al.* (1993) conducted a literature review as part of the study for the possible congestion charging scheme in London. They identified the values shown in Table 6.52 as being likely.

Table 6.52 Likely fare elasticity values for London from the literature review carried out by Halcrow Fox *et al.* (1993)

	Short run	*Medium run*	*Long run*
Bus	-0.30 to -0.45	-0.30 to -0.80	-0.40 to -1.20
Metro	-0.40	-0.45	-0.69
Suburban rail	-0.69	-0.80	-1.08

Source: Halcrow Fox et al. (1993)

The Industry Commission (1993) in Australia reviewed a number of studies from around the World and concluded that the values shown in Table 6.53 are appropriate. The short run values seem fairly low, while the long run value for rail seems rather high.

Table 6.53 Likely fare elasticity values from the literature review carried out by the Industry Commission in Australia

	Short run	*Long run*
Bus	-0.13 to -0.34	-0.57
Rail	-0.23 to -0.62	-1.59

Source: Industry Commission (1993)

The Victoria Transport Policy Institute (2001) reports that:

The overall average price elasticity of bus ridership is -0.4 (Linsalata and Pham, 1991); (Pratt et al., 2000). Large cities (more than 1 million population) tend to have a lower elasticity (-0.36) than small cities (-0.43), and peak hour travel is less elastic (-0.23) than off-peak (-0.42). Discounted senior citizen fares tend to have an elasticity of -0.21. Rapid transit fare elasticities tend to be significantly lower, typically in the -0.17 to -0.18 range, probably because rail passengers tend to be higher-income commuters and so are less price sensitive than bus passengers (Pratt et al., 1999). Somewhat higher elasticities are found in European countries (Nijkamp and Pepping, 1998).

The Victoria Transport Policy Institute (2001) results for bus patronage compare well with those found here. Their metro, which they call rapid transit, fare elasticities are rather closer to the 1980 report than those found here. This may be a reflection on the fact that the results are dominated by two different areas: the results found by the Victoria Transport Policy Institute, (2001) were focused on North America, while this report's results concentrate on the London Underground.

Further work by the Victoria Transport Policy Institute has produced the recommended public transport elasticity values shown in Table 6.54. It should be noted that no distinction is made between rail and bus in these values.

Table 6.54 Summary public transport elasticity values by Litman (2002)

	Short run	*Long run*
Peak	-0.15 to -0.3	-0.4 to -0.6
Off-peak	-0.3 to -0.6	-0.8 to -1.0
Suburban commuters	-0.3 to -0.6	-0.8 to -1.0
Overall	-0.2 to -0.5	-0.6 to -0.9

Source: Litman (2002).

In the 1980 report, off-peak travel was found to be about twice as elastic as peak travel and people who have a car available are more sensitive to fare changes than those who are 'captive' to public transport. Off-peak travel now seems to be 2 to 3 times as elastic as peak travel.

In the 1980 report, for short-distance journeys, where walking offers an acceptable alternative mode to public transport, the fares elasticity appeared to be relatively high at -0.3 to -0.6, compared with -0.1 to -0.3 for longer trips. From the current report the ratios of the values for short distance and long distance trips are similar, although the actual values have increased. In the 1980 report, travel by urban metro systems seemed to be less sensitive to fare changes than bus travel, and that is still the case.

6.16 Concluding remarks

Fare elasticity varies significantly depending not only on the mode, and the time period over which it is being examined, but also on the specific circumstances in which a mode is operating. Broadly speaking: bus fare elasticity averages around -0.4 in the short run, -0.55 in the medium run and -1.0 in the long run; metro fare elasticities average around -0.3 in the short run and -0.6 in the long run, and local suburban rail around -0.6 in the short run.

Short-distance trips have a higher fares elasticity than longer distance trips, as walking may offer an acceptable alternative. In particular, in larger towns and cities the fare elasticity is less than in smaller towns and cities. Fare elasticities are also affected by time of day: in the off-peak, it is around twice that of the peak, which may be a reflection on the trip purpose and the quality of journey offered by the competing modes.

A summary of the range of fare elasticities from figures in the Appendix to this Chapter 6 , according to mode, and time of day is given in Table 6.55.

7 Effects of quality of service: time factors

7.1 Introduction

The first version of 'The Demand for Public Transport' (Webster and Bly 1980) concluded that, in general, much less information was available about the effect of the various service factors than about the effect of fares on the demand for public transport. This was felt to be because studying the effects of changes in quality of service is more complicated than investigating fare changes as there is no single measure of service quality. In addition, there are difficulties in measuring the effect of such changes due to the incremental way in which they are imposed and the strong correlations between passenger demand and the capacity provided.

Quality of service may be defined by a wide range of attributes which can be influenced by planning authorities and transport operators. Some of these are directly related to the time spent by travellers on or between the different stages of their journeys. These are the subject of this chapter. Other attributes, despite their importance, may not be susceptible to direct quantitative measurement. These include reliability, comfort, convenience and safety. These are discussed in Chapter 8.

7.2 Travel time

In order to discuss the effects of quality of service on demand, it is important to understand the concept of travel time which can be broken down into several intermediate stages:

Walk from origin—Wait for vehicle—
Ride in vehicle—Walk to destination

In the case of private modes, the great majority of travel time will be in the vehicle itself (such as a private car). For public transport, the walk and wait times will be substantial, and usually not matched in other modes (except for search time and walking time where parking is not readily available at origin or destination). Where more than one mode or stage is involved in a public transport journey, then this cycle will be repeated, with interchange times at each point. A particularly marked difference will exist between slow feeder modes and high-speed intercity modes.

Table 6.55 Comparison of fare elasticities from individual studies, meta-analysis and 1980 black book

	Individual studies				
	Mean	*Range from*	*Range to*	*Meta analysis predicted*	*1980 study*
Public transport – UK and outside the UK – short run	-0.41	-0.07	-1.02	n/a	
Public transport – UK – short run	-0.44	-0.07	-1.02	n/a	
Public transport – outside the UK – short run	-0.35	-0.09	-0.86	n/a	
Bus – UK and outside the UK – short run	-0.41	-0.07	-0.86	n/a	
Bus – UK – short run	-0.42	-0.07	-0.86	-0.36	-0.30
Bus – outside the UK – short run	-0.38	-0.23	-0.58	n/a	
Metro – UK and outside the UK – short run	-0.29	-0.13	-0.86	n/a	
Metro – UK – short run	-0.30	-0.15	-0.55	-0.37	-0.15
Metro – outside the UK – short run	-0.29	-0.13	-0.86	n/a	
Suburban rail – UK and outside the UK – short run	-0.50	-0.09	-1.02	n/a	
Suburban rail – UK – short run	-0.58	-0.10	-1.02	-0.52	-0.50
Suburban rail – outside the UK – short run	-0.37	-0.09	-0.78	n/a	
Bus – UK – medium run	-0.56	-0.51	-0.61	n/a	
Bus – UK – long run	-1.01	-0.85	-1.32	-0.70	
Metro – UK – long run	-0.65	-0.61	-0.69	-0.54	
Bus – London – short run	-0.42	-0.14	-0.84	-0.37	-0.44
Bus – outside London – short run	-0.43	-0.07	-0.86	-0.36	
Suburban rail – SE England – short run	-0.61	-0.10	-0.95	-0.50	
Suburban rail – outside SE England – short run	-0.55	-0.15	-1.02	-0.60	
Bus – UK – peak – short run	-0.26	0.00	-0.42	-0.30	
Bus – UK – off – peak – short run	-0.48	-0.14	-1.00	-0.40	
Metro – UK – peak – short run	-0.26	-0.15	-0.35	-0.30	-0.38?
Metro – UK – off – peak – short run	-0.42	-0.23	-0.63	-0.44	-0.45?
Suburban rail – UK – peak – short run	-0.34	-0.27	-0.50	-0.42	
Suburban rail – UK – off – peak – short run	-0.79	-0.58	-1.50	-0.65	

The range is based on the values in the studies covered in the appendix to Chapter 6. In some cases, the values cited are the averages of several values presented in the studies, and so some values outside the range will have been obtained.

There is considerable evidence that, taking the whole population and all types of journey together the amount of time spent in travel (a 'travel time budget') is approximately constant, at about one hour per person per day. This is evident from the National Travel Survey since the mid-1970s, and in work by Brög (1993) in German cities, for example. Thus, over a long period, people tend to travel further within the same time budget as faster modes can be used. This would imply an overall elasticity of distance travelled with respect to total journey time of -1.0. In practice, for any particular public transport mode, a lower value will be found with respect to in-vehicle time, since only part of the trip is made in-vehicle. In the case above, for example, if the in-vehicle proportion represented only 10 minutes out of a 20 minute total journey time (which might typify a local bus service), a reduction of 5 minutes in the in-vehicle time (i.e. 50%) would only represent a 25% reduction in door-to-door journey time. Hence with a constant door-to-door travel time budget, the resultant elasticity with respect to in-vehicle time would be of the order of -0.5 rather than -1.0.

This effect may be particularly marked where successive increases in speed occur. For example, if the simple diagram above represented a high-speed inter-city link on which feeder journeys initially account for 30 minutes each and the trunk rail journey 3 hours (a total of 4 hours), a reduction in the rail journey to 2 hours (33%) would reduce door-to-door time by 25%. However, a further reduction of 33% of the in-vehicle time (by 40 minutes, to 80 minutes) would only reduce door-to-door time by 22% (i.e. 40 as a percentage of 180). One would thus expect in-vehicle time elasticity to fall as speed was successively increased.

So far, the argument has been based on a single mode. However, speed increases will also cause modal transfer (for example, from car to high-speed rail) which may push up the elasticity value.

Within the local and regional transport market there is relatively little evidence of the extent to which vehicle average speeds cause variations in demand, in the absence of large variations or good time-series data. Hence, use is made of examples from the high-speed long-distance sector, but caution must be expressed in applying them to shorter-distance conditions.

Another outcome of the structure indicated above is that walk and wait time form a large proportion of door-to-door journey time, especially for modes such as bus with short average journeys. While good time-series data for total door-to-door journey time are rarely available, proxies may be identified for the walking stage (usually by examining cross-section relationships between propensity to use public transport, and access times to a service), and waiting (either by directly measuring waiting time, or using service levels as a proxy).

Generally speaking, waiting time will incur greater disutility than in-vehicle time. Typically a factor of about 2 has been assumed, reflecting the discomfort and inability to use the time for other purposes (but note the evidence presented in Section 7.3).

Waiting time may also be related to service headway. This takes two forms:

- Where services are of high frequency, passengers will arrive independently of the service schedule. Hence, for a perfectly regular service, waiting time will equal half the service headway. The greater the variation in service headway, the greater will this waiting time become, i.e. if buses are not regular wait time may be more than half the headway. The term 'excess waiting time' may be used to identify this element.
- Where services operate at wider headways, passengers will normally time their journeys to wait for a specific departure (subject to quality of timetable information and reliability of service plus safety margin) but in such cases there is also schedule delay – the amount of time spent waiting at home/work etc.

Typically, this behaviour change occurs at a threshold of about 4-5 scheduled journeys per hour (i.e. headway of 12 to 15 minutes). This is supported in a case study of a service in North West London, converted from a 20-minute headway with large buses to a 10 minute headway with minibuses, in which passenger waiting time was observed directly, and in which passengers were asked about their waiting behaviour. This confirmed that in the initial case, most planned their journey, but in the latter case most arrived independently of the timetable (White *et al.*, 1992).

The effect of such changes on behaviour may be identified readily in the high-frequency case, since door-to-door journey time is directly affected. Given the disutility of waiting time, these two effects roughly offset each other - the expected wait would be about half the headway, but doubling this would give a value approximately equal to the headway.

At wider headways, there may be little variation in waiting time, but the convenience of the service is greatly reduced, i.e. the probability that its timing matches the desired move between activities by the traveller becomes smaller. Hence, similar or higher values may be observed for demand elasticity associated with service level.

The observed patterns may also be asymmetric, i.e. the typical passenger is making a round trip rather than isolated one-way journeys. On the outward journey from home, it may be possible to plan the departure to match the service timetable (e.g. for a shopping trip) but where the duration of the activity is not known (e.g. a business meeting) the desired return journey timing may be independent of the timetable, and hence potentially equal to half the headway, even for wide service intervals. In some cases, the start time of the activity may be beyond the passenger's control (e.g. a theatre or cinema performance) and hence similar difficulty occurs at the beginning of the round trip.

A useful proxy in many cases is to use vehicle-km operated (or timetabled) as the measure of service, since this is readily available as an aggregate indicator. For example, elasticities of bus passenger trips with respect to bus vehicle-km may be derived from both short- and long-run data (Dargay and Hanly, 1999). This can reflect a number of factors:

- Average frequency of service during a given period. For a fixed length route and fixed period of operation, frequency is by definition in direct proportion to vehicle-km.
- Length of day or week over which a service operates (expanding the schedule on a fixed route to cover a longer period at the same frequency e.g. in the evenings, would produce a proportional increase in vehicle-km)
- Route length and network density. Increased vehicle-km (at a network level) may also reflect extensions of routes and/or additional routes, thus increasing accessibility (i.e. shorter walking distances).

Elasticities derived from network-wide vehicle-data (the usual source) may thus encompass all three effects, although it is likely that service frequency is the predominant element.

Most of the information reported in the time-series studies of service changes referred to by Webster and Bly (1980) related to frequency and/or route changes and resulted in elasticity values relative to vehicle kilometres ranging from 0.2 to 1.2. Cross-sectional studies were deemed to over-estimate (due to problems of simultaneity) and yielded values of 0.6 to 1.4, while more reliable 'before and after' studies gave values of between 0.2 and 0.5. The elasticity with respect to travel time was estimated to be between -0.3 and -0.5.

Monitoring of conversions to minibus operations in four areas in the late 1980s indicated service level elasticities (passenger trips with respect to vehicle-km) averaging around +0.4 over a one year period after conversion, primarily associated with increased frequency. For example, in Newbury a doubling of frequency on an existing route gave an elasticity (on operator-reported data) of +0.4. In Swansea, where there was also some extension of routes further into housing areas with 'hail and ride' operation in addition to a frequency increase, the elasticity observed was +0.51. However, the highest figure was obtained in the case where the vehicle-km growth represented an increase in route length within a housing area (and hence a gain in accessibility), an elasticity of +0.75 (Turner *et al*., 1990). A further study in London gave a one-year elasticity of +0.4, being found where the growth was entirely attributable to a frequency change over an existing route.

The results reported in this chapter are largely based on models which work by assuming that travellers derive a degree of satisfaction (known as utility) from using each mode and will choose the mode which maximises their utility.

The utility functions are derived through the use of stated and revealed preference surveys, using multivariate statistics, including latent variables. The common form for such a utility function is:

$$U_i = \sum_j a_j . x_{ij}$$

U_i = Utility of alternative *i*.

i = mode of transport, e.g. Car, Bus. Rail etc (the effect of car ownership will be discussed in Chapter 10).

x_{ij} = measured attribute values e.g. cost, time etc.

a_j = unknown parameters to be evaluated.

Suppose we have a simple utility function as follows:

$$U_i = a_1\, IVT + a_2\, OVT + a_3\, FARE$$

where:

IVT = In-vehicle time.

OVT = Out-of-vehicle time (walk and wait time).

Then the Generalised Cost of Travel can be expressed as:

$$GC_i = a_1 / a_3\, IVT + a_2 / a_3\, OVT + FARE = U_i / a_3$$

where:

a_1/a_3 = Value of in-vehicle time

a_2/a_3 = Value of out-of-vehicle time.

In the passenger rail industry in Great Britain, the concept of Generalised Journey Time has also been developed. Given the formulation above, this would be written as:

GJT_i = $IVT + a_2 / a_1\, OVT$ and hence:

GC_i = $a_1/a_3\, GJT_i + FARE$.

The Generalised Cost of Travel can include different 'time' factors according to the mode:

- for car or motorcycle travel, the factors might include: In-vehicle time, monetary cost of travel and parking cost;
- for bus and rail travel, the factors might include: In-vehicle time, monetary cost of travel, interchange time, access time, wait time, and egress time. A number of 'softer' variables relating to reliability, overcrowding, vehicle quality, information provision etc. might also be included, although more usually they are brought together in an alternative specific constant. This is often referred to as a modal penalty as invariably car has advantages over bus and rail with respect to these softer attributes.

In certain cases, the Generalised Cost of Travel might be expressed in time units and is referred to as the Generalised Time of Travel:

GT_I = $IVT + a_2 / a_1\, OVT + a_3 / a_1\, FARE$

= $GC_i\, a_3 / a_1$

= U_i / a_i

Given the above, the structure of this chapter is as follows. The stages of a public transport journey are examined roughly in the sequence they are made In Section 7.3 we examine access time and, by inference, egress time. In Section 7.4, the influence of the amount of service provided and its impact on wait time is examined. The influence of in-vehicle time is examined in Section 7.5. Section 7.6 shows how elasticities may be inferred from attribute valuations using the ratio of elasticities approach. Lastly, in Section 7.7,we indicate some recommended values.

7.3 Effect of access time to boarding point and egress time from alighting point

The evidence for the impact of access and egress time is dominated by attribute valuation studies. A meta-analysis of 183 British studies is reported in Wardman (2001). The majority of these studies were based on use of stated preference, rather than revealed preference, techniques. Suburban studies dominated the sample (some two-thirds) with urban studies making up most of the remainder. Only around 7% of the sample comprised inter-urban studies. The average walk time weightings in the meta-analysis dataset are shown in Table 7.1.

Table 7.1 Walk time weightings from meta-analysis (in units of in-vehicle time)

Context	*Mode*	*Mean*	*Standard error*	*Sample*
All	All	1.68	0.05	183
Urban commuting	Car	1.37	0.12	29
	Bus	1.67	0.14	10
	Other	1.99	0.16	29
Urban leisure	Car	1.74	0.15	25
	Bus	1.66	0.23	13
	Other	1.97	0.35	9
Urban other	Car	1.55	0.10	34
	Bus	2.02	0.22	13
	Other	1.37	0.17	8
Inter urban	All	1.51	0.14	13

Source: Wardman (2001)

In situations where the mode of access is not specified, a general value for access time may be helpful. Earlier work by Wardman (1998) analysed access time that consists of any mode of access to the mode that constitutes the main mode of an individual's journey (Table 7.2).

Table 7.2 Access time weightings from meta-analysis

Category	*Value (in-vehicle time mins)*	*Standard deviation of value*	*Number of studies*
All	1.81	0.75	52
Employers business	1.95	0.65	10
Commuting (peak)	1.62	0.54	12
Leisure (off-peak)	2.13	0.93	17
Other purposes	1.43	0.54	13
Car users	1.54	0.54	16
Bus users	1.98	0.15	5
Rail users	1.31	0.43	4
Other users	2	0.88	27
Revealed preference	1.38	0.59	11
Stated preference	1.91	0.75	41
Suburban	1.46	0.56	18
Inter-urban	2.01	0.78	34

Source: Wardman (1998)

In Wardman (2001), a quantitative model that aims to explain variations in individual values of time as a function of relevant socio-economic and trip characteristics has been developed. The model has achieved a high degree of goodness of fit, and a large number of statistically significant, correct sign and plausible variations in the values of time have been estimated. Compared to other findings with relatively simple tabulations, the model provided a significant advance. It should be noted that this model is estimated using the dataset in the above mentioned meta-analysis.

Based on the estimated model, the author provides illustrative figures for a range of circumstances for the money value of in vehicle time and weighting of walk time, wait time and headway. The walk time weighting is reported in Table 7.3, while other values are reported in the following sections of the chapter. It should be noted that Table 7.1 reports the average value in the database, while Table 7.3 reports the value implied by the model, which is estimated using the same database.

Table 7.3 Walk time weightings implied by the quantitative model (in units of in-vehicle time)

Time (mins)	*Distance (miles)*	*Car*	*Bus*	*Rail*	*Under-ground*
2	2	2.18	1.68	1.28	1.5
5		2.79	2.15	1.65	1.93
10		3.37	2.59	1.99	2.33
20		4.07	3.13	2.4	2.82
2	10	1.72	1.49	1.14	1.33
5		2.2	1.91	1.46	1.71
10		2.66	2.3	1.77	2.08
20		3.21	2.78	2.13	2.5
2	25	1.5	1.39	1.07	1.25
5		1.92	1.79	1.37	1.6
10		2.32	2.16	1.65	1.94
20		2.8	2.6	1.99	2.34
2	50	1.35	1.32	1.02	1.18
5		1.74	1.7	1.3	1.52
10		2.09	2.05	1.57	1.84
20		2.53	2.47	1.9	2.23
2	100	1.22	1.26	0.97	1.13
5		1.57	1.61	1.24	1.45
10		1.89	1.95	1.49	1.75
20		2.28	2.35	1.8	2.12
2	200	1.1	1.2	0.92	1.07
5		1.41	1.53	1.18	1.38
10		1.71	1.85	1.42	1.66
20		2.06	2.23	1.71	2.01

Source: Wardman (2001)

In the table, the first two columns refers to the assumed walk time and distance travelled. The next four columns report the walk time weighting by each user type in different mode (e.g. how bus users value walk time for bus mode). The most noticeable feature of the IVT values of walk is that they vary considerably. In part this is because of differences in the money value of IVT by user type and mode, but there are other strong influences at work. The increase in the IVT values of walk time as the levels of walk time increase is quite clear, as is the fall in the values as distance increases.

Wardman *et al.* (2001b) provide a valuation of walk time in relation to interchange facilities, based on stated preference analysis. The attribute weights held by users of different modes are shown in Table 7.4.

Table 7.4 Walk values in association with interchange attributes, Edinburgh

Attribute	*Users*	*Value (IVT mins / trip)*	*95% confidence interval*
Walk time at interchange	Bus	1.6	27%
Walk time to bus	Car	1.3	40%
Between stations walk time	Rail	3.7	32%

Source: Wardman et al. (2001b)

7.4 Effect of service intervals

The effect of service intervals can be measured in a number of ways: total vehicle kilometres or hours, frequency, headway/service interval, wait time and schedule delay. Evidence is a mixture of elasticity and attribute value measures.

7.4.1 Elasticity based evidence

The dominant indicator is vehicle kilometres. Table 7.5 indicates that bus demand is relatively insensitive to service change with a short-run elasticity of approximately 0.4 and a long run elasticity of 0.7.

Table 7.5 Service elasticities, with range and standard deviation according to average values – Bus

Run	*Elasticity*	*Range*	*Standard deviation*	*No of measure-ments*
Short run	0.38	0.10 to 0.74	0.135	27
Long run	0.66	0.22 to 1.04	0.275	23

Sources: Appendix to Chapter 7

Table 7.6 shows that urban rail may be more sensitive than bus to service change but the evidence is limited to a small number of short-run estimates.

Table 7.6 Service elasticity, with range and standard deviation according to average values - Rail

Run	*Elasticity*	*Range*	*Standard deviation*	*No of measure-ments*
Run not stated*	-0.49	-0.33 to -0.65	0.23	2
Short run	0.75	0.65 to 0.90	0.13	3

** Based on headway.*
Sources: Appendix to Chapter 7.

The importance of service quality to meeting the needs of public transport customers and decreasing reliance on the car is indicated by the findings of Arsenio's (2000) examination of railway demand in Spanish cities (Table 7.7)

Table 7.7 Elasticities for Spanish cities

Elasticity	*Large cities*	*Small cities*
Price	-0.30	-0.32
Service quantity (Train kms)	0.78	0.39

The author states that

The main results that have to be pointed out are the values of elasticities with respect to rail quality and price. In both cases railway demand appears to be inelastic, although it shows a greater response with respect to quality changes than to prices.

Arsenio estimates a short-run service elasticity of 0.53 and long-run of 0.83 (with quality defined as number of places-km offered by operator RENFE divided by length of suburban rail network at each city). For large cities, a service elasticity of 0.78 is reported and, for small cities, 0.39. Arsenio explains these findings and points to the importance of service quality to maintaining public transport's market share particularly in large cities saying:

While in large cities the standard result of a higher (in absolute terms) demand elasticity with respect to quality than to prices is found, in smaller cities the two values are much closer, although their difference is statistically significant. This implies that commuters in larger cities implicitly value quality improvements more than their counterparts in smaller urban areas. Such different valuation could be due to the traffic conditions faced by car users in each case. Higher congestion rates over longer distances for car drivers in large cities can explain a higher willingness to change mode in response to improvements in railway quality taking the form of increased frequencies and/ or available space.

Dargay and Hanly (1999) note that there is a strong positive correlation between vehicle kilometres operated per capita and journeys per capita. They have illustrated the results with a scattergram (Figure 7.1).

Increasing vehicle kilometres operated increases ridership, according to Dargay and Hanly (1999), but the elasticities vary greatly from study to study. However, the elasticity of off-peak travel was greater than for the peak. Service elasticity is lower in Metropolitan areas than in rural areas (Dargay and Hanly (1999). This is likely to be because the rural service is poorer and therefore improvements on that service will have a greater impact on demand. The two regions with the lowest level of service, the English Shire counties and Wales also have the lowest levels of patronage. It is further noted that Scotland shows the highest level of service and the middle level of patronage while London had the highest level of patronage but the second highest level of service, and English Metropolitan areas had the second highest level of patronage and the middle level of service. Overall, Dargay and Hanly recommend short run service elasticities of 0.4, rising to 0.8 in the long run (see also Table 7.5 which recommends values of 0.38 and 0.66 respectively).

Service elasticities were also estimated by time of day by Preston (1998). The main finding was that demand in the evening and on Sunday was sensitive to service but demand in the inter-peak period was insensitive to service.

Table 7.8 Service elasticities - Bus (Metropolitan PTE)

Description	*Elasticity*
Short run	
Early morning/peak	0.38
Inter-peak	0.17
Evening	0.35
Saturday	0.52
Sunday	1.05
Long run	
Early morning/peak	0.58
Inter-peak	0.30
Evening	1.95
Saturday	0.67
Sunday	1.61
All periods	0.13

Source: Preston (1998)

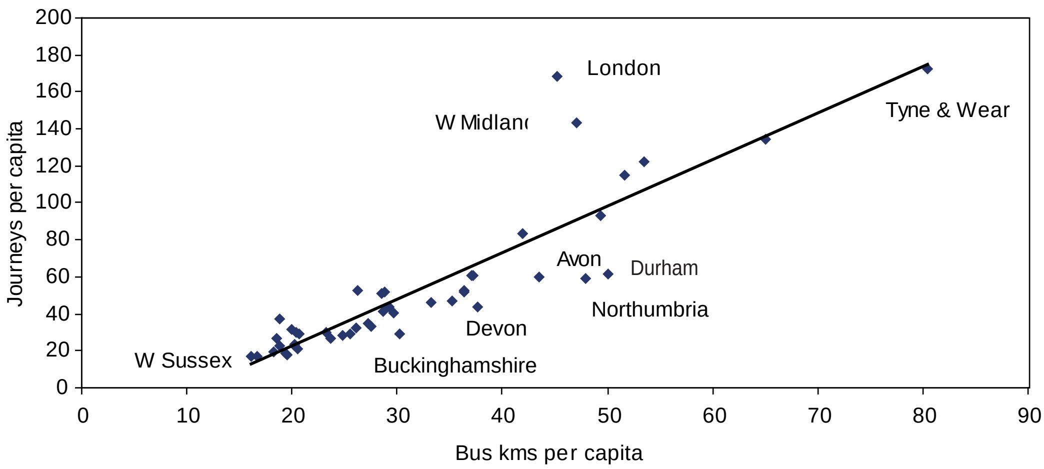

Figure 7.1 Relationship between bus vehicle kilometres and bus journeys in English counties (average 1987 to 1996) *(Dargay and Hanly, 1999)*

Mitrani *et al.* (2002) suggest a service elasticity for London buses of 0.65 (± 0.32) for smoothed bus miles. This represents an increase from the former recommended value of 0.17 (Kincaid *et al.*, 1997). The smoothed series is calculated as follows:

Smoothed Miles in period t = a* Miles in period t + (1-a)*Smoothed Miles in period t –1.

The parameter is a set at 0.5 implying that 90% of the impact of a service change occurs in the first three four week periods. This elasticity seems to have varied substantially over time. During a period of service disruption (1977-79) it was found to be as high as 1.15 (± 0.21). However, in other periods (1970-77 and 1980-86) it was found to be insignificantly different from zero.

For London Underground, Mitrani *et al.* (2002) recommend an elasticity with respect to unsmoothed train miles of 0.08, which is little changed from the earlier recommendation of 0.09 (Kincaid *et al.*, 1997). Mitrani *et al.* (2002) also detect a cross-elasticity of underground demand with respect to smoothed bus miles of -0.13.

Preston (1987) reports a walk/wait time elasticity of -0.6 for local rail travel in West Yorkshire. Preston and James (2000) estimate a wait time elasticity of -0.64 based on analysis of data for bus in 23 UK towns. Table 7.9 summarises their other key findings with respect to wait time.

Headway elasticities indicate the percentage change in ridership observed or expected in response to a change in the headway (Pratt *et al.*, 2000). Change in patronage can also be reported in the form of a service hours elasticity. Both of these measures are shown below for a number of service changes in various locations (Table 7.10).

Table 7.9 Elasticities with respect to wait time - Bus

Dependent variable	*Time period/destination*	*Elasticity with respect to wait time*
Total trips		-0.64
Adult trips		-0.74
Adult trips	Peak/town centre	-0.65
Adult trips	Off-peak/town centre	-0.85
Adult trips	Peak/other	-0.39
Adult trips	Off-peak/other	-1.17
Total trips	Peak/town centre	-0.64
Total trips	Off-peak/town centre	-0.64
Total trips	Peak/other	-0.50
Total trips	Off-peak/other	-1.05

Source: Preston and James, 2000

Aside from providing new facilities or lower fares, fixed rail systems are for the most part restricted to scheduling and frequency changes as a form of service improvement. Commuter rail lines typically serve middle and upper income areas. Although they have relatively long time intervals between trains, they also predominantly serve long trips.

It is interesting to note that if the effects on demand of changes to fare and frequency are compared for urban transit, either type of change may have the greater impact depending on circumstances. It is reported in the US

Table 7.10 Bus service elasticities for frequency changes observed in 1990s

Transit system or route	*Time span*	*Headway change (mins)*	*Service measure*	*Arc elasticity*	*Notes and comments*	*Source*
Tasta to central Stavanger, Norway.	Early 1990s.	From 30 to 15.	Headway.	-0.26.	Negative headway elasticity (as expected).	Lunden (1993).
Santa Clarita CA, Transit.	1992/3 – 1997/8.	Primarily 60 to 30 with service hours enhancements.	Service (bus) hours.	+1.14.		Kilcoyne (1998a and 1998b).
Foothill Transit LA, CA (system).	1993-96.	Various, plus new weekend service.	Service hours.	+1.03 (all hours).	Frequency upped on all lines.	Stanley (1998).
Community Transit Snohomish County System WA.	1994-96.	Primarily 60 to 30 plus new services as well.	Service hours.	Over +1.0.	Confounding factors include introduction of university pass.	Stanley (1998).
Santa Monica CA, Big Blue Bus System.	1996-98.	Various, plus some new service.	Service hours.	+0.82 (all hours).		Catoe (1998).
Lincoln Blvd Route, Santa Monica CA.	Mar – Sept 1990.	20 to 10 (40 to 10 on link to Los Angeles Airport).	Service hours.	+0.97.	6am – 6pm.	Catoe (1998).

CA, LA and WA refer to California, Los Angeles and Washington.

Transportation Research Board Interim Handbook (Pratt *et al.*, 2000) that in Dallas, the following fare and service elasticities were calculated in the period 1985-87 when fare and service changes were introduced (Table 7.11).

Table 7.11 Fare and service elasticities - Dallas

	Fare elasticity	*Service elasticity*
Urban bus	-0.35	+0.32
Suburban express bus	-0.26	+0.38
Suburban local	-0.25	+0.36

The authors describe these findings as:

> *…statistical analysis covering two years of fare and service changes in greater Dallas revealed greater sensitivity to fares than service in the center city, and the converse in the suburbs, for both suburban express and local services. (Allen, 1991).*

The effect of route and schedule restructuring on demand for travel in Riverside, California has been described in the handbook:

> *The restructuring was accomplished in the Fall of 1995 within the constraint that total bus service hours not be increased by more than 4 percent. Ridership increased by 20.4 percent over the prior year. Route restructuring focused on enhancing direct travel. The schedule restructuring emphasized consistency and ease of transfer, in addition to providing increased frequency on heavily travelled routes within the service hours constraint. All schedules were standardized to be on 15, 30 or 60 minute on-the-hour headways (Stanley, 1998)*

The handbook suggests that the effects of waiting time are influenced by a number of external factors. For instance, protection from weather in wet, hot or cold climates makes a difference in a rider's perception of waiting and transfer times.

Outstanding responses to service hours and frequency enhancements in Santa Clarita and Santa Monica, California (elasticities of +1.14 and +0.82 respectively) were accompanied by aggressive marketing ranging from direct mail campaigns and free-ride coupons to image building keyed to a striking new bus paint design (Stanley, 1998; Catoe, 1998).

Wallis and Yates (1990) have estimated service elasticities for New Zealand as shown in Table 7.12.

Table 7.12 Service elasticities - New Zealand

Source	*Public transport kilometres elasticity*
Christchurch 1975-89	0.4 to 0.5
Auckland	0.67
26 NZ Urban areas	1.0
Wanganui 1978-85	0.7
Wellington Rail 1970-85	0 to 0.5
International 'standard' values	0 to 0.8
Average elasticity	0.51
Standard deviation	0.34

Source: Adapted from Wallis and Yates (1990)

The Isotope Research Study (European Commission, 1997) reported service elasticities for bus in a number of European cities by city size (small: population<500,000) (see Table 7.13).

Table 7.13 Service elasticities for bus in European cities

Elasticity	*Small city*	*Large city*
Service	0.33	0.49

Demand is shown to be more service elastic in big cities than small 'because of the competition from other public transport modes' (European Commission, 1997). The report also suggests that service is valued more highly in large cities due to higher income levels with the implied values of service being 0.54 ECUs per bus km in small cities and 1.44 ECUs in large cities.

Service frequency also has a strong impact on public transport demand elasticity. Elasticity for low frequency services is greater than for high frequency services. Cheung (citied in Booz Allen Hamilton, 2003) found elasticities for lower frequency services were up to four times greater than high frequency services.

Scheduling and frequency modifications are among the most common service changes that transit operators make to improve service effectiveness. According to Pratt *et al.* (2000), scheduling and frequency most particularly affect that aspect of transit service quality which is the waiting time patrons encounter and perceive in making a transit trip. Individual changes may have the objective of reducing wait time at the start of a transit trip, or minimizing wait time if a transfer between two vehicles is required. Scheduling changes may be made to increase the ease of passenger comprehension of the schedule. Related actions may have the objectives of improving the reliability of the service, reducing both real and perceived passenger wait times, and lowering passenger anxiety. These service quality objectives support the goals of providing a more attractive service, increasing transit ridership, and shifting travel out of low occupancy autos.

FitzRoy and Smith (1998a) studied the demand for rail transportation in European countries and described the significance of high frequencies for maintaining market share:

> *With respect to passenger rail, Switzerland, the Netherlands and Eire were most successful in maintaining their share of the market during the 1980s. This may be partly explained by the fact that the former two countries, in particular, are notable for their extremely high train frequencies.*

Ford and Haydock (1992) identify two main philosophies of timetable planning for the passenger market. The first consists of trying to provide passenger carrying capacity exactly when and where detailed market research shows it is needed, maximising seat occupation as far as possible. This approach is described as market-led (or perhaps more accurately demand-led). The authors describe SNCF as market-led saying:

> *SNCF is the leading exponent of tailoring the timetable exactly to the travel market. Many of its trains have variations on Friday, Saturday, Sunday and Monday, with only Tuesday to Thursday having the same service.*

The second approach involves providing a 'regular interval timetable' which maximises frequency and regularity. This is described as being production-led, but a case could be made for this approach being described as market–led. 'Clockface' departures are easily remembered by passengers and staff but may force passengers to adapt to train times which may not suit them. Ford and Haydock go on to describe the introduction of production-led timetabling:

Once traffic on a line reaches a level where more than 10-15 trains, spread throughout the day, are justified, the timetable planner may decide to operate the service with a regular stopping pattern at a regular hourly interval; this is known as a clock-face or regular interval timetable (RIT).

RITs have been common throughout Europe for many years, particularly on intensive suburban services, but less so on Inter City routes. The successful Verbund regionally coordinated services described by Pucher and Kurth (1995) in Hamburg, Munich, Rhein-Ruhr, Vienna and Zurich provide a service at

…regular intervals to make schedule easier for riders to remember and to facilitate transfers between lines and different public transport modes.

When Austrian Federal Railways (ÖBB) inaugurated their NAT 91 (Neue Anstro-Takt) network of seven principal routes operated at two-hourly frequencies, train kilometres were increased by over a quarter and by over 41% for fastest trains (Schnellzuge). Earlier introductions of regular interval timetables in Switzerland had produced patronage increase of up to 30% on specific areas, although the introduction of a nationwide system (Taktfrahrplan) in 1982 did not produce large patronage increases but did prevent traffic losses. Similarly, introduction of regular interval timetable in Belgium in 1984 led to small increases in demand (up 2%) and receipts (up 8%) in the following year (Ford and Haydock, 1992).

7.4.2 Attribute value based evidence

Wardman (2001) provides a meta-analysis of 62 studies in which wait time was a service attribute. The results are shown in Table 7.14. It was found that wait time was valued at about 1.6 times in-vehicle time for urban bus and 1.2 for underground rail.

Table 7.14 Wait time weightings from meta-analysis (in units of in-vehicle time)

Context	*Mode*	*Mean*	*Standard error*	*Sample*
All	All	1.76	0.10	62
Urban	Bus	1.59	0.22	11
	UG	1.17	0.04	11
	Car and PT	2.06	0.14	30
Inter	All	1.70	0.28	10

Source: Wardman (2001)

In other studies the weight placed on departure time shifts relative to travellers' desired departure times are considered. The results of assessing 56 such studies are given in Wardman (1998) and are shown in Table 7.15. These findings indicate the impact of schedule delay is valued at 0.34 in-vehicle time minutes for bus and 0.9 for rail. These are less than the wait time values, particularly for bus.

Table 7.15 Departure time shift weightings from meta-analysis

Category	*Value (in-vehicle time mins)*	*Standard deviation of value*	*Number of studies*
All	0.72	0.64	56
Employers business	0.57	0.31	12
Commuting (peak)	1.03	1.08	14
Leisure (off-peak)	0.58	0.52	12
Other purposes	0.69	0.32	18
Car users	0.61	0.72	31
Bus users	0.34	0.19	2
Rail users	0.9	0.51	23
Urban	0.44	0.23	6
Suburban	1.06	1.26	9
Inter-urban	0.82	0.41	20
General	0.58	0.48	21
Depart earlier	0.64	0.59	23
Depart later	0.69	0.71	24
Depart either earlier or later	1.03	0.58	9

Source: Wardman (1998)

As in Section 7.3, Wardman (2001) provides illustrating examples of wait time weighting for a range of circumstance based on the estimated quantitative model. The results are reported in Table 7.16.

Table 7.16 Wait time weightings implied by the quantitative model (in units of in-vehicle time)

Time (mins)	*Distance (miles)*	*Car*	*Bus*	*Rail*	*Under-ground*
2	2	3.68	2.57	2.51	2.93
5		4.25	2.97	2.9	3.38
10		4.73	3.31	3.24	3.77
20		5.28	3.69	3.61	4.2
2	10	2.9	2.29	2.24	2.6
5		3.35	2.64	2.58	3.01
10		3.73	2.94	2.88	3.35
20		4.16	3.28	3.21	3.74
2	25	2.53	2.14	2.09	2.41
5		2.92	2.47	2.42	2.81
10		3.26	2.75	2.69	3.13
20		3.63	3.07	3	3.5
2	50	2.28	2.03	1.99	2.31
5		2.64	2.35	2.3	2.67
10		2.94	2.62	2.56	2.98
20		3.28	2.92	2.85	3.32
2	100	2.06	1.93	1.89	2.2
5		2.38	2.23	2.18	2.54
10		2.65	2.49	2.43	2.83
20		2.96	2.77	2.71	3.16
2	200	1.86	1.84	1.8	2.09
5		2.15	2.12	2.07	2.42
10		2.39	2.36	2.31	2.69
20		2.67	2.64	2.58	3

Similar to the in-vehicle-time (IVT) value of the walk time, the IVT value of wait time varies considerably. As the level of wait time increases or the distance travel decreases, the IVT value of wait time increases. Comparing Table 7.16 to Table 7.3, for corresponding levels of walk and wait time and the same journey distance, the values of wait time tend to be greater than the value of walk time.

Another way of considering service interval attributes is in terms of the headway. Wardman (2001) provides an analysis of 164 British studies in which headway weightings were specified (Table 7.17). The key finding was that headway weightings were slightly less than unity at around 0.77.

Table 7.17 Headway weightings from meta-analysis (in units of in-vehicle time)

Context	*Mode*	*Mean*	*Std error*	*Sample*
All	All	0.77	0.04	164
Urban commuting	Car	0.85	0.11	18
	Bus	0.84	0.20	6
	Other	0.70	0.17	5
Urban leisure	Car	1.00	0.13	19
	Bus	0.97	0.17	12
	Other	0.84	0.12	10
Urban EB	All	1.22	0.25	5
Urban other	Car	0.63	0.07	22
	Bus	0.61	0.08	13
	Other	0.75	0.03	4
Interurban commuting	All	0.47	0.09	7
Interurban leisure	All	0.52	0.07	17
Interurban EB	All	0.69	0.11	14
Interurban other	All	0.95	0.17	12
Interurban	Car	0.63	0.14	7
	Rail	0.49	0.08	16
	Other	0.78	0.09	27

The quantitative model developed by Wardman (2001) enables a more detailed breakdown of headway weighting by distance. Table 7.18 provides the implied headway weighting across distance and purpose which are the factors which influence it. The strong distance effect is very apparent, with the headway valuation being much higher for shorter distance trips.

In terms of waiting attributes at interchange facilities, Wardman *et al.* (2001b) report the results of stated preference analysis of bus and (separately) rail users (Table 7.19). The key finding is that value per trip for interchange facilities is relatively low ranging from 0.1 to 1.7 IVT mins/trip.

Wardman (2001) has also summarised other findings on interchange, reporting that:

- the interchange penalty is found to increase over time as GDP increases;

Table 7.18 Headway weightings implied by the quantitative model (in units of in-vehicle time)

Distance	*Purpose*	*Car*	*Bus*	*Rail*	*Under-ground*
2	EB	0.88	0.85	0.96	1.12
2	Non EB	0.71	0.69	0.78	0.91
10	EB	0.57	0.62	0.70	0.81
10	Non EB	0.46	0.50	0.57	0.66
25	EB	0.44	0.52	0.58	0.68
25	Non EB	0.36	0.42	0.47	0.55
50	EB	0.37	0.45	0.51	0.59
50	Non EB	0.30	0.37	0.41	0.48
100	EB	0.30	0.39	0.44	0.52
100	Non EB	0.25	0.32	0.36	0.42
200	EB	0.25	0.34	0.39	0.45
200	Non EB	0.20	0.28	0.31	0.37

EB = Business trips

Table 7.19 Value per trip for interchange attributes - Edinburgh

Attribute	*Users*	*Value(IVT mins / trip)*	*95% confidence interval*
Wait time at interchange (mins)	Bus	1.2	22%
Guaranteed connection	Bus	3.6	42%
Interchange wait time (mins)	Rail	1.7	39%

Source: Wardman et al. (2001b)

- there is a pronounced effect on interchange penalty from distance;
- commuters have lower values than leisure travellers;
- car users have very much higher values than public transport users.

In geographical terms, Wardman reports that values of interchange penalty for travellers in the south east are lower, despite their higher income on average, saying this is:

> *…presumably a function of the familiarity and high service frequency effect, whilst it may also be that interchange facilities are better in the south east and that there is an appreciation of a more integrated transport system which uses interchange to promote a wider range of journey possibilities within a relatively high quality and large network.*

7.5 Effect of changes in time spent on board the vehicle

7.5.1 Elasticity based evidence

New evidence on elasticities with respect to in-vehicle time is limited but the Victoria Transport Policy Institute suggests in-vehicle time elasticities of -0.58 for urban bus, -0.86 for urban rail, -2.11 for interurban bus and -1.58 for interurban rail (based on Small and Winston, 1999).

Gunn *et al.* (1998) have estimated the total door-to-door time elasticities of the number of journeys by purpose for public transport in Paris. The most in-vehicle time sensitive trips are non home-based other (-0.86), the least in-vehicle time sensitive trips are non home-based work (-0.37) (Table 7.20).

Table 7.20 Total journey time elasticities of number of journeys by public transport by purpose - Paris

Purpose of trip	*Public transport time elasticity*
Work – white collar	-0.51
Work – blue collar	-0.55
Business	-0.24
Education	-0.74
University	-0.41
Regular shop	-0.74
Other shop	-0.6
Other	-0.56
Non home-based work	-0.37
Non home-based other	-0.86

York (1996) found that bus priority schemes alone have a limited impact on bus patronage. This was believed to be due to the fact that most priority schemes result in only small time savings which are not perceived by bus passengers. This was confirmed by Daugherty *et al.* (1999) who reviewed a number of bus priority schemes in Great Britain. In only one instance (Aberdeen), did they find evidence of increased patronage. In any event, this patronage growth was modest (4%) and largely attributable to park and ride. Survey work suggested patronage growth of 1.4% attributable to bus priority (with a range of 0.4% to 4.5%). The observed journey time reduction on this route was around 3.5% (although the perceived reduction was 9%). This would suggest an in-vehicle time elasticity of around -0.4.

Mackett and Nash (1991) and Mackett and Bird (1989) report in-vehicle time elasticities of between -0.63 and -0.7 for rail in general. Steer Davies Gleave (1999a) found the UK average in-vehicle time elasticity for rail to lie between -0.6 and -0.8.

In-vehicle time elasticities for rail in the south-east of England provided in Mackett and Nash (1991) and Mackett and Bird (1989) are summarised in Tables 7.21 and 7.22.

Table 7.21 In-vehicle time elasticities – Rail

Run	*Short*	*Medium*	*Long*
Average in-vehicle time elasticity	-0.74	-0.51	-0.84
Standard deviation	0.3727	0.212	0.41
No of observations	6	2	6

Based on models of the Chiltern Line and South-East Sector

Table 7.22 In-vehicle time elasticities – All modes

Description	*Elasticity*
All modes trips to central London, Chiltern line corridor, short run	-0.98
All modes trips to central London, South-east sector corridor, short run	-0.26
All modes trips to central London, Chiltern line corridor, long run	-1.13
All modes trips to central London, South-east sector corridor, long run	-0.34

Source: Mackett and Nash (1991) and Mackett and Bird (1989)

Preston (1987) has estimated a journey time elasticity of -0.418 for journeys on local rail in West Yorkshire.

Generalised Cost (GC) brings together fare, in-vehicle time, walk time and wait time. GC elasticities vary by journey purpose. Halcrow Fox *et al*. (1993) reported Generalised Cost elasticities for bus in the range of -0.4 to -1.7, for underground of -0.4 to -1.85 and for British Rail of between -0.6 and -2.00 (Table 7.23).

The rail industry in Great Britain makes use of the concept of Generalised Journey Time which consists of station to station journey time, a service interval penalty and an interchange penalty. The Passenger Demand Forecasting Handbook (Association of Train Operating Companies, 2002) recommends a default Generalised Journey Time elasticity for rail journey of less than 30 miles of –0.9. For journey above 30 miles, this value varies depending on the attractiveness of rail (measured by Q which is Generalised Journey Time divided by distance) and the strength of competition from other modes.

7.5.2 Attribute value based evidence

The value of in-vehicle time, the ratio of the importance of time spent on board to fare paid, provides a means to derive journey time elasticities from fare elasticities. The value of in-vehicle time also enables attributes expressed in units of in-vehicle time to be converted into money values.

The TRACE project found that most car driver values of time are generally higher than those of public transport users. This difference is partly attributed to a ‘selection’ effect: a person for whom time is of high value tends to choose fast modes. It could also be an income effect:

Table 7.23 Generalised cost elasticities

Purpose	*Mode*	*Low income*	*Medium income*	*High income*
Home - work	Bus	-0.40 to -0.50	-0.50 to -0.70	-0.60 to -0.80
	Underground	-0.40 to -0.60	-0.50 to -0.70	-0.70 to -0.90
	BR	-0.60 to -0.70	-0.70 to -0.90	-0.80 to -1/0
Home - other	Bus	-1.30 to -1.50	-1.40 to -1.60	-1.50 to -1.70
	Underground	-1.40 to -1.60	-1.50 to -1.70	-1.65 to -1.85
	BR	-1.30 to -1.50	-1.60 to -1.70	-1.70 to -2.00
Employers business	Bus		-0.60 to -0.80	
	Underground		-0.50 to -0.70	
	BR		-1.50 to -2.00	

those with higher incomes may be more likely to be car drivers and therefore less susceptible to changes in public transport service changes. The project found that most value of time outcomes for car were around £3.60 (5 ECU) /hour, whereas for public transport they were all between 0 and £3.60/hour (deJong and Tegge, 1998).

It should also be noted that values of time for travel on employer's business (Table 7.24) are higher than for all other purposes, particularly if the chosen mode is public transport:

- for public transport, value is between £7.20 and £14.40 (10 and 20 ECU/hour);
- for car, value is £14.40 (20 ECU/hour).

Wardman (2001) provides average values of time segmented by the key variables of user type, journey purpose and whether the context is one of urban or inter-urban journeys. Key findings of this study of value of time are:

- a GDP elasticity of 0.723 has been obtained;
- the value of IVT increases with distance, with a larger increase for the car mode. Walk and wait time values do not increase as strongly with distance whilst headway becomes less important as distance increases;
- when one distinguishes between user type and mode valued within the car user category, rail users have higher values of IVT than car users, with bus users having the lowest values. Bus has the highest value of IVT and rail the lowest for a given user type;
- the values of walk, wait and headway also vary with user type. Car users are particularly averse to walking and waiting whilst bus users have the lowest values of these attributes;

Table 7.24 Values of time provided by TRACE in £ per hr

Country	*Source*	*Mode*	*Employers business*	*Commuting*		*Other*
Austria	Winkelbauer (1996)	All modes	11.23/12.38	3.31		
Belarus	Brown *et al.* (1996)	Train passenger	0.72			
Belgium	Mouchart and Rutgeerts (1983)	Car or public transport user		2.88 to 3.38		
Finland	Pekkarinen (1993)	All modes		11.02		
Finland	National Road Administration (in Pursula and Kurri, 1996)	All modes	15.34	2.59		1.51
Finland	Preliminary national VOT study (in Pursula and Kurri, 1996)	Urban bus passenger		1.22 to 2.45		
France	Lyon – Turin study (Jincheng, 1996)	Rail passenger		6.41 to 16.27		
Germany	Forschungsgesellschaft für Straßen-und Verkehrswesen (FGSV) (1996)	Bus		45.43		
Ireland	Gibbons *et al.* (1998)	PT passenger Slow modes		1.15 to 3.67 2.38 to 7.34		
Moldova	Brown *et al.* (1996)	Train passenger		0.22 to 1.73		
Netherlands	1988 national VOT study (in Hague Consulting Group 1998)	Train passenger Bus/tram passenger	13.25 13.18	4.68 3.82		3.17 2.23
Norway	National VOT study 1997 (Ramjerdi *et al.* 1997)	Rail inter-urban Bus inter-urban Rail urban Bus/light rail urban	10.44 6.77 9.58 9.58		4.90 4.32 4.32 2.59	
Russia	Brown *et al.* (1996)	Train passenger		0.72 to 1.08		
Sweden	Jansson and Blomquist (1994)	Public transport passenger		0.72 to 0.94		
Sweden	National VOT study (Algers *et al.* 1996)	IC train >50 km	10.87		6.26	
		X2000 train >50 km	11.30		8.57	
		Regional train <50km		3.02		3.60
		Regional train >50km			5.90	
		Long distance bus <50km		3.96		2.38
		Long distance bus >50km			5.47	
		Regional bus <50km		3.60		2.38
		Regional bus >50km			4.25	
Ukraine	Brown *et al.* (1996)	Train passenger		0.50		

Converted from Jan 98 ECUs to £ using PPP 1 ECU = £0.72 (OECD Main Economic Indicators).

- the values of walk and wait time vary with the levels they take. The variation seems plausible. For walk time the variations in the values seems to centre around twice in-vehicle time but they are higher for wait time.

The values of IVT are reported in Table 7.25 and are expressed in year 2000 quarter 3 prices. Two sets of figures are given according to the elasticity used to account for income growth. One adjustment uses an elasticity of one as used by the then Department of the Environment, Transport and the Regions in its recommended procedures. The other adjustment involves an income elasticity of 0.5, in line with cross-sectional evidence from the first British value of time study (MVA *et al.*, 1987), the second British value of time study (Hague Consulting Group and Accent Marketing and Research, 1999), studies in the Netherlands (Gunn, 2001) and previous time series evidence from meta-analysis (Wardman, 2001).

Table 7.25 Overall values of IVT (pence per minute, quarter 3, 2000 prices)

Context	*Income elasticity = 1*		*Income elasticity = 0.5*		
Mode	*Mean*	*Std. error*	*Mean*	*Std. error*	*Sample*
Urban commute					
Car	6.0	0.4	5.5	0.4	64
Bus	4.2	1.0	3.8	0.8	17
Rail	7.2	0.9	6.2	0.7	17
Underground	9.2	0.9	8.2	0.8	5
Car and PT	7.6	0.7	5.8	0.4	44
Urban leisure					
Car	6.5	0.5	5.8	0.4	73
Bus	2.6	0.3	2.4	0.3	22
Rail	6.5	1.0	5.7	0.8	14
Underground	7.3	0.7	6.5	0.6	16
Car and PT	4.7	0.5	4.3	0.4	25
Urban business					
Car	13.2	3.6	11.7	3.1	11
Rail and Underground	19.2	9.0	17.8	8.3	8
Urban other					
Car	6.4	0.4	5.8	0.4	84
Bus	3.2	0.3	2.9	0.3	27
Other	6.4	0.8	5.5	0.6	29
Interurban					
Car	10.5	1.8	10.0	1.7	11
Rail	12.6	0.8	11.5	0.8	21
Other	9.1	1.0	7.7	0.9	9
Interurban leisure					
Car	9.2	1.1	8.2	1.0	23
Rail	13.3	1.2	12.0	1.1	44
Car and PT	13.7	1.5	11.8	1.4	10
Other	11.7	1.3	10.0	1.1	8
Interurban business					
Car	18.3	2.6	17.6	2.6	16
Rail	32.2	3.5	29.3	3.3	34
Rail 1st	52.3	5.7	46.0	5.4	17
Car and PT	13.7	1.5	11.8	1.4	11
Interurban other					
Car	7.4	0.5	7.4	0.6	10
Rail	17.6	1.5	15.3	1.3	18
Other	8.6	0.9	7.6	0.8	15

Source: Wardman (2001)

A number of relationships are apparent within the figures presented in Table 7.25. Inter-urban trips have generally somewhat higher values than urban trips and, as expected, employer's business trips have higher values than trips for other purposes. For urban trips, commuting journeys have higher values than leisure trips for all modes other than car. For inter-urban trips, there is little difference between the values of time for commuting and leisure.

The values of time vary quite appreciably according to the mode used. For urban journeys, underground (UG) users appear to have the highest values whilst bus users have the lowest values. The figures seem to indicate that rail users have higher values than car users, particularly for inter-urban trips although there may be a distance effect at work here since inter-urban rail trips tend to be longer than inter-urban car trips.

The Department of the Environment, Transport and the Regions (2001d) recommended values of time for a number of categories contained in Table 7.26. These are behavioural values and hence directly comparable with those contained in Table 7.25. They have been adjusted from mid 1998 prices and income to 2000 quarter 3 prices and income using the recommended income elasticity of one.

Table 7.26 Department of the Environment, Transport and the Regions – Values of Time

Business – driver	39.7
Business – rail	57.3
Business – Underground	48.1
Non work	8.5

Wardman says that as far as non-work travel is concerned, the recommended values seem to be far too high for urban trips yet too low for inter-urban trips. Across all trips, however, the recommended non-work value compares favourably with the large amount of empirical evidence.

Table 7.25 reports the average value of time in the meta-analysis dataset; a more detailed breakdown of value of time by user types, modes and distances, as implied by the quantitative model estimated using the same dataset, is presented in Table 7.27. Absolute values in pence per minute and 2000 quarter 3 prices are given as well as ratios of these values to car users' values of car IVT.

Car users' values of car are higher than for train and generally lower than for bus. Although car time does become more highly valued than bus time, this only occurs at long distances where there are very few observations for bus travel. We are unable to test whether there is any positive incremental effect on the distance elasticity for bus journeys over long distances.

The distance and journey purpose effects are readily apparent as are the low values of bus users and the high values of rail users. The figures are in stark contrast to recommended values in that they exhibit a considerable amount of variation.

Table 7.27 Money values of IVT implied by the quantitative model

		Absolute values						*Relative to car users' values of car time*				
User type	*Miles*	*Bus*	*Under-ground*	*Rail*	*Car*	*Car*	*Car*	*Bus*				
Mode valued		*Bus*	*Under-ground*	*Rail*	*Rail*	*Bus*	*Car*	*Bus*	*Under-ground*	*Rail*	*Rail*	*Bus*
Comm	2	3.0	9.5	5.7	4.4	6.1	4.6	0.65	2.05	1.23	0.95	1.33
	10	4.0	12.7	7.6	5.9	8.2	7.0	0.58	1.82	1.09	0.84	1.18
	25	4.8	15.1	9.0	7.0	9.8	8.9	0.54	1.70	1.01	0.79	1.10
	50	7.0	n/a	13.2	10.3	14.3	13.8	0.51	n/a	0.96	0.75	1.04
	100	n/a	n/a	15.0	11.7	n/a	16.5	n/a	n/a	0.91	0.71	n/a
Leis	2	2.7	5.1	5.1	4.0	5.5	4.2	0.65	1.22	1.23	0.95	1.33
	10	3.7	6.8	6.9	5.3	7.5	6.3	0.58	1.08	1.09	0.84	1.18
	25	4.3	8.1	8.1	6.3	8.8	8.0	0.54	1.01	1.01	0.79	1.10
	50	6.4	n/a	12.0	9.3	13.0	12.4	0.51	n/a	0.96	0.75	1.04
	100	7.2	n/a	13.6	10.5	14.7	14.9	0.48	n/a	0.91	0.71	0.99
	200	8.2	n/a	15.5	12.0	16.7	17.8	0.46	n/a	0.87	0.67	0.94
EB	2	7.1	13.4	13.5	10.4	14.6	11.0	0.65	1.22	1.23	0.95	1.33
	10	9.6	18.0	18.1	14.0	19.6	16.7	0.58	1.08	1.09	0.84	1.18
	25	11.4	21.3	21.4	16.6	23.2	21.2	0.54	1.01	1.01	0.79	1.10
	50	16.7	n/a	31.5	24.4	34.2	32.8	0.51	n/a	0.96	0.75	1.04
	100	19.0	n/a	35.8	27.8	38.8	39.2	0.48	n/a	0.91	0.71	0.99
	200	21.6	n/a	40.7	31.5	44.1	46.9	0.46	n/a	0.87	0.67	0.94

Comm = Commuting trips.
Leis = Leisure trips.
EB = Business trips.

7.6 Inferring elasticities from attribute valuations

There is plenty of evidence on most of the main effects. In addition, evidence can be inferred from knowledge of price elasticities and valuations of attributes through the ratio of elasticities approach. There is limited evidence on break-downs by city type, time of day/week, journey purpose, socio-economic group but what evidence there is suggests that these segmentations are important.

In this section, some illustrative examples are given, where the ratio of elasticities approach is used to derive elasticities with respect to certain attributes. It should be noted that the values derived should be viewed as indicative rather than definitive. This is because it is very difficult to obtain the real value of the input factors, such as fare elasticities, value of the attributes, mean level of the attributes, etc. As a result, the derived elasticity will be affected by the accuracy of the input values. Nevertheless, the examples not only provide indications of the elasticity values with respect to certain attributes and their variation across segments, but also illustrate the relationship between different attribute values and elasticities.

Table 7.28 illustrates the elasticities for bus demand with respect to in-vehicle-time varies for various journey types. In this example, the mean level of IVT, fare elasticity and average fares are UK national average figure and they are constant across segments. As a result, the parameter in the formula that determines the IVT elasticity is the value of IVT. As there is marked difference of IVT values for the business trips and other trips, the IVT elasticity is also substantially higher for the business trips.

For each journey purpose, the IVT elasticity is lower for rail demand than that for bus demand (Table 7.29). This is mainly due to the effects of higher average fares for rail journeys. Although the travel time costs for rail travel are also higher than bus, the relative value of total IVT compared to fares is lower for rail. Consequently, the sensitivity of rail demand to IVT change is lower than the bus mode, although the sensitivity of rail demand to fare change is higher.

Table 7.28 Elasticities for bus demand with respect to In-Vehicle-Time (IVT) by journey purpose

Journey type	*Elasticity wrt IVT*	*Value of IVT (pence/ minute)[a]*	*Mean level of IVT (minutes)[b]*	*Fare elasticity[c]*	*Average fares (pence)[d]*
Commute	-0.43	3.00	20.00	-0.43	60.69
Leisure	-0.38	2.70	20.00	-0.43	60.69
Business	-1.01	7.10	20.00	-0.43	60.69

Source: a. Table 7.33; b. Average journey length 4 miles from DETR 1999; mean speed is assumed to be 12 mph; c. Table 6.4; d. Calculated from total passenger receipt and total passenger journey from DETR (1999).

Table 7.29 Elasticities for rail demand with respect to In-Vehicle-Time (IVT) by journey purpose

Journey type	*Elasticity wrt IVT*	*Value of IVT (pence/ minute)[a]*	*Mean level of IVT (minutes)[b]*	*Fare elasticity[c]*	*Average fares (pence)[d]*
Commute	-0.42	9.00	31.00	-0.51	336.41
Leisure	-0.27	5.10	31.00	-0.58	336.41
Business	-0.53	13.50	31.00	-0.43	336.41

Source: a. Table 7.27; b. Average journey length 31 miles from DETR 1999; mean speed is assumed to be 60 mph; c. Table 6.34; d. Calculated from total passenger receipt and total passenger journey from DETR (1999).

Tables 7.30 and 7.31 show that the ratio of elasticity approach is not only useful in deriving IVT elasticity, but is applicable to other attributes, such as wait time and walk time. The wait time elasticity for bus demand is lower than the IVT elasticity. This is because that the total wait time costs is lower than the total journey time costs, so the sensitivity of bus demand to wait time change is consequently lower. The walk time elasticities show a similar picture except that the business travel has marginally higher walk time elasticity than IVT elasticity. However, it should always be borne in mind that the examples given here are illustrative as the real values of the parameters are very difficult to establish.

Table 7.30 Elasticities for bus demand wrt Wait-Time (WTT) by journey purpose

Journey type	*Elasticity wrt IVT*	*Value of IVT (pence/ minute)[a]*	*Mean level of IVT (minutes)[b]*	*Fare elasticity[c]*	*Average fares (pence)[d]*
Commute	-0.34	4.77	10.00	-0.43	60.69
Leisure	-0.30	4.29	10.00	-0.43	60.69
Business	-0.80	11.29	10.00	-0.43	60.69

Source: a. Table 7.27 and 7.14; b. By assumption; c. Table 6.4; d. Calculated from total passenger receipt and total passenger journey from DETR (1999).

Table 7.31 Elasticities for bus demand wrt Walk-Time (WKT) by journey purpose

Journey type	*Elasticity wrt IVT*	*Value of IVT (pence/ minute)[a]*	*Mean level of IVT (minutes)[b]*	*Fare elasticity[c]*	*Average fares (pence)[d]*
Commute	-0.35	5.01	10.00	-0.43	60.69
Leisure	-0.32	4.48	10.00	-0.43	60.69
Business	-1.02	14.34	10.00	-0.43	60.69

Source: a. Table 7.27 and 7.1; b. By assumption; c. Table 6.4; d. Calculated from total passenger receipt and total passenger journey from DETR (1999).

7.7 Conclusions

This chapter has examined a mix of elasticity measures and attribute values for three factors: access/egress, service intervals and in-vehicle time. The summary of the empirical evidence on these three factors is as follows.

In terms of access/egress, we find walk time is valued on average at 1.68 times the value of IVT, based on 183 observations. However, values vary with the overall trip length and the amount of walk time. For short bus trips with considerable amounts of walking to and from the bus stop values in excess of 2.0 may be found. When considering all possible access modes (including park and ride, kiss and ride and feeder bus) access time is found to be valued on average at 1.81 time the value of IVT (based on 52 observations). This higher valuation may in part reflect an interchange penalty.

With respect to service levels, we find from Table 7.32 a short run elasticity of bus demand with respect to vehicle kms of 0.38, rising to 0.66 in the long run, although we would expect this to vary by time of day, by the existing level of service and by other factors. Evidence on local rail's service elasticity is more sparse but Table 7.32 suggests that it might be higher than that of local bus. This might reflect that improved local rail services almost always abstract demand from local bus services whereas improved local bus services only rarely abstract demand from local rail. We find, based on 62 observations, that wait time is valued at 1.76 times the value of IVT. However, for short bus trips, where wait time forms a large element of generalised cost, we would expect wait time values to be in excess of twice those of IVT. We find, based on 164 observations, that on average headway is valued at 0.77 times the value of IVT. As expected this is less than half the value of wait time, reflecting that time spent waiting at a bus stop is valued more highly (i.e. has greater disutility) than time spent waiting at home, work or elsewhere.

Table 7.32 Service elasticities, with range and standard deviation according to average values - bus and rail

	Elasticity	*Range*	*Standard deviation*	*No. of measurements*
Bus short run	0.38	0.10 to 0.74	0.14	27
Rail short run	0.75	0.65 to 0.90	0.13	3
Bus long run	0.66	0.22 to 1.04	0.28	23

With respect to in-vehicle time, evidence on elasticities is limited, particularly for bus. This may reflect that bus speeds are often beyond the control of operators, being largely determined by traffic conditions. Our best estimates are that a representative in-vehicle time elasticity for local bus might be in the range of -0.4 to -0.6, whilst for rail this might be -0.6 to -0.8. There is substantially more evidence on passenger valuations. At 2000 prices, we find the mean value of time for commuting by urban bus as 4.2 p/min (based on 17 observations), whilst for leisure travel by urban bus it is 2.6p/min (based on 22 observations). For urban rail, we find the corresponding values to be 7.2 p/min for commuting (based on 17 observations) and 6.5 p/min for leisure (based on 13 observations)

8 Effects of quality of service: other factors

8.1 Introduction

This chapter discusses a number of service quality factors which are not directly measurable in terms of time, although there may be time elements in some cases. For example, the effect of an interchange on demand may depend on both the time taken to effect the transfer between services and the quality of the interchange area and the facilities provided. Other factors considered are waiting environment, service reliability, vehicle quality and a number of bus-specific issues.

In addition to elasticity information, the relative importance of quality of service characteristics is often expressed in terms of an attribute weighting relative to another journey component. This weighting may be in terms of equivalent in-vehicle time. For example, a real time information system may equate to a 3 minute reduction of in-vehicle time per trip. Alternatively, service attributes may be expressed in money terms, such as a minute of wait time being worth the equivalent of 10 pence in fare.

This chapter includes literature on attribute weightings because, when incorporated within demand forecasting procedures, they provide a crucial input in determining passenger responses to enhanced service levels.

Various types of forecasting procedure can be used. In brief, the possible techniques include:

- Converting attribute weightings into an equivalent fare change. When combined with an appropriate price elasticity the equivalent fare change can be used to estimate demand changes.
- Equivalent generalised cost change. This has some parallels with the fare method and requires a generalised cost elasticity, the journey time and cost components that make up generalised cost, and the corresponding weightings for each of these components.
- Ratio of elasticities. With a knowledge of an elasticity for one user group, market shares for different groups and journey characteristics, the elasticities for other user groups may be determined (see Section 5.6).

Studies that include attribute weightings are usually commissioned by local authorities or transport operators and carried out by consultancies. Such studies rarely enter the public domain. Meta analysis of such studies, however, avoids the need to report individual studies and hence maintains anonymity.

A typical forecasting framework based on attribute weightings is that adopted in the PDFH which converts each attribute change into an equivalent change in rail fare and takes the form:

$$I_F = [(F_{new} - (\{C + RS + OB + SF + IP + SY + CS\} * F_{base}) / F_{base})]^f$$

where:

I_F	is the proportionate change in demand.
F_{new} and F_{base}	are the fares in the new and forecast years respectively.
C	is the value of Crowding changes (= base average crowding cost minus new average cost of crowding, expressed as a % of basic fare divided by 100).
RS	is the value of Rolling Stock changes (% of base fare divided by 100).
OB	is the value of On Board Facilities changes (% of base fare divided by 100).
SF	is the value of Station Facilities changes (% of base fare divided by 100).
IP	is the value of Information Provision changes (% of base fare divided by 100).
SY	is the value of Security changes (% of base fare divided by 100).
CS	is the value of Cleanliness changes (% of base fare divided by 100).
f	is the fare elasticity for the market segment.

Note that if Fnew = Fbase, then the index of demand is:

$$I_F = \left(I\{C + RS + OB + SF + IP + SY + CS\}\right)^f$$

Reporting weightings in terms of the equivalent in-vehicle time avoids the need to adjust money values from the estimation year to the year in which application is taking place. Thus, when a study reports both time and money equivalents only the time equivalent is reproduced here.

The European Local Transport Information Service (ELTIS) describes quality factors that it feels a public transport service needs to exhibit in order to be a desirable alternative to a car:

- travel time door-to-door must be competitive;
- comfort must be noticeably improved;
- comfort and feeling of safety in relation to connections between modes at interchange points are important; and
- provision of information to the traveller at home (on routes, timetables etc) and individual marketing are a part of promoting a modern public transport system that is not restricted to its role of providing a social service for those without a car.

In addition, ELTIS suggests that services for transport users must try to address the problems which prevent the use of public transport. These obstacles include:

- logistical barriers: lack of ticket integration, uncoordinated timetables;
- financial barriers: cost differential between public and private transport;
- psychological barriers: poor perception of travel time and image, lack of control over journey, poor perception of true cost of car travel;
- institutional barriers: impact of competition between operators, impact of deregulation;
- information barriers: lack of appropriate information, lack of co-ordinated information;
- physical barriers: accessibility, comfort, travel time differential; and
- social barriers: personal safety and security.

Improvements in service quality can help to overcome these barriers, for example, increased publicity about the true cost of private and public transport will lead to a better informed public, while ensuring that up-to-date information on services is readily available can help people make better choices of public transport.

8.2 Effect of the waiting environment

In describing the main features of the successful regional Verbund services, Pucher and Kurth (1995) say:

> *…bus stops and stations have been expanded, modernized and redesigned to improve the comfort and safety of passengers waiting to transfer from one bus line to another, or between rail and bus lines.*

Above all, passengers are now better protected from the weather, and pedestrian access has been improved, both for the transfer from one public transport mode or line to another, and from the surrounding neighborhood.

Steer Davies Gleave (1996) estimated values for bus stop characteristics by means of stated preference analysis. Table 8.1 summarises these findings.

Table 8.1 Value per trip for bus stop facilities - London

Attribute	*Value (1996 pence / trip)*
Shelter with roof and end panel	5.6
Basic shelter with roof	4.5
Lighting at bus stop	3.1
Moulded seats at bus stop	3.4
Flip seats at bus stop	2.2
Bench seats at bus stop	0.9
Dirty bus stop	-11.8

Source: Steer Davies Gleave (1996) in Bristow and Shires (2001)

Steer Davies Gleave (1996) recommends that a package of service enhancements, including those in other tables in this chapter, be capped at 26.1 pence, on the basis of stated preference analysis of a package of enhancements.

Wardman *et al.* (2001b) provide a range of evidence of different bus stop and terminal facilities (see Table 8.2).

Table 8.2 Value per trip for interchange facilities, Edinburgh

Attribute	*Value (IVT mins/ trip)*	*95% confidence interval*
Shelters/bus stops		
Shelter with lighting, roof and end panels and seats	1.7	±13%
Shelter with lighting and roof	1.2	±16%
A newsagents	0.3	±63%
Shelters/station interchange		
Closed circuit television	0.8	±20%
Intercom connection to control room	0.5	±32%
Eating and drinking facilities	0.4	±47%
Toilets	0.7	±21%
Station interchange		
Staff presence	1.1	±24%
Good signs showing where buses go from	1.2	±22%
Change machine	0.1	±117%

Sources: Wardman et al. (2001b)

Hensher and Prioni (2002) find that seats and shelter at a bus stop are valued at around 7 pence per trip, whilst a seat alone is valued at around 3 pence.

For rail, MVA (2000b) report an average value for a station refurbishment of 19.4p per one-way journey in 1990 prices, or 11% of the average fare. This was based on a stated preference survey of 100 users of refurbished stations in Lancashire. This suggests that values for rail may be higher than for bus.

The typical value for a station refurbishment package is quoted in the PDFH as being worth up to 5% of the fares of originating and interchanging passengers. For short-distance passengers, a minimum value of 36p per journey, in 2000 prices, should be applied. These values will be higher for more extensive station improvements, especially those which affect longer distance inter-urban and interchanging passengers. A typical package of extensive improvements might include a travel centre, waiting rooms, provision of monitors/shelter, ticket office, tannoy system and toilets. Any such package should have a maximum value of 10% of the fare and care should be taken to ensure that enhancements such as the provision of passenger information are not double counted.

The PDFH notes that station improvements will exhibit diminishing returns when considered as a package. Thus reducing valuations by 70% to 80% of their individual valuations in well designed studies and 40% to 50% in studies prone to biases. However, there may be increasing returns when the station facilities on a whole line are refurbished. There are also certain aspects of station design that can be assessed in terms of journey time. Any refurbishment that affects the queues at ticket offices or the delays at ticket barrier etc. can be measured in terms of time savings. Any such time savings should be valued at least twice as highly as in-vehicle time. In addition the provision of facilities at interchange stations will also reduce the interchange penalty at these stations. Table 8.3 provides some values for a range of station improvements for interchanging passengers, which can also be applied to originating passengers.

Table 8.3 Interchange station facilities

	Commute	*Business*	*Leisure*
Intercom to control centre	4	23	20
Real time information monitors	23	38	37
Additional Staff Present	10	15	30
CCTV	10	14	13
Heated and refurbished waiting room	5	7	10
Clear departure information	3	21	21
Plenty of seats on platform	17	25	24
Better lighting	3	4	4
Additional printed timetable information	0	12	12

Values are in pence per journey at 2000 quarter 4 prices and incomes. Adjustments for inflation and income growth should be made in the same manner as outlined for the value of time and for overcrowding values.

Source: ATOC (2002).

8.3 Staff and security

The PDFH notes that the availability, the quality and the attitude of front-line staff towards customers, has a significant effect on passengers' perceptions of rail travel. Good and helpful staff can minimise the effects of an otherwise poor service. Alternatively, poor staff attitude can damage the perceptions of all aspects of a train service.

Another area where the presence of staff has an important influence is the perception of security and safety by passengers. A number of potential passengers, particularly women and the elderly are deterred form using rail at particular times because of fears about personal security.

Evidence from surveys suggests that staffing and visibility are the main solutions to passenger worries about security. In some cases retail outlets can serve a similar purpose as can passenger alarm button (at stations and on trains).

Valuing security is very difficult because it is very much a perceived attribute. It is somewhat easier to measure staff presence but it must be remembered that additional staff are also valued for the information and physical assistance they can provide. A number of the facilities identified in this Chapter will improve security, however as with additional staff, they may also serve other purposes.

8.4 Effect of vehicle or rolling stock characteristics

People want to travel in modern, comfortable vehicles which they can board and leave easily:

> *…all five of the Verbund systems have greatly improved the quality of their vehicles. Buses, trams, trolley buses and rail cars…have been thoroughly modernized, offering increased comfort, higher capacity, and easier exit and entry (Pucher and Kurth, 1995)*

8.4.1 Bus service characteristics

Steer Davies Gleave (1996) provides estimates of diverse service-related aspects for London, on the basis of stated preference surveys (Table 8.4).

Table 8.4 Value per trip for service attributes - London

Attribute	*Value (1996 pence / trip)*
Hail and ride services	
Bus stops close to kerb	5.8
Bus branding	2.8
Driver characteristics	
Driver gives change when needed	4.0
Interaction: appearance & ID	2.5
Interaction: appearance & ID badge	2.2
Interaction: appearance & attitude	1.9
Helpful driver	1.5
Smart driver appearance	0.1
Driver shows ID badge	-0.8
Moving to seat	
Medium crowded (vs low)	-4.7
Medium smooth vehicle motion (vs smooth)	-6.4
Highly crowded (vs low)	-9.5
Rough vehicle motion (vs smooth)	-10.5
Travelling whilst seated	
Dirty bus interior	-8.5
Leaving the bus	
Driver announcements on PA	-0.9

Source: Steer Davies Gleave (1996) in Bristow and Shires (2001)

Bristow and Shires (2001) report on a study by Steer Davies Gleave (1996) which found values per trip for bus attributes in London. Some findings were that low floor buses were valued at 2.8 pence/trip, (1998 prices) while ‘some seats sideways on’ were valued at -3.0. They also recommend a value of 16.27p (2001 prices) per trip for package effects for non-London based bus travel.

Table 8.5 Value per trip for bus attributes, London

Attribute	*Value (1996 pence / trip)*
Low floor buses	2.8
Moving to seat	
Luggage area replaced with standing room	2.0
Some seats sideways on	-3.0
Travelling whilst seated	
Roomy seats (vs cramped)	3.0
Bucket seats (vs standard seats)	-1.1
Ventilation grille (vs opening windows)	-2.5
Leaving the bus	
Two sets of doors	4.2
Electronic display of next bus stop name	3.9

Source: Steer Davies Gleave (1996) in Bristow and Shires (2001)

Hensher and Prioni (2002) have estimated a number of values of bus attributes from survey work in Australia (Table 8.6).

Table 8.6 Bus specific attributes (1999 Prices)

Bus specific attribute	*Value per trip(pence)*
Air conditioning at 20% extra fare	13
Wide entry/2 steps	7
Wide entry/no steps	8
Ride – generally smooth	16
Ride – very smooth	27
Clean enough	11
Very clean	15
Driver friendly enough	15
Driver very friendly	32
Very safe	15
Reasonably safe	12

Accent Marketing and Research (2002) have undertaken Stated Preference surveys in England which suggest that bus users value CCTV on buses at between 4.2 pence and 18.1 pence per trip (2001 prices). The corresponding values for CCTV on buses and at stops were 5.8 pence and 16.6 pence per trip. Similarly, polite helpful and cheerful drivers were valued at between 7.7 and 13.8 pence per trip. New buses were valued at between 7.8 and 12.7 pence per trip, whilst new low floor buses with no steps were valued at between 4.7 pence and 14.3 pence per trip.

8.4.2 Low-floor vehicles

Improvements in technology have made it possible to provide ‘low floor’ (sometimes known as ‘Super Low Floor’, SLF) buses and light rail vehicles for regular urban service. These now comprise all new vehicles for local bus service in Britain. For a substantial part of the vehicle, a low flat floor is provided, at a height similar to that of a pavement kerb. Hence, from a slightly raised kerb (or light rail platform) access can be made into the vehicle at the same level. Room is provided within the vehicle for wheelchairs, pushchairs etc., shared with standing passengers. A short ramp is provided, avoiding the need for a separate lift for wheelchairs. This has two main benefits:

- Certain types of passenger not previously able easily to make use of bus and light rail services can now do so. These include wheelchair users, and those with shopping trolleys and/or child pushchairs. Some other categories, notably the elderly may also find access easier
- Dwell time at stops is reduced, especially in comparison with older light rail vehicles in which several steps have to be negotiated by passengers. Topp (1999) estimates savings of up to 40%, giving reductions in journey time analogous to those through priority measures and off-vehicle ticketing. However, for buses the reduction in boarding and alighting times tends to be off-set by the additional time needed for vehicles to kneel and rise. The net effect on dwell times depends on numbers of boarders and alighters at each stop. York and Balcombe (1998) found that on a typical London route, the overall time for a single-deck low-floor vehicle exceeded that for a conventional double-deck vehicle by approximately one minute.

As in other cases of innovation, low-floor access may often by combined with other service quality measures, such as improved driver training and better passenger information, Extensive publicity given to introduction of low-floor buses and new colour schemes may themselves attract new users, simply through increased awareness. Some very high percentage growth figures must thus be treated with caution. York and Balcombe (1998) studied the effects of introducing low-floor buses on five London bus routes and one in North Tyneside. Changes in patronage ranged from -6.7 to +17.0%, but in most cases there were comparable changes on nearby control routes It was possible to identify a significant change due to low-floor buses on only one London route: the apparent increase was 11.8%. Some examples showing the range of growth encountered in other areas, excluding extreme instances, but not necessarily taking overall demand trends into account, are given below:

Kentish Bus 480 (Gravesend - Dartford) 5% (Local Transport Today, 1996).

Blackpool 22% - associated with extensive publicity (Transit, 1997).

Ipswich 2-3% (Coach & Bus Week,1997).

Plymouth 5% (Transit, 1998a).

Birmingham (Travel West Midlands) route 9 5% (Transit, 1998b).

Birmingham (Claribels) 9% (Coach & Bus Week, 2000b).

Truronian, Cornwall (rural service) 15% (DETR, 1998b).

London route 242, operated by Arriva 10% (Coach & Bus Week, 1999).

Southampton - Winchester (Solent Blue Line) 7.5% (Coach & Bus Week, 2000a).

Southampton cross-city route 5% and Southampton-Eastleigh 3.5% (Solent Blue Line) (Transit, 2000).

While cases of substantial simultaneous changes in service and fare levels have been excluded, it may be the case that some of the larger growth figures are associated with simultaneous marketing initiatives, etc. as well as introduction of low-floor vehicles.

York and Balcombe (1998) assessed the effects of low-floor buses on the travel habits of ambulant disabled passengers and passengers with pushchairs. The results showed that ambulant disabled passengers in London valued low-floor buses at one penny per trip more than a trip in a double-decker and that in Tyneside the difference was 57 pence more per trip. The reason for the large differential was attributed to the free travel available to passengers in London that resulted in considerable resistance to any form of payment. The values reported by those people with pushchairs (both areas) was between 4p and 12p per trip in favour of low floor buses, giving an average value of around 7.4p per trip compared with a trip on a double-decker.

8.4.3 New railway rolling stock

Wardman and Whelan (2001) provide a comprehensive assessment of the impact of new railway rolling stock in Great Britain. A novel feature was the development of revealed preference (RP) models based on actual choices between different stock types to complement traditional stated preference (SP) models. A total of 2348 RP and 7047 SP choices were available. The joint RP-SP choice model contained journey time, egress time, headway, crowding levels, fare and the ratings of different rolling stock types. The cost coefficient was allowed to vary with income whilst the time and stock coefficients varied with journey purpose. The values obtained expressed as proportions of the fare or journey time are given below. In contrast to the vast majority of other evidence, the values are on the low side (Table 8.7).

The study also used SP methods to estimate the separate values associated with ride quality, seating layout, seating comfort, noise, ventilation and ambience. This was done by reference to the levels existing on different types of train with which the respondent would be familiar. As in a number of other studies, a package effect was present in that the sum of the values of individual attributes exceeded the estimated value of the overall package.

Table 8.7 Railway rolling stock valuations

Stock types (preferred first)	*Money value*	*Time value*		*Moneyvalue*	*Timevalue*
Express sprinter v sprinter	0.9%	1.9%	Mark 2 v SE slam door	1.4%	2.2%
Networker v sprinter	0.7%	0.8%	Mark 3 v SE sliding door	1.5%	2.0%
Express sprinter v SE slam door	1.5%	3.0%	Mark 2 v SE sliding door	0.7%	1.0%
SE sliding door v SE slam door	0.6%	0.9%	Mark 3 v networker	0.6%	1.1%
Networker v SE slam door	1.0%	1.1%	Mark 2 v networker	0.6%	1.3%
Wessex electric v SE slam door	1.2%	2.8%	Mark 3 v Mark 2	0.1%	0.2%

It was found that refurbishment which changes the level of seating layout, ride quality, ventilation, ambience, noise and seating comfort from levels associated with old south east slam door stock to new air conditioned south east stock was worth around 2.5% of the fare. However, most refurbishments would be worth somewhat less than this, with 1.5% being a representative figure.

The report also reviewed evidence relating to the package effect across four studies as well as providing fresh evidence. The average package effect across these studies was 0.5, indicating that the sum of the valuations of individual stock attributes is, on average, twice the value of the corresponding overall package.

In addition, a large-scale review of 18 previous SP studies was conducted. The values tended to be high. It was suspected that many had been subject to strategic response bias. These high valuations were not supported by eight studies based on analysis of ticket sales as in four studies there was no significant change in demand after new rolling stock introduction whilst in the other four demand increases of between 3% and 8% were found but with broad confidence intervals.

A regression model was developed to explain the variations across 45 valuations of rolling stock expressed as a proportion of the fare paid. A variable denoting whether the purpose of the study would have been readily perceived to have been stock valuation found that rolling stock values were three times higher in such instances. This was taken to signify the presence of strategically biased responses. In addition, familiarity with the types of new rolling stock being proposed was found to yield values 44% lower than where there was unfamiliarity. The results of this review do allow some degree of reconciliation between the findings of econometric analysis of ticket sales data and the values obtained from stated preference studies.

8.4.4 Crowding

There has also been considerable work on valuing the impact of overcrowding in the passenger rail industry. A recent study is that of MVA (2000a). This study was undertaken for the Strategic Rail Authority and its objective was to value the benefits from alleviating crowding on services to and from London. A stated preference survey was used which featured cost, journey time and different crowding conditions in which the journey was made. The services surveyed were GNER and Midland Mainline services to and from London, outer suburban services of South West Trains and Chiltern and Inner Suburban services of South West Trains and LTS. Surveying was conducted in February 2000 and a sample of over 2000 passengers was obtained.

Models were estimated for inner suburban, outer suburban, intercity leisure, intercity commute, intercity business and intercity first class. Within each set of flows, models were estimated for a number of other categories, such as journey purpose, journey time, income group, gender and age group. The results for the main categories of interest are given below. The values are expressed in pence per minute in quarter 1 2000 prices and incomes. The results are not entirely consistent. For example, the results for InterCity 1st class are not plausible whilst there are several other cases where the relationship between valuations does not conform to expectations.

Table 8.8 Values of time in different crowding conditions (p/min)

Flow	*S1*	*S2*	*S3*	*S4*	*S5*
Inner suburban commute	7.7	11.4	10.4	24.1	28.0
Outer suburban commute	18.6	11.6	15.3	32.2	31.3
Intercity leisure	12.9	8.3	14.0	n.a	37.9
Intercity business	123.5	112.6	89.9	n.a	319.3
Intercity 1st class	-93.9	-92.9	-217.7	n.a	n.a

S1 Sitting at the lowest level of crowding.
S2 Sitting at the medium level of crowding.
S3 Sitting at the highest level of crowding.
S4 Standing at the medium level of crowding.
S5 Standing at the highest level of crowding.

An alternative approach to evaluation of crowding is to use crowding values in conjunction with fares or generalised costs. Crowding values are related to the amount of time spent in a train and are therefore presented as pence per minute values (see Table 8.9). In addition the values vary by journey and route purpose. With the exception of commuting, crowding penalties occur when load factors reach 60%. The penalties for commuters do not start until load factors reach 90% and 100%, and are justified because crowding is the norm in this market. It should be noted that the crowding penalties in Table 8.9 only refer to individual passengers on particular trains. If values are being calculated for average train loads the PDFH recommends that the crowding penalties are increased by 10%.

8.4.5 On-board facilities

It is recognised that on-train catering does affect rail demand, but the PDFH is unable to provide any recommended values for catering provision. What is noted is that the cost of not providing catering services on services that have them advertised is likely to be far higher than any benefit gained from their presence. There is also evidence that suggests trolleys are regarded as a nuisance and have a negative value. This is contradicted by another study that found that a trolley was preferable to a buffet car, with a value of about £3.50.

Clearer evidence exists that passengers are prepared to pay higher fares for packages of 'added service benefits'. These are outlined in Table 8.10 and cover a wide range of services. It is, however, unlikely that any of these are applicable to urban rail journeys.

8.4.6 Cleanliness

Cleanliness is an important attribute for both commuting and off-peak urban journeys. It is ranked above seating comfort for the former and second only to punctuality/ reliability for the latter.

The values recommended by the PDFH come from the Network SouthEast Quality of Service research. Two recommended values are made for rolling stock, both

Table 8.9 recommended crowding penalties for passengers (p / min)

		Leisure		*Business*		*Commuting*			
						London			
Load factor		*London*	*Non London*	*London*	*Non London*	*Inner*	*Outer*	*Non London*	*1st Class London*
50%	Sit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60%	Sit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70%	Sit	0.2	0.17	2.4	0.7	0.0	0.0	0.0	0.0
80%	Sit	0.4	0.35	4.7	1.3	0.0	0.0	0.0	0.0
90%	Sit	0.8	0.52	9.2	1.9	0.0	0.25	0.4	6.0
100%	Sit	1.1	0.70	13.7	2.5	0.6	0.50	0.8	12.1
110%	Sit	1.5	1.20	18.2	3.6	1.2	0.75	1.2	–
120%	Sit	1.8	1.70	22.7	4.6	1.8	1.00	1.6	–
130%	Sit	2.2	2.20	27.2	5.7	2.4	1.25	2.0	–
140%	Sit	2.5	2.70	31.7	6.7	3.0	1.50	2.4	–
150%	Sit	–	–	–	–	3.6	–	–	–
160%	Sit	–	–	–	–	4.2	–	–	–
100%	Stand	22.0	22.0	100.0	48.0	12.0	12.0	6.5	–
120%	Stand	26.4	26.4	120.0	50.5	13.0	13.0	7.5	–
140%	Stand	30.8	30.8	140.0	53.0	14.0	14.0	8.5	–
160%	Stand	–	–	–	–	15.0	15.0	9.5	–

All values are in 2000 quarter 4 prices and incomes.

The values should be inflated to current prices using the retail price index.

Adjustments for income growth should be made by adjusting the business values using a GDP per capita elasticity of 1.0 and adjusting the leisure values using a GDP elasticity of 0.723.

All crowding costs are zero at 60% load factor. All intermediate values should be calculated by linear interpolation.

The London / non-London split applies to the trains, not necessarily the passenger's journey.

Source: ATOC (2002).

Table 8.10 Values associated with on-board facilities

Packages	*Value £s*
Standard class package – segregated accommodation (a quieter environment), free tea/coffee and a tabloid newspaper.	1.30 – leisure and self paid business traveller. 0.16 – season ticket holders. 5.00 – employer-paid business travellers(all above in 1996 prices).
First class premier – free refreshments, quality newspaper, on-train magazine, novel/magazine on request, free car parking or taxi (up to three miles) and breakfast/light snack voucher.	5.30 – business travellers. 16.10 – leisure travellers.
As above but not free car parking or taxi (up to three miles).	0.00 – business travellers.
Standard class premier – free tea/coffee/soft drink, quality newspaper, on-train magazine and a quiet environment.	0.53 – leisure travellers. 2.29 – business travellers (employers pay).
A quiet environment.	0.08 – business travellers (employers pay). 1.08 – business travellers (paying for themselves)(all above in 1999 prices).

extremes. For 'litter on the floor', a possible value of 2p per passenger minute is recommended, whilst for 'litter on floor and seats' a possible value of 5p per passenger minute is given. Cleanliness accounts for 1-2% of the 5% value attributed to station refurbishment. Again care needs to be taken to avoid double-counting the cleanliness benefit if a refurbishment has taken place.

8.5 Effect of interchanges between modes

Pucher and Kurth (1995) describe Munich as:

> *…perhaps the premier example of rail system integration, with long-distance, medium-distance and short-distance rail systems merging underneath the long pedestrian mall extending from Karlsplatz to Marienplatz in the city's centre*

Interchange should be made as easy as possible with information readily available on connections and waiting time minimised and made pleasant. As with any public transport waiting environment, there should be shelter from the weather, security and adequate facilities for comfort such as toilets, seats and shops. In addition, efficient interchange between modes such as car or bike and public transport can be facilitated through the provision of adequate parking facilities. Pucher and Kurth (1995) have identified this aspect of inter-modal coordination as a factor to encouraging more public transport use:

All five Verkehrsverbund in this study dramatically increased the number and capacity of park-and-ride facilities…and most systems have greatly increased the number and quality of bike storage facilities at train stations, including, sheltered bike racks and convenient lockers.

Wardman (1998) provided evidence on interchange penalties from meta-analysis of 47 British studies (Table 8.11). The key finding was that passengers dislike interchange with a reported penalty equivalent to 21 minutes for bus and 37 minutes for rail, but note that this includes additional walking and waiting time as well as the inconvenience of interchange *per se*.

Table 8.11 Interchange penalty weightings from meta-analysis

Category	*Value (in-vehicle time mins)*	*Standard deviation of value*	*Number of studies*
All	31.29	22.94	47
Employers business	32.36	13.46	7
Commuting (peak)	14.25	5.26	11
Leisure (off-peak)	35.13	25.28	12
Other purposes	39.17	26.67	17
Car users	13.91	5.64	8
Bus users	20.83	9.36	6
Rail users	36.8	20.07	13
Other users	37.79	27.53	20
Revealed preference	43.08	32.86	10
Stated preference	28.1	18.81	37
Suburban	16.22	8.41	21
Inter-urban	43.46	23.8	26

Source: Wardman (1998)

On the basis of separate stated preference experiments with bus, rail and car users, Wardman *et al.* (2001b) provide attribute values for the interchange penalty and interchange connection times shown in Table 8.12. The key findings for Edinburgh, which are dominated by frequent, intra-urban services, were a value per trip for interchange penalty of 5 minutes for bus and 8 minutes for rail.

Table 8.12 Value per trip for interchange attributes - Edinburgh

Attribute	*User type*	*Value (IVT mins/ trip)*	*95% confidence interval*
Interchange penalty	Bus	4.5	±65%
Interchange penalty	Car	8.6	±83%
Interchange connection time (mins)	Car	1.7	±61%
Interchange penalty	Rail	8	±78%
Change platform walk time (mins)	Rail	1.5	±79%

Source: Wardman et al. (2001b)

8.6 Reliability

Qualitative and attitudinal studies of travel choice behaviour have found that the punctuality, reliability and dependability of a transport system are rated by users as a very important feature, affecting both their perceptions and levels of use for different modes.

In spite of its importance, public transport demand elasticities (or other quantitative estimates) with respect to service reliability are limited and often only qualitative estimates of passenger response to reliability have been made. Bly (1976b) is an early work that developed a theoretical model for estimating the effects of random service cuts on passenger waiting times (cited by Booz, Allen and Hamilton, 2003). This model indicated that, for high frequencies, the percentage increase on average waiting times is about twice the percentage of bus services not operated; while for low frequencies this factor increases to three or more (ie. a 10% random service cut will increase waiting times by around 20% for frequent services, 30% or more for less frequent services). Further the 'excess' waiting time experienced by passengers is likely to be valued at 2-3 times ordinary waiting time, reflecting the anxiety and annoyance caused.

Noland and Polak (2002) note that there are two main approaches to modelling reliability. The first they term the mean-variance approach and is the method most commonly used in public transport studies. Then second they refer to as the endogenous scheduling approach. Examples of the latter are rare in public transport.

An example of the mean –variance approach in relation to wait time and wait time reliability is the work of WS Atkins and Polak (1997), who estimate weightings in relation to in-vehicle time, suggesting that the standard deviation of wait time has a similar weight to the mean value of wait time, indicating that delays can have a significant impact on demand (Table 8.13).

WS Atkins and Polak (1997) also give values for bus in-vehicle time and in-vehicle time reliability (Table 8.14).

Table 8.13 Values of bus wait time reliability relative to average in-vehicle time

	By journey purpose			*By time period*	
Variable	*Journey to work*	*Shopping*	*Other purposes*	*Peak*	*Off-peak*
Wait time	2.6	1.3	3.1	2.6	1.7
Wait time s.d.	2.5	1.0	1.9*	3.0	1.2
Observations	598	616	254	679	870

** Not statistically significant.*

Source: WS Atkins and Polak (1997).

Table 8.14 Values of bus in-vehicle time reliability relative to average in-vehicle time

	By journey purpose			*By time period*	
Variable	*Journey to work*	*Shopping*	*Other purposes*	*Peak*	*Off-peak*
Bus in-vehicle time	1.4	0.8	1.3	1.4	0.9
In-vehicle time s.d.	2.0	0.8	2.3	1.8	1.2
Rho-sq (0)	0.293	0.189	0.278	0.293	0.205
Observations	598	616	254	679	870

Source: WS Atkins and Polak (1997).

Hensher and Prioni (2002) find that bus reliability (in terms of minutes late) is valued at around 1.82 times in-vehicle time. Accent (2002) found that if buses were always on time, this would be valued at between 4.2 and 18.2 pence per trip (2001 prices).

As well as SP work, there are also some cases where researchers have calculated an observed elasticity of demand with respect to 'lost km' compared with scheduled changes. In London, estimates of the impact of schedule coverage' gave an elasticity of about +1.5 to +1.6, compared with an overall elasticity with respect to bus-miles of +0.78 (Kennedy *et al.*, 1995). This ratio is similar to work by Bly reported in the original handbook and referred to above.

Noland and Polak (2002) discuss the concept of the reliability ratio, defined as the value of travel time variability (measured by the standard deviation of travel time) over the value of travel time. They report that for rail commuters this values is between 1.04 and 1.22 but for leisure travellers this ratio was estimated to be around 0.66.

An example of the endogenous scheduling approach applied to the rail industry is described by Bates *et al.* (2001). They quote a value of expected schedule delay early of 56 pence per minute, compared to a value of schedule delay late of 114 pence per minutes. They also find a value of headway of 5 pence per minute and a value of delay of 127 pence per minute of delay. However, their survey work included business travellers with high values of time. The Passenger Demand Forecasting Handbook interpreted this work as implying, on average, a value of late time of around 3 times that of in-vehicle time. Most of this was due to the annoyance of being late but a significant element (equivalent to 0.5 times the value of in-vehicle time) was due to penalties associated with rescheduling activities. This was a particularly prominent feature for commuters using high frequency services because they have tightly constrained schedules.

8.7 Effect of information provision and promotional activity

8.7.1 General effects

Good passenger information is an essential ingredient of a successful public transport system; ill informed travellers may not be able to identify services which best suit their needs, leading to poor perceptions and low use of public transport.

Information provision and promotional activity can take many forms.A good review is provided by Rickman (1991) using West Yorkshire PTE (Metro) as a case study. Metro's general policy has been:

> *'the promotion of the network in such a way as to maintain and increase patronage, by good information about the services available, prompt notification of changes, encouraging loyalty to the public transport system, presenting a unified system of services to the public and seeking to make non users aware of the significant benefits of public transport' (West Yorkshire PTE/Metro, 1991).*

To these ends Metro provides a number of publicity services (in the broadest sense):

Timetable leaflets.

These are the main source of detailed information to enable usage of the system. They are distributed via Metro Travel Centres, bus and rail stations, libraries and Tourist Information Centres. Metro will post up to ten timetables to those requesting them (but the service is not heavily advertised). Leaflets are not distributed to households despite trials that illustrate the cost effectiveness of this method (Ellson and Tebb, 1978, 1981, found that revenue increases were three to ten times greater than costs in an initial five month period) nor are they usually distributed on-vehicle.

Timetables are the main source of publicity for public transport despite the fact that research has indicated that 70% of those making regular journeys and 60% of occasional passengers never consult timetables (Balcombe and Vance, 1998). In West Yorkshire, it has been found that 42% of those using buses once a month had a timetable leaflet in their home, but only 37% were sure that it was up to date (Harris Research Centre, 1989). This indicates that bus travel is largely an experience good. People gain information on the product from their experience of using it.

Area guides

Bus and train guides for each of West Yorkshire's five districts are produced annually including route maps and summaries of the services in the area. The first version of these guides was distributed to all households but subsequently they have been distributed in the same manner as timetable leaflets.

Metro travel centres

Centres in Leeds, Bradford, Huddersfield and Halifax are open 0830 - 1730 Monday to Friday and 0900 - 1630 Saturdays, whilst bus companies also have travel information centres. Harris Research Centre (1989) found that 35% of bus users had visited a travel centre in the previous year, with 85% being able to find all the information they require.

Telephone enquiry service

Metro has set up a Busline system. A survey by Bonsall and Tweddle (1990) indicated that 96% of callers were satisfied with the service but that on average demand was double the number of callers getting through to Busline. It was estimated that Busline led £450k of extra revenue per annum.

Information at bus stops, bus and rail stations

Of the 13,600 bus stops maintained by Metro, timetable cases are provided at 2,650. This coverage of around 20% is significantly better than the other PTEs but it is still surprising that 80% of sales outlets for bus travel in West Yorkshire have no information at all about the product they are selling. Moreover, the information displayed is normally based on the timetable leaflets and is very difficult to read. Experiments with information based on departure times from the stop were undertaken but have since been abandoned.

West Yorkshire PTE have experimented with computer information points at Brighouse, Cleckheaton and Normanton, but have not supplied real time information which advises customers when vehicles will arrive at stops. Evidence on whether such systems increase patronage is mixed. Work on London Underground (Sheldon *et al.*, 1985, Forsyth and Silcock, 1985) and in Ottowa, Canada (Suen and Geehan, 1986) indicate that demand can be increased by up to 10%. Evidence from London Buses (Wardman and Sheldon, 1985) and the Tyne and Wear Metro (James, 1986) is less positive.

On-board information

Metro's on-board information is limited to details concerning service changes and advertising material concerning pre-paid tickets. Route maps and next stop indicators are not provided.

Metro has also undertaken TV advertising of prepaid ticketing. Market research on the effectiveness of this showed that although 82% of those surveyed could recall the advertisements, only 37% could recognise the message conveyed and sales were only increased by 3% as a result (Quaestor, 1990). It may be that the message conveyed was too complex for a TV advertisement and press advertising may have been more effective. A similar finding was detected for Network SouthEast (Barnes, 1989). An earlier TV campaign in West Yorkshire promoting public transport in general may have been more successful. Cottham (1986) estimates that a £300k campaign boosted revenue by £1.6 million. Work on the national rail system suggested that continuous, low weight advertising of the Senior Citizens' rail card boosted sales by 8% (O'Herlihy Associates Limited, 1987).

A survey by Greater Manchester PTE (1991) indicates that West Yorkshire PTE's promotional activity was greater than that of the other PTEs. Rickman (1991) notes that between 1985/6 and 1988/9, bus use nationally decreased by 10%, in the English PTE areas it was down by 16% but in West Yorkshire it was up by 2%. It was believed that much of this difference could be attributed to the better marketing of public transport in West Yorkshire than elsewhere (although there has been a subsequent decrease in use in West Yorkshire. This finding is similar to the finding by Preston and James (2000) from a case study of 22 towns that marketing activity could boost demand by 17%.

Rye (2002) has collated evidence on the impact of travel plans in UK and abroad. Within the UK the following case studies are highlighted:

- Between 1996 and 2000, Manchester Airport doubled its bus use and tripled cycle use for trips to work reducing the proportion of staff who drive alone from 83% to 63%. This was achieved with a combination of parking charges, improved cycle access and facilities, more public transport services and discounts on public transport.
- Astra Zeneca have decreased individual car commuting by 8% over two years. Bus use by staff increased from 10 to 170 as a result of improved bus services and subsidised travel.
- At Buckinghamshire County Council's headquarters sites in Aylesbury and High Wycombe, a travel plan that included discounts of 30% on local buses and trains secured a reduction of 20% in vehicle trips to work by staff over an 18 month period.
- Wycombe District Council reduced the proportion of its staff driving alone to work from 79% in 1998 to 59% in 1999 due to an increase in cycle use and car sharing and the introduction of parking charges.
- Nottingham City Hospital reduced the share of single occupant car commuting from 72% to 58% of the workforce between 1997 and 2001. Bus use has risen from 11% to 18% of the workforce and car sharing from 2% to 11%. This has been achieved by bringing three cross city bus routes into the site and by introducing parking charges.
- The Head Office of a supermarket chain in Bracknell launched a free bus link between the railway station and the site in June 2001, with public transport use increasing by 25%.
- At Stockley Park, car use decreased from 88% in 1997 to 84% in 1999. Public transport use increased from 10% to 12% over the same period, with cycling more than doubling.
- At Hewlett Packard in Edinburgh, the proportion of staff driving alone fell from 65% in 1997 to 59% in 1999 due to an increase in rail use from 8% to 14% over the same period.

Rye also reviews evidence from the United States and the Netherlands. In the State of Washington, where travel plans are mandatory for firms with over 100 employees, the percentage of employees who drove alone to work fell from 72% to in 1994 to 68% in 1999 for those firms affected by the legislation. In the Netherlands, reviews of the trip reduction achieved by travel plans have been carried out by Touwen (1997) and Ligtermoet (1998). They concluded that on average the reduction in drive alone commute trips from a travel plan was as follows:

- About 5-8% for a plan with only basic measures that cost little.
- About 8-10% for a plan with the basic measures and other more expensive measures such as additional bus services to the site and reduced fares.
- About 10-15% for a plan with all the above measure and disincentives to car use, such as car park charging.

Rye speculates that the average effectiveness of travel plans in the UK might be a 6% reduction in drive alone car travel to work. Although some trips will transfer to car share and cycling, an important element will transfer to public transport where appropriate services are provided.

Taylor (2002) reports that the introduction of individualised marketing in Perth, Australia, in 1997 increased public transport usage by 21% amongst a sample of 400 households, around one-third of which were pre-disposed to switching from car. This approach was subsequently extended to a city wide initiative entitled Travelsmart. A similar approach, called Travel Blending, has been adopted in Adelaide.

A targeted public transport marketing programme in Helsinki, Finland, has had similar results. In the target group, the modal share of public transport rose from 35 % to 42 % (up 20%). The relative share of trips by car declined from 45 % to 40 % in the target group but remained unchanged in the control group. Half of this growth in public transport use was still evident a year after the promotion (see www.eltis.org).

Public transport information has been described as a key factor in increasing ridership in the successful Verbund regionally-coordinated public transport systems operating in Hamburg, Munich, Rhein-Ruhr, Vienna and Zurich (Pucher and Kurth, 1995):

In addition to providing more and better services, all five of the Verbund systems have made considerable investments in improved information for passengers.

This information is provided by computerised, individual timetables, route and fare information over the telephone and through personal computers. Information about current status of trains is also given with information boards on station platforms showing actual arrival and departure times and digital displays on-board vehicles indicating the next stop, supplementing audio announcements.

The Norwegian Institute of Transport Economics and the Ministry of Transport and Communications (1993) report on an extensive marketing campaign in 5 counties in Norway Hedmark Oppenland, Vest-Agder, More og Romsdal, and Nord-Trondelag following the introduction of new services, and in More og Romsdal an environmental travelcard. This produced mixed results, but was quite successful in promoting bus use. Surveys found that around 50% of the people (ranging from 21% in one county to 82% in another) were aware of the campaign. Of those 17% could not describe its contents, 25% described the general measures, and 60% could describe the specific targeted measures. It was found that whatever else they did not recall, people seemed to get the general idea that they should use the bus more.

8.7.2 Evaluation of passenger information

The vast majority of quantitative evidence on information provision takes the form of attribute valuation. For example, Bristow and Shires (2001) report the findings of stated preference surveys on information provision of 947 London Transport Buses' passengers undertaken by Steer Davies Gleave (1996) (Table 8.15).

Wardman *et al.* (2001b) undertook SP experiments of attribute values held by travellers interchanging between buses on-street and at bus stations and this is shown in Table 8.16.

Values may also be inferred from the work of Balcombe and Vance (1998) as shown in Table 8.17 and from the work of Colqhoun Transportation Planning (1992) as shown in Table 8.18.

Table 8.15 Value per trip for information facilities - London

Attribute	*Value (1996 pence / trip)*
Pre-trip information	
Standard timetables, at home	5.5
Standard maps, at home	3.9
Five star phone service	2.8
Customised local information at home	2.0
Information at the bus stop	
Guaranteed customised local information at stop	10.0
Real-time information (Countdown)	9.0
Guaranteed current information at stop	8.8
Payphones	3.8
Countdown & medium bus reliability (headway <= 10 min)	-5.0
Countdown & best bus reliability (headway >= 10 min)	-5.3

Negative values represent the reduction in value relative to countdown alone.

Source: Steer Davies Gleave (1996) in Bristow and Shires (2001).

Table 8.16 Value per trip for information facilities for bus interchange - Edinburgh

Attribute	*Value (in vehicle time mins / trip)*
Real time information monitors on bus arrival times	1.4
Printed timetable information	1.3

95% confidence interval for both attributes ±13%.

Source: Wardman et al. (2001b)

Table 8.17 Percentage of respondents indicating willingness to pay for information options

	Hertford -shire		*York -shire*		*Birming -ham*		*Man -chester*	
Information option	*Pay*	*Not*	*Pay*	*Not*	*Pay*	*Not*	*Pay*	*Not*
At home								
Personal timetables £5	8	74	5	71	7	76	3	75
Personal timetables £3	15	59	11	59	14	58	9	55
Personal timetables £2	24	50	22	47	31	52	24	42
Enquiry terminal 50p	17	60	12	61	20	61	17	55
Enquiry terminal 30p	28	45	25	45	31	44	26	40
Enquiry terminal 20p	41	38	39	35	51	34	39	29
At bus stop								
Full timetable 25p on fare	7	76	6	78	12	72	14	68
Full timetable 15p on fare	13	68	13	65	21	61	23	52
Full timetable 10p on fare	20	54	30	45	34	46	32	37
Real-time display 50p	6	85	2	90	4	88	4	85
Real-time display 300p	8	72	5	82	3	78	6	74
Real-time display 20p	19	53	13	59	19	57	13	53
At town centre								
Enquiry terminal 25p	22	59	9	63	16	61	11	56
Enquiry terminal 15p	34	38	20	45	34	39	21	40
Enquiry terminal 10p	54	26	41	32	54	27	40	23

Percentages undecided not shown.

Table 8.18 Valuation of bus service information levels (pence per journey)

Information accuracy	*Work*	*Non-work*
10 minute displays	3.0	1.9
5 minute displays	4.7	3.8
1 minute displays	6.5	5.1

Other evidence is provided by Hensher and Prioni (2002) who, based on work in Australia, suggest that timetables may be valued by adult bus users by as much as 22 pence per trip, reducing (somewhat counter-intuitively) to 15 pence per trip for the provision of a timetable and a map (1999 prices). Accent (2002) found timetables and route maps at bus stops were valued by bus users by between 4.3 and 10 pence per trip whilst real time information provision was valued at between 3.8 and 19.9 pence per trip, depending on the type of route (2001 prices). They found substantially higher (and arguably implausible) values of bus information for car users.

The importance of advances in information provision has been described by ELTIS:

State of the art passenger information systems increasingly draw upon advanced telematics solutions to maximise achievable benefits. Emphasis is on development of fully integrated passenger service systems which ensure that every potential barrier to a seamless travel experience is eliminated.

Marketing of public transport is equally useful as a provider of information. Pucher and Kurth (1995) provide an example of good practice:

As a free public service, large stores in Zurich even place public transport ads on their shopping bags. Moreover, public transport advertising appears regularly in each of the Verbund regions' newspapers, in cinemas, and on radio and television stations. Millions of informational brochures and pamphlets are regularly distributed to all households with postal addresses in the Verbund regions. The ads emphasize the environmental and social benefits of public transport, but they also depict public transport as a safe, convenient, money-saving alternative to the automobile.

The provision of information is consistently rated as being of importance by rail passengers. The PDFH defines three basic levels of information provision outlined below:

- *Basic:* printed timetables at stations; no information on trains.
- *Standard:* station indicator showing timetabled information (platform/scheduled time/calling points) for next train, with occasional announcements; occasional on-train announcements about calling points.
- *Enhanced:* continually updated station monitors showing train information and expected departure/arrival times; permanent displays in carriages showing information about all station stops, including expected arrival times, interchange details, and reasons for delay.

A key requirement for every level of information provided is that the information is 'relevant' and 'accurate'. In many instances information is sought by passengers for reassurance, often from several different sources. It is therefore essential that the information supplied by staff and display boards is consistent and constantly updated. The PDFH notes that whilst the provision of information is important to passengers, the same passengers are also reasonably satisfied with the current levels of information provision. The PDFH recommendations for valuing information are as follows:

- A move from 'basic' to 'standard' might be worth about 5% of originating and interchanging revenue for the station provision, plus 5% of on-train revenue for the train announcements.
- A move from 'standard' to 'enhanced', on the other hand, is estimated to be worth only about 1% of revenue in each case.

8.8 Impact of marketing campaigns and service quality

8.8.1 General considerations

The PDFH has no recommended values for the advertising and promotion of rail services. Instead it recommends that serious consideration be given to measuring the effectiveness of advertising campaigns and promotional schemes.

Following a period of intensive 'on the road' competition between bus operators following the deregulation of local services in Britain in 1986, a more mature approach has been adopted in recent years. Considerable consolidation has been seen in the industry, and more stable conditions have been experienced by operator groups of all sizes. Greater emphasis has been placed on product quality and promotion.

As part of this study the four largest operator groups (First, Stagecoach, Arriva and Go-Ahead) have provided data on the impact of such activities. For commercial reasons, it is not possible to identify specific routes or operators, and results have therefore been generalised, except where technical press reports or marketing activities already in the public domain have been cited.

Marketing campaigns are generally undertaken in conjunction with other quality and price initiatives, rather than in isolation. However, impacts on ridership may be maximised by concerted initiatives by local authorities and operators (for example, low-floor vehicles, better staff training, and extensive bus priorities), this has the disadvantage from the analytical viewpoint that separating different causal factors becomes difficult. One approach, as identified in Chapter 4, is to use a simple time-series model for factors such as known changes in real fares and service levels, and then estimate the difference between observed and expected outcomes (see further discussion in Section 8.8.6).

A distinction may be drawn between quality improvements whose main effect is to raise frequency of travel by existing users, and campaigns directed specifically toward attracting those who do not currently use buses. Hence, the degree of 'market gearing' (Chapter 4) may be changed. Marketing campaigns may also be directed at reducing the rate of lapsing by existing users (an example of the turnover effect).

In some cases, however, efforts have been largely devoted to improved information and awareness of existing services, with little change in other quality factors – for example, some direct marketing campaigns. This makes identification of effects somewhat more explicit.

8.8.2 Use of monitoring data for perceptions of service quality

Increased emphasis has been placed both by government and operators on monitoring passengers' perceptions of service quality on a regular basis. In Britain, quarterly surveys are now undertaken of local bus users in England (Department for Transport, 2003b), and twice-yearly of users of the privatised Train Operating Companies (TOCs) (Strategic Rail Authority, 2003).These enable overall perceptions to be monitored and trends to be derived. Establishing links between such changes in perceptions and ridership is difficult in the case of published data for the bus industry, since data are aggregated at regional scale, rather than by named operator. In the case of TOCs, however, statistical relationships may be established between user ratings of companies, and subsequent ridership changes

Individual operator groups also monitor quality ratings regularly, as well as making 'before and after' assessments of specific campaigns. Weightings have been derived for the importance of different elements predicting an overall quality rating. For example, First have calibrated a model to identify predictors of overall quality ratings, for their local bus services in Britain, with the following weightings out of 100 (Confederation of Passenger Transport 2002):

Reliability	34
Frequency	17
Vehicles	14
Drivers	12
Routes	11
Fares	7
Information	5

Both overall quality ratings and those for specific aspects of service may be monitored at regular intervals to provide guidance to management on actions that may be required. In the absence of publicly-disclosed ridership data at the individual company or network level (in the British case) it is not possible to establish statistical relationships between ratings and ridership from data in the public domain, but such studies could be undertaken internally by operator management.

A limitation of many monitoring surveys, both those by public bodies and operators, is that much (if not all) interview data are collected from existing users of bus and rail services. Hence, it is subject to two forms of bias:

- Within the public transport user market, more frequent users have a higher probability of being intercepted. Hence, overall average results will be more strongly influenced by this group (for example, a user travelling five days week is five times more likely to be intercepted than someone travelling one day per week). While the sample is probably representative in terms of trip purpose, it would not be directly representative of users when considered as separate individuals. There is evidence that more frequent users tend to give lower ratings than less frequent users on some aspects, both from the DfT's quarterly surveys, and market research by some major operators. For example, those travelling five days per week or more give lower ratings for reliability than those travelling less often, and the same applies to those travelling for work or education purposes (Department for Transport, 2003b). This may be considered a logical outcome, since they are more likely to be travelling at peak periods when road congestion (and bus journey time at passenger stops) is likely to be greater. Some groups are aware of the danger of over-representing frequent users, and have adjusted their survey methods to include a greater proportion of infrequent users, so as to understand the factors that may encourage more frequent use by them.
- Omission of non-users. If public transport operators are seeking to attract users of other modes, then it is necessary to identify their perceptions, which may differ from users, both in the weightings attached to different aspects, and the ratings given to them. Household or on-street surveys may be required. Operators are aware of the need to obtain views of non-users, and one major group in Britain now conducts an annual 'non users' survey.

8.8.3 Direct marketing

Traditionally, public transport operators have relied on conventional forms of communication, such as printed timetables, adverts in vehicles, and a limited amount of poster and newspaper/other media advertising. Apart from household distribution of timetables, little effort may have been made to communicate directly with non-users.

Travel plans, both at an employer and/or neighbourhood level, can be seen as one means of achieving this, although typically not initiated by the transport operator. For example, the pioneering 'TravelSmart' project in Perth, Western Australia, identified scope for modal diversion from car driver to other less energy-intensive modes (including car passenger, bus, walk and cycle) by provision of more comprehensive information at the household level. The area tested was of relatively low density and high car ownership. Following the campaign, the bus market share rose from 6% to 7% of all trips, and the absolute number of bus trips in the area by 17%. Apart from some improvement to inter-peak services, this appears to be almost wholly attributable to the information provision (TravelSmart, 2001).

In more recent examples, operators have taken more direct initiatives. The Stagecoach group in Britain has undertaken telephone direct marketing in two medium-sized urban areas in which it is the major bus operator – Grimsby and Perth - providing a comprehensive network. Residents in the area served (i.e. living along or close to existing routes) were contacted by telephone. After excluding current bus users, about one quarter of the total number contacted expressed interest in receiving an information pack and free travel voucher for one week's travel, encouraging them to sample the service. Those actually converting the voucher into a week's free travel pass were subsequently re-contacted to establish use actually made and their perceptions of the service quality offered. In the first urban area subject to this approach, the mix of those attracted from car to bus was fairly typical of existing bus users in terms of gender and socio-economic group, but displayed a better spread in terms of age distribution, with over 60% attracted from the 25-64 age group. Factors cited most frequently in the personal reasons for switching from car to bus comprised parking difficulties and costs, and price or time advantages offered by bus. Between 7 and 9% of car users contacted made use of the free pass.

In both urban areas, those using the voucher generally rated the bus service as excellent or good, and a clear majority indicated they would use services again.

Despite the costs of contacting a large number of potential users by phone, such campaigns may be financially viable with a relatively small take-up level. For example, the cost of contacting 7,000 residents, and the provision of materials, may be justified by attracting fewer than 50 regular travelcard purchasers over the following 12 months.

8.8.4 Other aspects of consumer market research

Consumer-based research may also be used to establish attitudes of existing users to services offered, and the extent to which they show 'loyalty' to either a particular mode, or named operator (where alternatives exist). Means may be devised of increasing the attractiveness of services so that those now 'captive' users (i.e. without other modes or operator alternatives available) may be converted to a more positive view of the service, and thus hopefully retained in future (i.e. reducing the 'turnover' effect). Expectations and perceptions both of existing users and non-users may be identified to highlight areas for management action and improvement.

8.8.5 The time scale of responses to service improvements and marketing campaigns

The impact of improvements and associated marketing campaigns is not always immediate, since it may take some time for awareness of changes to percolate through the local population. A minimum evaluation period of one year would in any case be desirable to avoid problems of seasonal variation.

Experience from the 'Kick start' project of Stagecoach Group in Perth, in which a cross-town service was subject to extensive improvements, indicates that a period of about two years is required for the full impacts to be observed, and resulting demand growth to 'level off': following a doubling of inter-peak service frequency and other measures, a passenger growth of 56% was observed in the first two years[11], with a projected growth of 63% for a three-year period (Stagecoach Group 2003). A similar outcome was observed from the improved 'Interconnect' interurban bus services in Lincolnshire from 1998 (Lincoln - Skegness). This implies a greater impact of service innovations over a period of two to three years, than in the very short run. Such outcomes also have implications for use of public funding to initiate service improvements which may subsequently become commercially viable, although not so in the very short run.

8.8.6 Inferring impacts of marketing and quality factors from aggregate data

With the assistance of several operators in Britain, cases were identified where substantial ridership growth was observed. Rather than naively attributing this wholly to marketing and service quality factors, the effects of known changes in real revenue per passenger trip (as a proxy for fares charged) and vehicle-km run (as a proxy for frequency) were also identified. Their effect on ridership was assessed by assuming short-run constant elasticities of -0.4 and +0.4 respectively, consistent with averages derived in chapters 6 and 7. In the absence of good local data on car ownership, an underlying trend decline of -1.5% per annum due to this factor was assumed. Where ridership was affected by takeover of another operator in the same area and boardings per vehicle-km were similar on both the existing services and those taken over, a vehicle-km/passenger trips elasticity of about +1.0 was assumed (i.e. pro rata increase) for the effect on total ridership of the service transfer, since the elasticity attributable to marginal service changes would clearly be inappropriate in such examples.

Where longer-run elasticities are used (for example, -0.8 for fares and +0.8 for service levels) a different result may be obtained, dependent upon the relative changes in fares and service levels. For example, where ridership had grown despite an increase in real fare levels, then a greater difference could be observed between the 'observed' and 'expected' values where the long-run price elasticity was used.

Data over several years were considered, from a suitable base year, in which the cumulative difference between 'expected' and 'observed' ridership was calculated.

Ideally, one would use elasticities derived specifically from the area concerned from an earlier period. However, securing a good series of consistent data for this purpose is often difficult.

Several cases were considered, including:

a An operator in a medium-density urban area, with little constraint on car use. An extensive marketing campaign was conducted, including route branding, coincident with introduction of low-floor buses, and diversion to serve the main rail station.

b An operator in a denser urban area, with a higher-frequency service network, on which a number of initiatives were taken both by the operator and the principal local authority in the area served, in respect of simplified network marketing, simpler fares structures, bus priorities, better passenger information and greater parking restraints.

In these cases the differences between estimated and observed ridership were 8% for operator A (but with a much higher percentage growth on the specific routes affected by marketing initiatives) and 12% for operator B.

8.9 Bus specific factors

8.9.1 Boarding and alighting

Getting on and off vehicles is an integral part of public transport journeys. The time taken by an individual to board and alight is not normally a significant fraction of his overall journey time, but he may be adversely affected by the cumulative boarding and alighting times of other passengers. This is more likely to hold for bus rather than rail services, since bus stops are more closely spaced, and bus fares are more commonly collected by bus drivers as passengers board. This has three effects:

- Average journey times are increased.
- Greater variability in journey times results - this will affect waiting time at stops en route, as well as delays to passengers already in the vehicle. Given the higher weighting for disutility of waiting time than in-vehicle time (see Table 7.18) this may be of critical importance.
- The increase in dwell time at stops may cause additional delays under high-density operating conditions, since following buses are unable to enter the stop area. This may also affect the potential peak flows that can be accommodated.

The impact of passenger demand will therefore be evident through the response to increased journey time and its variability, and benefits through faster boarding speeds will be analogous to those from bus priority measures.

As an illustrative example, the following ranges may be considered:

Assumed urban average bus operating speed exclusive of dwell time at stops:

15 km/h.

20 km/h.

Boarding time per passenger:

3 seconds (typical of cases where most passengers have off-vehicle ticketing).

6 seconds (typical of cases where a high proportion involve cash transactions).

9 seconds (where almost all ticketing involves cash transactions and change-giving).

The average increment in bus journey time will thus depend on the rate of passengers boarding per bus-km. For metropolitan areas in Britain in 2001/02 this was 1.03 (from Tables 10 and 12 in DfT, 2002d). Hence, the overall effect is small. At 15 km/h, bus journey time per kilometre is 4 minutes, and the marginal increment between the best and worst rates per boarding passenger (on the illustrative example above) is only 6 seconds (2.5%).This rises to 3.3% at 20 km/h.

However, under heavier loadings and peak conditions, the effect is much greater. For example, in the case of a 10 km journey and a vehicle with a maximum capacity of 90 passengers, total boarding time would range from 270 seconds or 4.5 minutes (at 3s per passenger), to 810 seconds or 13.5 minutes (at 9s per passenger). At 15 km/h (excluding dwell time), total journey time would range from 44.5 minutes to 53.5 minutes, an increase of 9.0 minutes (20.2%) associated with the difference in boarding speeds. At 20 km/h the net increase would be 30%.

There is thus an interaction between vehicle size, boarding time per passenger and total journey time. For example, with a 30-passenger midibus, even with the highest boarding time per passenger, total boarding time would be 270 seconds (4.5 minutes) compared with 13.5 minutes for the 90-passenger vehicle, a difference of 9.0 minutes. Where minibuses have replaced larger vehicles, this difference in journey time at peaks may be a significant component of the extra ridership generated, in addition to increased frequency (see Section 7.2), possibly leading to some exaggeration of the frequency elasticity derived.

Insofar as a substantial proportion of bus ridership takes place under peak conditions, the proportion of passengers affected by such journey time differences will be greater than the proportion of bus-kilometres thus operated, and hence the impact on total ridership.

There are few studies available which document the ridership impacts of different fare collection systems. However, is it possible that the conversion to one-person operation in Britain from the 1960s onward while retaining a high proportion of cash fare payment was an element in the decline in bus use. If not made explicit, it would aggravate ‘trend’ decline factors, or, where correlated with changes in vehicle-kilometres and/or real fares, the elasticities associated with them.

Experience in London in the early 1970s indicated losses of about 10% on individual routes converted from conductor-operated Routemasters (with open rear platforms) to one-person-operated buses (with front entrance doors). However, a substantial part of this represented a diversion to other parallel routes, the net loss of passengers being 3% to 4% (Fairhurst, 1974). In this case the convenience of boarding and alighting at points other than official stops may also have been an element. The retention of conductor-operated vehicles on busier London routes was influenced by such considerations.

Another approach would be to incorporate differences in boarding time in measures of generalised journey time or generalised journey cost to which an elasticity could be applied. For example, the Stagecoach group in Britain assume a generalised cost elasticity of +1.4 in relation to the effect in demand of changes in door-to-door journey times (House of Commons Transport Commitee, 2002)

It also follows that a shift to simplified off-vehicle ticketing such as Travelcards may cause a growth in demand not only due to the convenience element and financial savings to individual users, but also through reducing total boarding times. This will affect journey times of all users (i.e. including those still paying in cash).

Alighting time will also have some effect on total journey time, but displays much less variation with ticketing type, typically averaging around 1.0 - 1.5 seconds per passenger. Total dwell time at stops may be reduced by separating boarding and alighting movements, for example through a separate doorway for alighting, but the benefits of this will only be evident at stops where simultaneous movement takes place. In practice, most bus services are likely to display asymmetric patterns (e.g. boarding at most bus stops into a town centre in the morning peak, alighting at the last few) and hence the impact may be small.

8.9.2 Accessible buses

Low-floor buses are a means of improving accessibility for a variety of people (mobility-impaired, people with small children or heavy shopping, and so on). These were first introduced in Britain, in London and North Tyneside, in 1993.

In conventional buses the first step from the ground is about 250mm, with two or three successive steps up onto the bus to a bus floor level of around 600 to 700mm. A low floor bus has a single step of around 320mm. Furthermore, on some low floor buses, when the bus is stationary the suspension can be lowered to make the bus 'kneel' 240mm from the ground. It is also possible to extend a wheelchair ramp from beneath the floor (although as this takes time, it is at the driver's discretion at each stop). The introduction of low-floor buses on a route is often accompanied by accessibility improvements to the infrastructure of the route, for example the introduction of Kassel Kerbs, which facilitate accurate alignment of the bus with the boarding area.

It is possible for people in wheelchairs, or parents with children in pushchairs, to wheel straight onto the bus. Designated areas are provided where wheelchairs or buggies can be safely parked. The low floor also makes access easier for people who are mobility-impaired, for example using crutches or a walking stick, as well as elderly people and others with minor mobility difficulties. The introduction of low-floor buses means that people who have any kind of mobility impairment are more likely to be able to travel unescorted by bus. Therefore they are less reliant on taxis or lifts, thereby increasing their independence.

Surveys (York and Balcombe 1998) in 1994, found that in general disabled people seem to prefer the low-floor bus to using a taxi. Possible reasons for this are the easier access afforded by low-floor buses, and the ability to travel with other members of the public. It is much easier for people with small children to take their children on the bus with them: they have less need of babysitters or of asking doctors or health visitors for home visits, or of taking a friend or relative with them to help them with the child's pushchair.

Low-floor bus boarding times are generally shorter than those for conventional vehicles. This applies to most, if not all, user-groups. Consequently any time that is lost through the bus 'kneeling' is generally compensated for in the quicker boarding times, which may aid reliability of service.

The effects on demand on four routes in London and one in North Tyneside were mixed. In most cases, having made adjustments for patronage trends on nearby routes, no significant changes were discernible, but there was an increase of about 12% on one London route.

Under the 1995 Disability Discrimination Act wheelchair accessibility is to become a legal requirement, for all buses and coaches with over 22 seats on scheduled public services. The dates for implementation are as follows:

New vehicles		*Old vehicles withdrawn*
Double-deck buses	31/12/00	01/01/17
Single-deck buses	31/12/00	01/01/16
Single-deck coaches	31/12/00 (postponed)	01/01/20
Double-deck coaches	01/01/05	01/01/20

Many bus companies have started converting all their routes to low-floor operation long before they are legally required so to do.

8.9.3 Flexible routing and stopping patterns

The flexibility of bus services enables patterns other than fixed routes with fixed stops to be observed. The simplest form is 'hail and ride', in which a fixed route is followed, but the bus stops at any safe point on designated sections of routes. In Britain, this was pioneered with minibus operation in the 1980s, but also can be provided by any size of bus. Sections thus served are generally off major roads, and within residential areas. In effect, accessibility is improved by reducing walking distance to/from the bus. There may be a greater tendency to use hail & ride for setting down, the passenger requesting the driver to do so in advance, which may be of particular benefits to the elderly and/or those with heavy shopping. If extensively used, hail & ride may produce disbenefits to other passengers as a result of average speeds being reduced both through additional stops being served, and drivers proceeding more cautiously to identify prospective passengers.

In most cases, hail & ride has been introduced simultaneously with other changes, notably high-frequency minibus conversion. It is thus difficult to isolate its impact from these other changes. However, in a before-and-after study of minibus conversion it was cited as an important factor by respondents in explaining their higher use of services. In a town in South Yorkshire, in which a route was extended further into a housing area (rather than being increased in frequency) provision of hail & ride was cited most often as an aspect of the service changes which users liked (41.2% of all responses). Of responses indicating a factor which caused respondents to travel more often it was also the most frequently cited (36 of 73 responses). In a case where major frequency improvements also took place (Swansea) it was cited as the second most important factor (18.0% of 'likes' responses, after 44.6% for frequency; and 115 out of 497 responses indicating that higher frequency of travel resulted, compared with 229 attributable to bus service frequency). The overall passenger trips/bus kilometre elasticities derived in these cases were approximately +0.6 (South Yorks and +0.5 (Swansea), suggesting that hail & ride formed a significant component in the values obtained, possibly leading to some overstatement of the frequency effects.

Ideally, one could take a case where a section of route was converted to hail & ride without other changes such as frequency occurring, and impacts monitored. Few, if any, such cases appear to be documented.

Another variant on hail & ride is to offer such facilities at certain times of day, notably in the late evenings when passenger security is likely to be a major consideration, rather than all day on certain routes. This mode of operation has been introduced in several German cities.

The concept of flexible operation can be taken further through introduction of demand-responsive services in which the route taken is varied according to individual passenger demands in real time. These comprise several types:

- *'One-to-many'*. A common origin (such as a rail station) is served at given timings, with flexible routeing to set down within a defined area.
- *'Many-to-one'*. The opposite concept. In practice, both may be combined within the same operation.
- *'Many-to-many'*. Links between all points within a defined area.
- *Flexible routing over parts of a service*. A largely fixed route may be followed, with diversions made on request in lower-density areas. A common case would be a rural service between towns, serving larger villages at fixed points, with selective diversion over other sections of route, such as the 'Call Connect' services in Lincolnshire.

Following a phase of 'dial a bus' innovation in the 1970s, such operations were seen as very costly, partly due to high control and supervision costs, and in most cases became confined to specialised needs, such as services for disabled users unable to reach their nearest fixed bus stop. However, more flexible software has made the concept of entirely flexible routing attractive once more as a general public service. A number of examples have been introduced, although largely, in rural areas. Examples in Britain include operations in the Dengie Peninsula (Essex), the 'Call Connect Plus' services in Lincolnshire, and 'Cango' services in Hampshire

As yet, few operational results are available. Since the main aim of many demand-responsive services has been to serve new areas and types of demand, it is difficult to apply traditional elasticity concepts to such services. Given low densities of areas served, cost per passenger (in total financial cost, and net subsidy from public funds) is often very high. However, as such services become more widespread, it should become possible to identify cases in which 'before and after' conversion can be assessed (i.e. an area formerly served only by a fixed route is served by a replacement demand-responsive service), and the net change in ridership assessed.

8.9.4 Simplified networks

Where headways of around 10-12 minutes or less are offered, passengers tend to arrive randomly at stops. The effort needed to consult a timetable is greater than the time savings it would produce, and in many cases service reliability is such that passengers may allow a margin of about 5 minutes or more to ensure catching a specific journey. Bus networks typically provide a much greater density than rail systems, such that the greater majority of the population is within 500 metres (around 6 minutes' walk) of the nearest bus stop. However this can result in very complex networks, with low frequencies on each route.

Concentrating provision on fewer high-frequency routes, while retaining lower-frequency services to provide local access, enables a more attractive service to be offered overall. Examples in Britain include:

The network in Brighton and Hove, in which about 50% of passenger demand is handled on a small number of trunk routes operating at least every 10 minutes Monday-Saturday daytime.

The 'Overground' concept introduced by First Group, in which similar high frequencies are offered on a trunk network, which is identified by a diagrammatic map in similar style to the London Underground. The network in Glasgow, in which First is the major operator. The simplified network was introduced in September 1999, and within a two-year period to April 2002 a ridership growth of 11% was observed, although this may have also been influenced by improvements in vehicle quality, and ticketing.

8.9.5 Accessible rural services

Brown and Tyler (2001) claim that the conventional Community Bus Service operating in rural areas, does not address the needs of people living in remote rural areas as well as a social-inclusive bus service could. A Community Bus Service in a remote area in Cumbria was set up around 1982, mainly to cater for elderly people making shopping trips. It's user profile has not changed much since. It tends to be used mainly by retired people, even if there are younger people living in the area. There is little choice in day or time of travel, the bus visits a village mostly once on a set day of the week, it is thought that this timetable is not convenient for young people, hence they do not use it. The service tends to be used for shopping and medical trips into town, and surveys, in April 2000, have not shown users as making any inter-village journeys. Nor do they use it for any education journeys (the timetabling makes that impractical).

Of the users about half had access to a car, the remainder relied on trains or taxis. It was also noted that the bus is not fully accessible. The drivers tend to be drawn from a pool of about 30 volunteers. Surveys have shown that some users would like it to be more frequent e.g. more than one day a week, while others would like stops in more convenient locations e.g. outside a medical centre. Many users wanted the bus made more accessible e.g. low step,.wide aisle, space for shopping, wheelchairs and pushchairs.

In a neighbouring area, with similar demography, in April 1999, the research project Accessible Transport In Rural Areas (APTRA) had provided a new bus service. The service was routed to serve the centre of each village it passes through. Similar surveys were carried out to those on the old community bus. The APTRA bus is fully accessible, in fact it had to be specially designed as at that time there was no fully accessible vehicle large enough to carry 12 passengers including two wheelchairs and yet small enough to travel on narrow country lanes (in Cumbria some of them are very narrow). It has 2-3 local drivers, well known to passengers, who are not only fully trained and licensed they are also police checked and trained in disability awareness. As a result parents are more likely to allow young children to travel on the bus unaccompanied by adults. The bus operates 6 days a week and journeys are spread throughout the day, every 3 hours. In addition to bus stops the service is also 'hail and ride'. Timetables were provided in a variety of forms, including braille and compact disc. A tactile map was also provided.

Surveys in April 2000 found that the APTRA bus has a wide age-range of users, including 36% in the 10-19 age group. There is approximately equal use of the bus by schoolchildren, working people and retired people. In roughly equal numbers, people use it for shopping, work and education, but almost twice as many use it for social purposes. Over 30% of users had access to a car, others would have used a bus, walked or cycled. Users were interested in the proximity of the bus route to their homes, its low cost, and the fact that they no longer had to rely on lifts. 17% of users, of all ages, used the service to travel between villages. Surveys have indicated that some users would like the bus to run on Sundays, and others would like the timetable to make better evening connections with local train services. Overall it has been found that by making a reasonably frequent service available, using local drivers, and an accessible vehicle, with reasonably accessible information provision has led to an increase in independent travel opportunities for the elderly, mobility impaired, and young people in a rural community, without needing to rely on access to a car (either their own or a lift from someone else).

The service is a model for how local rural public transport may be structured so that people can retain an independent lifestyle in a rural area, and use public transport. SP surveys are unlikely to have shown what an impact such a service would have had. Providing the service, however, has stimulated demand for public transport that was previously suppressed due to the means of using it simply not being there. The APTRA project was so successful with the local community, that the community itself subsequently sought funding to continue the service for themselves.

Recent work for the Commission for Integrated Transport, in which the Transport Studies Unit, University of Oxford, has been involved, has examined a number of new and existing rural transport schemes that are suggestive of some of the opportunities for rural transport. These are summarised in Table 8.19. It should be noted that A to G are new schemes serving rural settlements of less than 3,000 population in remote locations. By contrast, H is a long established service serving some rural settlements of above 3,000 population and relatively near to a major conurbation. Service I is a long interurban route linking two medium sized urban areas via a rural hinterland. The schemes vary greatly in terms of the type of vehicles used, route flexibility, frequency and mean fare (excluding concessionary fare reimbursement). White (2002) notes that conventional rural bus services are usually either rural-urban (route H) or interurban (route I) in nature. Interurban services usually have higher loadings due to a more balanced traffic profile and are usually more profitable than rural-urban services. This is the case in Table 8.19, although both services are loss making.

Table 8.19 also shows that all of the new schemes A to G have relatively low usage rates and concomitant high subsidy rates per passenger of between £4.70 to £17.00. This has led to suggestions that taxis may be more cost effective in such locations. A review of the Wiltshire Wigglybus by consultants EcoLogica has come to a similar conclusion (Transit, 5/4/02, page 5). The funding support required was found to be £6.23 per journey, considerably higher than Wiltshire County Council's maximum long term level of support of £3.50. By contrast, the two conventional services examined have the highest annual patronage, the highest fares (excluding the taxi scheme F) and by far the lowest subsidy per passenger at between £0.55 and £0.67.

Norway has a long tradition of using small buses (Norwegian Institute of Transport Economics/Ministry of Transport and Communications, 1993). A trial scheme in the early 1990s found using a fleet of vehicles of varying sizes, mini and midibuses to be an effective means of matching capacity to population, especially when serving

Table 8.19 Some examples of rural transport projects

Scheme	*Vehicle type*	*Vehicle access*	*Route flexibility*	*Journey timing*	*Pax fare per single journey*	*Annual usage (000)*	*Subsidy per passenger (£)*
A	Mini bus.	Low floor.	Fixed.	Every three hours, 6 days per week.	25p	11.9	4.70
B	Mini bus.	Low floor.	Fully demand responsive.	Hourly, 6 days a week.	50p	48.1	5.10
C	Mini and Midi bus.	Low floor.	Fixed with deviation and demand responsive.	Hourly, 6 days a week.	71p	37.7	9.90
D	Midi bus.	Low floor.	Mainly demand responsive.	4 times per day, 6 days per week.	71p	5.5	10.70
E	Midi bus.	Low floor.	Mainly fixed.	4 times per day, 6 days per week.	92p	3.0	17.00
F	Taxi.	High floor.	Fully demand responsive.	6 times per day, 7 days per week.	150p	1.9	9.70
G	Midi bus.	Low floor.	Fixed with deviations.	Hourly, 6 days per week.	60p	23.4	4.60
H	Single deck.	High floor.	Fixed.	Hourly, 6 days per week.	112p	65.7	0.67
I	Single deck.	High floor.	Fixed.	Hourly, Mon – Sat daytime, less frequent in evening and Sunday.	119p	323.3	0.55

the elderly during the daytime. Smaller buses have the advantage of being able to travel on smaller local roads, which increases route flexibility, meaning that routes can be designed to minimise the distances passengers have to walk to get to the bus stop. The experiments included some routes which were designated as 'service routes', a special facility for the elderly, whereby elderly or disabled persons could request the bus to stop anywhere on the route. The schedule was arranged to allow time for drivers to get out and assist passengers with boarding and alighting if necessary. The service routes have not been found to be commercially profitable (only meeting between 15 to 50% of their costs). However, they have been found to make a substantial contribution to welfare, alleviating social exclusion, and enhancing the lives of local people, especially among the elderly and disabled. This sort of bus services enables people who would otherwise be isolated to get out and about and make trips that would otherwise not have been possible for them. It has been discovered that some users of the service used it simply for the ride, as a way of getting out of the house and meeting people.

The VIRGIL project has identified a number of examples of good practice in rural transport in Europe (see www.bealtaine.ie/virgil), including a database of some 100 examples. These include:

- The integration of scheduled and non-scheduled public transport e.g. Allarbus, Galicia, Spain and Kuxabussarna, Ockelbo, Sweden.
- Demand responsive public transport systems e.g. MobiMax, Achterhoek, Netherlands and Videobus, Borgo Panigale, Italy.
- Taxi feeder systems e.g. TaxiTub, Douai, France and Taxibus, Lüdinghausen, Germany.
- Post/Parcel Buses e.g. KTEL, Magnesia, Greece and Lisdoonvarna, County Clare, Ireland.

8.10 Conclusions

This chapter has examined a mix of elasticity measures and attribute values for five factors: waiting environment, vehicle characteristics, interchange, service reliability and information provision. The summary of the empirical evidence on these factors is as follows.

In terms of the waiting environment, there have been a number of studies that have examined the impact of improved shelter and facilities. Individual improvements may only have modest impact, with a mean valuation of 1.7 p per trip (based on 16 observations). Packages of improvement measures may have a greater impact particularly if implemented on an entire route or network. However, there is also evidence to indicate decreasing returns in that the value of a package of improvements at a particular site may be less than the value of the individual components.

When considering the impact of vehicle quality, similar issues arise as when considering the impact of the waiting environment. Overall, we find the mean value of a vehicle improvement being equivalent to 4.0 p per trip, based on 20 observations. However, there is considerable variation in this figure based on the type of vehicle improvement and the way the impact of the improvement is measured. There is considerable evidence to suggest that naïve stated preference experiments will lead to overestimates of the impact of improved vehicle quality.

With respect to interchange, we find an average bus penalty of 20.8 mins (based on 6 observations) and an average rail penalty of 36.8 mins (based on 13 observations). However, these estimates include connection time, that is the additional walking and waiting time associated with interchange. The pure interchange penalty may be considerably less than this, with values between 5 and 10 minutes per interchange being typical.

In terms of reliability, we find bus wait time's standard deviation valued at 1.0 to 2.5 times the value of IVT, whilst bus IVT's standard deviation is valued at 0.8 to 2.3 times the value of IVT. For rail, recent evidence suggests late time is valued at 3.0 times the value of IVT.

With respect to information provision, we find the mean valuation of pre-trip information to be 3.6 p per trip in outturn prices but this is only based on four observations. There are more valuations of at-stop information (43 observations) where we find a mean value of 4.3 p per trip.

9 Effects of demand interactions

9.1 Introduction

The work in this guide so far has concentrated on the impacts of the changes in the attributes of a particular public transport service on the demand for that service. This chapter looks at the impacts of changes in the attributes of a particular transport service on the demand for other transport services. We refer to such demand interactions as cross effects. We distinguish between two types of cross effect: that emanating from the competition between modes and that emanating from competition within modes.

9.2 Competition between modes

The main way that the demand impact of the competition between modes is measured is through the use of cross-elasticities[12]. Cross-elasticities are highly dependent on relative market share and are therefore not readily transferable across time and space. The evidence on cross-elasticities is reviewed. This is done in three sub-sections, covering evidence from London, Great Britain and the rest of the world. Emphasis is placed on studies undertaken since 1980. The available evidence up to that point is summarised in Table 9.1.

9.2.1 London

The most evidence on public transport cross-elasticities in Great Britain has been collected in London, usually in research undertaken by, or sponsored by Transport for London and its predecessors. Some early results are given by Table 9.2. It should be noted that these elasticities refer to the impact on demand after one year. This work also suggested a bus demand elasticity with respect to underground service of 0.1 and an underground demand elasticity with respect to bus service of 0.2, which was raised to 0.7 in 1978.

Table 9.1 A synthesis of the empirical evidence on the cross-elasticity of urban public transport fares

Elasticity context	*Result*	*Data type*	*Reference*
Car use with respect to bus fares for peak work trips			
London (1970-5).	0.06	Time series.	Glaister and Lewis, 1997.
Boston (1965).	0.14	Cross-section.	Kraft and Domencich, 1972.
Chicago (1961).	0.21	Cross-section.	Warner, 1962.
San Francisco (1973).	0.12	Cross-section.	McFadden, 1974.
Melbourne (1964).	0.19	Cross-section.	Shepherd, 1972.
Car use with respect to train fares for peak work trips			
Sydney (1976).	0.09	Before and after.	Hensher and Bullock, 1979.
Rail use with respect to bus fares for peak work trips			
San Francisco (1973).	0.28	Cross-section.	McFadden, 1974.
London (1970-5).	0.14	Time series.	Glaister and Lewis, 1997.
Rail use with respect to bus fares for off-peak travel			
San Francisco (1973).	0.28	Cross-section.	McFadden, 1974.
Rail use with respect to bus fares for all hours			
London (1970-3).	0.25	Time series.	Fairhurst and Morris, 1975.
Bus use with respect to rail fares for peak work trips			
San Francisco (1973).	0.25	Cross-section.	McFadden, 1974.
London (1970-5).	0.14	Time series.	Glaister and Lewis, 1997.
Bus use with respect to rail fares for off-peak work trips			
London (1970-5).	0.28	Time series.	Glaister and Lewis, 1978.
Car use with respect to rail fares for off-peak work trips			
San Francisco (1973).	0.13	Cross-section.	McFadden, 1974.
London (1970-5).	0.06	Time series.	Glaister and Lewis, 1997.
Bus use with respect to rail fares for all hours			
London.	0.25	Time series.	Glaister and Lewis, 1997.

Source: Hensher and Brewer, 2001.

Table 9.2 London Transport cross-elasticities

Mode	*With respect to*	*Elasticity*
Underground	Bus fare	+0.21
Underground	Rail fare	+0.18
Bus	Underground fare	+0.10
Bus	Rail fare	+0.05

Source: Fairhurst et al. (1987) cited in Goodwin et al. (1992).

Earlier work by London Transport gave more detailed breakdowns in terms of peak/off-peak. The results are shown in Table 9.3. This work also distinguishes between a conditional own cross-elasticity (in which the attributes of all public transport modes are changed by the same proportion and there are no cross effects) and the total own elasticity which takes into account the existence of cross effects. It can be seen that the (absolute) total own elasticity equals the sum of the (absolute) conditional elasticity and the relevant cross-elasticities. This result derives from the homogeneity condition discussed above.

As Table 9.4 shows, these values have fluctuated slightly over time as different model forms and data sets have been used. When holding fares constant, a dominant, but not exclusive, trend of (absolute) own and cross-elasticities decreasing emerges.

Table 9.3 Breakdown of London Transport cross-elasticities

	Weekday	*Off-peak*	*Peak*	*Total*
Bus				
Conditional component	-0.33	-0.38	-0.28	-0.34
Transfer to Underground	-0.17	-0.17	-0.17	-0.17
Transfer to BR	-0.02	-0.02	-0.02	-0.02
Total	-0.52	-0.57	-0.47	-0.53
Underground				
Conditional component	-0.18	-0.26	-0.15	-0.19
Transfer to bus	-0.15	-0.15	-0.15	-0.15
Transfer to BR	-0.07	-0.07	-0.07	-0.07
Total	-0.40	-0.48	-0.37	-0.41

Source: Frerk et al. 1981.

Mitrani *et al.* (2002) also estimate that a 10% increase in car ownership per capita in Greater London would lead to an 8.5% decrease in bus fare paying traffic and a 5.3% decrease in underground fare paying traffic.

Gilbert and Jalilian (1991) developed a multi-modal model of the demand for travel and travelcards in London, based on time series data for the period 1972:1 to 1987:10. This gave elasticity estimates as shown by Table 9.5. It should be noted that the results in Table 9.5c and 9.5d

Table 9.4a London Underground models - price elasticities (1995 fare levels)

	R273 1971-85	M(97) 711971-95
Own price	-0.49	-0.49
Cross price elasticity, Bus	+0.21	+0.20
Cross price elasticity, BR	+0.10	+0.08
Conditional elasticity	-0.19	-0.20

Table 9.4b London Underground models - price elasticities (2000 fare levels)

	M(97) 71 1971-95	1971-2000
Own price	-0.48	-0.41
Cross price elasticity, Bus	+0.20	+0.12
Cross price elasticity, BR	+0.07	+0.08
Conditional elasticity	-0.21	-0.21

Table 9.4c London bus models - price elasticities (1995 fare levels)

	R273 1971-85	M(97) 711971-95
Own price	-0.71	-0.64
Cross price elasticity, Underground	+0.16	+0.13
Cross price elasticity, BR	+0.17	+0.16
Conditional elasticity	-0.40	-0.35

Table 9.4d London bus models - price elasticities (2000 fare levels)

	M(97) 71 1971-95	1971-2000
Own price	-0.60	-0.64
Cross price elasticity, Bus	+0.12	+0.13
Cross price elasticity, BR	+0.14	+0.15
Conditional elasticity	-0.34	-0.37

Sources: Fairhurst et al., 1987; London Transport, 1993a; Kincaid et al., 1997; Mitrani et al., 2002

have been restricted so as to be theoretically consistent with the symmetry conditions discussed above.

Glaister (2001) has up-dated his earlier work (for example, Glaister and Lewis, 1997) and produced estimates for London of a full set of cross-elasticities. These are shown by Table 9.6.

Mackett and Nash (1991) and Mackett and Bird (1989) have produced some estimates of the cross-elasticity of car, bus and walk trips to suburban rail journey time and fares. The results are given in Tables 9.7 and 9.8.

Mackett and Bird (1989) looked at rail fare cross-elasticities for car, bus and walk trips both in general and to central London. These results are given in Table 9.8:

9.2.2 Rest of Great Britain

Outside London there has been limited work on public transport cross-elasticities. However, some important evidence has been collated on diversion rates. This evidence is summarised by Tables 9.9 and 9.10.

Outside London, some work has been undertaken which infers elasticities based on knowledge of diversion rates (as given above), own elasticities and market shares. The own elasticities and market shares are derived from meta-analyses of mode choice studies. The cross elasticities are then inferred using the theoretical relationships outlined in Section 5.5. The earliest work in this area was by Acutt and Dodgson (1995) and is shown in Table 9.11. Some later work by Wardman and colleagues is given in Tables 9.12 and 9.13 for urban and interurban travel respectively.

One advantage of this approach is that it permits the use of elasticities from mode choice models. These are only partial estimates because they fail to take into account demand generation and suppression. The full elasticity of demand for mode i with respect to the price of mode j equals to the mode choice elasticity of the demand for i with respect to the price of j plus the elasticity of total travel demand with respect the price of j (see, for example, Taplin, 1982). The latter can be estimated if the mode choice elasticity of j with respect to j's own price is known, along with the proportion of j's additional demand that is generated and j's modal share.

A review by Dodgson (1990) found the most convincing cross elasticities of car use with respect to bus fares to be 0.025 in London and 0.0105 in the six English metropolitan counties. Grayling and Glaister (2000) use a cross-elasticity of 0.09 for London, whilst Glaister uses values of ranging from 0.032 to 0.067 for the Metropolitan areas.

Table 9.5a Estimated short-run price elasticities

	Prices			
	Bus	Underground	British Rail	Non-travel
Bus	-0.839	0.476	0.082	0.281
Underground	0.041	-0.355	0.160	0.114

Table 9.5b Estimated long-run price elasticities

	Prices			
	Bus	Underground	British Rail	Non-travel
Bus	-1.318	0.897	0.193	0.229
Underground	0.356	-0.688	0.211	0.120

Table 9.5c Estimated short-run price elasticities with long-run symmetry imposed

	Prices			
	Bus	Underground	British Rail	Non-travel
Bus	-0.788	0.414	0.096	0.278
Underground	0.078	-0.396	0.182	0.058

Table 9.5d Estimated long-run price elasticities with long-run symmetry imposed

	Prices			
	Bus	Underground	British Rail	Non-travel
Bus	-1.185	0.724	0.240	0.221
Underground	0.661	-0.983	0.166	0.156

Table 9.6 Matrix of cross-elasticities for London

	Bus use	*Underground use*	*Rail use*	*Car use*
Bus fare	–	0.13	0.06	0.04
Underground fare	0.06	–	0.03	0.02
Rail fare	0.11	0.06	–	N/C
Bus miles	–	0.22	0.10	0.09
Underground miles	0.09	–	0.04	0.03
Bus journey time	–	0.18	0.08	0.06

Source: Glaister, 2001.

Table 9.7 Cross-elasticities of car, bus and walk with respect to rail journey time

Mode	*Location*	*Short run*	*Medium run*	*Long run*
Car	All trips from zones on the Chiltern Line.	0.07		0.06
Bus	All trips from zones on the Chiltern Line.	0.12		0.11
Walk	All trips from zones on the Chiltern Line.	0.05		0.05
Total	All trips from zones on the Chiltern Line.	0.00		0.00
Car	Trips to central London on the Chiltern Line.	0.37		0.18
Bus	Trips to central London on the Chiltern Line.	0.42		0.25
Walk	Trips to central London on the Chiltern Line.	–		–
Total	Trips to central London on the Chiltern Line.	-0.98		-1.13
Car	All trips from zones in the south-east sector.	0.10		0.10
Bus	All trips from zones in the south-east sector.	0.14		0.14
Walk	All trips from zones in the south-east sector.	0.07		0.09
Total	All trips from zones in the south-east sector.	-0.00		-0.01
Car	Trips to central London from zones in the south-east sector.	0.24		0.20
Bus	Trips to central London from zones in the south-east sector.	0.21		0.19
Walk	Trips to central London from zones in the south-east sector.	0.11		0.12
Total	Trips to central London from zones in the south-east sector.	-0.26		-0.34
Car	All trips from zones on the Chiltern Line and south-east sector corridors.	0.10	0.11	0.11
Bus	All trips from zones on the Chiltern Line and south-east sector corridors.	0.21	0.21	0.21
Walk	All trips from zones on the Chiltern Line and south-east sector corridors.	0.07	0.08	0.08
Total	All trips from zones on the Chiltern Line and south-east sector corridors.	0.00	0.00	0.00
Car	Trips to central London on the Chiltern Line and south-east sector corridors.	0.95	0.97	0.96
Bus	Trips to central London on the Chiltern Line and south-east sector corridors.	0.91	0.94	0.94
Walk	Trips to central London on the Chiltern Line and south-east sector corridors.	0.60	0.67	0.68
Total	Trips to central London on the Chiltern Line and south-east sector corridors.	0.00	0.00	0.00

Source: Mackett and Nash (1991) and Mackett and Bird (1989).

Table 9.8 Cross-elasticities with respect to rail fare

	Elasticity	
Mode	*All trips*	*Trips to central London*
Car	0.05	0.40
Bus	0.10	0.36
Walk	0.03	0.25

Source: Mackett and Bird (1989)

Table 9.9 Diversion rates (%) - urban

To	From					
	Rail	Bus	Car	Cycle /Walk	Gener -ated	No. of studies
Rail	–	41	33	1	24	4
Bus	6	–	31	42	21	2
Car	24	48	–	6	22	1

Sources: Vicario, 1999, Chartered Institute of Transport, 1996, Centro, 1998, 1999, MVA, 2000a.

Table 9.10 Diversion rates (%) - interurban

To	From					
	Rail	Coach	Car	Air	Gener -ated	No. of studies
Rail	–	20	60	6	14	2
Coach	60	–	22	–	18	1
Car	42	10	–	1	47	1

Sources: Vicario, 1999, Gordon (2000).

Table 9.11 Deduced public transport and car cross-elasticities

Market	PT use with respect to petrol price	Car use with respect to PT fares
Inter city	0.0939	0.0118
Network SE	0.0409	0.0026
Regional rail	0.0909	0.0022
London underground	0.0171	0.0006
London buses	0.0199	0.0005
Other local buses	0.0132	0.0018

Source: Acutt and Dodgson (1995)

Table 9.12 Deduced cross-elasticities – urban

	Car use	Rail use	Bus use
Car cost	–	0.59	0.55
Rail cost	0.054	–	0.08
Bus cost	0.057	0.24	–

Sources: Toner (1993), Wardman (1997b).

Table 9.13 Deduced cross-elasticities – interurban

	Car use	Rail use	Coach use
Car time	–	0.33	0.60
Car cost	–	0.25	0.34
Rail time	0.057	–	0.20
Rail cost	0.066	–	0.32
Coach time	0.054	0.17	–
Coach cost	0.014	0.17	–

Source: Wardman (1997a).

Preston and Wardman (1991) report the arc-elasticity of car use with respect to bus cost changes of between 10% and 300% as being 0 to 0.33. This was based on transfer price questions, adjusted for non-traders.

Polak *et al.* (1993) use the stated intentions technique to examine short-term responses to the introduction of road pricing. These are shown in Table 9.14. The report also assesses longer term impacts, allowing for 'lifestyle impacts'.

Table 9.14 Stated intentions responses to road pricing

Response	Method of charging	
	Distance-based (1260 respondents)	Cordon-based (585 respondents)
Pay charge	42.0%	45.3%
Shift to earlier time	13.6%	11.9%
Shift to later time	4.1%	2.8%
Use public transport	16.1%	16.1%
Use car and PT	3.6%	4.3%
Cycle or walk	5.3%	3.5%
Switch route	4.2%	5.1%
Change destination	5.0%	4.1%
Other	6.1%	6.9%

Source: Polak et al. (1993).

Recent work undertaken for the Commission for Integrated Transport has estimated the cross-elasticity of the demand for car travel with respect to bus price based on a 10% bus fare increase (Institute for Transport Studies and Transport Studies Unit 2002). The results are shown in Table 9.15.

Table 9.15 Cross-elasticity of demand for car with respect to bus fare

Route type	Cross-elasticity
Large radial	0.018
Orbital	0.026
Medium radial	0.027
Park and ride	0.097
Small radial	0.045
Inter-urban	0.008
Rural radial	0.026

Work in the passenger rail market by Steer Davies Gleave (1999a) has inferred a series of urban and interurban cross-elasticities. These values have been used in the Rail Industry Forecasting Framework (RIFF) and version 4 of the Passenger Demand Forecasting Handbook. They are shown in Tables 9.16 and 9.17.

Finally, some illustrative examples are reported to reveal the principle of cross-elasticity estimation. Such an exercise is based on the review of car price elasticity carried out by Hanly *et al.* (2002). They conducted a literature review of price and income elasticities in the demand for road traffic. The data used in the review consist of the results of 69 different published elasticity studies. The comprehensive work by Hanly *et al.* (2002) provides us with a ground for the inference of cross-elasticities with respect to car fuel prices. Combining Hanly *et al.* (2002) findings with the diversion rate figures from Tables 9.9 and 9.10 as well as the relative market share data from Department of the Environment, Transport and the Regions (1999), we are able to derive the relevant public transport cross-elasticity with respect to car price (fuel costs).

Table 9.16 Cross-elasticities of urban rail demand

	Fuel cost	*Car time*	*Bus cost*	*Bus time*	*Bus head -way*	*Under -ground cost*
London Travelcard area						
Commuting	0.2	0.1	0.1	0.05	0.025	0.1
Business	0.2	0.1	0.0	0.0	0.0	0.0
Leisure	0.2	0.1	0.2	0.05	0.025	0.2
S.E. to London						
Season	0.0	0.0	0.0	0.0	0.0	–
Daily	0.19	0.24	0.17	0.17	0.03	–
S.E. from London						
Season	0.25	0.30	0.20	0.20	0.05	–
Daily	0.24	0.30	0.20	0.20	0.03	–
S.E. non London						
Season	0.25	0.30	0.20	0.20	0.05	–
Daily	0.24	0.30	0.20	0.20	0.03	–
R.O.C. to London (< 100 Miles)						
First	0.12	0.30	0.00	0.00	0.00	–
Full	0.18	0.30	0.12	0.12	0.02	–
Reduced	0.25	0.30	0.23	0.23	0.04	–
Total	0.22	0.30	0.18	0.18	0.03	–
Non London (<20 miles)						
Season	0.30	0.25	0.20	0.15	0.025	–
Daily	0.34	0.25	0.22	0.14	0.025	–
Pre-paid	0.40	0.20	0.30	0.10	0.05	–

S.E. = south east, R.O.C. = Rest of Country
Source: Rail Industry Forecasting Framework as in PDFH version 4.

Table 9.17 Interurban rail demand cross-elasticities

	Fuel cost	*Car time*	*Bus cost*	*Bus time*	*Bus head -way*	*Air cost*	*Air head -way*
R.O.C. to London (200 m +)							
1st	0.12	0.30	0.00	0.00	0.00	0.25	0.05
Full	0.18	0.30	0.12	0.12	0.02	0.25	0.05
Reduced	0.25	0.30	0.23	0.23	0.04	0.25	0.05
Total	0.22	0.30	0.18	0.18	0.03	0.25	0.05
Non London[1]							
20-100m	0.27	0.30	0.17	0.17	0.04	0.25	0.05
100-200m	0.27	0.30	0.17	0.17	0.04	0.25	0.05
200m +	0.27	0.30	0.17	0.17	0.04	0.25	0.05
Non London[2]							
1st	0.12	0.30	0.00	0.00	0.00	0.25	0.05
Full	0.18	0.30	0.12	0.12	0.02	0.25	0.05
Reduced	0.25	0.30	0.23	0.23	0.04	0.25	0.05
Total	0.20	0.30	0.13	0.30	0.03	0.25	0.05
Airports							
	0.25	0.30	0.10	0.10	0.03	–	–

[1] *Over 20 miles, less than 10% using first and full tickets.*

[2] *Over 20 miles, more than 10% using first and full tickets.*

R.O.C = Rest of country.

Source: Rail Industry Forecasting Framework as in PDFH version 4.

Table 9.18 reports the short-term bus and rail elasticity with respect to fuel costs. It is estimated based on formula (17) (Section 5.5). It shows that the cross-elasticities with respect to fuel price are higher for urban bus and inter-urban rail, which is mainly due to the higher diversion rate for these two segments.

Table 9.18 Short-term public transport cross-elasticity with respect to fuel costs

	Cross elasticity with respect to fuel price	*Car elasticity with respect to fuel price*	*Relative market share (car/PT mode)*	*Diversion rate (from PT mode to car)*
Urban rail	0.35	-0.10	14.40	0.24
Urban bus	0.72	-0.10	15.10	0.48
Inter rail	0.60	-0.10	14.40	0.42
Inter coach	0.15	-0.10	15.10	0.10

Source: Estimates based on Hanly et al. (2002).

Table 9.19 reports the long-term public transport cross-elasticity with respect to fuel costs. The estimated cross-elasticity values are rather high, suggesting strong effects of car costs on public transport use in the long run. Nevertheless, the examples given here are regarded as illustrative rather than definitive, as the car price elasticity and relative market share do not distinguish between urban and inter-urban journeys.

Table 9.19 Long-term public transport cross-elasticity with respect to fuel costs

	Cross elasticity with respect to fuel price	*Car elasticity with respect to fuel price*	*Relative market share (car/PT mode)*	*Diversion rate (from PT mode to car)*
Urban rail	1.00	-0.29	14.40	0.24
Urban bus	2.10	-0.29	15.10	0.48
Inter rail	1.75	-0.29	14.40	0.42
Inter coach	0.44	-0.29	15.10	0.10

Source: Estimates based on Hanly et al. (2002).

9.2.3 Evidence from abroad

There is evidence on cross-elasticities from abroad, particularly Australia. For example, Johnson and Hensher (1982) developed a Multinomial Probit model of passengers' choices between car and train. This model was calibrated on panel data collected in the suburbs of Sydney, between 1971-73 for 163 observations. Elasticity estimates were based on PC, the probability of choosing car, and PT, the probability of choosing train. The results are shown in Table 9.20.

Hensher (1997) estimated cross-elasticities between ticket-types and between modes (rail, bus, and car) for commuters in Sydney. The elasticity matrix is shown in Table 9.21. This table indicates how changes in various types of transit fares and car operating costs affect the use of other types of transit fares and car travel. This is based on a survey of residents of Newcastle, a small Australian city.

Table 9.20 Car and rail own and cross-elasticities, Sydney, Australia

	Model						
Elasticity	*DS71 Logit*	*DS71 Probit*	*DS73 Probit*	*DS73 Dummy linkage*	*DS73 Sequen-etial linkage*	*Naive pooling*	*Auxil-iary pooling*
PC/invt$_C$	-0.400	-0.445	-0.609	-0.556	-0.625	-0.533	-0.109
PC/invt$_T$	+0.665	+0.467	+0.642	+0.605	+0.658	+0.562	+0.120
PC/cost$_C$	-1.260	-0.971	-0.387	-0.255	-0.383	-0.622	-0.119
PC/cost$_T$	+1.780	+0.612	+0.312	+0.199	+0.386	+0.449	+0.085
PT/invt$_C$	+0.905	+0.418	+0.859	+0.823	+0.899	+0.627	+0.108
PT/invt$_T$	-0.387	-0.439	-0.905	-0.880	-0.947	-0.662	-0.119
PT/cost$_C$	+1.52	+0.911	+0.546	+0.371	+0.552	+0.733	+0.118
PT/cost$_T$	-0.751	-0.574	-0.440	-0.290	-0.441	-0.529	-0.084

Table 9.21 Direct and cross-share elasticities for Sydney, Australia

	Train Single fare	*Train Ten fare*	*Train Pass*	*Bus Single fare*	*Bus Ten fare*	*Bus Pass*	*Car*
Train, single fare	-0.218	0.001	0.001	0.057	0.005	0.005	0.196
Train, ten fare	0.001	-0.093	0.001	0.001	0.001	0.006	0.092
Train, pass	0.001	0.001	-0.196	0.001	0.012	0.001	0.335
Bus, single fare	0.067	0.001	0.001	-0.357	0.001	0.001	0.116
Bus, ten fare	0.020	0.004	0.002	0.001	-0.160	0.001	0.121
Bus, pass	0.007	0.036	0.001	0.001	0.001	-0.098	0.020
Car	0.053	0.042	0.003	0.066	0.016	0.003	-0.197

Hensher (1998) noted that previous studies which evaluated and modelled modal choice in terms of an average fare ignored the reality of ticket-switching within that mode. However, on modelling using ticket types, it was found that people were more likely to switch mode than ticket. This was contrary to a *priori* expectations.

In terms of commuter travel, Taplin *et al*. (1997) cited in the Australian Bureau of Transport Economics (2001), have provided optimally adjusted elasticities for travel by various modes in Sydney, as shown in Table 9.22.

Table 9.22 Optimally adjusted commuter elasticities condensed to modes

	Elasticity with respect to fare or cost of trip			
Travel mode	*Train*	*Bus*	*Ferry*	*Car*
Train	-0.156	0.032	0.003	0.037
Bus	0.063	-0.070	0.006	0.046
Ferry	0.039	0.037	-0.195	0.003
Car	0.016	0.011	0.000	-0.024

A recent study of inter-urban transport in Spain (Coto-Millan *et al*., 1997) reported short term cross-elasticities for rail demand (millions of passengers per km of route) with respect to the price of petrol of 0.74 for Talgo (fast) trains, and 0.56 for standard trains. These results conform to the expectations that elasticities should be higher where the competition is stronger. Road is generally faster than rail in Spain, although there are exceptions (for instance the Madrid – Seville AVE high-speed train).

TRACE (1999) provides detailed elasticity and cross-elasticity estimates for various types of travel (car-trips, car-kilometres, transit travel, walking/cycling, commuting, business, etc.) and conditions, based on numerous European studies. The findings of the TRACE project are summarised in De Jong and Gunn (2001). Table 9.23 reports the impact of car costs and car time on public transport. The cross-elasticities for the number of public transport trips and public transport kilometres travelled with respect to each explanatory variable are reported. The elasticities with respect to fuel price in general turn out to be quite small, with long run values of around 0.1. The car time has a greater impact on public transport demand, with average long run elasticity of 0.25.

Table 9.23 Cross-elasticity of public transport demand with respect to car costs and car time

Explained	*Explanatory*	*Short run*	*Long run*
PT trips	Fuel price	0.33	0.07
PT kms	Fuel price	0.07	0.10
PT trips	Car time	0.27	0.15
PT kms	Car time	0.52	0.36

Source: De Jong and Gunn, 2001.

The public transport elasticity with respect to car costs also varies with journey types. The results from the TRACE project shows that in general the public transport demand with respect to car costs is most elastic for commuting but least elastic for education journeys. Table 9.24 summarizes elasticities of trips and kilometres with respect to fuel prices in areas with high vehicle ownership (more than 450 vehicles per 1,000 population).

Table 9.24 Cross-elasticity of public transport demand with respect to car costs by journey purpose

Journey purpose	*Explained: PT trips*	*Explained: PT kms*
Commuting	0.20	0.22
Business	0.24	0.05
Education	0.01	0.00
Other	0.15	0.18
Total	0.13	0.14

Source: TRACE (1999) cited in Litman (2002)

There is also a body of international evidence on diversion rates (see, for example, Booz Allen and Hamilton, 1999). This evidence is context specific and requires careful interpretation. Table 9.25 summarises some international evidence for urban rail schemes. Overall, this work suggests on average that around 66% of the use of new urban rail schemes comes from existing public transport with 17% coming from car, 10% generated and 7% coming from other sources (cycling and walking). In part these diversion rates will be determined by mode shares so that the abstraction rate from car will be high in North America and Australia and lower in Europe. With respect to diversion from car, Booz Allen and Hamilton (op cit.) suggest that two-thirds will come from drivers and the remainder from passengers.

Table 9.25 Diversion rates (%) - international evidence from new urban rail schemes

Scheme	New PT users	Of which: From car	Of which: Gener -ated	Of which: Other	Source
Adelaide – O bahn	31	57	27	15	Bray, 1995
Berlin – U bahn	28	55	30	15	Younes, 1995
Grenoble LRT	12	40	25	35	Walmsley and Pickett, 1992
Nantes LRT	33	30	48	21	Walmsley and Perrett, 1991
Melbourne tram	32	49	15	36	Kinnear, 1993
San Diego trolley	44	68	23	9	Cox and Love, 1991
Average	34	50	28	34	

Source: Booz Allen and Hamilton (1999).

9.3 Within mode competition

9.3.1 Introduction

Evidence on within mode competition in public transport is limited. There is some evidence on competition between ticket types (see for example Table 9.22). In West Yorkshire, the METROCAST model estimated that the elasticity of farebox demand with respect to travel card price was 0.11 (Grimshaw, 1984). A corresponding figure for Merseyside was estimated by Preston *et al.* (1994) at 0.05. The Institute for Transport Studies and TecnEcon (1996) estimated that in West Yorkshire the cross-elasticity of demand from adult bus users using MetroCard (travelcards for a week or more) with respect to cash fares was between 0.012 and 0.246. The variation depended on the time of day, with demand being most price sensitive in the inter-peak period. Similarly, the cross-elasticity of demand from adult bus users using DayRover (a one day travelcard) with respect to cash fares was estimated to be 0.943. For adult rail travel in West Yorkshire, it was found that the cross-elasticity of demand from cash fares with respect to the price of MetroCards was 0.168 in the peak and 0.112 in the off-peak. Similarly, the cross-elasticity of demand for adult rail travel by MetroCard with respect to cash fares was estimated at 0.14.

In the rail industry, there have been some recent attempts to develop a consistent series of cross-elasticities with respect to ticket type. These cross-elasticities have been incorporated into the Passenger Demand Forecasting Handbook, version 4. Most of the estimates relate to long-distance inter-urban trips but some results with respect to trip of 20 to 100 miles to/from the London Travelcard area are given in Table 9.26.

Evidence on competition between firms within the same mode is even more limited, being based largely on simulation models of various types.

According to Whelan *et al.* (2001), commercial transport modelling software such as EMME/2, SATCHMO, TRIPS

Table 9.26 Elasticities by ticket type for rail travel 20 – 100 miles to/from London

	1st class price	Stand -ard class - full fare	Stand -ard class -reduced fares	Condit -ional elasti -city
1st class demand	-0.80	0.30	0.00	-0.50
Standard class demand – full fare	0.25	-1.20	0.35	-0.60
Standard class demand – reduced fares	0.00	0.25	-1.25	-1.00

Source: ATOC (2002).

and VIPS all provide the facility to model public transport networks and their interaction with private cars in considerable detail, applying matrix-based demand models alongside public transport assignment models. There would clearly be benefit in 'bolting on' a competition model to existing software if possible. In the context of competition between rail operators, none of these models was found to be appropriate in a previous review (Ash and Wardman, 1998). Whelan *et al.* reach the same conclusion for the bus market. A review of public transport modelling approaches that offer greater promise are discussed below.

9.3.2 Operational models

Economic Modelling Approach (Dodgson et al., 1993)

The Economic Modelling Approach (EMA) was born out of a desire to model predation in the bus industry. The model predicts the non-cooperative Nash equilibrium that might occur, as well as predicting cooperative equilibria. The EMA uses operator-specific direct demand models with own and cross-price elasticities for each of the two operators included. Passengers' choice of bus is determined by a rooftop model modelled at an aggregate level, that is, allocating portions of the demand profile to particular services. In principle, it is possible to have the operators placed asymmetrically in terms of the elasticities, though in practice that was an added complication. The EMA can demonstrate the situations in which either, both or neither of the incumbent and the entrant are able to make profits and hence yield a set of rational strategies.

PRAISE (Preston et al., 1999) and MERLIN (Hood, 1997)

PRAISE (Privatisation of Rail Services) adopts a hierarchical structure to model the effects of fares competition on the railway system. The top nest determines the overall size of the market, the middle nest splits the traffic between first and standard class, and the bottom nest splits demand between services and ticket types. Novel features of the model include the treatment of outward and return legs of the journey, the analysis of advanced purchase tickets and the possibility of the rail market expanding or contracting consistently within the hierarchical structure. A key finding of the model for an inter city route was that were there was evenly matched competition, with two operators each having 50% of the market, the elasticity of demand for one operator's services with respect to the price of another operator was around –3. This in turn would imply a price of elasticity of around 4.

The cost model adopted was essentially an accounting-based approach in order to achieve fully allocated costs. There is separate identification of operating and capital costs and both types of cost are composed of both fixed and variable elements. The outputs of PRAISE can be checked to see if the effects of changes in prices or services accord with external evidence. The competitive strategies which can be modelled include: cream-skimming; head-on competition with service matching; price wars; and product differentiation. MERLIN (Model to Evaluate Revenue and Loadings for Intercity) has a similar demand structure to PRAISE but with the generation/suppression effects being incorporated by application of known market elasticities to changes in average fares and generalised times.

Quality bus model (Whelan et al., 2001)

This model was designed to provide information to be used to:

- determine demand and cost implications of Quality Bus Partnerships (QBPs);
- assess the likelihood of market entry and exit;
- evaluate pricing, service level and quality of service strategies; and
- undertake an economic evaluation.

The model has a degree of flexibility so that it can be applied to a range of possible QBP scenarios. In the first instance, the spatial and temporal dimensions of the model are described. This is followed by an outline of the demand and cost models and finally the way in which the demand and cost models can be linked and dynamics added to the system is examined.

The model structure is simple but flexible enough to deal with a variety of QBP arrangements. Working on the assumption that there exist well-defined corridors that form the basis for operator strategies the model consists of a series of n zones, with j parallel bus routes running through each zone. Demand for travel between any two zones in the network is then allocated to available individual services (e.g. the 0704 departure from zone 2 on route 1) according to the sensitivity of demand to the generalised cost of travel and the socio-economic characteristics of the travellers.

The temporal aspects of the model are constrained, by and large, by the availability of base input data. For example, if data on base demand levels are only available as daily totals there is little point in trying to model the spread of traffic throughout the day. The default timescale for the model is set to be a representative one-hour period. Here, the analyst can run the model for key hour periods during the day/week/season and gross-up the estimates to give weekly or annual totals. With relatively minor changes to the source code, the model can be set up to cover any time period desired. A key requirement of the model is that it should be able to predict year round profitability. Applications of the model should therefore take account of seasonality.

The purpose of the demand model is firstly to determine the overall size of the bus market and secondly to divide the market between operators, ticket types and departure times. This information can then be combined with fare data to generate forecast revenues. It has been assumed that the individual is the decision-making unit and that all decisions are taken at ‘point of sale’. Using decision rules based on utility maximisation, a given individual has to consider:

- whether or not to make the journey; and
- which mode to use.

If they choose to make a journey and travel by bus, the following additional considerations are of interest:

- which stop to board at and alight from (if available);
- which operator to travel with (if available);
- which service to use (time of departure); and
- which ticket type to use.

The interrelated choices set out above can be represented in a range of demand models, from models with complex hierarchical structures to relatively simple direct demand models. Our preferred approach makes the best use of documented evidence on bus passengers’ valuations of journey attributes (e.g. in-vehicle time) and sensitivities to changes in costs and involves a two level choice model:

- *Level 1* - Choice of service (route, departure-time, operator and ticket type).
- *Level 2* - Choice of mode (including not travel).

This structure allows for the allocation of passengers between operators, ticket types and services and for the overall size of the bus market to expand or contract as service levels change.

The way in which the model is applied is outlined below:

i For each OD pair on the network in a given operational period (e.g. a peak hour), generate a sample of, say, 500 individuals with a given distribution of tastes (attribute values), characteristics (e.g. child, adult, pensioner) and most preferred departure times.

ii For each individual, estimate the generalised cost of each service and ticket type available and select the best n options. Each of these is then allocated a probability by level 1 of the model with all other options assigned a zero probability.

iii The market shares for each service and ticket type (for a given OD pair in a given operational period) are then estimated by averaging the derived probabilities over all 500 individuals.

iv The overall size of the bus market (total number of passengers for a given OD pair in a given operational period) is then determined in Level 2 of the model and subsequently assigned to individual services using market share estimates.

On this basis, total demand and revenue estimates can be derived for each service and ticket type. Where services are estimated to reach capacity, service levels are automatically increased through the use of duplicated vehicles.

This model produces a 'snap shot' of company profits (revenue minus costs) under different operating assumptions. The model is run for key operating periods and then grossed-up to generate weekly or annual estimates. Three different ways of applying the model can be envisaged:

- *Scenario approach*. The first approach is the most straightforward and involves the analyst specifying a number of likely scenarios and assessing the outcomes individually. The models will be iterated to generate pay-off matrices for the most likely competitive situations and game theory used to assess the outcomes (see for example Preston, 1991).
- *Optimisation*. A different approach would be to define objectives for the operators and optimise the objectives subject to a set of constraints. Where competition is based on output, a Cournot or von Stackleberg equilibrium may arise (see Dodgson *et al.* 1993 and Savage 1985 respectively); alternatively, where competition centres on price, a Bertrand equilibrium may arise (see James 1996).
- *Generalisation*. The third approach is a hybrid approach. It involves specifying, perhaps, 1000 scenarios and running the model in batch mode for each scenario. Simple regression models could then be estimated on the output. This would allow us to develop general demand, revenue and profit functions for each firm. This approach was used in Whelan *et al.* (2001).

In each instance explicit behavioural response and decision rules should be used to assess where entry is feasible and sustainable.

Whelan *et al.* (2003) used an adapted Quality Bus model to examine within mode competition along two urban bus corridors. The scenario approach was applied to investigate the impacts of competition on the bus demand and profitability of the operators. Different entry strategies by the new competitor, as well as different quality and fares combinations are considered.

The model was run for a large urban radial route and a medium radial route. The results show that additional service introduced by competition leads to the growth of the bus market, although the amount of growth was relatively small compared to the scale of additional services.

In the competition scenarios, the new competitor uses either the niche market entry strategy or the full market entry strategy. In the former case, the new entrant provides 20% additional service frequency; in the latter, it provides the same level of service as the incumbent. The new entrant is either the quality operator or the low-quality with lower fares, while the incumbent is assumed to be a quality operator. The modelling results for the large radial route and the medium radial route are reported in Table 9.27 and Table 9.28.

Table 9.27 shows that market entry by a quality operator is more effective in boosting bus demand. Moreover, a quality new entrant is placed in a better competitive position in terms of market share. A low quality competitor, on the other hand, is much less capable of boosting overall bus demand and capturing market share.

Table 9.28 reveals a similar picture for the medium radial route in terms of the effects of an entry strategy. It also shows that the increase of bus demand in the medium radial route as a result of competition is more substantial than that in the large radial route. This is due to the fact that the medium radial route has a lower frequency level, which leaves more scope for service increase. This suggests that market growth is more significant if competition is introduced in a less frequent route.

An important empirical issue is the cross-elasticity of demand for one bus operator with respect to another operator's fares. Whelan *et al.* (2001) assumed an operator specific elasticity of demand with respect to generalised cost of -4. This was set to be consistent with a market fare elasticity of -0.4 and suggests absolute individual bus operator price elasticities in excess of unity. A House of Commons Select Committee (1995) report discusses case where 50% cuts in bus fares led to 100% increases in bus demand. Colson (1996) discusses a routes where fares

Table 9.27 Head-on competition simulation results - large radial route

		New entrant		*Incumbent*		
Model run	*Entry strategy*	*Fares*	*Quality*	*Fares/Quality*	*Incumbent share*	*Bus market growth*
36	Niche market	As now	Medium	As now/Medium	85.3%	2.6%
37	Niche market	-10%	As now	As now/Medium	90.7%	0.7%
38	Full service	As now	Medium	As now/Medium	50.0%	12.0%
39	Full service	-10%	As now	As now/Medium	64.3%	6.0%

Table 9.28 Head-on competition simulation results - medium radial route

		New entrant		*Incumbent*		
Model run	*Entry strategy*	*Fares*	*Quality*	*Fares/Quality*	*Incumbent share*	*Bus market growth*
36	Niche market	As now	Medium	As now/Medium	83.2%	8.8%
37	Niche market	-10%	As now	As now/Medium	87.1%	5.6%
38	Full service	As now	Medium	As now/Medium	50.0%	27.0%
39	Full service	-10%	As now	As now/Medium	59.8%	18.9%

were halved and ridership increased by 275%. However, in both cases these demand changes occurred in competitive situations and reflect operator-specific effects. These results suggest operator-specific arc elasticities of around -1.0 and -2.2 respectively. Assuming a market fares elasticity of -0.4, this would imply cross-elasticities of 0.6 and 1.8 respectively.

9.4 Concluding remarks

Dargay and Hanly (1999) conclude that, although the empirical evidence is limited, bus fares appear to have negligible effects on car travel. The effects of motoring costs on bus travel, however, are slightly greater. They believe that the cross-elasticity between bus patronage and motoring costs appears to be negligible in the short run, and about 0.3 to 0.4 in the long run. Clearly, there is a price-substitution between bus and car use, although comparatively small. We must keep in mind that these elasticities were estimated over a period in which bus fares rose substantially in comparison to motoring costs, and an opposite development need not produce an equivalent impact.

Oum *et al.* (1992) conclude that it is important that a mode's demand specifications include the prices and quality of service of competing modes. Because some studies do not take into account intermodal competition, their elasticity estimates may partly reflect the intensity of intermodal competition, and as a result underestimate the own-price elasticity if the competing modes have changed their prices in the same direction.

Acutt and Dodgson (1995) state: *'..... any cross-elasticity estimates from one study will not be directly applicable to another because the cross-elasticity values depend on the relative size of the two markets represented'.* We therefore avoid recommending a single set of cross-elasticity values for urban travel. A partial exception is London where a number of cross elasticities have been estimated. These are summarised by Tables 9.29 and 9.30.

The studies in Table 9.29 also found a cross-elasticity of car use with respect to rail fare in the range 0.05 to 0.40, with corresponding cross elasticities for bus use and walk in the range 0.10 to 0.36 and 0.03 to 0.25 respectively. The high cross elasticities refer to trips to/from central London where rail has a high market share.

Overall, it is concluded that there is less evidence on cross-elasticities than direct elasticities, particularly in terms of dynamic studies. In part, this reflects estimation problems and means that cross elasticities will often have to be inferred. With the exception of trips to central London, it might be expected that the cross-elasticity of car demand with respect to public transport attributes is low, although non-zero. The cross-elasticity of public transport demand with respect to car attributes might be expected to be more substantial. Similarly, the cross effects between public transport modes can be substantial.

The various models that have been developed to examine this issue have been reviewed. Particular attention has been paid to the PRAISE and MERLIN models that inform the rail Passenger Demand Forecasting Handbook and the QBP (Quality Bus Partnership) model that has been used recently to examine bus subsidy options. It has been noted that there is limited empirical evidence on operator specific own- and cross-elasticities.

Table 9.29 Summary of cross-elasticities for London – fares

Demand	*With respect to*	*Mean*	*Range*	*Number of observa-tions*
Bus - short run	Underground price	0.45	0.41 – 0.48	2
Bus - long run	Underground price	0.57	0.10 – 0.90	3
Bus - short run	BR price	0.09	0.08 – 0.10	2
Bus - long run	BR price	0.18	0.17 – 0.19	2
Underground - short run	Bus price	0.06	0.04 – 0.08	2
Underground - long run	Bus price	0.41	0.20 – 0.66	3
Underground - short run	BR price	0.11	0.04 – 0.20	3
Underground - long run	BR price	0.51	0.36 – 0.66	2

Sources: Fairhurst et al. (1987), Gilbert and Jalilian (1991).

Table 9.30 Summary of cross-elasticities for London – journey time

Demand	*With respect to*	*Mean*	*Range*	*Number of observa-tions*
Car - short run	Rail journey time	0.30	0.07 – 0.95	6
Car - long run	Rail journey time	0.27	0.06 – 0.96	6
Bus - short run	Rail journey time	0.34	0.12 – 0.91	6
Bus - long run	Rail journey time	0.31	0.11 – 0.94	6
Walk - short run	Rail journey time	0.15	0 – 0.60	6
Walk - long run	Rail journey time	0.17	0 – 0.67	6

Sources: Mackett and Bird (1989), Mackett and Nash (1991).

10 Effects of income and car ownership

10.1 Introduction

This chapter deals with the effects of income and car ownership upon the demand for public transport. Traditionally these variables have been deemed 'background factors', as compared to the endogenous factors within public transport such as fares, service levels, journey times and vehicle quality. The broad relationships between these factors and the demand for public transport are well documented, but despite this the exact relationships and the correlation between all three factors, and in particular between income and car ownership, would appear to be only marginally clearer 23 years on from the 1980 Demand for Public Transport publication.

The last 23 years have seen marked increases in real income and car ownership levels in the UK and across Europe. For example, in this period GDP increased by around 68% in Great Britain whilst the number of cars per household increased from 0.76 to 1.11. In that time, local bus journeys have fallen by around a third. The position for rail is more mixed. The performance of rail at a local level depends on congestion levels and, because of the perceived higher quality of rail, is less sensitive to increases in car ownership than bus. Indeed, central London rail commuter traffic has increased by 13% since 1980.

Income is expected to increase the number of trips and their average length. It is likely that this additional travel will be split between increased public transport trips and increased car trips, depending upon the level of car availability and assuming that public transport is a normal good. Income is also a key determinant of car ownership and hence there will be a secondary and negative impact on the demand for public transport via car ownership.

In contrast to the marked impacts of income and car ownership, the impact of socio-economic factors is likely to be less dramatic. Although trip making patterns vary substantially with socio-demographics, changes in demographics and household sizes are very much long term in nature and as such are less significant in terms of changes in travel over time. However, results presented here indicate that these factors may be very important in explaining differences in trip making patterns between areas.

Other chapters in this document categorise the empirical evidence according to whether it is obtained from aggregate or disaggregate models. Given the comparatively few studies in this area, such a distinction does not here seem sensible and evidence from both sources is taken together. Moreover, the nature of the effects considered in this chapter is such that the empirical evidence is firmly based upon actual behaviour rather than responses to hypothetical questions of one form or another.

The structure of this chapter is as follows. Section 10.2 outlines the effects of income and car ownership on the demand for public transport from a theoretical perspective and discusses the practical problems involved in disentangling the separate effects of each. Section 10.3 considers the evidence relating to the impact of income on travel expenditure and distance travelled. The empirical evidence relating to the effect of income on public transport demand is discussed in Section 10.4, followed by consideration of the effect of car ownership on the demand for public transport in Section 10.5. Studies which have addressed both income and car ownership simultaneously are reviewed in Section 10.6 whilst Section 10.7 speculates as to how the effect of income changes on the demand for public transport may vary over time. A summary and concluding remarks are provided in Sections 10.8 and 10.9.

10.2 The expected effects of income and car ownership on public transport demand

Potter *et al*. (1997) have identified rising car and licence ownership, income growth and the declining real cost of car ownership as the key factors that have shaped personal travel patterns in the last twenty years. Whilst a host of other background factors can be cited (see Figure 10.1) four key relationships are outlined below that underpin the rest of the discussion in this chapter:

- An increase in income will, depending upon the level of income, lead to an increase in car ownership and so car availability, or to an increase in public transport use (a relationship missed out in Figure 10.1).
- An increase in car ownership/availability will, other things being equal, lead to a reduction in the demand for public transport modes.
- The sign and magnitude of demand elasticities for public transport with respect to car availability and income will vary depending upon the income levels.

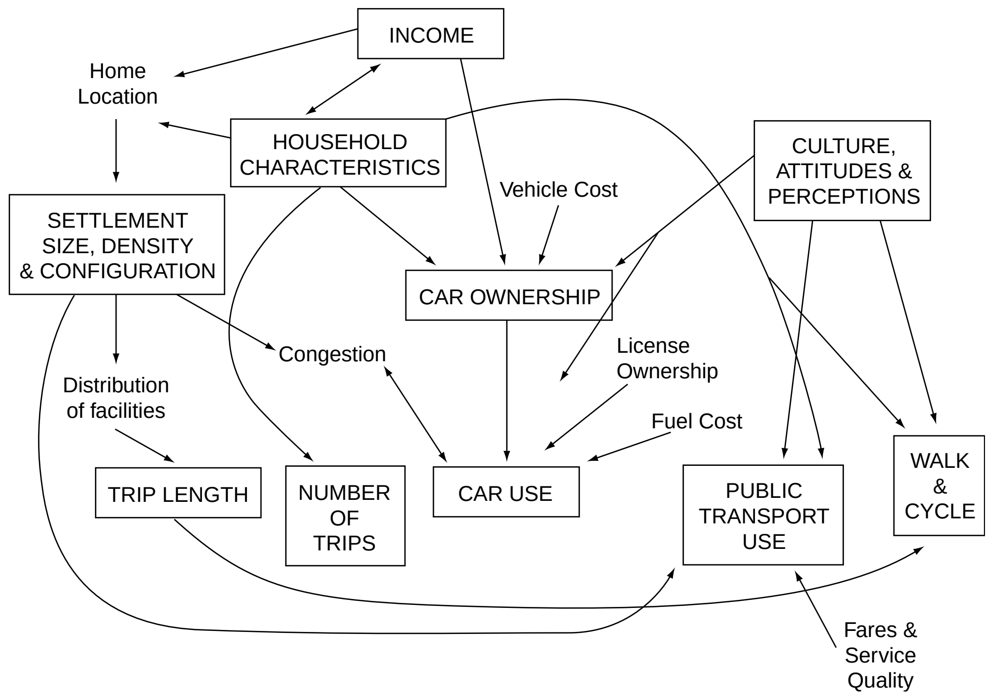

Figure 10.1 Linkages between factors affecting trip generation and modal choice
(Source: Potter et al., 1997)

- Income growth can be expected to increase average trip length, in part alongside changing patterns of land use but also independently of them.

The relationships discussed above for the greater part mean that considerable care must be taken when interpreting public transport demand elasticities that have been estimated with respect to income and car ownership. Income elasticities estimated using demand models that do not have car ownership amongst their explanatory variables will pick up the negative effect that car ownership has on public transport. This could lead to results which contradict the 'accepted thinking' that public transport is not an inferior good. The problem with estimating models that include both variables is the collinearity that exists between them. The first Demand for Public Transport book noted this in detail and twenty years on the problem of collinearity still exists and is particularly noticeable for models that have been calibrated using time series data.

To illustrate the problem of disentangling the effects of income and car ownership, various models were estimated to rail ticket sales data (CAPRI) for journeys on non-season tickets in the south east as part of an update to the Passenger Demand Forecasting Handbook (ATOC, 2002). The ticket sales related to annual trips covering the years 1991 to 1999 between a wide range of stations.

The results are given in Table 10.1. Separate GDP elasticities are reported for trips to London, trips from London and other trips within the south east. NCO denotes the proportion of households without a car. It is specified to influence rail demand (V) as:

$$V = e^{\beta NCO}$$

The elasticity of rail demand with respect to NCO is therefore βNCO which falls as NCO falls and car ownership tends to saturation. Fuel and car time denote cross elasticities of rail demand with regard to the costs and times involved in using car. A Department for Transport fuel price index was used for fuel cost whilst assumptions were made about car journey time increases over the period.

Where a parameter is freely estimated, its 95% confidence interval is given in brackets. The absence of a confidence interval indicates that the parameter was constrained to equal the value given. This is a means of overcoming collinearity problems. The constrained NCO parameter was estimated to NTS data, effectively holding income constant, whilst the constrained fuel and car time cross-elasticity terms were taken from recommendations used in the railway industry (Steer Davies Gleave, 1999b) weighted by journey purpose (Table 10.1).

Model I in the table constrains the NCO, fuel and car time parameters to the best available evidence. The GDP elasticities are therefore our best estimates conditional upon the constraints used for the other three terms. NCO is freely estimated in Model II but has the wrong sign albeit with a large confidence interval. This wrong sign stems from the large correlation between the NCO coefficient estimate and the GDP elasticities for trips to, from and not involving London of 0.66, 0.67 and 0.76.

Removing NCO from the model as a way of avoiding the collinearity problem is represented by Model III. The GDP elasticities are all lower than for Model I, as would be expected, because the GDP elasticities are now discerning the car ownership effect. Model IV demonstrates further sensitivity of the GDP elasticity estimates, this time to the removal of the cross-elasticity terms. Given the trend growth in fuel cost and car times, this positive effect on rail demand is now discerned by the GDP elasticites. Model V simply demonstrates in this context the impossibility of obtaining sensible results, due to multicollinearity, when all parameters are freely estimated.

As is clear from the above, the interpretation of income elasticities, and for that matter car ownership elasticities, should be undertaken with great care since they are conditional upon what other variables are entered into the model. Matters are further complicated because the rate of car ownership growth will decline as saturation is approached. Ideally, we want the income elasticity conditional upon the best available car ownership elasticity estimate or, what should in principle be the same thing, the car ownership elasticity conditional upon the best available evidence of the income elasticity.

10.3 The effect of income on travel expenditure and distance travelled

In almost all western European countries total person-km has risen at around 1 to 2% per annum, a little less than the growth in real GDP. Table 2.9 (in Chapter 2) illustrates the growth experienced within Western Europe between 1990 and 1999, with total person-km for motorised modes rising by 19%. The greatest growth was experienced in air travel (65%), followed by car (18%), bus and coach (9%), rail (8%), and tram and metro (5%).

Table 10.1 Elasticity estimates for trips in the south east

	GDP					
Model	*To London*	*From London*	*Non London*	*NCO*	*Fuel*	*Car time*
I	1.74 (±0.36)	1.04 (±0.20)	1.39 (±0.30)	0.71	0.19	0.24
II	1.28 (±0.42)	0.74 (±0.28)	0.93 (±0.36)	-0.89 (±0.80)	0.19	0.24
III	1.54 (±0.32)	0.90 (±0.20)	1.19 (±0.24)	–	0.19	0.24
IV	2.00 (±0.32)	1.38 (±0.20)	1.68 (±0.23)	–	–	–
V	-1.32 (±0.84)	-2.32 (±0.83)	-2.03 (±0.86)	1.44 (±1.04)	-0.31 (±0.50)	3.31 (±0.58)

Fare was included in all models and its elasticity hardly varied around -0.70.

This evidence and the trend evidence presented in Chapter 2 of this report suggests that income has a positive impact upon the total amount of travel, but what is the impact of income growth on the proportion of income that is devoted to travel? The figures from the Family Expenditure Survey for Great Britain reported in Table 10.2 show that the percentage of household expenditure on transport and travel has slowly increased over time, rising from 14.9% in 1981 to 17.1% in 1999/00. These figures include expenditure on air travel which has seen significant growth (nearly 50% more passenger kms between 1989 and 1999) during the last twenty years. Even with the cost of air travel taken out the trend is still a positive one.

Table 10.2 Percentage of overall household expenditure spent on transport and travel in Great Britain

Year	*%*	*Year*	*%*
1981	14.9 (14.8)	1991	15.3 (15.2)
1982	14.8 (14.5)	1992	15.8 (15.6)
1983	14.7 (14.6)	1993	15.6 (15.2)
1984	15.0 (14.8)	1994/95	15.1 (14.7)
1985	15.2 (14.9)	1995/96	14.9 (14.8)
1986	14.3 (14.1)	1996/97	15.7 (15.6)
1987	15.1 (14.8)	1997/98	16.7 (16.3)
1988	14.8 (14.5)	1998/99	17.0 (16.8)
1989	16.0 (15.7)	1999/2000	17.2 (16.9)
1990	16.2 (15.8)		

Figures in brackets do not include expenditure on air travel. Derived from Transport Statistics Great Britain (Department of the Environment, Transport and the Regions 2001b).

Intuitive as the evidence relating to passenger kilometres travelled and income might be, it is still not possible to say with certainty that rising incomes themselves have led to a growth in traffic. Other factors, such as changes in land use patterns and employment and supply side changes might have had an influence.

Given little change in the population, traffic growth comes from two sources: people making additional trips and people making longer journeys. The issue of the impact of income and car ownership on the number of trips made by public transport is considered below. Before that, some evidence on the impact of income on trip length is presented.

Recent work by Wardman and Preston (2001) and Shires and Wardman (2002) gives an insight into how income affects journey length. Both pieces of work report models that have been estimated to NTS data for the period 1985 to 1997 in order to explain variations in average trip length over time and across individuals in terms of the socio-economic and demographic characteristics. Table 10.3 reports the estimated income elasticities from models segmented by four modes and three journey purposes (see the Appendix to Section 10 for the full regression model outputs).

There is clear evidence that trip lengths are increasing with income, although the effects are not particularly strong. In general, the elasticities lie in the range 0.09 to 0.21 but with noticeably stronger growth for car commuting, business trips by rail and business trips by bus. The latter is not a particularly significant category, whilst the figures for train business trips will include longer distance journeys. The figure for car commuting reflects the continued dispersion of employment opportunities, particularly away from city centres, migration from urban residential locations and the fact that the car can service such trends far more easily than other modes. The insignificant income elasticity for train may well reflect its inability to serve newer out-of-town developments.

Table 10.3 Journey length income elasticities by mode and purpose

Purpose	*Car*	*Passenger*	*Bus*	*Train*
Commuting	0.21 (±0.03)	0.16 (±0.07)	0.11 (±0.05)	n/s
Obs.	19,472	3,333	3,791	1,936
Leisure	0.09 (±0.02)	0.15 (±0.02)	0.18 (±0.03)	0.05 (±0.06)
Obs.	37,549	53,380	28,764	5,133
Business	0.15 (±0.05)	n/s	0.26 (±0.14)	0.21 (±2.6)
Obs.	9,858	2,613	999	904

95% confidence intervals are reported in brackets.
n/s: Not significant.

Additional work saw the same models estimated but without any variables which are associated with income such as employment status, social class and age. The extent to which these variables have effects independent of income is uncertain, and hence the results in Table 10.4 provide an upper bound to the income elasticities. As expected, the income elasticities are somewhat higher than in Table 10.3. These elasticities would be more appropriate when forecasts of the impacts of income growth on trip length are being made and no account is taken of changes in other socio-economic variables. The full models are reported in the Appendix to Section 10.

Table 10.4 Journey length income elasticities with income related socio-economic variables removed

Trip type	*Car*	*Passenger*	*Bus*	*Train*
Commuting	0.31 (±0.03)	0.17 (±0.07)	0.14 (±0.05)	0.11 (±0.07)
Leisure	0.13 (±0.02)	0.19 (±0.02)	0.19 (±0.02)	0.05 (±0.05)
Business	0.27 (±0.05)	0.19 (±0.10)	0.35 (±0.14)	0.23 (±0.17)

95% confidence intervals are reported in brackets.

10.4 The effect of income on the demand for public transport

This section covers the findings of models where the only variable representing external factors was income and hence the estimated elasticities will also contain the negative effects on public transport demand of increased income through its effect on car ownership.

The net effect will depend upon the relative strength of the expected positive income effect on the propensity to make trips and the negative effect through increased car ownership. In addition, some models face problems of correlation with other variables, such as trend changes in fares and service levels.

10.4.1 Bus demand

An early example of modelling work that only included income amongst its explanatory variables was reported for the bus industry by Gwilliam and Mackie (1975), who estimated long run elasticities ranging from -0.4 to -1.0.

Extensive econometric analysis of the bus market was conducted by Dargay and Hanly (1999). Time series data from different sources and at different levels of aggregation were analysed, and a feature of the work was a distinction between short run effects apparent after a year and long run effects. Table 10.5 presents results which illustrate the findings of the study for models which contained only income as a measure of the effect of external factors.

Table 10.5 Bus income elasticities

	Short run	*Long run*
National data (journeys)	0	-0.45 to -0.80
National data (pass-kms)	0	-0.15 to -0.63
Regional data (journeys)	0 to -0.29	-0.64 to -1.13
County data (journeys)	-0.3 to -0.4	-0.6 to -0.7
PTE data (journeys)	-0.7	-1.6

The variation in the estimated income elasticities could simply be sampling variation. However, there is the possibility that high correlations between income and other factors, such as fares and service quality, could contribute to these findings. Dargay and Hanly (1999) also report a series of models which contain both income and car ownership. These are covered in Section 10.6.1.

Selvanathan and Selvanathan (1994) developed a system of equations to explain competition between private transport, public transport and communications in the UK and Australia. Aggregate time series data for the years 1960-86 were used. The study was able to estimate income elasticities of +2.11 and +2.27 with respect to demand for private transport in the UK and Australia respectively and public transport income elasticities of 0.98 and 0.80. Given that bus demand will represent a large proportion of the public transport demand, these income elasticities seem rather high. Evidence from Spain also indicates a positive income elasticity for public transport as a whole, albeit associated with a case in which car ownership has risen from a lower base than in Britain and urbanisation has occurred more recently (Asensio *et al.*, 2003).

10.4.2 Rail demand

A very large number of rail demand models have incorporated some measure of income as an independent variable, although only a relatively small number are estimated to the demand for suburban and urban rail trips. However, most have included variables in addition to income to discern the effects of external factors and are considered in Section 10.6.2.

McLeod *et al.* (1985) examined 300 London commuter flows using quarterly ticket sales between 1973 and 1983. Disposable income was the measure of economic activity used, although employment would in some instances have been more appropriate. The average elasticity across flows was 0.84 for season tickets and 0.54 for other tickets.

AEAT (1999) estimated models to annual ticket sales data covering the years 1991 to 1999 which contained only GDP to represent external factors. For trips under 30 miles, the GDP elasticity was 0.9 for all tickets except seasons. The elasticities split by ticket type were 1.6 for first class, and 0.8 for both full fare and reduced fare standard class.

As part of research to update the Passenger Demand Forecast Handbook (ATOC, 2002), models were estimated to annual ticket sales data for non London flows of less than 20 miles and flows within the south east which tended to be of relatively short distances. Reported in Table 10.6 are models which contain only income as a measure of the effect of external factors, although they did include car time and cost cross-elasticity terms constrained to equal industry recommended values to isolate these effects which are highly correlated with income.

Table 10.6 Income elasticities for short distance rail trips (non seasons)

Flow	*Elasticity*
South east to London	2.07 (±0.64)
South east from London	1.90 (±0.42)
South east non London	0.89 (±0.40)
Non London	0.11 (±0.10)

These are different to the south east elasticities reported in Table 10.1 since they relate solely to trips of 30 miles or less.

Strong positive income elasticities are apparent for the south-east. Car ownership levels are already high here and hence the negative effect on rail trips will be less than elsewhere. The income elasticity for non London flows of less than 20 miles is very much lower. In part this will reflect stronger impacts from increasing car ownership, but it is nonetheless surprisingly low.

10.4.3 Summary of income elasticities

The empirical evidence clearly indicates that the bus income elasticity which includes the car ownership effect is negative. It appears to be quite substantial, in a range between -0.5 and -1.0 in the long run although somewhat smaller in the short run. This would explain the sustained reductions in bus demand over time. However, as car ownership approaches saturation, the income elasticity can be expected to become less negative. Whether it might become positive is addressed in Section 10.7.

The position is somewhat different for rail, and indeed within the rail market there are large differences between market segments and across distance bands (ATOC, 2002) which are also apparent in the results reported above for short distance trips. As with the bus income elasticity, the rail elasticity can also be expected to increase over time and evidence for such an effect is considered in Section 10.7.

10.5 The effect of car ownership on the demand for public transport

This section covers the empirical evidence relating to the effect of car ownership on public transport demand where income is not entered into the model. There are somewhat fewer instances where car ownership is the sole variable representing external factors. From an econometric standpoint, this is as it should be since car ownership is not an exogenous variable and therefore it is more appropriate to use income as an independent variable in standard multiple regression models or else use a statistical procedure which accounts for car ownership's endogeneity.

10.5.1 Bus demand

We are not aware of studies of urban bus travel where the volume of demand has been related solely to car availability as a measure of external effects. Notwithstanding this, urban mode choice models, of which very many have been estimated, can be used to determine the effect of car ownership on bus demand. This is because the choice set for those without a car contains just the public transport alternatives but is expanded to include car when one becomes available.

10.5.2 Rail demand

Most rail demand models which contain car ownership effects relate to inter-urban travel (Fowkes *et al.*, 1985; Rickard *et al.*, 1986; Wardman, 1996) and hence are beyond the scope of this report.

Wardman and Dunkerley (1999) specified a model based on NTS data which related rail trip rates per person to, amongst other things, whether there was no car in the household. The data did not distinguish between long and short distance trips and was based solely on leisure trips. The data were grouped into various socio-economic categories, relating to gender, age group, socio-economic group, whether a car was owned and household type. Trip rates were calculated for each combination of the various categories whilst the average income level for that category was also obtained. The correlation between average income within a category and whether those in the category had a car or not was less than 0.3. The form of the model estimated was:

$$V = \mu e^{\beta NCH + \sum_i \lambda_i X_i} \prod_j Z_j^{\gamma^j}$$

where V is the volume of rail trips per person in a particular category, NCH is a dummy variable denoting whether there was no car in the household, the X_i are dummy variables relating to the other socio-economic categories, and the Z_j are the average levels within each category of continuous variables such as income and walk time to the station. Given average income levels varied little across categories, its effect was insignificant and hence the model contained only car ownership as a measure of external effects.

In the above specification, the exponential of β denotes the proportionate effect on rail trip rates per person of not having a car in the household. The parameter estimated to the NTS data was 0.937 (±0.3). This indicates that, for constant income, those without a car in the household made around 2½ times more rail trips[13].

Studies by TCI (1989), Harris research Centre (1987) and Southgate and Associates (1986) demonstrate that car ownership increases the choice of travel modes available and increases the elasticities of rail service quality and price. What is also clear is that an increase in competition leads to higher rail demand elasticities, although the size of these changes depends upon journey purpose and the type of competition.

10.5.3 Summary of car ownership elasticities

Few studies have concentrated solely on car ownership as a predictor of the effects of external factors on public transport demand. What evidence there is indicates that, as expected, the impact is negative. This is further illustrated by Table 10.7. It shows that, on average in Great Britain, a person in a car owning household is likely to make considerably fewer trips by both bus (66% less) and rail (25% less)[14] per week than a person in a non-car owning household.

The dearth of evidence of car ownership effects alone is perhaps surprising. The very many urban mode choice models in Great Britain rarely contain income as an explanatory variable but they do indicate the effect of car ownership through its impact on the set of alternatives between which the forecasting models allow individuals to choose. In addition, census data are readily accessible at a spatially disaggregated level and contains figures relating to household car ownership and to mode shares for the journey to work. It would be a straightforward matter to examine how modal shares vary with car ownership levels.

Whilst car ownership will have a negative impact upon the demand for public transport the size of this impact does differ from country to country. Table 10.8 shows the

Table 10.7 Journeys and kilometres per person a week according to household vehicle availability 1991/93 in Great Britain

Travel mode	*No vehicles*	*Bicycles only*	*Motorcycle /moped*	*1 car*	*2 cars*	*3 or more cars*	*All households*
Journeys per person							
Bus	3.3	3.0	2.1	1.1	0.7	0.5	1.5
Rail	0.4	0.5	0.2	0.3	0.3	0.3	0.3
Kilometres per person							
Bus	26.7	23.6	15.7	14.1	10.1	8.8	15.5
Rail	11.7	14.7	10.4	12.1	11.3	13.2	12.0
Number of households	2,631(25.3%)	623(6.0%)	47(0.5%)	4,565(43.8%)	2,068(19.9%)	401(3.8%)	10,413(100%)

Source: Potter et al. (1997).

Table 10.8 Car ownership and modal share in the EU (1999)

Country	*No of cars per 1000 inhabitants*	*GDP per head in PPP (EU=100)*	*Car modal split (pkm in % for 1999)*	*Public transport modal split (pkm in % for 1999)*
Belgium	450 (6)	111 (5)	81.8	17.1
Denmark	341 (13)	118 (2)	79.4	19.8
Germany	515 (3)	107 (7)	81.4	16.9
Greece	275 (15)	67 (15)	66.7	21.9
Spain	424 (8)	82 (13)	78.6	17.9
France	465 (5)	101 (10)	84.3	14.2
Ireland	346 (12)	112 (3)	80.3	18.9
Italy	544 (2)	99 (12)	76.6	15.9
Luxembourg	610 (1)	180 (1)	79.0	19.2
Netherlands	398 (11)	112 (3)	81.5	16.6
Austria	494 (4)	111 (5)	73.1	25.2
Portugal	330 (14)	75 (14)	78.1	15.6
Finland	407 (10)	103 (8)	81.6	17.0
Sweden	440 (7)	101 (10)	80.2	18.6
United Kingdom	414 (9)	102 (9)	86.8	12.5
EU 15	460	100	81.0	15.9

Source: Statistical data – Eurostat (2001)

relationship between car ownership and modal share in EU member states for 1999. It can be seen that the UK has on average 414 cars per thousand inhabitants and a public transport modal split of 12.5%. In comparison Luxembourg has 47% more cars per thousand inhabitants but a public transport modal split of 19.2%. The lowest level of car ownership can be seen in Greece with 275 cars per thousand inhabitants, yet the highest share of public transport is in Austria (25.2%) that has a car ownership level of 494 cars per thousand inhabitants.

The figures in Table 10.8 help illustrate that, whilst car ownership has a strong influence on the demand for public transport, there are other direct and indirect influences at work. These include:

- The cost of purchasing and operating a car, such as fuel, taxes and insurance.
- The cost of public transport, such as whether it is subsidised and whether the operators are efficient.
- Levels of congestion, for example, capital cities compared to medium sized cities.
- Land use and social issues.

10.6 Joint effects of income and car ownership on the demand for public transport

In this section, we consider models which have included both income and car ownership, or at least some proxy for the latter, to explain variations in rail and bus demand. Whilst there are few studies which consider car ownership in isolation, there are a number of studies which include it alongside income.

10.6.1 Bus demand

Clark (1997) reported a number of demand elasticities estimated to aggregate time series data. Short and long run GDP per head bus demand elasticities of 0.33 and 0.45 are reported for Great Britain as a whole, with short and long run car ownership elasticities of -1.04 and -1.43. Separate models were estimated for London, the Metropolitan areas, the non-Metropolitan areas, Wales and Scotland and the GDP and car ownership elasticities are reported in Table 10.9.

Table 10.9 Bus GDP and car ownership elasticities by area

	London	*Metro -politan*	*Non metro -politan*	*Wales*	*Scotland*
GDP	0.19 (±0.08)	0.41 (±0.14)	0.43 (±0.16)	0.29 (±0.23)	0.39 (±0.17)
Car ownership	-0.70 (±0.48)	-1.04 (±0.23)	-1.23 (±0.27)	-2.01 (±0.41)	-1.35 (±0.30)

The variation apparent across routes will no doubt have been influenced by the sampling distribution, since the elasticities are not very precisely estimated, but there are no clear symptoms of the expected collinearity problems.

A study by Fairhurst and Edwards (1996) estimated regional UK bus trips per head using aggregate time series data from 1970-94. The model for non-London flows demonstrated the multi-collinearity problems that can arise when both income (in this case consumer spending) and car ownership are used in the same model. The model produced estimates that were intuitive in sign and magnitude (+0.17 and -0.58 respectively) but, however, both were insignificant.

Dargay and Hanly (1999) estimated a structural model of bus and car use to national time series data. Four equations were specified, representing bus passenger kilometres, bus journeys, car ownership and car passenger kilometres. Independent variables included car ownership, bus fare, income and motoring costs. The income and car ownership elasticities are reported in Table 10.10.

Table 10.10 Bus income and car ownership elasticities

	Bus pass-kms	*Bus journeys*
Car ownership short run	0	0
Car ownership long run	-0.73	-0.64
Income short run	0.14	0.38
Income long run	0.07	-0.26

Although there is the issue of high correlation between car ownership and income, there is some evidence for a negative income effect in contrast to established thinking. This finding is apparent in another study considered below.

The National Travel Survey (NTS) provides a wealth of information on travel behaviour at the individual and household level and trends in it over time. Whilst its ability to represent the fare and service quality characteristics of different modes is poor, it is able to examine the impact of a wide range of socio-economic and demographic variables including income and car ownership which are of particular interest here.

Another desirable feature of this type of data is that the degree of correlation between the relevant measures of income and car ownership at the household or individual level is not high[15]. At the aggregate level, which covers most of the studies we have dealt with in this chapter, income is represented by GDP and car ownership is represented by the proportion of households who have various numbers of car or the number of cars per capita. The degree of correlation between these aggregate statistics is very high. In contrast, NTS data allows analysis to be conducted at the level of the individual. The relevant income measure is therefore household or individual income and the number of cars per household or whether the individual has a car. Whilst it is true that those with higher incomes have a greater probability of having a car, the degree of correlation between household income and household car ownership is not a cause for concern when the analysis is conducted at this level of detail. For example, the correlation between GDP and the number of cars per household between 1985 and 1997 is 0.70. The correlations in the NTS data for the same period between household income and whether the household has one car or two or more cars are -0.09 and 0.36 respectively.

Wardman and Preston (2001) report mode choice and car availability models which allow the estimation of the impact of income on the demand for rail and bus for the journey to work. The mode choice model is of the multinomial form and contains car driver, passenger, bus and rail and covers the years 1985 through to 1997. It has been recalibrated to remove time trend terms so that all inter-temporal effects are discerned by income and changes in the choice set. The choice set of whether a car is available for the journey to work is analysed using a logit model for the same years and again the time trend terms in the model reported by Wardman and Preston have been removed. The estimated models are reported in the Appendix to Chapter 10.

The models have been used to forecast the effect of changes in income on mode share for the journey to work. This includes the indirect effect of income on car availability, which varies those who can choose car, and the direct effect of income on mode choice. For a 2% increase in income, which roughly corresponds with annual income growth, the overall income elasticity was –1.08 for bus. This figure does not vary greatly with the size of the income variation.

Analysis of the same NTS data between 1985 and 1997 for business and leisure trips involved the development of two models. The first model determines whether an individual made a bus trip in the survey period and the second model analyses variations in the number of bus trips by those who make them. The full models are reported in the Appendix to Section 10. A logit model is used to explain whether an individual makes any bus trips as a function of variables such as income, whether the household has one or more than one car, employment status, age, gender, region and a number of other socio-economic and demographic factors. For those who do make bus trips, a further model is estimated to explain variations across individuals and over time as a function of the same range of socio-economic and demographic variables.

In the models of whether bus trips are made or not, it was found that the income effect was positive for business but was absent for leisure trips whilst the coefficients relating to whether the household had one or more than one car both indicated a negative effect with the latter larger than the former.

In the model based on explaining the number of bus trips given that at least one is made, the income elasticity was effectively zero for business but actually negative albeit small (-0.04) for leisure trips. As income increases, there may be a greater tendency to use taxis, although trends in social attitudes may be at work here. Whether the household had one car reduced the number of bus leisure trips by 24% whilst more than one car in the household reduced the number of trips by 29%. For bus business trips, there were no effects apparent from household car ownership.

Income will therefore have a direct effect on the number of bus trips and also indirectly through car ownership. Table 10.11 reports income elasticities for 2%, 5% and 10% increases in income for the final year in the data sets analysed of 1997. Increases in the number of households with one car and two or more cars solely as a result of income growth was forecast using the Department for Transport's car ownership forecasting model (Whelan, 2001).

Table 10.11 Bus income elasticities (including car ownership effects)

Income	*Business*	*Leisure*
+2%	0.49	-0.33
+5%	0.50	-0.33
+10%	0.51	-0.33

The overall income elasticity for business trips is positive and quite strong, although this is a relatively unimportant market segment. For leisure trips, the overall elasticity is negative, in line with the income elasticities estimated when it is the only variable to represent external effects. The measure of income used is household income. Whilst a better measure would be a variable relating to national income, which reflects the level of economic activity, variation in household income over time will tend to correlate with variation in national income. Section 10.7 considers how the income elasticity will vary over time as car ownership levels more closely approach saturation.

10.6.2 Rail demand

Within the rail industry, there has been a long tradition of specifying the effects of external factors in terms of GDP and a time trend. The latter term represents the effects of a range of external factors, but is generally taken to be dominated by increasing car ownership and hence is expected to be negative.

Glaister (1983) examined rail commuting into London. The earnings elasticity varied between 0.56 and 1.69 depending upon route and model formulation, with a small positive time trend and also small unemployment elasticities of the expected signs for the origin and destination location.

Palomo (1996) estimated models to time series data relating to trips on Network South East services. These are dominated by trips to London, with commuting trips and shorter distance trips forming a large proportion. The GDP elasticity was estimated to be 1.1 with a negative time trend of -1.7% per annum. In similar analysis, Clark (1997) estimated the GDP elasticity to be 0.62 and the car ownership elasticity to be 0.32 for these flows. The positive car ownership effect is presumably due to strong correlation with income.

TCI-OR (1997) estimated models to rail tickets sales data relating to the periods quarter 2 1987 through to quarter 4 1995. Separate models were estimated to flows less than 25 miles and the results are presented in Table 10.12.

Table 10.12 GDP elasticity and time trend estimates (journeys < 25 miles)

	Seasons		*Other*	
Flow	*GDP*	*Trend*	*GDP*	*Trend*
Intercity non London	0.1	-1.3%	-0.32	-1.3%
South east London	3.5	-7.6%	1.94	-2.1%
South east non London	2.2	-4.3%	1.21	-2.8%
Regional	1.8	-3.6%	0.47	3.1%

Whilst we might expect variation in these parameters across routes, the results are consistent with the presence of multicollinearity. Thus larger GDP elasticities will be associated with more negative time trends, and this pattern is apparent in the results. This study also examined a lag structure but found no strong support for such a specification.

Similar findings are apparent in the study of Centre for Economics and Business Research (1998) where the specification of rail demand models for trips in the south east into London included a measure of economic activity and a time trend. Models were developed to time series CAPRI data for season tickets, standard and first class tickets, and reduced fare tickets, for the period 1987-1996, and the key findings for various corridors are reported in Table 10.13.

Table 10.13 Economic activity and trend parameters for London and south east rail flows

Ticket type / *Variable*	*All*	*South*	*South West*	*North West*	*North*	*North East*
Season tickets						
Employment	2.0	1.3	0.9	2.6	1.7	1.9
Trend	1.4%	1.3%	1.6%	2.4%	1.2%	1.3%
Full fare tickets						
GDP	1.9	0.7	2.0	2.2	3.4	1.6
Trend	-3.2%	-3.7%	-3.4%	-2.4%	-4.7%	-2.3%
Reduced tickets						
Spending	1.9	1.8	1.9	2.4	1.9	1.7
Trend	2.2%	1.1%	2.8%	2.6%	2.2%	2.4%

As expected, given the highly congested roads that face commuters into London, the employment elasticity exceeds one since the proportion of additional trips generated by employment growth that use rail will exceed the existing rail market share. Nonetheless, the figures exceed one by some considerable amount, and the employment elasticity may also be discerning other effects, such as trends in car journey times and costs. In this context, there will be little negative impact due to car ownership. This along with rail demand growth due to increased road congestion presumably accounts for the positive trend.

There is also a suspicion of correlation problems in the results for full fare, with a correlation between the time trend and GDP elasticity estimates of -0.42. However, some of the variation could simply be due to sampling distribution. The stark difference between the results for full fare and reduced tickets suggests that there might have been switching between ticket types which has not been adequately accounted for.

As part of a study to develop a rail industry forecasting framework, models were estimated to time series ticket sales data for trips in the south east to London (Steer Davies Gleave, 1999b). Separate models were estimated for season tickets, full fare tickets and reduced tickets for trips less than 35 miles. For season tickets, an employment elasticity of 1.32 was estimated along with a quarterly negative time trend of -0.59%. For full fare tickets, the GDP elasticity was 2.57 with a trend of 0.12% per quarter whilst for reduced tickets the corresponding values were 1.05 and 0.35% per quarter. The large negative time trend for season tickets is a cause for concern, whilst the GDP elasticity for full fare tickets seems large, particularly given the positive trend associated with these tickets. Switching between ticket types was not explicitly allowed for and could well have influenced these results.

The problem of correlation between economic variables and the time trend or other measures such as car ownership is evident in many studies of longer distance travel (ATOC, 2002). A 'solution' in some studies is to constrain the time trend. For example, in analysis of ticket sales data to determine the impact of service disruptions due to the major redevelopment of Leeds station, Wardman *et al.* (2001b) constrained the time trend in a model of suburban rail trips to equal -2% per annum which was the then recommended figure in the Handbook. The resulting GDP elasticity was 1.66 for all flows except 4.44 for trips to Leeds. The high value for the latter is the result of using national figures which dramatically underestimated the growth in the Leeds economy in the period in question. In addition, increases in fuel costs and car journey times were not accounted for and can have been expected to inflate the GDP elasticity.

Subsequent developments in forecasting in the rail industry have placed more emphasis on car ownership levels. The rail industry forecasting framework (Steer Davies Gleave, 1999b) includes a car ownership elasticity for leisure trips and also for business trips outside the south east, whilst retaining a time trend in some market segments. In contrast, the most recent version of the Passenger Demand Forecasting Handbook (ATOC, 2002) includes a non-car ownership term and removes the time trend altogether. The recommended forecasting framework in the Handbook for what are termed external factors is:

$$I_E = \left(\frac{GDP_{new}}{GDP_{base}}\right)^g \times \left(\frac{POP_{new}}{POP_{base}}\right)^p \times \exp\left(n\left(NC_{new} - NC_{base}\right)\right) \times$$

$$\left(\frac{FUELCOST_{new}}{FUELCOST_{base}}\right)^f \times \left(\frac{CARTIME_{new}}{CARTIME_{base}}\right)^c \times$$

$$\left(\frac{BUSCOST_{new}}{BUSCOST_{base}}\right)^b \times \left(\frac{BUSTIME_{new}}{BUSTIME_{base}}\right)^t \times$$

$$\left(\frac{BUSHEAD_{new}}{BUSHEAD_{base}}\right)^b \times \left(\frac{AIRCOST_{new}}{AIRCOST_{base}}\right)^r \times$$

$$\left(\frac{AIRHEAD_{new}}{AIRHEAD_{base}}\right)^f$$

As part of research conducted to update the handbook, fresh evidence was obtained on the GDP elasticity (g) conditional upon constrained parameters for n, f and c and assuming that in the ticket sales data analysed any changes that did occur in bus and air had an essentially random effect on rail demand. Annual data were analysed covering the years 1991 through to 1999. Fuel costs were assumed to change over time in line with indices used by the Department for Transport and various assumptions were made about car journey time increases. The parameter n was obtained from analysis of NTS data as reported in Section 10.5.2 and weighted by journey purpose.

Most of the handbook's recommendations relate to longer distance journeys which are beyond the scope of this document. However, elasticities estimated using this procedure for relatively short distance flows, and which are now included as handbook recommendations, are set out in Table 10.14.

There is some variation by ticket type, although any relationship with journey purpose is not readily apparent. Income elasticities for longer distance trips seem to be higher. The tendency for trip length to increase with income will have contributed to the latter but a journey purpose effect could well be at work here in that the London and south east to London flows will tend to have the greatest number of business trips whilst the short distance Non London trips will have the lowest number of business trips. The low value for PTE areas could be because pre-paid area-wide PTE based tickets were becoming increasingly dominant and hence reduced the increase in demand in the off-peak market for the point-to-point rail tickets that were analysed.

We can combine the direct income effect and the indirect effect through car ownership to determine how rail trips will vary with income. For consistency with other similar forecasts for bus and rail in this chapter, this is done for 2% income growth from income and car ownership conditions prevailing in 1997. The car ownership forecasts were produced using the Department for Transport's car ownership forecasting model (Whelan, 2001) with only income varying. The 2% income growth reduces the proportion of households without a car from 31.18% to 30.80%. The overall income elasticities are reported in Table 10.15 and generally indicate that rail demand will grow strongly with income.

Corresponding analysis of the NTS data for 1985 through to 1997 as was reported for bus travel in Section 10.4.1 was also conducted for rail travel, with a simultaneous examination of the effects of income and car ownership.

Table 10.15 Overall rail income elasticities

Flow and ticket type	*Elasticity*
London 20 – 100 Miles	
First	1.14
Full	1.93
Reduced	1.33
All (without Apex)	1.43
All (with Apex)	1.51
South east non seasons	
To London	1.60
From London	0.90
Non London	1.25
Non London non seasons	
Up to 20 miles PTE	-0.11
Up to 20 miles non PTE	0.25
20-100 miles	0.40

Table 10.14 GDP elasticities for relatively short distance rail flows

Flow and ticket type	*GDP*	*n*	*Assumed car journey time increases*
London 20 – 100 Miles			
First	1.16 (±0.11)	0.09	Within 40 miles of London, rate of increase 2.5% per year up to 1995 and 4% thereafter. Beyond 40 miles, rate of increase 1.25% per year and 1.5% thereafter.
Full	2.00 (±0.20)	0.37	
Reduced	1.46 (±0.13)	0.70	
All (without Apex)	1.54 (±0.08)	0.57	
All (with Apex)	1.64 (±0.06)	0.70	
South east non seasons			
To London	1.74 (±0.36)	0.71	Within 40 miles of London, rate of increase 2.5% per year up to 1995 and 4% thereafter. Beyond 40 miles, rate of increase 1.25% per year and 1.5% thereafter.
From London	1.04 (±0.20)	0.71	
Non London	1.39 (±0.30)	0.71	
Non London non seasons			
Up to 20 miles PTE	0.05 (±0.22)	0.84	For up to 20 mile journeys in PTE areas, rate of increase 2% per year up to 1995 and 2.5% thereafter.For up to 20 mile journeys outside of PTE areas, rate of increase 1.5% per year up to 1995 and 2% thereafter.For over 20 miles, rate of increase of 1.25% per year up to 1995 and 1.5% thereafter.
Up to 20 miles non PTE	0.41 (±0.12)	0.84	
20-100 miles	0.56 (±0.15)	0.84	

For commuting trips, the combined car availability and mode choice model implied an income elasticity for rail in 1997 of 0.34. For business and leisure trips, separate models were estimated to explain whether a rail trip was made in the survey period and to explain variations in trips by those who made them. No distinction was made between urban and inter-urban trips. Full details of the models are reported in Appendix 6.3.

For both business and leisure trips, the probability of making a trip increases with income but falls as car ownership per household increases. With respect to variations in the number of trips by those who make rail trips, the income elasticity is positive for leisure trips but zero for business trips. The effects of car ownership on the number of rail trips is slight. For business trips, no significant effect was obtained whilst for leisure trips the presence of one car per household reduced rail trips by 9% and two or more cars per household reduced rail trips by 11%.

The overall income elasticities, combining the direct effect of income and its indirect effect through car ownership, were obtained using the same procedure as for bus reported in Section 10.6.1 and again relate to 1997. The elasticities are given in Table 10.16 and again would imply healthy growth in rail demand with income growth.

Table 10.16 Rail income elasticities (including car ownership effects)

Income	*Business*	*Leisure*
+2%	0.72	0.41
+5%	0.74	0.42
+10%	0.76	0.43

10.6.3 Summary of combined income and car ownership effects

In studies based on the volume of demand, there is strong correlation between income and car ownership which means that it is difficult to disentangle the separate effects of each. In some instances, it has even resulted in coefficients of wrong sign. Various studies have attempted to overcome this problem using outside evidence and constrained estimates whilst analysis of trip patterns at the individual level, as is possible with NTS data, does not face serious correlation problems.

There is some evidence to suggest that variations in the demand for bus purely as a result of income growth are negative, but in any event the overall effect after the introduction of car ownership is negative. Although car ownership has a negative impact on rail demand, it is less than for bus and, although there are quite large variations across studies and type of route, the overall effect of income on rail demand is quite strongly positive.

10.7 Posible variations in income elasticity over time

It is often argued that multicollinearity is not a particular problem for forecasting provided that the degree of correlation is maintained over the forecasting period. However, this is unlikely to be the case in the context of income and car ownership. With regard to bus travel demand, Dargay and Hanly (1999) state that, 'It should be stressed, however, that the negative income elasticity pertains to a period of rising car ownership and use. As private motoring reaches saturation, which it must do eventually, or is limited by political means, it is likely that income's negative effect on bus patronage will become smaller, and possibly become positive'. For the same reasons, rail income elasticities can be expected to become larger.

To address the extent to which the income elasticities might increase, we have repeated the forecasting exercises reported in Tables 10.11 and 10.16 based on NTS models. This has been done for 2% income growth from the income and car ownership situations for 2005, 2015 and 2025. It is assumed that income grows by 2% per annum. The car ownership forecasts for zero (P0), one (P1), two (P2) and three plus cars (P3+) per household, again based on the Department for Transport's official model, assume only that income changes over time. The forecasts produced by this model are given in Table 10.17.

Table 10.17 Car ownership forecasts used in calculating income elasticities

Year	P_0	P_1	P_2	P_{3+}
1997	0.3118	0.4378	0.2059	0.0446
+2%	0.3080	0.4380	0.2085	0.0455
2005	0.2828	0.4382	0.2273	0.0518
+2%	0.2802	0.4380	0.2293	0.0525
2015	0.2496	0.4342	0.2542	0.0619
+2%	0.2468	0.4336	0.2567	0.0629
2025	0.2215	0.4270	0.2789	0.0726
+2%	0.2187	0.4262	0.2813	0.0738

The overall income elasticities for 2% income growth in each of several future years and based on models which have analysed NTS data are reported in Table 10.18. The models project significant increases in the overall rail income elasticities over time. For bus, the findings are mixed. In the business market, there is growth in the elasticity but this is a minor market segment, yet in the leisure market there is hardly any variation in the overall income elasticity over time and by no means could it be concluded that the overall income elasticity would become positive. The increasing negative elasticity in the bus commuting market is a result of the logit model's property that the absolute value of an elasticity will increase as bus market share falls over time and as income grows over time.

Table 10.18 Overall bus and rail elasticities based on analysis of NTS data

	Commuting		*Business*		*Leisure*	
	Bus	*Train*	*Bus*	*Train*	*Bus*	*Train*
1997	-1.08	0.34	0.49	0.72	-0.33	0.42
2005	-1.27	0.40	0.66	0.89	-0.30	0.52
2015	-1.60	0.49	0.80	1.09	-0.29	0.61
2025	-2.08	0.53	1.00	1.34	-0.28	0.75

10.8 Conclusions and recommendations

10.8.1 Conclusions

The main focus of this chapter has been to disentangle the effects of income and car ownership upon the demand for public transport. In so doing a number of other topics have been covered.

Examination of the effect of income on travel expenditure and distance travelled has shown that the percentage of overall household expenditure spent on transport and travel has been rising steadily in Great Britain since 1981. There is clear evidence that trip lengths are increasing with income for all modes and all trip purposes, though the effects are not particularly strong. In general, the elasticities lie in the range 0.09 to 0.21, with noticeably stronger growth for car commuting, business trips by rail and business trips by bus.

The empirical evidence of the of the effect of income and car ownership respectively on public transport demand clearly indicates that the bus income elasticity which includes the car ownership effect is negative, ranging from -0.5 to -1.0 in the long run. It was felt that has car ownership approaches saturation, the income elasticity can be expected to become less negative. Few studies have concentrated solely on car ownership as a predictor of the effects of external factors on public transport demand. What evidence there is indicates that, as expected, the impact is negative.

Regarding the joint effects of income and car ownership on the demand for public transport, there is some evidence to suggest that variations in the demand for bus purely as a result of income growth are negative, but in any event the overall effect after the introduction of car ownership is negative. Although car ownership has a negative impact on rail demand, it is less than for bus and, although there are quite large variations across studies and types of route, the overall effect of income on rail demand is quite strongly positive.

An attempt was made to examine the possible variations in income elasticity over time. The results from a number of forecasted models signify significant increases in the overall rail income elasticities over time. For bus the findings are mixed. In the business market, there is growth in the elasticity but this is a minor market segment. In the leisure market there is hardly any variation in the overall income elasticity over time and by no means can it be concluded that the overall income elasticity will become positive.

10.8.2 Recommendations

The analysis of NTS data indicates overall income elasticities for bus of -1.08 for commuting and -0.33 for leisure trips. Bearing in mind the balance between commuting and leisure trips, these figures are broadly consistent with Dargay and Hanly (1999) who estimated long run elasticities of:

- National -0.45 to -0.80.
- Regional -0.64 to -1.13.
- County -0.6 to -0.7.

We therefore recommend that the NTS figures can be used as long run elasticities, and also to provide a disaggregation by purpose and for changes in elasticities over time.

With regard to suburban rail, the ticket sales evidence covers a large range, with values of 0.5 to 2.0 representing London and 0.1 to 0.9 representing elsewhere. However, there are other confounding effects apparent, such as switching between ticket types and increasing road congestion.

The NTS evidence for rail indicates elasticities of 0.34 for commuting, which is in addition to employment effects, 0.72 for business and 0.42 for leisure. These figures can be taken as broadly consistent with the ticket sales evidence.

For rail, it is recommended that the NTS evidence is used. This also provides segmentations by purpose and allows for changes in the overall income elasticity over time. In addition, a key driver of commuting trips is employment.

Finally the NTS evidence on journey length and income there is clear evidence that trip lengths are increasing with income, although the effects are not particularly strong. In general elasticities lie in the range of 0.09 to 0.21 but with noticeably stronger growth for car commuting. These elasticities are somewhat higher, between 0.11 to 0.35, if variables associated with income (employment status etc) are stripped out.

11 The relationship between land-use and public transport

11.1 Introduction

The relationship between land use and transport is complex and difficult to fully unravel. Both are part of a dynamic system and interact at several different scales within the urban environment – at the neighbourhood level, at the city district level through to the urban region (i.e. the urban area and the hinterland which it services) and beyond. Land-use patterns are also a difficult concept to quantify and are a result of the interaction of many historical forces. Generally, land use patterns are described using a number of different characteristics such as the distance from the urban centre, settlement size, mix of land uses, the level of provision of local facilities, the density of development, proximity to transport networks, settlement shape and urban form. Each of these measures is only indicative of one aspect of land use. Boarnet and Crane (2001) found that the measured relationship between land use and transport was very sensitive to the choice of empirical methodology. Different land-use characteristics are often associated with each other. For example, historically areas of high population densities tended to be located near the city centres in areas with good public transport provision. However, just because this association has existed in the past, it does not mean that with the creation of high-density residential areas in the future that good public transport provision will follow.

The relationship between land-use and transport is complicated still further by the close association of both elements with a number of socio-economic factors such as car ownership and income, which themselves are interrelated. Different land-use characteristics are often associated with different socio-economic factors, and socio-economic factors also affect travel patterns (Stead *et al.*, 2001). Variations in socio-economic characteristics add to the complexity of the problem, making it difficult to establish the precise relationships between public transport demand and land-use patterns.

The chapter begins by considering the effect of land-use patterns in general on transport demand and the effect of different planning policies on travel patterns. It then goes on to explore the effect of transport infrastructure and provision on economic growth and development patterns, which will in turn affect the demand for public transport, before briefly addressing how transport policy can be used to guide planning policy.

11.2 The effects of land-use on public transport demand

Land-use patterns and built form can influence transport demand in the following ways:

Interspersion of activities	→	trip lengths and trip frequency.
Shape of the urban area	→	trip lengths.
Density	→	trip lengths and trip frequency.
Clustering of trip ends	→	public transport.
Settlement size	→	trip lengths, public transport.

(Adapted from Owens,1986)

All these elements are interrelated, and the relationship between them and transport will depend on the definition of the variable used to measure each element.

The effect of land use on travel varies by trip purpose. As with fares, the effect of land use change on a particular journey will depend on the degree to which the journey start/end time, mode, route and destination can be changed, whether the journey is essential or non-essential and the degree to which it is (and can be) linked with other trips. Maat (1999) suggests that land-use has the biggest effect on commuting trips and local/convenience shopping journeys. Boarnet and Greenwald (2000) suggest for non-work trips land-use influences the distances travelled rather than the number of trips made.

11.2.1 Density

It can be expected that the number of journeys made per person by public transport will increase with density; whilst the average length of journeys will decrease with increasing density. This is reflected in the results shown in Tables 11.1 and 11.2. As can be seen both bus and rail use increase with density. Walking also increases with density, whilst car use decreases. Van Diepen (2000) found similar results in an analysis of 1995 travel survey data for the Netherlands.

The relationships between journey distance and density seem to be weakening over time. ECOTEC (1993) also found some evidence that the relationship between density and mode split has been weakening over time. This is possibly due to decentralisation, with an increasing

Table 11.1a Distance travelled per person per week by mode and population density 1985/6

Density Persons per hectare	*Distance travelled per person per week by mode*					
	All modes	*Car*	*Local bus*	*Rail**	*Walk*	*Other†*
<1	206.3	159.3	5.2	8.9	4.0	28.8
1-5	190.5	146.7	7.7	9.1	4.9	21.9
5-15	176.2	131.7	8.6	12.3	5.3	18.2
15-30	152.6	105.4	9.6	10.2	6.6	20.6
30-50	143.2	100.4	9.9	10.8	6.4	15.5
>50	129.2	79.9	11.9	15.2	6.7	15.4
All areas‡	159.6	113.8	9.3	11.3	5.9	19.1

** Includes long distance rail.*
† Other refers to two-wheeled motor vehicles, taxis, domestic air travel, other public transport and other types of bus (school, hire, express and works).
‡ Data excludes all trips less than 1.6km and only refer to the main mode used for a trip.
Source: Based on ECOTEC (1993).

Table 11.1b Distance travelled per person per week by mode and population density 1999/2001

Density Persons per hectare	*Distance travelled per person per week by mode*						
	All modes	*Car*	*Local bus*	*Rail**	*Walk*	*Bicycle*	*Other†*
<1	171.51	145.56	4.21	6.17	2.57	0.86	12.14
1-5	159.43	133.22	3.93	8.72	2.70	0.82	10.03
5-15	133.97	111.11	3.89	6.23	3.23	0.73	8.78
15-30	124.19	96.57	4.41	9.42	3.21	0.79	9.78
30-50	111.75	86.38	5.02	7.59	3.45	0.61	8.71
>50	94.75	63.02	6.13	15.04	3.63	0.64	6.28
All areas‡	130.41	103.93	4.58	8.84	3.17	0.73	9.17

** Includes long distance rail, LT Underground and Light Rail.*
† Other refers to two-wheeled motor vehicles, taxis, domestic air travel, other public transport and other types of bus (school, hire, express and works).
‡ Data only refer to the main mode used for a trip.
Source: Department for Transport 2002b.

number of businesses relocating away from the city core to suburban and fringe locations.

ECOTEC (1993) found the following relationships between population density and travel patterns:

- Higher pop densities widen the range of opportunities for the development of local contacts and activities, without the need to use motorised transport.
- Higher pop densities increase the scale of local expenditure widening the range of services which potentially can be supported and therefore:
- Higher pop densities will tend to reduce average distances between place of residence and the places at which services/employment opportunities can be accessed (provided that the higher population densities are accompanied by increases in commercial densities, for example Frank and Pivo (1994) showed that high employment density, high population density and a mixed land use pattern all help increase public transport use for work and shopping trips.

Table 11.2a Number of journeys per person per week by mode and population density 1985/6

Density Persons per hectare	*Journeys per person per week by mode* All modes	Car	Local bus	Rail*	Walk	Other†
<1	13.59	9.72	0.55	0.11	1.40	1.81
1-5	14.81	10.28	1.04	0.23	1.78	1.48
5-15	14.69	10.10	1.28	0.25	1.87	1.19
15-30	14.12	8.74	1.53	0.24	2.38	1.24
30-50	13.97	8.38	1.77	0.37	2.33	1.12
>50	12.99	6.68	2.21	0.63	2.47	1.00
All areas‡	13.98	8.75	1.52	0.33	2.14	1.25

** Includes long distance rail.*

† Other refers to two-wheeled motor vehicles, taxis, domestic air travel, other public transport and other types of bus (school, hire, express and works).

‡ Data exclude all trips less than 1.6km and only refer to the main mode used for a trip.

Source: Based on ECOTEC (1993).

Table 11.2b Number of journeys per person per week by mode and population density 1999/2001

Density Persons per hectare	*Journeys per person per week by mode* All modes	Car	Local bus	Rail*	Walk	Bicycle	Other†
<1	19.42	13.16	0.56	0.12	4.40	0.31	0.88
1-5	19.95	13.80	0.66	0.23	4.27	0.33	0.66
5-15	20.64	13.36	0.92	0.23	5.18	0.29	0.66
15-30	19.90	12.26	1.13	0.36	5.14	0.35	0.65
30-50	19.19	11.36	1.28	0.37	5.27	0.27	0.63
>50	18.32	8.26	1.85	1.14	6.20	0.25	0.63
All areas‡	19.63	12.07	1.09	0.40	5.10	0.30	0.67

** Includes long distance rail, LT Underground and Light Rail.*

† Other refers to two-wheeled motor vehicles, taxis, domestic air travel, other public transport and other types of bus (school, hire, express and works).

‡ Data only refer to the main mode used for a trip.

Source: Department for Transport 2002b.

- Increasing the density of population shortens the access distances to the public transport network and creates greater numbers of personal movements along specific corridors, thus improving the viability of public transport.

All of the above impacts of increased population densities assume that the areas of high population density are within reasonable proximity to a range of services, facilities and public transport. In addition the benefits from any increases in population can only be accrued if they are accompanied by similar increases in commercial densities. However, these greater numbers of movements can also create greater levels of congestion, which could slow down public transport movements, discouraging trips.

However, the relationships outlined above also suggest that at high densities, shorter journey lengths could result in an increase in non-motorised trips leading to a decrease in public transport. Indeed this was one of the findings of the ECOTEC report (ECOTEC, 1993). ECOTEC found that the number of journeys made on foot increased with higher neighbourhood densities but unlike public transport, this relationship was unaffected by car ownership and the occupational characteristics of the area.

A major problem when analysing the effect of density on travel patterns is the high degree of association between density, socio-economic characteristics (including income), public transport provision and prices, and car ownership. For example, Fouchier (1997) found a relationship between car ownership and what he refers to as 'net human density' for the Paris region. Net human density or 'urban intensity' is defined as (population + employment)/urban hectares. Fouchier found that the correlation between 'non-motorisation' (the number of households with no car) and density was stronger (R=+0.71) than the relationship between average car ownership levels and density. Fouchier surmises that this confirms the theory that higher densities provide for the possibility of not using a car. Unfortunately, Fouchier does not go on to relate density to levels of public transport use.

Breheny (1995a) suggests that social class and car ownership are likely to explain additional variations in the relationship between density and public transport use. Breheny used journey to work data from the 1991 Census of Population to compare public transport use with density for Greater London. The data refer to the main mode usually used for the journey to work, and the overall population density for urban areas[16]. Breheny found that public transport use (bus and rail) for the journey to work was related to density (R^2 = 52%). The regression equation is given as:

%Bus/Rail = 19.2 + 0.337 Density

Including social class in the regression analysis increased the R^2 value to 56%:

%Bus/Rail = 29.2 + 0.269 Density - 0.244 Social Class

The inverse relationship between bus/rail use and social class indicates that the higher the percentage of households in social classes 1 and 2, the lower the level of commuting by public transport. Breheny repeated the analysis for a selection of counties in the rest of the south east (ROSE). In this case relationship between density and public transport use was much weaker (R^2 = 0.11). Similarly, he found no clear relationship between public transport use and social class.

Newman and Kenworthy (1989)[17] examined the link between urban form and transport using data from 32 world cities. They found strong correlations between urban form and transport. Measures of public transport use examined included public transport passenger km per capita, private car/public transport balance (% of total passenger kms on public transport), public transport passenger trips per person and the proportion of public workers using public transport. Urban form variables examined included population and job densities across the urban area, in the CBD, and in inner and outer areas; as well as the distribution of population and jobs between the different areas. No significant correlations were found between transport and CBD job density. Newman and Kenworthy (1991) conclude from this that it would appear that in order to lessen automobile dependence it is more important to have higher residential densities mixed in with the employment activity. Residential density in the CBD does correlate strongly with transport patterns. A study of US cities by the Transit Cooperative Research Program (TRCP, 1995 cited in Newman and Kenworthy, 1999) confirmed the exponential relationship found by Newman and Kenworthy between density and public transport ridership. The study estimated that elasticity for residential density and ridership was 0.6.

Breheny and Gordon (1996), amongst others, make several criticisms of the Newman and Kenworthy work. The key criticism concerns the degree of association between density, public transport provision, prices, income and car ownership, which Newman and Kenworthy failed to account for in their analysis. Breheny and Gordon (1996) used regression analysis to combat the problem of association and found that almost as high a value for R^2 could be produced when density was excluded from the regression model as when it was included.

Cervero (1996) showed that the probability of commuting by public transport decreases if one lives in a neighbourhood with single-family detached dwellings and increases in areas of attached housing. But, he found that other variables such as an adequate public transport service and living near the city centre were more significant than the land-use pattern, and that increasing car ownership had a major impact. Similarly, Friedman *et al.* (1994) show that public transport use is higher for all trip purposes in traditional neighbourhoods compared with suburban areas.

There is also a relationship between density and parking provision (Hall, 2001). In high density areas parking provision may be limited. If parking is in short supply, then residents may choose not to own a car. Also, they will be less likely to use the car if other modes, such as walking, can be substituted, due to the length of time it may take to find a suitable parking space on their return.

A second complication is the measurement of density itself. The relationship between density and public transport use varies considerably depending on whether the density is averaged across an estate, district or city region and the unit of measurement i.e. dwellings, buildings, or population. For example, Stead (2001) analysed the relationship between travel distance, land-use characteristics and socio-economic characteristics using a number of different data sets including the National Travel Survey. He found no evidence of a link between travel distance and local authority population density. However, he did find a link between ward level density and average travel distance, with residents of low-density wards travelling longer distances than the residents of most other wards.

The location of the boundaries of the area across which density is calculated is also important. For example, many local authority districts boundaries are not closely aligned with urban areas. Some borough boundaries include a rural area as well as the main urban area as in the case of Milton Keynes; other urban areas are under-bounded by the district boundary, e.g. Reading. Under-bounding is likely to increase the density value whilst over-bounding will reduce the density value. In addition, density can vary considerably across a district and neighbourhood densities may be as important as city densities in determining travel behaviour as these will affect aspects such as the distances travelled to reach a bus stop. Ecotec (1993) found that density at the local authority level had a positive influence on the proportion of work-related travel undertaken by public transport and that this relationship also holds at the urban level.

11.2.2 Settlement size

Another element of built form that could influence transport is settlement size. Settlement size, in terms of population, affects the choice of facilities available to meet a particular activity need and the extent to which higher order services and facilities are provided within the local urban area. Settlement size will also affect the distances that need to be travelled to reach particular services and facilities. This is also dependent on the density of the settlement and its form. Finally, settlement size will affect the modes of transport that can be supported by the urban area.

Public transport ridership tends to increase with increasing settlement size (Table 11.3), as does the distance travelled on public transport per person per annum (Table 11.4). However, the mean trip distance tends to decrease with increasing settlement size (Table 11.5).

ECOTEC (1993) found using 1985/6 National Travel Survey data that population size was not related to travel behaviour in a simple linear relationship. Whilst the distance travelled per person per week by local bus was found to decrease with decreasing size, no obvious pattern was found for rail travel. These findings still hold true. Table 11.3 shows that while the number of bus trips made per annum per head of population between 1999 and 2001 increases with increasing settlement size, the number of rail trips per head of population shows no obvious trend. Average bus journey lengths tend to increase with decreasing settlement size, but again with rail it is difficult to discern a trend (Table 11.5). Rail trips made by residents of London tend to be considerably shorter than the average GB rail trip; whilst rail trips from rural areas tend to be considerably longer than average. The balance between bus and rail travel is different

Table 11.3 Trips per person per year by mode in Great Britain by area type, 1999/2001

	Total number of trips per head					
	Walk	*Car*	*Local bus*	*Rail**	*Other‡*	*Total*
London Boroughs.	299	468	94	87	42	990
Metropolitan built-up areas.	264	591	94	8	38	995
Large urban areas, over 250k population.	271	628	66	12	42	1019
Medium urban areas, over 25 to 250k.	268	658	47	12	44	1029
Small/medium urban areas, 10 to 25k.	261	714	38	10	45	1068
Small urban areas, 3 to 10k.	253	674	29	†	51	1007
Rural areas.	204	742	27	7	36	1016
All areas.	263	638	57	20	41	1019

* *Includes long distance rail.*
† *Sample size too small for reliable estimate.*
‡ *Includes some rounding errors.*
Source: Department for Transport (2002b).

Table 11.4 Total distance travelled by mode in Great Britain by area type, 1999/2001

	Average distance travelled per year in miles					
	Walk	*Car*	*Local bus*	*Rail**	*Other‡*	*Total*
London Boroughs.	237	3544	333	996	342	5452
Metropolitan built-up areas.	184	4300	375	221	278	5358
Large urban areas, over 250k population.	190	4925	246	418	396	6175
Medium urban areas, over 25 to 250k.	200	5460	185	392	436	6673
Small/medium urban areas, 10 to 25k.	191	6813	219	290	375	7888
Small urban areas, 3 to 10k.	167	7054	214	†	853	8288
Rural areas.	130	7835	195	340	389	8889
All areas.	189	5565	245	425	391	6815

* *Includes long distance rail.*
† *Sample size too small for reliable estimate.*
‡ *Includes some rounding errors.*
Source: Department for Transport (2002b).

Table 11.5 Mean length of trips by mode in Great Britain by area type, 1999/2001

	Mean length of trips in miles					
	Walk	*Car*	*Local bus*	*Rail**	*Other‡*	*Total*
London Boroughs.	0.79	7.57	3.54	11.45	8.14	5.51
Metropolitan built-up areas.	0.70	7.28	3.99	27.63	7.32	5.38
Large urban areas, over 250k population.	0.70	7.84	3.73	34.83	9.43	6.06
Medium urban areas, over 25 to 250k.	0.75	8.30	3.94	32.67	9.91	6.48
Small/medium urban areas, 10 to 25k.	0.73	9.54	5.76	29.00	8.33	7.39
Small urban areas, 3 to 10k.	0.66	10.47	7.38	†	16.73	8.23
Rural areas.	0.64	10.56	7.22	48.57	10.81	8.75
All areas.	0.72	8.72	4.30	21.25	9.54	6.69

* *Includes long distance rail.*
† *Sample size too small for reliable estimate.*
‡ *Includes some rounding errors.*
Source: Department for Transport (2002b).

for metropolitan areas compared with non-metropolitan areas (Tables 11.3-11.5).

Commuting by bus increases with increasing settlement size (Table 11.6). Whilst school trips by bus show a more complex pattern, with a minimum of 25% for medium sized urban areas (over 25k and under 250k). Local Education Authorities (LEAs) in Britain are obliged to provide free travel for pupils above certain distances from school. In lower-density rural areas this will result in an increased share by bus (both special contract services, and use of public scheduled services by pupils).

The relative concentration of homes and facilities in larger settlements maximises accessibility to transport routes and encourages people to use them (Owens, 1992). Table 11.7 shows how accessibility to bus and rail vary with settlement size in Great Britain. There is little

Table 11.6 Percentage of trips by bus to work and school by area type, 1998/2000

	To work	*To school (11-16 year olds)*
London Boroughs	12	36
Metropolitan built-up areas	11	29
Large urban areas, over 250k population	10	30
Medium urban areas, over 25 to 250k	5	25
Small/medium urban areas, 10 to 25k	5	31
Small urban areas, 3 to 10k	–	46
Rural areas	–	55
All areas	7	32

Source: Department for Transport, Local Government and the Regions (2001b).
Trips to school include school buses.

Table 11.7 Percentage of population living within a six minute walk of a bus stop or railway station, 1989/1991 and 1999/2001

	Within a 6 minute walk of a bus stop		*Within a 6 minute walk of a railway station*	
	1989/1991	1999/2001	1989/1991	1999/2001
London Boroughs.	89	88	27	24
Metropolitan built-up areas.	93	91	10	7
Large urban areas, over 250k population.	91	90	5	6
Medium urban areas, over 25 to 250k.	92	90	6	6
Small urban areas, 3 to 25k.	85	82	4	7
Rural areas.	75	77	3	3
All areas.	89	87	8	8

Source: Department for Transport (2002b)

variation in terms of the percentage of population within a six minute walk of a bus stop for settlements over 25,000 population. However the percentage decreases with decreasing settlement size below that point. The percentage of population living within a six-minute walk of a railway station declines with decreasing settlement size. The apparent changes over time may not all be statistically significant in view of the sample sizes on which they were based, but they suggest that the percentage of people living within a six-minute walk of a bus stop or railway station has been decreasing over time for almost all settlement sizes. The main exception is rural areas where accessibility to public transport has increased.

11.2.3 Population location

Combining housing, employment, shopping and other facilities in mixed-use developments provides residents with the opportunity to work and carry out other activities locally, without having to drive. Combining these types of development with a transport node or interchange may help to increase public transport patronage. Simmonds and Coombe (2001) found, from a modelling exercise using the Bristol Area Transport Model developed by MVA, that residential development at transport nodes and close to the city centre increased the number of public transport trips made compared with the same transport policies modelled applied to a compact city by 29%.

Cervero (1994) found that residents living near BART stations were five times as likely to commute by rail as the average worker resident in the same city. Many of these people may have explicitly chosen to live near to the BART station in order to use it, so this evidence should not be interpreted as suggesting that building a new public transport system automatically causes modal switching. In fact multi-family housing was built near to the BART stations in order to encourage commuting on BART (Cervero and Landis, 1997). Cervero (1994) concluded that for this type of development to be successful, there needs to be employment growth oriented towards the public transport system and programmes that impose the full costs of motoring and parking on car users. Cervero and Landis (1997) argue that local government has an essential role in promoting development near stations.

Masnavi (2001) compared four estates in West Scotland – two estates of mixed-use (one high density – Garnethill, Glasgow, and one low density – East Mains, East Kilbride) and two estates of single residential use (again one of high density – Hyndland, Glasgow, and one of low density – Stewartfield, East Mains). The estates were chosen to have residents of similar socio-economic characteristics. Masnavi found for the two high density estates little difference in public transport use between the mixed use and the single use estate (Table 11.8). However, there was a notable difference in public transport usage between the two low density estates. Other factors such as distance from the town centre and the heterogeneity of the neighbourhood (i.e. whether non-residential premises clustered in a section of the neighbourhood or spread evenly across it) were not found to influence public transport use.

Table 11.8 Frequency of public transport trips

	High density	*Low density*
Mixed use	3.38	4.78
Single use housing	3.80	0.89

Source: Masnavi (2001)

Van and Senior (2001) also studied the effect of mixed-use development on travel behaviour by comparing different estates. They compared three areas of Cardiff. One with high land use mix – Carton, one with low mix – South Fairwater and one with no mix – North Fairwater. The three areas had similar population and dwelling densities but slightly different socio-economic profiles. Carton had a higher socio-economic profile than the two Fairwater areas. Van and Senior found that car use for commuting declined as mixed use increased, but bus use did not exhibit the opposite effect. They concluded that lots of car trips transferred to non-motorised modes with increased land-mix. They also looked separately at different trip types. Only light shopping was significantly affected by land mix and car ownership was always a significant influence on mode choice.

Farthing *et al.* (1994) compared a number of large-scale housing developments in Avon with differing levels of facility provision. For three-quarters of the facilities surveyed local provision led to local use, i.e. Farthing *et al.* found that a significant proportion of trips were to the local facility. Provision of specialist and less frequently visited facilities such as dentists and churches had limited impact on travel compared with the 'everyday' facilities such as food store, newsagent, open space, post office, primary school, pub, supermarket and secondary school. Provision of these eveyday facilities is key to reducing average trip lengths. However, the authors found that local provision does not necessarily encourage walk trips or affect public transport. Public transport journey lengths were found to be longer than those for the car on all the developments surveyed. Possibly as a result of poor route coverage to the locally provided facilities. For those using the local facilities three-quarters walked (with the exception of post offices and secondary schools).

Headicar and Curtis (1994) compared 5 locations in Oxfordshire, all within 15 miles of Oxford. The locations consisted of Botley on the periphery of Oxford, Kidlington – a dormitory town, and three free standing towns with different types of transport accessibility – Bicester (with motorway access), Didcot (with good rail connections) and Witney (with neither rail or motorway connections). Travel diaries were used and the responses were weighted to average socio-economic characteristics. The mean distance travelled per week by public transport for regularly journeys varied from 7.1 miles for Bicester to 34.0 miles for Didcot. The number of public transport trips per person was lowest for Bicester (0.1 trips) and highest in Kidlington (0.8 trips per person per week). The variation in public transport use (distance and numbers of trips) was not related to distance from Oxford but to proximity to the major rail stations of Oxford and Didcot. Although the high numbers of public transport trips made by residents of Kidlington (and its shorter public transport trip length) is a result of the significant component of bus use. Headicar and Curtis attribute this to the relatively large proportion of households with less than one car per adult found on the estate sampled in Kidlington. Proximity to a major route had substantial effect on work travel, total distance travelled and the proportion of car travel. Thus, proximity to a major rail station fosters long distance commuting but reduces the proportion of trips made by car. However, Headicar and Curtis also found that the established pattern was important. In Bicester most residents moved in before the modernisation of the Chiltern Line to High Wycombe and London. Rail was not prominent in residents travel patterns. Workplace accessibility was a dominant factor in location choice.

11.2.4 Employment provision

The degree of centralisation of employment and facilities also influences travel behaviour - a greater degree of centralisation encourages public transport use and reduces the use of the car; peripheral locations tend to be much more car dependent. However, this is distorted by a number of other partially related variables such as occupational structure and the availability of parking spaces (Ecotec, 1993).

A before and after study of a company in The Hague changing its location to a site with high public transport accessibility showed an increase in public transport use by company employees increased from 25% of employees travelling by rail to 57% and from 9% travelling by bus and tram to 20% (Banister and Marshall, 2000).

A modelling exercise carried out by Simmonds and Coombe (2001) on Bristol found that concentrating employment in the part of the central area of the city best served by public transport increased passenger trips by 17% compared with a compact city scenario which did not specify particular locations for increased employment and residential densities. The use of bus and rail decreased slightly, whilst use of the light rail system included in both scenarios increased substantially. Combining the concentration of employment in the central area with a concentration of residential development close to the city centre and along the LRT lines produced even higher volumes of public transport travel – a 45% increase compared with the compact city scenario.

11.2.5 Urban form

There are a variety of urban geometries commonly referred to the literature. Newton (2001) identifies a number of architypal urban geometries including dispersed, compact, edge city, corridor and fringe.

The compact city is usually identified with the traditional monocentric urban form commonly found in Europe, with a high density central business district surrounded by residential areas which decrease in density with increasing distance from the centre. This is frequently associated with a radial transport network. There is some debate as to the transport efficiency of this urban form, with proponents suggesting that it provides a more attractive market for conventional public transport due to a combination of high densities and the dominant bi-directional flows created. However, the compact form also decreases the distances required to reach services and facilities thus increasing the possibilities for non-motorised forms of transport, depending on the size of the settlement. Simmonds and Coombe (2001) compared transport policies applied to a compact city with the same transport policies applied under trend conditions of dispersal using the Bristol area transport model. They found that the compact city form resulted in a slight increase (<3%) in passenger travel by public transport whilst walking and car-use decreased slightly. However, others such as Breheny (1995b) suggests that this form is inefficient for a number of reasons – a) settlements over a certain size or with particularly high densities get lots of congestion in the central area as a result of being the main destination for most trips; this increases journey times. b) flows will be predominantly towards the city centre in the morning and out from the centre in the evening. This heavy demand during peak hours in a single direction puts strain on the transport system. The effect of the compact city on public transport demand, thus depends on the size of the settlement. Small compact settlements may well encourage walking at the expense of public transport due to the distances involved; whilst at the other end of the scale congestion and overcrowding may adversely affect ridership levels.

Alternatives to the monocentric compact city which would have many of the transport advantages and fewer of the disadvantages have been suggested e.g. polycentric city and decentralised concentration or urban villages. The Confederation of British Road Passenger Transport (Addenbrooke *et al.*, 1981) suggests that a 'beads on a string' development pattern is the most efficient form for increasing the level of bus use and for economic bus operations. This involves high residential densities around bus stops and local amenities sited along the routes at the centre of the beads.

A number of studies have attempted to compare the effects of urban form on transport. For example, Rickaby *et al.* (1992) modelled five variations of an archetypal town:

a containment (densification around district centres);

b containment (corridor densification);

c combination of a and b;

d peripheral expansion;

e infill on city edge.

The archetypal town was based on data from a number of towns in Great Britain. The results showed very little variation in mode split (less than 2%) between the different versions of the town. Rickaby *et al.* suggested the reason for the low level of variation was due to a combination of factors including the fact that no bus lanes were included in the models, thus restricting bus journey times to the same or longer than those of cars; and the low levels of congestion assumed.

Murto (2000) also found that the effect of different development location policy options on modal split was slight. Murto modelled, for the Tampere region, the likely effects on travel patterns of three different land use policies:

1 An urban expansion/urban infill policy, with two-thirds of population growth in the region being allocated to the Tampere commune and the remainder being distributed between the smaller communes.

2 Transport corridor development, with housing and employment placed near rail stations or on bus lines.

3 Establishment of a number of village centres in the rural parts of the region. Each village contained basic services and some employment.

Using a traffic model based on EMME/2, Murto found that the effect of the three policy options on modal split was slight. The expansion option (1) resulted in 20% of daily trips being made by public transport, the public transport corridor and villages options both had 21.5% of daily trips being made by public transport. This compares with 21.7% of trips in 1999. Daily distance travelled by bus for corridor option increased by 7.3% over 1999 levels, the villages option resulted in an increase in daily distance travelled (all modes) of 23.4%. The expansion option had no discernable effect on daily travel distance.

Research by Konings *et al.* (1996) (cited in Banister and Marshall, 2000) found a slightly greater variation in mode split between different location types. Konings *et al.* analysed the journey to work mode split for 25 new residential developments in the Dutch province of Noord-

Brabant and found that the proportion of trips made by public transport varied according to location type and density (Table 11.9). They distinguish between three classes of locations (intra-urban or urban concentration, urban extensions and rural) and three density classes. Developments within the existing city limits produced the highest percentage of commute trips by public transport. Interestingly, the percentage of commute trips made by public transport was the same for low-density developments built as an extension to the urban area as for medium-density rural developments. The medium density rural developments were also found to have the highest levels of walking and cycling.

Table 11.9: Percent of commute trips made by public transport by location type and density

Location type	*Rural*		*Urban extension*		*Urban concentration*
Density (dwellings/hectare)	<=20	20-30	<=20	20-30	>30
Public transport	2	3	3	10	12
Car	74	66	76	67	61
Cyclist, pedestrian	24	31	21	23	27
Total	100	100	100	100	100

Source: Konings et al. (1996)

Work by the IBI Group (1990, cited in Anderson *et al.,* 1996) on the effects of urban form on travel patterns for the Greater Toronto area also found significant variation in public transport share for different urban forms. The IBI group modelled the effects of three urban form scenarios:

1 Spread or decentralisation.

2 Central or compact city.

3 Nodal.

Transit share for the scenarios was found to be 26%, 35% and 29% for the decentralised, compact city and nodal forms respectively. Transit share increased compared with the base year transit share of trips of 25%. Average journey to work trip length by transit followed similar patterns, with the shortest distance for central scenario (11.8 km), and longest for the spread scenario (15.2 km).

11.3 The use of land-use policy to increase the demand for public transport

Land-use policy to influence transport is more often aimed at travel reduction rather than explicitly at increasing the demand for public transport. Banister and Marshall (2000) identify three ways in which travel reduction can be achieved. 1) Remove trips i.e. reduce the number of trips being made. This could be through trip substitution, i.e. by making a single trip to fulfil several needs, by use of telecommunications (teleworking, teleshopping, online banking etc.) or by simply not undertaking that activity. 2) Reduce distance travelled and 3) mode switching. Obviously mode switching is the most relevant to public transport but policies put in place to reduce car travel through the other two mechanisms may also adversely affect public transport trips. For example, if the distance to shops and facilities is reduced making it possible for car users to walk then it is likely that it will also then be possible for public transport patrons to walk. Banister and Marshall go on to describe two types of travel reduction policy – push policies which create conditions unfavourable to the car and pull policies which create conditions favourable for walking/public transport; and three types of land use measures – i) location of land uses and activities, ii) spatial layout and structure of settlements, and iii) design of infrastructure to support walking/public transport. These categories overlap with some land use policies falling into more than one category.

Land use policies that can affect transport use include the location of new residential developments, zoning of commercial and industrial uses, mixed-use developments, the design of locations, car-free development, and transit-orientated development. It is important to note that planning policy can only influence development location where market forces coincide, i.e. if planning policy requires development to occur in an unfavourable location with regard to the market then no development will take place.

Analysis by Babalik (2000) suggested that the urban planning policies that may help to enhance the patronage of light rail are:

- Adapting plans to the new system by rezoning.
- Incentives for transit-oriented development.
- City centre redevelopment projects/actions.
- Urban renewal projects.
- Joint development projects.
- Locating public development at stations.
- Pedestrianising streets.

The systems which are operated with these policies are shown in Table 11.10. The effectiveness of the policies in enhancing the success of the system, based on the views of the people who developed the system is also shown.

Similar policies can also be used with respect to other forms of public transport, particularly mass-transit systems such as rapid bus transit (including busways and guided bus systems).

11.3.1 Density

Increasing density can increase the population within the catchment area for public transport nodes. However, evidence and experience suggest that density policies need to be treated with a degree of caution. Fouchier (1997) warns of the possibility of ending up with 1960s ghetto syndrome. There is a need to create a pleasant and safe environment around the public transport node in order to encourage walking to the station, stop or interchange. Combining increased residential densities with mixed-use developments close to the node is more likely to create a lively well-used location, and not just as an interchange point. These ideas are dealt with in more detail below on in the section on transit-orientated development.

Another cautionary note with regards to density is that the existing relationship between density and mode split may not be static or reflect what happens if the density changes (Bouwman, 2000). Car ownership, public

Table 11.10 Experience of the systems with urban planning policies

System	*Adapting plans to the new system by rezoning*	*Incentives for transit -oriented development*	*City centre re development projects and actions*	*Urban renewal projects*	*Joint development projects*	*Locating public development at stations*	*Pedestrian -ising streets*
Calgary						⊗	
Vancouver	●	●		*	●	●	
Manchester			●				●
Sheffield				⊗			
Tyne and Wear			*				●
Baltimore				○	○		
Los Angeles	●				●	●	
Portland	●	●	●		●	●	●
Sacramento		⊗				⊗	●
San Diego	●	●	*		○		○
St Louis	●	●	●	*		●	

Source: Babalik (2000), Mackett and Babalik (2001b).

* *These are the projects in which systems were integrated into the second transport planning policy; therefore, they are not shown under urban planning policies to avoid double counting.*

● *The policy has been effective in enhancing the success of the system.*

⊗ *The policy has been implemented but failed to have significant effects.*

○ *It is not clear whether the policy has had any effect on the performance of the system.*

transport accessibility and income patterns may remain unaffected by the density changes and these all affect the demand for public transport. Barrett (1996) found that those moving into new rural developments tended to adopt a more car dependent lifestyle than that of the established rural residents. Headicar and Curtis (1994) also draw similar conclusions based on a survey of residents of new developments in Oxfordshire.

11.3.2 Zoning and development Restrictions

Zoning and development restrictions can be used to ensure that those types of development that potentially generate/ attract a high number of trips, such as office developments, are located close to public transport nodes or are clustered in district and town centres. Planning policy can only influence development location where market forces coincide. If planning policy dictates development in an unfavourable location with regard to the market then no development will take place.

In order to reduce car travel, the Netherlands set conditions (the Dutch ABC location policy) on where businesses can locate based on the accessibility characteristics of an area and the business type. Locations are categorised into 3 groups:

A: highly accessible by public transport but with tight restrictions on parking;

B: good accessibility by car and public transport;

C: highly accessible by car but less accessible by public transport.

Type A locations are deemed suitable for labour and visitor intensive companies such as offices or public facilities; whilst type C locations are targeted at companies that need to be accessible by truck or car. However, locations are often graded by the municipalities using the B category in order to maximise the opportunities for development since this category is the most flexible (Banister and Marshall, 2000). There are however recorded examples of the policy having worked. For example the Dutch Ministry of Housing located its new offices in a category A location (next to the Central station in The Hague). As a result in the change in travel destination the mode split changed in favour of public transport (from 34 to 77% of trips) (op cit).

Within the UK planning policy guidance and the local plan system are used to restrict development to favoured locations. Planning policy guidance on housing (PPG3) (Department of the Environment, Transport and the Regions, 2000c) suggests that the focus for additional housing should be in existing towns and cities and requires local planning authorities to 'exploit and deliver accessibility by public transport to jobs, education, health facilities, shopping, leisure and local services'. PPG3 also mentions the need for higher densities of development at locations with good public transport accessibility, such as around interchanges, along public transport corridors and in city, town, district and local centres.

Planning policy guidance on town centres and retail developments supports a sequential approach to retail developments, with preference given to town centre sites, 'followed by edge-of-centre sites, district and local centres and only then out-of-centre sites in locations that area accessible by a choice of means of transport' (Department of the Environment, 1996). Cairns (1995) questions the success of this policy in terms of increasing the use of public transport. For food shopping the majority of people will visit the nearest store to their home. Of the non-car owners 20-30% do their main food shopping by car (either getting a lift or by taxi) and most of the rest prefer walking to using public transport. Cairns found that those shoppers using out of town superstores are more likely to buy in bulk and therefore make fewer trips, or combine the trip with another activity. Those using town centre stores are also likely to combine food shopping with other activities but will tend to make more frequent trips than the out-of-town shopper. The most frequent food shoppers were those using intra-urban stores and these shoppers were also the least likely to use the car.

Planning policy guidance on transport (PPG13) (Department of the Environment, Transport and the Regions, 2001e) states that 'a key planning objective is to ensure that jobs, shopping, leisure facilities and services are accessible by public transport, walking and cycling' and encourages local authorities to identify preferred sites and areas where land uses can be located with a particular emphasis on accessibility. The most highly accessible sites by public transport should be allocated for travel intensive sues such as offices, retail, and commercial leisure. Sites that are unlikely to be well served by public transport should be allocated for uses that are not travel intensive.

Another UK example of development restriction is the greenbelt system, with wide bands around many UK towns within which development is severely restricted. This has had the effect in many areas of containing growth and thus increasing densities inside the urban area. However, those wishing to live outside the urban area, are forced to live long distances away, increasing journey lengths. This is particularly evident ie the south east. ECOTEC (1993) examined a number of case study areas and found that urban infill performed better in terms of reducing the percentage of journeys made by car than peripheral expansion.

In North America rezoning is used to encourage location of activities that will produce many light trips near to stations. Sometimes local ordinances are varied, for example allowing higher buildings close to stations than would normally be allowed. Rezoning has been used successfully in Vancouver, Los Angeles, Portland, San Diego and St Louis to increase patronage levels (Mackett and Bablick, 2003).

11.3.3 Urban design, mixed-use development and urban villages

Krizek (2000) discusses urban design in terms of less auto-dependent urban form. He defines less auto dependent urban form as being a function of dwelling and population density, street pattern, and land-use mix. Krizek found that households in less automobile dependent areas had the shortest mean trip distances and the highest percentage of travel by alternative modes (transit, cycling and walking). However, Krizek found, from analysis of longitudinal data from Puget Sound, that when households relocated to an area with a different urban form, they did not necessarily adopt the travel patterns associated with the new location. This may be that travel behaviour will only change if the household experiences large changes in the auto-dependency of the neighbourhood form as a result of relocation.

The Confederation for British Road Passenger Transport (Addenbrooke *et al.*, 1981) make the following recommendations with regard to the design of new developments:

a provide direct routes for buses between points of primary attraction;

b provide balanced housing densities along such routes within convenient walking distance;

c provide pedestrian access to stops at regular intervals;

d locate secondary attractions (schools, post offices, public buildings etc) along the route;

e larger developments should be sited where they form logical extensions to the existing network;

f smaller developments should be sited adjacent to the existing network;

g Government guidelines - walking distance to bus stop 400m (5 mins). Also need to consider aspects such as crossing points (preferably at ground level), effect of gradient on access to the bus stop;

h footpaths should radiate from bus stops to minimise walk distance, provide most direct routes. Bus stops at junctions location to minimise interchange distances.

Bucharest implemented a mix of land-use and transport policies including encouraging mixed-use developments. The transport policies included establishing a new trolley bus route and new signalling. As a result of these policies public transport patronage increased by over 40% (RATB, 1997 cited in Banister and Marshall, 2000).

Moving the origin and destination closer together only work where the quality of the destination is less important such as with food stores. Quinn (1994) suggests that mixed-use development is unlikely to bring about significant reductions in travel for employment as factors such as job type, pay and conditions are more important than convenience in this case.

Walkable communities have a higher propensity to use public transport than car-orientated communities. Klonheim and Ketcham (2000) compared the outer areas of the Paris region with areas in New York with similar densities and levels of transit provision. These areas of Paris had 10% less car use and 10% more public transport use for trips not headed to the centre than New York. Klonheim and Ketcham attribute this to the high level of rail connectivity between the urban and village clusters of the Paris region.

11.3.4 Transit-orientated development

Transit-orientated development consists of intense, comprehensive development around transit stations (Belzer and Autler, 2002). The development will be mixed use for local services with the transport node providing access to a wider range of goods and services. Typically transit-orientated development is based around light rail or urban rail services but could also be based on bus services, particularly rapid or guided bus systems. Transit-orientated development is context specific; its precise characteristics will be different for different locations. Bernick and Cevero (1996) emphasise the built form aspects of this type of development – high density, diversity in terms of employment, facilities and housing and good urban design. It works best when the development can act as both an origin and a destination for trips (Belzer and Autler, 2002). Belzer and Autler also stress the importance of separating parking and housing costs, allowing households opting not to own a car to benefit financially. Finally, the more the region is linked into the public transport network, the more viable each development becomes and the more viable public transport becomes.

Several of the urban planning policies shown in Table 11.10 are related to the concept of synergy between the light rail scheme and major urban development schemes: the urban development generates passengers for the light rail system, the light rail system provides access for customers, staff and residents who will make the urban development scheme more successful. These include offering incentives for transit-oriented development as has happened in Vancouver, Portland, Sacramento (unsuccessfully), San Diego, and St Louis. Other ways urban projects can be used to encourage use of the light rail system are by undergoing major redevelopment projects in the city centre, or elsewhere, undertaking joint projects which the light rail scheme is an integral part, and locating public development at stations, either facilities for public use or offices in which public servants work. Vancouver, Los Angeles, Portland and St Louis are the cities where such policies have been used most successfully. These types of urban planning policy have been used most extensively in Vancouver and Portland. They have not been used much in Calgary, Baltimore and the British cities. However, transport development areas are now being proposed in the UK.

11.3.5 Car-free zones, pedestrian zones etc.

The final complementary policy to be considered here is the creation of pedestrian zones. This means closing streets to cars to make them available for pedestrians, and in some cases, public transport vehicles. This means that the public transport system can operate in the city centre without interference from cars, pedestrians can access shops without having to worry about traffic in crossing streets, the whole environment can be landscaped and made more pleasant, and car journeys to the centre are discouraged. Often park and ride facilities on the public transport system means that motorists can travel efficiently to the city centre without taking their cars all the way. Issues such as deliveries have to be addressed. This is a good example of a situation in which the introduction of a new light rail scheme can be used to instigate a whole series of improvements to the city.

A street or zone need not necessarily be made a pedestrian or car-free zone in order to encourage walking and create a more pleasant and safe environment for pedestrians, cyclists and public transport users as they embark/alight. Traffic calming can also be used to achieve these effects. This can be achieved through careful design of the street (i.e. through the use of chicanes, neck-downs, and landscaping), as well as by using traffic engineering devices such as speed bumps.

See also Section 13.2.3 on road space reduction.

11.4 The effects of public transport on economic growth and development

New public transport systems can affect cities in several ways. It can affect residential location, as occurred for example with the opening of the Munich metro and Crossrail. It may stimulate regeneration and economic growth as has been the case with a number of new light rail schemes. There is a reasonable amount of evidence of the links between light rail and economic growth and development, which is covered in detail in the sections below. However, obtaining evidence on the links between bus and economic growth is more problematic. There are several reasons for this lack of evidence. There are very few examples of large-scale new bus routes being established, any land-use changes associated with smaller schemes is likely to be difficult to detect. In addition, because bus routes do not require any additional infrastructure and thus lack permanency, developers and business may not be particularly attracted to a new site on the basis of a new bus route.

11.4.1 The contribution of light rail to economic growth

It is pertinent to consider some of the evidence from rail studies. A major study was carried out of the impact of the Bay Area Rapid Transit (BART) in San Francisco. BART was found to have little impact on the net regional employment and population patterns (Dyett and Escudero, 1978), confirming evidence collect by Knight and Trygg (1977), and suggesting the need for the presence of other favourable factors (Knight, 1980). Kreibich (1978) examined the effects of the building of the Munich metro. He found that high-income families tended to move outwards and so exacerbated the separation of home and jobs. There have been a number of studies which have examined the impact of new or improved rail links on land values, particularly in the United States and Japan. It can be argued that changes in land values reflect the pressure for development. However, it is difficult to obtain suitable data on land values in this country. An interesting example is the work on the Tyne and Wear Metro (Pickett and Perrett, 1984), where residential property value was found to have increased by 1.7% two months after the opening of the line compared with values two months prior to the opening. It is worth quoting their findings on the North American work:

- i In San Francisco there was a small but significant effect on property values at three of the six station areas studied.
- ii In Washington, distance from a Metro station and the opening date affected property values.
- iii In Philadelphia property value increases are related to daily time savings that the commuter receives.
- iv Industrial property values increased in Atlanta.
- v In Toronto it has been shown that direct savings in commuting costs have been capitalized in housing values.

Contribution of Manchester Metrolink to economic growth

According to Law *et al.* (1994) there is not much evidence of effects of Manchester Metrolink on the office market or on retailing, but this may be due to recession. Its presence may have helped influence the development at GMEX and Victoria in the city centre, but the development might have gone ahead in the absence of Metrolink (Mackett and Edwards, 1993).

In Manchester, some sites in the southern part of the Central Business District (CBD) have been redeveloped as office and residential uses as a result of the efforts of the Central Manchester Development Corporation, and the Metrolink may have helped in this process, but there are many other declining areas served by Metrolink, so it seems that it is not serving as a catalyst for development (Babalik, 2000).

Forrest *et al.* (1996) found no discernible effect of Metrolink on house prices, but this may be because housing market was generally fairly static at the time they were investigating.

Manchester Metrolink is discussed further in Section 12.2.5.

Contribution of Sheffield Supertram to economic growth

Sheffield Supertram runs through an area where a comprehensive regeneration project by the Sheffield Development Corporation was being implemented (see also Section 12.2.6). However, there was poor co-ordination between the two schemes with the Supertram running along the margin of the new developments with poor access from the redevelopment scheme to the tram stops (Lawless, 1999). Better integration of the two schemes could have been very synergetic.

Crocker *et al.* (undated) have examined the economic and development impact of Sheffield Supertram. They considered its impact under five headings:

- The image of the city.
- Property values.
- Development and land use.
- Business operations and location.
- Labour market.

Using evidence from surveys of 10 national and regional agencies, 10 Sheffield-based agencies, 300 visitors to Sheffield and 200 residents, Crocker *et al.* (undated) concluded that Supertram has had a positive impact on the city's image. In particular, external agencies seem to have improved their perception of the impact of Supertram as an agent to improve the city's image. Local agencies have continued to see Supertram in a positive light. Supertram is seen as a very useful element in the city's visitor and tourist promotion programmes.

The construction of Supertram caused considerable disruption to the centre of Sheffield and areas along the route over an extended period. This seems to have had a negative effect on the efficiency and productivity of companies along the route. Crocker *et al.* (undated) argue that new road construction has had a stronger impact on industrial and commercial development proposals than Supertram. They examined three areas to see if Supertram had had any impact on land use, and concluded that about 12-15% of the land use change in those areas could be attributed to Supertram. They also concluded that most development schemes would have gone ahead in the absence of Supertram, but that it might have brought some forward in time. Crocker *et al.* (undated) argue that the more positive image of Supertram since it opened should lead to more positive impacts on businesses in Sheffield.

It should be borne in mind that Supertram opened in a time of economic recession, so that there would have been little movement in either the local economy or the property market at the time.

Similarly, Crocker *et al.* (undated) found little impact on the Sheffield labour market. Some evidence was found of people being able to gain access to areas such as Mosborough served by the system and others finding that it helped them to look for work over a wider area of the city than previously, but these effects were small. They calculated that Line 1 might lead to the creation of 295 jobs, while Line 2 might lead to between 380 and 1275 jobs being created (these are jobs in the local economy, not jobs associated with the construction of the system which, by definition, are only short term). It is interesting to compare these figures with the claims made in the application for funding under Section 56 of the 1968 Transport Act under which the Government is prepared to provide funding for schemes in order to obtain non-user benefits such as road congestion reduction, accident reduction and job creation. In the application it was claimed that Line 1 would create 1135 jobs and Line 2 would lead to 3000 new jobs.

Contribution of other systems to economic growth

Little direct evidence of the contribution of the new systems to economic growth was found by Mackett and Edwards (1998) apart from claims that there was development around the stations in Vancouver and companies locating near the line in San Jose.

Babalik (2000) examined the impacts of light rail systems on land use and urban growth patterns in terms of the stimulating development at the city centre, stimulating development in declining areas, and improving the pattern of urban growth. She considered 13 light rail systems: two in Canada (Calgary C-Train and Vancouver Skytrain), one in France (Rouen Tramway), three in the UK (Manchester Metrolink, Sheffield Supertram and Tyne and Wear Metro), seven in the US (Baltimore Light Rail, Los Angeles Light Rail, Portland MAX, Sacramento Light Rail, San Diego Trolley, San Jose Light Rail, and St Louis MetroLink).

Babalik (2000) found that the St Louis and San Diego systems had greatest impact on their city centres. In St Louis the positive image of the new system, plus the free journeys within the city centre are seen as making it more attractive. In San Diego the Trolley was well integrated with residential blocks and shopping centres. Transit oriented development (TOD) incentives were used to encourage developers to locate close to the Trolley line, for example, tax reductions and relaxation of car parking requirements.

The Tyne and Wear Metro has had some positive impacts on the city centre of Newcastle Upon Tyne. In the centre of Newcastle, the retail and commercial centre moved northwards to be closer to the Monument and Haymarket Metro stations. This process was aided by pedestrianisation and regeneration projects. The Portland, San Jose, Calgary and Rouen systems are all claimed to have had some impact on development in the city centre. Babalik (2000) reported that there was evidence of impact on city centre development in Manchester.

The other systems had very little impact on development in the city centres. In the case of Vancouver SkyTrain, it was not an objective to stimulate development in the city centre: rezoning was used to help encourage mixed development in the city centre, including some residential development to prevent the area only being occupied by commerce. In Baltimore, Los Angeles and Sacramento there was negligible impact on the city centre.

All the systems except Calgary C-train and Portland MAX serve declining inner urban areas. Only the Vancouver, San Jose and Rouen systems were reported as having a positive impact on these areas. In particular, in Vancouver, complementary redevelopment policies plus new commercial and residential developments in areas served by the system were used to help stimulate development in declining areas.

Light rail systems can be used to help improve the pattern of urban growth by sensitive choice of route location. Babalik (2000) found evidence of this in Vancouver, Portland, San Diego and Rouen. In Vancouver, rezoning at increased densities along the SkyTrain route plus tax incentives and permits to build higher near stations were used to steer development in the desired directions. Conversely, development was restricted in areas of the city not served by SkyTrain. In San Diego, the initial line down to the Mexico border served a well-developed corridor, so the Trolley did not have any significant development impact on this corridor, but the line to the east was used to stimulate development with incentives offered to encourage high density development around stations.

Summary of the contribution of light rail to economic growth

The stimulation of development is a key objective for the building of many light rail systems. A new light rail system will not, on its own, induce development, but it can form part of a package to facilitate development. It plays several roles in the process: it provides a modern, efficient way for residents to reach jobs outside the area, it provides access into the area for workers, shoppers and those on leisure trips, it demonstrates a commitment to the area by various levels of government, it provides a useful theme for marketing the area, and so on. In order to implement these concepts there needs to be investment in housing, jobs, shops and leisure facilities. Most of this will be by the private sector which will see the commitment made by the public sector to the light rail system and will recognise that the system will convey workers and customers in a suitably high technology style, that a bus simply would not do. In order to start the development process off, incentives of various sorts may have to be offered, such as tax reductions or reductions in planning restrictions.

In terms of the systems examined here, neither Manchester Metrolink nor Sheffield Supertram seem to have had much impact in terms of development. There are at least two reasons why this may be the case: from about 1989 to about 1994, Britain was in economic recession, so there would not be much happening in the form of development with or without light rail, and secondly, the survey work was carried out within a few months of the opening of the system, and it could take several years for definite evidence of development induced by the light rail system to show.

Evidence of development impacts was found for the new systems in St Louis, San Diego, San Jose, Portland, Calgary, Vancouver, Rouen and Tyne and Wear. In these cases complementary policies were used and there have been at least some years since they opened when their national economies have not been in recession.

Some other systems, those in Baltimore, Los Angeles and Sacramento, have not induced development to any significant degree, and are regarded as generally not very successful (Babalik, 2000, Mackett and Babalik, 2001a).

It can be seen that light rail systems can be used with complementary policies to stimulate development in particular areas. In some cases this may be simply a matter of shifting development from one area to another, and therefore not necessarily adding to the overall level of economic development in the city. In other cases, it may be making the city served by the light rail system more attractive than other cities without such a system, and so adding to economic growth locally, but not at a regional or national scale. That may not matter if it is desired to stimulate development in a particular area, for example to help 'kick-start' a major regeneration process.

Light rail systems are further examined in Section 12.2.

11.4.2 Effects of public transport on land use

Knight and Trygg (1977) showed that the BART system in California had had little effect on where urban growth occurred and in what form. Cervero and Landis (1997) looked at the situation twenty years later, and found that BART has had a modest effect in shaping metropolitan growth patterns. Some economic centres have emerged, and the presence of BART has helped to maintain downtown San Francisco's pre-eminence as a regional economic and commercial centre.

In the early 1980s the Glasgow Rail Impact Study (Gentleman *et al.*, 1983) was carried out to look at the effects of the opening of the Argyle Line across Glasgow and the modernisation of the Glasgow Underground. These were found to have had little impact on land use. There were signs of increases in the numbers of planning applications, house prices and pedestrian movement in areas served by the new lines. Also there was new development in areas served by the line.

Cevero (1996) suggests that land-use impacts are greatest when transit investments occur just prior to an upswing in regional growth. Drawing lessons from Toronto, San Francisco and elsewhere, Cevero (1996) found that transit redistributes rather than creates growth; and that in order for this to occur the regional economy must be healthy.

11.4.3 Pull factor for new development both housing and employment

Public transport can act as a pull factor or focus for new development. The extent of this pull factor can be observed in several ways – through an increase in land and property values, through increased occupany levels, and through increased levels of development – redevelopment around the site at higher densities or higher levels of new development compared with locations not serviced by public transport. Table 11.11 summarises the findings of a number of studies that assessed the impact of public transport schemes for new development (RICS Policy Unit, 2002).

The Tyne and Wear metro was found to have a localised effect on the housing market in a few inner urban areas. In these areas the attractiveness of the housing increased and some redevelopment took place. Bollinger and Ihlanfeldt (1997) found that Atlanta's MARTA rail transit system had no discernable impact on total population or employment in areas close to the stations, but the composition of employment in these areas had changed, with a greater number of people employed in the public sector. Cevero and Landis (1997) could expect the BART system to induce clustering around rail stations. However, the impacts cannot be generalised easily. In other words, the extent and type of impact is extremely dependent on local conditions.

11.5 Public transport as an instrument of planning policy

Building new transport infrastructure can be used to spark regeneration or new development in an area. The majority of the evidence relates to light rail schemes. The influence of new bus schemes on development is small; the schemes are unlikely to be high profile so attract additional investment in an area. Few metro or heavy rail schemes have been implemented in the last few years. The most notable scheme of recent years is the jubilee line extension, which was used, in part, to stimulate regeneration of the Greenwich peninsula. To date no results have been published from the Jubilee Line Extension study.

11.5.1 Light rail as an instrument of policy

Before considering the impact of light rail as a policy instrument it is very important to consider why such systems are developed. It is not reasonable to criticise systems for not achieving certain objectives if such objectives were not amongst the objectives the systems were designed to meet.

A study of the decision process underlying the choice of technology (metro, light rail guided bus or conventional bus) for a number of systems around the World was carried out in the Centre for Transport Studies at University College London in 1991-1994 under the name Urban Transport Operations and Planning using Intelligent Analysis (UTOPIA). As part of that work interviews were held with a number of experts involved in the development of some systems to collect information on various aspects of the decision-making process including discussion on why the systems were developed. A postal survey was carried out on other systems. The systems examined are shown in Table 11.12. Table 11.13 shows the objectives for developing the systems cited by the experts.

It can be seen in Table 11.13 that the most popular reason for developing the systems was to stimulate development (13 cases out of 25). In three cases, Brisbane, Copenhagen and London Docklands, the light rail system was an integral part of the redevelopment of a large area. For the Calgary, Croydon, Leeds and Dallas systems, the objective was to help stimulate development in the city centre by providing easier access to the economic activities there. General promotion of economic development in the urban area was cited for Nottingham, Baltimore and Kansas City. It was the only major objective in the case of Kansas City.

An example that relates development to travel demand was Dallas where the new system was designed to enable companies to choose locations that would enable them to meet their legal obligations to reduce the number of cars being used by their employees.

Clearly, it is believed that light rail systems can help to stimulate development. It is not clear what the mechanism is that underlies this process. In fact, in some of the interviews the experts were asked if they were aware of any evidence that demonstrated what the mechanism is. Generally the response was in terms of 'image', 'confidence' and so on. The only evidence cited was in the case of Leeds (Pope, 1994) where a survey of businessmen showed that many of them would support the investment in a new public transport system. Apparently some of the major store chains would be more likely to expand their shops in Leeds if such a system were developed.

The objective cited the second largest number of times was 'to improve public transport', cited in 12 cases. It might be argued that this is axiomatic, but usually it was linked to a social objective, for example, providing better access for those without a car. A related issue is that of serving the city centre, because segregated public transport is very good at this, as it can serve efficiently the main corridors which focus on the city centre where most economic activity takes place and interchange is easier. An interesting variant on this is to provide transport from the inner city where there is often high unemployment outwards to newer employment centres. This was mentioned for the Croydon, Tyne and Wear and West Midlands systems.

'To reduce traffic congestion' was cited in 10 cases, implying that a significant transfer of trips from car to the new system was anticipated. 'To improve the environment' was cited in five cases. Generally this means reducing atmospheric emissions from cars and so is related to reducing car use. These two reasons imply that some planners believe that developing new light rail schemes can reduce car use significantly.

The 'other' reasons include a variety of factors. For example, the Manchester and Tyne and Wear systems were developed as ways of dealing with heavy rail lines in need of renewal. Replacing heavy rail by light rail meant that the system could be brought into the city centre to improve access there. In Dallas, a prime motivating factor was to help to promote Dallas as a 'World city'. The logic was that all 'World cities' have a modern public transport system so Dallas had to have one.

It has been shown that a number of policy initiatives underlie the development of new light rail systems. These relate to improving public transport, reducing car use, improving city centre access and stimulating development.

Table 11.11 Summary of studies on the impact of public transport on development

Source	*Case/Location*	*Impact of*	*Impact on*	*Impact*
[1] APTA (2002)/ after Diaz (1999).	North America.	Proximity to rail (heavy and light).	Residential and commercial property values.	In general, positive (via accessibility).
[2] APTA (2002)/ Weinstein and Clower (1999).	DART (Texas).	Proximity to DART/LRT station.	Property values.	Positive+25%.
			Class A office.	+
			Class C office.	+
			Strip retail.	+
			Class A occupancy.	80% 1994 to 88.5% 1998(+11%).
			Class A rent.	$15.6 to $23/sqft (+47%).
			Strip retail occupancy.	+ 49.5%.
			Strip retail rent.	+ 64.8%.
[3] APTA (2002)/ Cervero and Duncan (2002).	Santa Clara, California.	Walking distance of LRT.	Commercial land values.	Positive+$4/sqft (+23%).
		¼ mile of Cal Train station.	Commercial land values.	+$25/sqft (+120%) above mean.
[4] APTA (2002)/ Gruen and Associates (1997).	Chicago.	Proximity to transit (MTA/Metro).	Value of single family homes. Apartment rent value. Apartment occupancy.	Positive. Positive. Positive.
[5] APTA (2002)/ Armstrong (1994).	Boston.	Community with a commuter rail station.	Single-family residential property values.	Positive +6.7%.
[6] APTA (2002)/ Sedway Group (1999).	San Francisco Bay area.	BART.	Value of single family homes.	Positive $3200 to $3700 depreciation per mile distance from BART station.
			Apartment rental.	Positive +15%to 26%.
			Land price for office properties.	Positive $74/sqft within ¼ mile $30/sqft over ½ mile.
[7] APTA (2002)/ Cervero (1994).	Washington DC and Atlanta.	Systemwide ridership.	Average office rents.	Positive.
		Joint development near rail station.	Annual office rents.	Positive +$3/grsqft.
			Office occupancy rate.	Positive.
			Share of regional growth.	Positive.
[8] Chesterton (2000).	London Jubilee Line extension.	Set radii from the stations – 1000m and 3000m.	Residential.	Capital values - positive.
			Commercial.	Occupancy levels from estate agents, developers and investors perceptions – positive.
[9] Chesterton (2002).	London Jubilee Line extension.	Set radii from the stations – 1000m. Note that impact greater where rail infrastructure was poor – 25% increases in 7 out of 10 stations.	Residential.	Capital values - positive, but variable. Highest for maisonettes and flats.
			Commercial.	Occupancy levels from estate agents, developers and investors perceptions – positive.

Continued ....

Table 11.11 (Continued) Summary of studies on the impact of public transport on development

Source	*Case/Location*	*Impact of*	*Impact on*	*Impact*
[10] Pharoah (2002)	London JLE	Note that sites close to stations more attractive to commercial and mixed use developments, and those further from stations more attractive for residential developments.	Residential.	Development applications – variable impact by accessibility, potential and development history – positive, but in limited areas.
			Commercial.	Sites close to stations sought for mixed use and commercial developments.
[11] Wrigley and Wyatt (2001).	Review paper.	Multi sector.	Residential and commercial property values.	Intra urban and regional, capturing agglomeration and network effects.
[12] Hillier Parker (2002).	London Crossrail (projected).	Assumed impact area set at 1km from the stations.	Commercial.	Additional floor space of 10.87 million sq metres by 2025.
			Residential.	54,804 new dwellings in study area by 2025.
[13] Henneberry (1998).	Sheffield Supertram.	Assumed impact area at 1km along either side of line.	Residential property values.	House prices reduced with anticipation of construction of tram lines, but negative impact disappeared after opening.
[14] Dabinett (1998).	Sheffield Supertram.	LRT.	Non residential property value.	Unable to identify any discrete Supertram influence.
[15] Dabinett (1998).	Sheffield (and Manchester).	LRT.	House prices.	Influence so small that it cannot be separately distinguished.
[16] Laasko (1992).	Helsinki.	Metro and rail.	Property values.	Overall, +$550-$650 million gain in value (US$, 1990 prices).
[17] TRL (1993).	Tyne & Wear.	Metro.	House prices.	200m+2% above those further away.
[18] Wacher (1971).	London Victoria Line.	Metro.	Property values.	Values in catchment area of line increased between 1% and 5% compared with properties outside the catchment.

Source: RICS Policy Unit (2002).

Table 11.12 Status of systems examined for their objectives

Country City	Type of system	Status
Australia		
Brisbane	Light rail	Abandoned
Melbourne	Light rail	Operational
Sydney	Light rail	Operational
Canada		
Calgary	Light rail	Operational
Scarborough	Automatic light rail	Operational
Vancouver	Automatic light rail	Operational
China		
Tuen Mun, Hong Kong	Light rail	Operational
Denmark		
Copenhagen	Automatic light rail	Operational
Sweden		
Stockholm	Light rail	Operational
Switzerland		
Lausanne	Light rail	Operational
UK		
Croydon	Light rail	Operational
Leeds	Light rail	Planned
London Docklands	Automatic light rail	Operational
Manchester	Light rail	Operational
Nottingham	Light rail	Under construction
Sheffield	Light rail	Operational
Tyne and Wear	Light rail	Operational
West Midlands	Light rail	Operational
USA		
Baltimore	Light rail	Operational
Dallas	Light rail	Operational
Honolulu	Light rail	Abandoned
Kansas City	Light rail	Planned
Sacramento	Light rail	Operational
San Diego	Light rail	Operational
San Jose	Light rail	Operational

Source: Mackett and Edwards (1998).

The surveys upon which these data were based were carried out in 1992-1994. The status information has been updated.

Table 11.13 Objectives of developing light rail systems

City	*To improve public transport*	*To reduce traffic conges -tion*	*To improve the environ -ment*	*To serve the city centre better*	*To stimulate develop -ment*	*Other*
Brisbane					•	
Melbourne				•		
Sydney					•	
Calgary		•	•		•	
Scarborough	•			•	•	•
Vancouver						•
Tuen Mun, Hong Kong	•					
Copenhagen	•	•	•		•	
Stockholm	•	•	•			•
Lausanne	•				•	
Croydon	•	•			•	•
Leeds	•				•	•
London Docklands					•	
Manchester				•		•
Nottingham		•		•	•	
Sheffield						
Tyne and Wear	•			•		•
West Midlands	•	•		•	•	
Baltimore	•	•				•
Dallas	•	•			•	•
Honolulu						•
Kansas City					•	
Sacramento	•		•			
San Diego		•	•			•
San Jose		•				

Source: Mackett and Edwards (1998).

The information in this table is based upon interviews and postal surveys of experts involved in the development of the systems. For the list of experts see Mackett and Edwards (1998). The surveys upon which these data were based were carried out in 1995-1996.

11.6 Conclusions

The relationship between land use and public transport demand is complex. A number of different aspects of land use can influence both the number and length of public transport trips.

The higher the density of a city, the higher the demand for public transport in terms of ridership but the shorter the trip length. It should be recognised that factors such as high residential density and attached (terrace) housing tend to be associated with lower income households, whilst low residential density and detached housing tend to be associated with higher income households. In addition low incomes are associated with low car ownership. Hence, at least part of the effect of density on the demand for public transport will be due these income and car ownership effects.

Settlement size, urban form and mix of uses all too have an influence on public transport use, although it is difficult to establish the precise nature of these relationships. The more the region is linked into the public transport network, the more viable each development becomes and the more viable public transport becomes. Planning can be used to encourage this link through policies to encourage appropriate development types in appropriate locations.

Cities are decentralising, which tends to reduce the demand for public transport. Hence, there is a need to promote public transport in order to maintain patronage in order to counter the secular trends in decentralisation, suburbanisation, and increasing car ownership.

New public transport systems and their levels of patronage have implications for urban areas in terms of economic and physical development. Evidence of development impacts was found for the new systems in St Louis, San Diego, San Jose, Portland, Calgary, Vancouver, Rouen and Tyne and Wear. In these cases complementary planning and traffic management policies were used and there have been at least some years since they opened when their national economies have not been in recession. In some cases this may be simply a matter of shifting development from one area to another, and therefore not necessarily adding to the overall level of economic development in the city. In other cases, it may be making the city served by the light rail system more attractive than other cities without such a system, and so adding to economic growth locally, but not at a regional or national scale.

There are examples of public transport systems being used as instruments of urban planning policy, with the degree of success a function of the level of patronage. The nature of planning and financial systems can influence the strength of such relationships and the extent to which travel demand can influence the development of urban areas

12 New public transport modes

12.1 Introduction

In this chapter we consider how public transport demand might be affected by the introduction of new modes of public transport, which may replace or supplement more conventional modes. The modes considered are light rail and guided busways, of which several examples have been established over the last two decades, but are currently being proposed as an important ingredient of modern public transport strategies.

In Sections 12.2, 12.3 and 12.4 we discuss the merits and disadvantages of light rail systems, guided busways and Park and Ride; in Section 12.5 we present methods of forecasting demands for proposed new systems.

12.2 Light rail

12.2.1 The nature of light rail

Light rail is a modern form of public transport that runs on rails. It shares many characteristics with heavy rail systems such as metros and suburban rail, but has lower capacity. Its main advantage over these other systems is that it has lighter and generally smaller rolling stock. This enables light rail to accelerate and decelerate more rapidly, negotiate tighter curves and steeper gradients, and have a closer station spacing. It is cheaper and more flexible. Light rail spans the range from Tyne and Wear Metro through Docklands Light Railway to the modern tramways operating in Croydon and Manchester.

Light rail can run on a mixture of city streets and existing railway routes, even sharing tracks with suburban trains. It can be totally segregated from all other traffic, run at the margin or along the median of highways, or be operated on the street in mixed traffic. Light rail can also be elevated or built in tunnel. Often a combination of these is used to match local circumstances, for example by using disused railway embankments to provide a fast interurban route with street running in town centres.

Light rail usually has a much simpler signalling than heavier rail systems, and, in its tramway form, relies on the driver's judgement in a similar manner to the driver of a bus, particularly in mixed traffic conditions. When it is running along a highway it can be given priority at signalised junctions.

Light rail is nearly always powered by electricity which is usually supplied through overhead wires, but can be supplied through a third rail system. The latter can only be used when the system is completely segregated from the public except at stations. It is also possible to have driverless automatic systems which also have to be segregated.

In some ways light rail is simply a modern version of the tram, but in some cities, such as Amsterdam and Melbourne where there are extensive tram systems, light rail lines are being built, often with some segregation, to provide high speed links to areas not previously served by trams. Generally, light rail is modern, has at least some segregation from other traffic, and powered by electricity. New systems are usually the subject of extensive marketing campaigns, and branded with a suitable names such as 'Metrolink' or 'Supertram'.

12.2.2 The growth of light rail

Light rail has grown in popularity in recent years. Since 1970, 61 metros and 78 light rail systems have opened as Babalik (2000) has shown, using data from Taplin (1997, 2000). Given the complexity of definition it is difficult to be clear which was the first modern light rail system. Rogers (1975) defines the system in Edmonton in Canada which opened in 1976 as the first, regarding all previous examples as extensions to, or rehabilitation of, existing tram systems. Table 12.1 shows the number of new light rail systems opened around the World since 1970. It also shows the number of new metros opened since 1970 for comparison. The major difference between light rail and metros are that metros operate on dedicated lines that are segregated from other forms of transport. Metros also tend to operate mainly underground, with much heavier engines and passenger carriages.

Table 12.1 Number of light rail systems and metros opened since 1970

	Light rail systems			*Metros*		
	1970s	*1980s*	*1990s*	*1970s*	*1980s*	*1990s*
Western Europe	0	7	14	7	2	4
North America	1	13	8	3	2	1
Rest of the World	4	17	12	13	17	12
Total	5	37	32	23	21	17

Source: Babalik (2000) based on Taplin (1997, 2000).

It can be seen that in the 1970s the number of metros built outnumbered the number of light rail systems. Since then the picture has reversed completely, with 69 new light rail systems opened since 1980 compared with 38 new metros. North America led this trend in the 1980s, but since then most activity has been elsewhere. Now there are more light rail systems than metros in Western Europe and North America (Babalik, 2000).

12.2.3 The financial performance of light rail

The capital costs of light rail are high, but less than those of heavy rail or road construction. Babalik (2000) has collected data on a number of systems around the World. This is shown in Table 12. 2. This shows data for 23 light rail systems, plus five metros for comparison.

The light rail systems that were the most expensive to construct are the Vancouver Skytrain at £843 million and the London Docklands Light Rail at £775 million. Both of

Table 12.2 The cost of light rail systems (and metros)

Country City	Route length in km	Capital cost in £ million at 1998 prices	Annual operating costs in 1998 in £ million	Fare revenue in 1997 in £ million
Canada				
Calgary	29	643	6	n/a
Edmonton	14	362	n/a	n/a
Scarborough*	7	184	n/a	n/a
Vancouver*	29	843	22	8
France				
Grenoble	18	247	n/a	n/a
Nantes	26	271	n/a	n/a
Paris	9	67	n/a	n/a
Rouen	15	256	24	9
Strasbourg	11	207	n/a	n/a
Switzerland				
Lausanne	8	70	n/a	n/a
UK				
London Docklands*	28	775	n/a	12
Manchester	31	176	9	13
Sheffield	29	271	9	5
Tyne and Wear	59	533	27	21
USA				
Baltimore	49	503	15	4
Dallas	32	353	18	n/a
Denver	9	141	5	n/a
Los Angeles	57	717	34	3
Portland	24	309	15	3
Sacramento	30	165	10	4
San Diego	80	609	17	10
San Jose	32	527	17	3
St Louis	29	260	13	5
USA				
Atlanta	62	3679	63	20
Metros				
Baltimore	25	1136	22	6
Los Angeles	18	1278	21	1
Miami	33	1058	32	9
Washington DC	144	7372	190	n/a

Source: UK patronage figures are for 2001/02 and are from Department for Transport (2003a), US patronage figures are for 2000 and are from Federal Transit Administration (2003). Other patronage figures were from Bushell (1997), except for Calgary, Vancouver and Rouen which were obtained by Babalik (2000). Other data have been taken from Babalik (2000).

* *Indicates an automatic system. N/A indicates that data were not available. Capital costs represent the value of the investment in the year 1998. All costs and revenues are in UK Sterling at 1998 prices with currency conversions made using the purchasing power parity index provided by OECD (obtainable from http://www.oecd.org//std/nadata.htm).*

these are automatic which adds to the capital cost because of the extra technology required and because the systems have to be completely segregated. The most expensive non-automatic light rail systems were in Calgary, Los Angeles and San Diego which all cost over £600 million. The cheapest system shown here is the 8 km system in Lausanne in Switzerland which cost £70 million. It is worth noting that the capital cost of five new metro systems which ranged in cost from £7,372 million for the Washington DC Metro to £1,058 million for the Miami Metro. These are noticeably higher (but in the case of Washington DC, for a much longer system).

The most expensive schemes to develop in terms of capital cost per km of route, were the three automatic systems in Scarborough (Canada), Vancouver and London Docklands at about £28 million. Next comes Edmonton, which was the first modern light rail system and therefore may have had high costs because of its innovative nature. The other schemes range in cost from £6 million per km in Sacramento to £22 million in Calgary. It may be noted that the metros range in cost from £32 million per km for Miami to £71 million for Los Angeles. The variation in capital costs arises because of the different types of structure required: tunnel, elevated or at grade, the existing infrastructure (often disused railway track beds can be reused) and the quantity of utilities (gas, electricity, water and telecommunications) that have to be moved (rail-based transport systems cannot run over utilities because if a utility pipe or cable has to be repaired, the transport system cannot function, unlike a bus which can be diverted to another route). It can be seen that, in general, light rail systems are much cheaper to construct than metros, which partly explains their increasing popularity as was shown in Table 12.1. Putting it another way, the lower cost per km of light rail means that it may be regarded as feasible to develop a system in a city which is too small to support a metro.

The annual operating costs for the light rail systems varies from £5 million to £34 million for Los Angeles. The values for light rail are generally lower than those for the metros, which range from £21 million for Los Angeles to £190 million for Washington DC. Whilst, in general, longer systems tend to have higher costs, there are exceptions: the San Diego Trolley is the longest light rail system, but it does not have the highest operating cost.

The cost of a system is influenced by many factors including its size. It is also useful to consider costs in terms of patronage, and to compare operating costs and revenue to see how close to profitability the system is. Table 12. 3 shows the capital cost per kilometre of route, the annualised capital cost per passenger, the operating cost per passenger, the fare revenue per passenger, and the farebox recovery ratio, which is the ratio of revenue to operating costs. For comparison, the five metros are also included.

The operating cost per passenger varies considerably from £0.14 for Calgary to £2.49 in San Jose. To some extent, the high operating costs per passenger reflect low patronage levels. For example, the light rail systems in San Jose and Baltimore each carry only about 7 million passengers a year compared with over 20 million on the Los Angeles, San Diego, Grenoble, Nantes, Manchester and Tyne and Wear systems (the last carries about 35 million passengers a year). It does not necessarily matter if the operating costs are high if the revenue is also high. The relationship between these two figures is expressed as the farebox recovery ratio, which is the percentage of operating costs covered by fare revenue. It can be seen that, of the systems listed, only Manchester Metrolink covers its operating costs. It is run privately under a

Table 12.3 Cost and revenue indicators for light rail (and metro) systems

City	Capital cost/km £ million	Annualised capital cost/ pass -enger £	Oper -ating cost/ pass -enger	Fare revenue/ pass -enger	Farebox recovery ratio (%)
Calgary	22	1.27	0.14	n/a	n/a
Edmonton	26	2.92	n/a	n/a	n/a
Scarborough*	28	4.34	n/a	n/a	n/a
Vancouver*	29	1.67	0.53	0.19	38
Grenoble	13	0.90	n/a	n/a	n/a
Nantes	10	0.86	n/a	n/a	n/a
Paris	7	0.32	n/a	n/a	n/a
Rouen	17	1.50	1.73	0.64	37
Strasbourg	18	0.96	n/a	n/a	n/a
Lausanne	9	0.80	n/a	n/a	n/a
London Docklands*	28	3.04	n/a	0.72	n/a
Manchester	6	1.05	0.69	0.99	143
Sheffield	9	2.42	1.15	0.60	52
Tyne and Wear	9	1.25	0.76	0.58	77
Baltimore	10	5.87	2.14	0.53	28
Dallas	11	2.65	1.66	n/a	n/a
Denver	17	2.42	1.09	n/a	n/a
Los Angeles	13	2.47	1.41	0.15	7
Portland	13	2.15	1.23	0.25	20
Sacramento	6	1.68	1.20	0.49	40
San Diego	8	2.18	0.76	0.55	68
San Jose	16	6.27	2.49	0.48	20
St Louis	9	1.47	0.87	0.37	46
Atlanta Metro	59	3.89	0.82	0.23	32
Baltimore Metro	46	7.28	1.73	0.51	31
Los Angeles Metro	71	8.57	1.72	0.06	4
Miami Metro	32	6.46	2.40	0.67	29
Washington DC Metro	51	2.85	1.13	n/a	n/a

Source: Babalik (2000).

n/a indicates that data were not available. All costs are in UK Sterling at 1998 prices. The capital cost has been annualised by discounting the capital cost in the year 1998 over 30 years at 8%. This has been done for all systems to allow comparisons. It is not necessarily how it was originally done for economic evaluation of the scheme.

franchise agreement, and there is no subsidy to the operator. The private sector operator is only interested in operating the system if a profit can be made. The next nearest to making a profit is Tyne and Wear Metro in Britain in which 77% of the costs are covered. This is an older system which is still publicly owned. After that comes the San Diego Trolley, which covers 68% of its costs. The San Diego Trolley is interesting because it was initially built with no funding from the Federal Government, with funding coming from state petrol tax. This meant that construction could start sooner and that various regulations, such as prohibition of importing vehicles could be avoided (Wolinsky, 1994). The South Yorkshire Supertram in Sheffield was privatised in December 1997 and now receives no operating subsidy.

The metro systems do not perform any better financially than the light rail systems, with three of them covering about 30% of their costs through the farebox, and Los Angeles Metro only recovering 4%. In general, the light rail systems perform better than the metros. This may partly explain the growth in their popularity as discussed above: they are cheaper to build and they perform at least as well as a metro in financial terms.

It can be seen that some systems are nowhere near covering their operating costs, such as the light rail systems in Los Angeles, Portland and San Jose. This raises the question as to whether they were developed for non-financial objectives with the subsidy required regarded as a cost to be paid in order to meet the objectives.

It is worth noting that a number of commentators, particularly in the US, have criticised the development of light rail schemes for being extravagant and inappropriate uses of resources, even going as far as claiming that deceit has been used, for example in Dallas (Kain, 1990). Part of the problem has been that for a number of years the US Federal Government provided some funding for new urban pubic transport systems, with the amount of funding provided a function of the predicted level of patronage. Hence there was an incentive for planners to be optimistic in their forecasts of patronage. Pickrell (1992) demonstrated that there were significant differences between the forecast levels of patronage and those subsequently observed. A related concern is that money invested in light rail has not been well spent. Gomez-Ibanez (1985) examined the light rail systems in San Diego, Calgary and Edmonton. He found that not only were rail-based systems more expensive to construct than bus-based systems, but that the operating costs were higher. The systems did increase public transport patronage, but only modestly and at a high cost. He concluded that investment in bus-based systems would have been more cost-effective. Kain (1988) came to similar conclusions about the Los Angeles and Dallas systems.

As shown above, light rail is expensive to construct. The cost varies depending on whether it is built at grade, underground or elevated. If land has to be acquired, this may be very expensive, particularly if it is currently occupied by housing or economic activity. A major expense, typically about one quarter of the total cost of systems built recently in Britain, is the movement of utilities from under the road. Because the capacity of light rail vehicles is high, it is possible to have low operating costs per member of staff, possibly lower than on buses.

When a new light rail system is developed, it is common for sophisticated information systems to be provided, typically showing the arrival time of the next three trams at stops and next destination on board the tram. Such information can increase the perceived reliability of the system, making it more attractive to users. If the system is segregated from other traffic, predictions of arrival times are likely to be more accurate than those for buses which can be affected adversely by congestion.

12.2.4 The expected effects of a new light rail system on demand

A new light rail scheme will have both direct impacts as a new mode, and indirect impacts as an alternative to existing modes, particularly the car. The provision of a new light rail system will meet the travel demand for many trips by increasing the range of modes available. Some trips will transfer from existing modes, including car, bus, and walking. Other trips will be generated: a new fast public transport mode is likely to create trip opportunities that were not possible previously by opening up new trip attractions within a reasonable travel time, although the limited spatial coverage of a new system will mean that such opportunities tend to be focused in a limited number of corridors. Because light rail tends to be faster than other modes it will probably lead to a net increase in trip lengths. It will enable some of those without access to a car to reach work, shopping and leisure facilities that they could not reach within the time that they were prepared to spend. A modern low-floor light rail vehicle may mean that some people with disabilities are able to make journeys of a type that were previously almost impossible. There may also be considerable novelty value which generates trips for their own sake, with the new system becoming a tourist attraction in its own right. A new light rail system is not likely to have much impact on the time of travel unless an explicit decision is taken to operate for longer hours than buses.

12.2.5 The example of Manchester Metrolink

Manchester Metrolink is a light rail scheme in the county of Greater Manchester in the north of England. It opened in April 1992. It was constructed by taking over the mainline suburban rail lines to Bury and Altrincham that were in need of re-investment. These two lines are linked by an on-street section, with a spur into Manchester Piccadilly, the main heavy rail station in Manchester. Thus, the original system links Bury in the north and Altrincham in the south with Manchester city centre. A spur to Salford and Eccles opened in 1999.

The demand for travel by public transport in Greater Manchester is shown in Table 12.4: it has generally declined during the 1990s. Patronage on Metrolink was 8.1 million in its first year of operation, after which it grew to about 12-13 million where it seems to have stabilised. Patronage on other rail services in Greater Manchester has been fairly static. The fact the Metrolink overtook suburban rail in terms of patronage shows that the latter is not a very important mode in Greater Manchester. Bus is the dominant public transport mode and it is generally declining. Even though most users of Metrolink formerly used the bus, Babalik (2000) showed that the introduction of Manchester Metrolink did not seem to alter significantly the long-term downward trend in bus patronage in Greater Manchester. This is partly because bus has such a large share of the market. Even by 1998/99 Metrolink only had 5% of the market compared with 90% on the buses.

An alternative way of trying to see the impact of Metrolink on the use of other public transport modes is to compare what happened when it was opened with the trends in comparable areas. Table 12.5 shows the changes in the numbers of public transport trips between 1991/2 and 1992/3 in other metropolitan areas. Total public transport trips declined by 7% in the other areas, compared with a 1% decline in Manchester, suggesting that Metrolink may have helped to sustain public transport patronage in Manchester. Conversely, train patronage in Manchester fell by 16%, whereas it fell by only 3% elsewhere, suggesting that Metrolink may have attracted some users from heavy rail services (The heavy rail lines to Bury and Altrincham closed in August and December 1991 respectively, so this partly explains the decline in Manchester). Bus travel in Greater Manchester declined by 3% over this period compared with a 7% decline elsewhere, confirming the point made previously that Metrolink has not had a serious detrimental effect on buses in Greater Manchester.

Table 12.4 Number of journeys by light rail, bus and train in Greater Manchester (millions)

	1991 -1992	*1992 -1993*	*1993 -1994*	*1994 -1995*	*1995 -1996*	*1996 -1997*	*1997 -1998*	*1998 -1999*
Metrolink	-	8.1	11.3	12.3	12.6	13.4	13.8	13.2
Bus	260	252	236	226	224	212	211	217
Suburban rail	13.0	10.9	10.7	9.7	11.4	10.6	12.2	11.8
Total	273	271	258	248	248	236	237	242

Source: Department of the Environment, Transport and the Regions (2001a, 2001b).

Table 12.5 Total number of journeys in other metropolitan areas outside London, 1991/2 – 1992/3 (millions)

	1991 -1992	*1992 -1993*
Bus	1217	1130
Rail	120	117
Total	1337	1247

Source: Department of the Environment, Transport and the Regions (2001a).
The other metropolitan areas are West Midlands, Merseyside, South Yorkshire, West Yorkshire and Tyne and Wear.

As well as trips, the total distance travelled can be considered, as shown in Table 12. 6. It can be seen that in 1998/99 Metrolink had 12% of the market, heavy rail 15% and bus 76%. The total demand for public transport has declined over the 1990s, with bus declining fast, heavy rail between 210 and 220 million in most years, and Metrolink growing steadily. The faster rate of growth in total distance travelled than the number of trips by Metrolink implies that the average trip length is increasing.

Table 12.6 Number of passenger-km by light rail, bus and train in Greater Manchester (millions)

	1991 -1992	*1992 -1993*	*1993 -1994*	*1994 -1995*	*1995 -1996*	*1996 -1997*	*1997 -1998*	*1998 -1999*
Metrolink	-	53.0	72.6	78.6	80.8	85.6	117.0	153.3
Bus	1226	1117	1138	1141	1081	1040	1041	1009
Train	241.0	216.0	222.4	197.4	212.2	215.4	214.8	197.0
Total	1467	1440	1433	1417	1374	1341	1344	1323

Source: Department of the Environment, Transport and the Regions (2001a, 2001b)

It can be seen that the opening of Metrolink coincided with a decline of 2% in total public transport patronage in Greater Manchester. This compares favourably with a 5% decline in other metropolitan areas (see Table 12. 7). It should be borne in mind that this was a period of economic recession in Britain. Total rail patronage in Greater Manchester grew by 12%, compared with a static position elsewhere, which suggests that Metrolink helped rail travel to grow in Greater Manchester. Bus showed a 9% decline in Greater Manchester compared with a 6% decline elsewhere. Given that the number of bus trips in Greater Manchester went down less than elsewhere, this suggests that a number of longer bus trips have been lost to Metrolink, but there may be some more short trips being made by bus, possibly because of increased seat availability because of the transfer of some longer trips to Metrolink.

Table 12.7 Number of passenger-km in other metropolitan areas outside London, 1991/2 – 1992/3

	1991 -1992	*1992 -1993*
Bus	5008	4685
Rail	912	911
Total	5920	5596

Source: Department of the Environment, Transport and the Regions (2001a).

The other metropolitan areas are West Midlands (bus only), Merseyside, West Yorkshire and Tyne and Wear.

It is possible to see how much Metrolink contributes to meeting the total travel demand by mechanised modes. As Table 12.8 shows, it is only about 1%. Car is overwhelmingly dominant, with 91% of the market. Public transport has only 9%. Hence, in overall terms Metrolink is making a very minor contribution to meeting travel needs in Greater Manchester. However, by its nature, light rail is very location specific, so it will contribute much more than this in the corridors it serves.

Table 12.8 Number of passenger-km in Greater Manchester by car, light rail, bus and train, 1998

	Passenger-km (millions)	*%*
Car	13530	91
Metrolink	117	1
Bus	1041	7
Rail	197	1
Total	14885	100

Source: Department of the Environment, Transport and the Regions (2001a, 2001b).

The Metrolink figure is actually for the financial year 1998/9. The car figure is based upon the annual road traffic on main roads figure of 11 billion, of which 80% are cars and assuming a car occupancy of 1.54, which is the national average, based on figures from Department of the Environment, Transport and the Regions (2001b).

This localised effect is illustrated in Table 12. 9. The changes in rail demand in the Bury and Altrincham corridors are compared with adjacent corridors. The Altrincham corridor shows a 63% increase in the peak and 166% increase in the off-peak. This compares favourably with a 15% decline in the peak and a 3% growth off-peak in adjacent corridors. The Bury corridor is not so buoyant with a 3% decline in the peak and 101% growth off-peak. This can be compared to a 21% decline in adjacent corridors in the peak and a 109% growth off-peak in adjacent corridors.

Table 12.9 Change in rail demand in Greater Manchester corridors, 1990-93

Corridor	*Peak (07.00-10.00)*	*Off-peak (10.00-13.00)*
Bury	-3%	+101%
Northern corridors	-21%	+109%
Altrincham	+63%	+166%
Southern corridors	-15%	+3%

Source: Table 3.1 in Oscar Faber (1996a).

The northern and southern corridors exclude the Bury and Altrincham corridors.

According to Law *et al.* (1994) patronage was higher on Metrolink than the former British Rail lines because of:

- Higher service frequency.
- Better penetration of the city centre.
- The fare structure on Metrolink made many journeys cheaper.

The peak period patronage on Metrolink on the Bury line was lower than anticipated for two reasons:

- Price competition from buses.
- Higher fares than in the days of British Rail.

It is relevant to consider where the patronage on Metrolink has come from. Table 12.10 shows the estimated observed transfer from the monitoring study carried out by Oscar Faber (1996a, 1996b). It can be seen that the majority have transferred from rail, mainly the heavy rail lines that Metrolink replaced. Just over one quarter have come from bus, and about 13% from car. This table does not include any trips generated as a result of the existence of Metrolink. The table also shows the original forecasts of the proportions. A comparison of the two sets of figures suggests that the transfer from car and bus was underestimated in the forecasts and that from rail was overestimated.

Table 12.10 Comparison of estimated observed and forecast sources of Metrolink patronage

Mode	*Estimated observed proportion*	*Original forecast proportion*
Car	12.5-14.8%	11.5%
Bus	25.8-28.2%	19.9%
Rail	57.0-61.1%	68.5%

Source: Table 5.3 in Oscar Faber (1996a)

An alternative calculation of the modal origins of the Metrolink trips from the University of Salford Monitoring Study is shown in Table 12.11. This makes the comparison with the situation which would have been expected if the

Bury and Altrincham lines had still been operated by British Rail. This is used rather than the 'before' situation because there was a gap of several months when neither heavy nor light rail operated on these lines and a high quality bus service was operated, which may have influenced travellers' modal choice in the medium term. They estimate that there are 4.5 million more trips on Metrolink than would have used the heavy rail lines that they replaced. Of these, 2.6 million (58%) were previously car trips, 36% were bus trips, 4% used other rail lines, and 4% were not made previously.

Table 12.11 Estimated annual Metrolink patronage (millions) by previous mode

	Metrolink forecast	*Metrolink actual*	*Control situation: if Bury/ Altrincham lines still had BR services*	*Metrolink impact*
Not made 'new trip'	1.3	2.5	2.3	0.2
Car		3.3	0.7	2.6
Bus	3.0	2.6	1.0	1.6
Rail	7.6	3.5	3.3	0.2
Other	0.0	0.2	0.3	-0.1
Total	11.9	12.1	7.6	4.5

Source: Table 2 in Knowles (1996) from the Metrolink Impact Rail User Survey 1993.

Whilst there seems to have been quite a large transfer to Metrolink from the car, this does not necessarily mean that there will be a significant decrease in traffic flows because some people who were previously deterred from using their cars because of congestion may start using them. According to Law *et al.* (1994) there is evidence that car traffic has reduced in the Bury and Altrincham corridors, except in the peak period in the Altrincham corridor, where there has been little change. The effects are complex, but at that time (1993) it seemed reasonable to conclude that there had been some reduction in car use on roads parallel to Metrolink, but it was impossible to measure the effect precisely.

Oscar Faber (1996a) looked at the effects on highway demand in the city centre, as shown in Table 12.12. They concluded that there had been a 1.8% reduction in the number of cars entering the city centre in the morning peak and a 0.7% decrease off-peak. They also concluded that there has been a reduction in the number of parking acts: 690 long-stay and 520 short-stay.

Table 12.12 City centre impacts of Metrolink on highway demands

% reduction in cars entering the city centre – AM peak	1.8%
% reduction in cars entering the city centre – off-peak	0.7%
Number of long-stay parking acts likely to have been removed	690
Number of short-stay parking acts likely to have been removed	520

Source: Table 6.5 in Oscar Faber (1996a)

More recently Scheurer *et al.* (2001) claim that Metrolink has taken 2.5 million car trips a year off the roads, equivalent to a 10% reduction in traffic on the Metrolink corridor (but possibly releasing space for other car drivers, so that there might be no visible effect on traffic levels). According to Greater Manchester Passenger Transport Executive (1995) Metrolink may have affected the pattern of car purchases in the area it served because between 1991 and 1994, the number of cars per person dropped by 3% in the Metrolink corridor compared with a rise of 5% in the county as a whole.

12.2.6 The example of South Yorkshire Supertram

In July 1976 the Sheffield and Rotherham Land Use and Transportation Study recommended the development of a segregated passenger transport system on six corridors radiating from the centre of Sheffield which is a city in the north of England in the County of South Yorkshire. In 1979 the six lines were safeguarded by South Yorkshire County Council against conflicting development. In 1982-83 studies were carried out to consider alternative modes, followed by technical evaluation during 1984-85. In November 1985 a Private Bill was put before Parliament seeking powers to develop and operate the system. A further Bill was deposited in November 1988 for a line into the Lower Don Valley to assist in regeneration. Financial approval was given by the Department of Transport in December 1990. This required the setting up of two companies owned by South Yorkshire Passenger Transport Executive (SYPTE): one to own the infrastructure and trams, the other to use the assets under a concession agreement, with a view to privatisation at a later date. Construction took place from 1992 to 1994, with the first trams delivered in late 1993. The first line was opened on 21 March 1994 from the edge of the city centre to the Meadowhall shopping centre. The full system was opened by October 1995. In December 1997 the system was privatised with the bus operator Stagecoach taking over operation of the system. This led to a number of changes to the operation of the system, including new timetable and fares package (Haywood, 1999).

The demand for travel by public transport in South Yorkshire is shown in Table 12.13. Patronage on Supertram has not been as high as expected (Fox, 1996), but it has increased steadily as remedial action has been

Table 12.13 Number of journeys by light rail, bus and train in South Yorkshire (millions)

	1991 -1992	*1992 -1993*	*1993 -1994*	*1994 -1995*	*1995 -1996*	*1996 -1997*	*1997 -1998*	*1998 -1999*
Supertram	–	–	–	2.2	5.3	7.8	9.2	10.4
Bus	177	176	166	163	158	150	144	135
Suburban rail	6	6	6	6	6	6	6	6
Total	183	182	172	171.2	169.3	163.8	159.2	151.4

Source: Department of the Environment, Transport and the Regions (2001a, 2001b).

Rail services are those supported under Section 20 of the 1968 Transport Act.

taken. Total public transport demand in South Yorkshire declined throughout the period shown, and the opening of Supertram has not reversed this trend, but it might have slowed it down, since the decrease levelled off in 1993/94 to 1995/96. Bus patronage has been in long-term decline, and it is not obvious that Supertram has accelerated this trend, a point confirmed by analysis over a longer period by Babalik (2000). Heavy rail demand in South Yorkshire is low, and appears not to have been affected by the opening of Supertram, which serves different areas of the city.

This can be compared with the shift changes in patronage on bus and rail in other metropolitan areas at the time Supertram was opened as shown in Table 12.14. In the other areas there was a small growth in bus use whereas in South Yorkshire there was a small decline, suggesting that Supertram may have prevented a short-term growth in bus patronage in South Yorkshire which was probably associated with the improving economic situation at the time. Rail showed a decline in the other areas whereas it was about constant in South Yorkshire at a very low level.

Table 12.14 Number of journeys in other metropolitan areas outside London, 1993/4 – 1994/5

	1993 -1994	*1994 -1995*
Bus	935	941
Rail	109	100
Total	1044	1041

Source: Department of the Environment, Transport and the Regions (2001a).

The other metropolitan areas are West Midlands, Merseyside, West Yorkshire and Tyne and Wear (Greater Manchester has been excluded because of the introduction of Manchester Metrolink).

Table 12.15 shows where Supertram trips have come from. It can be seen that most trips (55%) have transferred from bus. 20% have come from car and 12% are new trips that would not have otherwise been made. Given that patronage on Supertram is low, 20% transfer from car would not make a huge difference even if no other travellers started using their cars because of the resulting reduction in congestion.

Table 12.15 Abstraction of Supertram trips from other modes

	%
New trips	12
Car	20
Bus	55
Other modes	12
Total	100

Source: W S Atkins and ESRC TSU UCL (2000).

12.2.7 The effects of other systems on demand

Reference has already been made to a number of light rail systems around the World. In most cases, specific monitoring studies have not been carried out, unlike the Greater Manchester and South Yorkshire systems, so it is not possible to draw detailed conclusions about their impacts. It is, however, possible to take information from the surveys of light rail and similar systems by Mackett and Edwards (1998) and Babalik (2000). The Manchester and South Yorkshire systems were included in both surveys and so will be included here where appropriate for comparison.

One useful indicator of demand is how well actual patronage matches that forecast since the forecast would have been used as part of the planning process and to help determine whether the project would be worthwhile financially. Table 12.16 shows the forecast and actual patronage for a number of modern light rail systems.

Table 12.16 Forecast and actual patronage on a weekday for light rail systems in thousands

	Forecast		*Actual*		
City	*Year*	*Patronage*	*Year*	*Patronage*	*% difference*
Vancouver	1996	100.0	1996	136.0	+36%
Manchester	1996	35.7	1996	44.5	+25%
South Yorkshire	1996	70.7	1996	18.7	-74%
Tyne andWear	1985	219.1	1985	208.9	-5%
Buffalo	1995	92.0	1995	29.0	-68%
Pittsburgh	1985	90.5	1992	31.1	-66%
Portland	1990	42.5	1995	24.0	-43%
Sacramento	1987	20.5	1987	12.0	-42%
San Diego	1981	9.5	1981	12.0	+25%
St Louis	1994	17.0	1994	44.4	+161%

Sources: Mackett and Edwards (1998) and Babalik (2000), using information from Pickrell (1990), Dunphy (1995), Warren (1995), Federal Transit Administration (2000) and Department of the Environment, Transport and the Regions (2001b).

It can be seen in Table 12.16 that there are huge differences between the forecast and out-turn patronage. Out of the ten systems shown, patronage was overestimated in four cases and underestimated in six, with errors of up to 161%. The one Canadian example, in Vancouver, was an underestimate by 36%. As discussed above, on Manchester Metrolink demand was underestimated by 25%, but as Knowles (1996) showed, the type of patronage forecast was very different to the actual, with much more off-peak travel and much less peak travel in reality than expected. Patronage on South Yorkshire Supertram has been well below that forecast. Various reasons for this have been cited: the assumptions about the transfer from bus to Supertram were not realised (partly due to deregulation), new developments which were expected to generate a number of trips did not take place (W S Atkins and ESRC TSU UCL (2000), and the way Supertram was operated differed from that expected (Haywood 1999). Forecasts for the Tyne and Wear Metro were fairly close to the actual values, but the patronage declined after 1985, largely due to deregulation and the removal of feeder bus services and were down to 126,900 per weekday by 1996.

The four US systems in which patronage was overestimated, in Buffalo, Pittsburgh, Portland and Sacramento, were all constructed using some Federal funding, giving some credence to the claim that patronage demand was often overestimated under these circumstances. On the two other US systems patronage was underestimated: San Diego Trolley which was initially built with no Federal funding and St Louis MetroLink which was constructed after the funding rules were changed.

Babalik (2000) has calculated the extent to which the total capacity of light rail systems is used, as shown in Table 12.17.

Table 12.17 Percentage of total capacity used on light rail systems

City	*% of capacity used*
Vancouver	38
Manchester	33
South Yorkshire	37
Tyne and Wear	75
Sacramento	33
San Diego	55
St Louis	45

Source: Babalik (2000).

The capacity used is the ratio of the average number of passenger trips per hour to the total passenger carrying capacity of the systems per hour.

The figures in Table 12.17 look low, in general, because they are averages over the whole day, including reverse flows during peak periods. The highest values are found for the Tyne and Wear Metro, the San Diego and the St Louis systems, all of which have been the most efficient in terms of matching supply to demand.

12.2.8 The use of operating and transport planning policies to increase demand

Two types of complementary policy that can help to enhance the benefits of a new light rail scheme will be considered here: operating policies and transport planning policies. The use of these policy instruments is considered for 11 systems: two in Canada (Calgary and Vancouver), three in Britain (Manchester, South Yorkshire, and Tyne and Wear), and six in the U S (Baltimore, Los Angeles, Portland, Sacramento, San Diego, and St Louis) (Babalik, 2000).

The operating policies that are considered likely to enhance the benefits of light rail systems are:

- High frequency service.
- Travelcards.
- Free transfer to buses.
- Free travel on part of system.
- Marketing and advertising.
- Security staff on board and at stations.

The systems which are operated with these policies are shown in Table 12.18.

It should be recognised that some of these indicators are rather subjective and imply an assessment of the extent to which the policy has been implemented: for example, all

Table 12.18 Experience of the systems with operating policies

System	*High frequency service*	*Travel -cards*	*Free transfer to buses*	*Some free travel*	*Marketing and adver -tising*	*Security staff on board and at stations*
Calgary		●	●	●	●	●
Vancouver	●	●	●		●	●
Manchester	●					
South Yorkshire		⊗			⊗	●
Tyne and Wear						
Baltimore		●			●	●
Los Angeles		●			●	●
Portland			●	●	●	
Sacramento		●	●		○	
San Diego		●	●		●	
St Louis		●		●	●	●

In Sheffield, introducing additional staff for ticket sale on board has enhanced the security image of the system.

● *The policy has been effective in enhancing the success of the system.*

⊗ *The policy has been implemented but failed to have significant effects.*

○ *It is not clear whether the policy has had any effect on the performance of the system.*

Source: Babalik (2000), Mackett and Babalik (2001b).

the systems have been the subject of some form of marketing and advertising even if it only coverage in the local press (adverse or otherwise), so a positive indication in the table implies the implementation of the policy to a significant extent, which is not necessarily the same as whether or not it was effective.

Of the systems being considered here, only Vancouver and Manchester are considered to offer high frequency service. (High frequency is defined as being at least 10 vehicles per hour in the peak and 5 vehicles per hour off-peak.) A travelcard is a period ticket which permits travel on all public transport modes in an area. The deregulation of buses in Britain (outside London) makes it very difficult to offer a travel card because it requires co-operation between companies whereas deregulation is designed to encourage competition. It is sometimes possible to offer a ticketing system that offers travel on several modes in a deregulated environment, but it is unlikely to be comprehensive. Such a system has been tried in South Yorkshire, but does not seem to have had a significant effect. All the other cities outside Britain, except Portland, have implemented such systems. Competition legislation makes it difficult to offer free transfer to buses on the British systems, but both the Canadian and three of the US systems do so.

Three of the systems, Calgary, Portland and St Louis offer some free travel. For example, free travel is offered between six stations in the city centre off-peak on St Louis MetroLink. The idea is that it will encourage those who would otherwise never use public transport to try it, thereby overcoming a mental barrier.

As mentioned above, all new light rail systems are likely to be the subject of publicity, but some systems have been the subject of explicit marketing and advertising campaigns. All the North American systems were the subject of such campaigns, but in the case of Sacramento it seems to have been fairly ineffective. Of the three British systems, only in South Yorkshire has there been an extensive campaign, but it appears not to have been very effective.

Like many examples of publicly-owned infrastructure, light rail systems can be the subject of vandalism. They can also be perceived as dangerous for lone travellers, particularly after dark. All non-automatic systems carry drivers usually locked in their driving cabs, partly for their protection. Thus the passenger areas are not actively supervised, which offers scope for passengers to travel without a ticket with subsequent loss of revenue. For all these reasons some systems have staff either at stations or on board. Whilst this increases costs, it can save money in terms of revenue protection and reducing vandalism, and can enhance revenue by encouraging those who would otherwise find travelling unescorted intimidating. For example, in South Yorkshire the ticket machines on the stations were subject to vandalism and there was considerable revenue loss from non-payment of fares. Conductors were introduced which has helped to increase revenue significantly.

The transport planning policies that are considered likely to enhance the benefits of light rail systems are:

- Integrating system into regional planning.
- Integrating system into existing urban projects.
- Locating stations at trip attractors or generators.
- Integrating bus services with new system.
- Providing car parking at stations.
- Restricting car parking in the city or in the CBD.

The systems which are operated with these policies are shown in Table 12.19.

Table 12.19 Experience of the systems with transport planning policies

System	*Integrating system into regional planning*	*Integr -ating system into existing urban projects*	*Locating stations at trip attrac -tors or gener -ators*	*Integr -ating bus services with new system*	*Provi -ding car parking at stations*	*Restrict -ing car parking in the city or in the CBD*
Calgary	●		●	●	●	●
Vancouver	●	●		●		
Manchester					○	
South Yorkshire		⊗			○	
Tyne and Wear	○	●		● *	○	
Baltimore			●	●	●	
Los Angeles			●	●	●	
Portland	●		●	●	●	
Sacramento				●	●	
San Diego		●	○	●	●	
St Louis		○	●	●	●	

** Policy was implemented and was effective during the first 5 years of the operation of the system.*

● *The policy has been effective in enhancing the success of the system.*

⊗ *The policy has been implemented but failed to have significant effects.*

○ *It is not clear whether the policy has had any effect on the performance of the system.*

Source: Babalik (2000), Mackett and Babalik (2001b).

The first two policies are to do with integration of the light rail system into the existing infrastructure, either by incorporating it into a regional plan as happened in Calgary, Vancouver, Portland and Tyne and Wear, or incorporating it into an existing urban project, such as regeneration of an area, as has happened in Vancouver, Tyne and Wear, San Diego and, unsuccessfully, in South Yorkshire.

A light rail system is more likely to be successful if it connects two large centres which generate or attract trips, preferably over the whole day, to ensure a continuous high level of patronage. This happened in Calgary, Baltimore, Los Angeles, Portland, St Louis and San Diego. In all cases except the last it seems to have helped increase patronage. The effects are not so clear in the case of San Diego.

Buses can serve a complementary role to a light rail system by acting as feeder services. This approach takes advantage of the bus's ability to go on any road, to collect passengers to take to the light rail system which can then take them into the city centre at high speed on a segregated track. Buses can also be used as distributors if appropriate. This method is used for the North American systems. It was used in Tyne and Wear until the buses were deregulated in 1986. Since deregulation such services are offered only if operators perceive them as commercial opportunities or local authorities regard them as socially necessary. In the UK this has tended not to occur possibly because passengers prefer direct bus trips to their destinations rather than make trips that require bus/rail interchanges.

The other two policies relate to car parking: providing car parks at stations means that the light rail system can be used for park and ride. Restricting parking in the city centre can make use of light rail relatively more attractive. Car parking has been provided at stations on all the systems except Vancouver. In the British systems it does not seem to have been very effective. Only in Calgary has car parking been restricted elsewhere as a policy to encourage light rail use.

Calgary seems to be the place where transport planning policies have been used most to encourage use of the light rail system. In Britain, some policies have been tried, but they do not seem to have been very successful, especially in Manchester and South Yorkshire. All the U S systems have been the subject of at least two complementary transport planning policies which seem to have been successful.

12.3 Guided busways

12.3.1 Introduction

Kerb-guided buses operate in a segregated busway using a guide wheel running along a kerb to steer the bus. The guideways allow buses to bypass congested sections of the network, or take more direct routes. This can result in both reduced journey times and substantially improved reliability.

Other traffic is prevented from using the guideway as a means of overtaking slow traffic, parking or unloading, by the barrier between the guideway and the general traffic lanes. Entrance to the guideway can also be controlled by use of a remote signalling system that lowers a barrier as the bus approaches. Additionally, the design of the guideway, with two concrete tracks separated by drainage channel filled with coarse chippings makes it difficult for other vehicles to use. The axle width of cars is too narrow – thus one wheel would be on the track whilst the other would be in the drainage channel. The guideway is generally too narrow for lorries, with their wider axle width, to use. Smooth transition between the guideway and normal carriageways is achieved using a funnel which gradually steers the bus into the guideway.

A second type of guided bus system, sometimes referred to as guided light transit (GLT), is a hybrid between road and rail (Smyth, 1994). The system is steered by a retractable roller mechanism, which runs in a central rail laid in the roadway. The rail is flush with the road surface. This system allows the benefits of a smoother journey to be achieved on mixed-use streets as well as on the guideway. However, the vehicles can be five times more expensive than kerb-guided buses (Smyth, 1994).

Guided buses can also use standard busways and bus lanes. Thus, at the end of the guideway, buses can go in different directions on the normal road network, thus allowing a greater number of destinations to be served without the need for interchange. Buses may also be able to leave the guideway part way along its length. Therefore a wide catchment area can make use of the improvements. This flexibility also allows the service network to adapt to changes in demand over time.

Guided buses may prove more attractive to passengers than conventional buses for several reasons:

- *Accessibility* – the use of the guide wheel allows the buses to stop extremely close to the kerb or platform edge with only a small (50mm) uniform gap between the bus and the platform edge, allowing for easy level boarding.
- *Comfort* – the combination of the high precision concrete track that the buses run along and controlled steering from the guide wheel, provide passengers with a faster and smoother ride than can be achieved with conventional buses.
- *Speed* – speed gains are made in two ways: if a separate guideway is used then the guided bus can by-pass traffic congestion. The guide system also adds to a faster journey, as steering is smoother around corners etc.
- *Image* – guided bus has the potential to be seen as a ‘new’ mode, shaking of the image of the conventional bus of slow, uncomfortable and dirty. To achieve this the scheme must be marketed in the right way, accompanied by strong branding and with consideration put into the design of the vehicles, the design of bus poles, stops and interchanges, and timetables etc.

However, these advantages come at a cost:

- The track is more expensive to construct than a standard busway, which at its simplest only requires the construction of a barrier between the busway and the main carriageway.
- Buses have to be converted to use the system. Standard buses can be used but must be fitted with guide wheels. This can add 10% to the cost of a new bus.
- The construction of the system prevents buses from passing each other, therefore express services and local services cannot usually be run at high frequencies along the same route. Although this will depend on the length of the guide way sections.

12.3.2 Examples of schemes in operation

Examples of cities with kerb-guided bus systems include Essen, Mannheim and Adelaide. The Trans val de Marne (TVM) busway in Paris is used by a Guided Light Train. There are also guided light train schemes in Caen and Nancy, although both schemes have suffered from technical problems causing them to be temporarily shut down. Three UK cities have guided bus schemes currently in operation: Leeds, Bradford, and Ipswich. All these schemes are kerb-guided systems. The UK schemes differ from the Essen and Adelaide schemes in that the guideway operates on short strips at points where previously buses tended to get stuck in traffic queues. The schemes in Essen and Adelaide include long stretches of uninterrupted guideway.

All the UK guideway schemes were constructed as parts of larger schemes to enhance the quality of a route or corridor. Other enhancements included higher specification buses, other bus priority measures, service frequency enhancements, street furniture design, general environmental improvements such as new planting, and customer-care trained drivers. In addition the schemes have been accompanied by strong image branding through initiatives such as specially designed bus stops and bus poles and the choice of bus livery.

Work started on the Ipswich Superoute 66 in 1993. Phase 1 began operating in January 1995 (Enoch, 1998). The route runs from Kesgrave to Ipswich and includes 200m of guideway in both directions, and includes a bus-only link between Martlesham and Kesgrave. The first Leeds scheme (superbus) which runs along Scott Hall Road (A65) opened in 1995. The East Leeds route, (branded elite) with guideways on York Road and Selby Road opened in November 2001. The guided busway in Bradford was constructed as part of the Manchester road quality bus initiative and opened on the 1st February 2002.

Costs for constructing an at-grade guideway are in the region of £1 million per lane kilometre but will vary depending on ground conditions. The Leeds superbus scheme cost £750,000 in 1995 to construct 450m of guideway, roughly £1600 per lane metre. This includes improvements to street lighting, traffic signals, and the environment. Two ‘docking stops’ on adjacent highway were also included in the scheme. The cost of the guideway excluding these environmental improvements was approximately £700 per metre (Enoch 1998). The cost of fitting the buses to run along the route with guide wheels was £3000 per bus. The Ipswich scheme involved £2 million of investment in new infrastructure and £0.5m on new buses.

12.3.3 Effects on journey times

The Leeds superbus scheme provided service time improvements of between 3 and 5 minutes during the morning and evening peaks, as well as improvements in the reliability and punctuality of the services using the route. The construction of the 450m outbound guideway along Scott Hall Road reduced variability in bus journey times by 75% (Daugherty and Balcombe 1999). The Ipswich scheme provided time savings of 3-4 minutes and again produced significant improvements in punctuality.

12.3.4 Effects on demand

Patronage on the Leeds superbus route increased by 45% after 1 year and by 65% since it began operating in 1995 (FirstGroup, 2003). Daugherty and Balcome (1999) found, that of 1585 trips made by 340 weekday passengers surveyed, that service improvements following the introduction of the superbus had generated 90 journeys per week, i.e. an increase in demand of 5.7%. Of these, over 80% were by new users, the remainder being by existing users changing the frequency with which they used the route. Steer Davis Gleave (1997) cited in (Daugherty and Balcombe 1999) estimated a patronage growth on the superbus route of 3% relative to growth across the rest of Leeds. The differences between these figures has not been satisfactorily explained; it may be due partly to the timing of the various before and after data collection exercises, and partly to difficulties for interviewees in disassociating reasons for change from bus service improvements.

The Ipswich scheme saw patronage grow along the route by 21% in the first quarter of operation and by 75% since opening (FirstGroup, 2003). Numbers of passengers boarding buses on the guideway section of the Manchester road initiative in Bradford rose by over 16% in the first 9 months of operation, whilst patronage in Bradford as a whole rose by 6% over the same period (West Yorkshire PTE, 2003).

The experimental kerb-guided bus scheme which operated in Birmingham from 1984 to 1987, along a section of road which experienced relatively little traffic congestion, was reported to have experienced a rise in patronage 26% above that for other services within the city (Bain, 2002).

The passenger profiles of both the Leeds superbus and Ipswich superoute 66 schemes are more like those for LRT than for conventional bus (Enoch, 1998). Between 20 and 25% of passengers on the Leeds superbus are car owners; between 10 and 20% of new passengers have shifted from the car (Bain, 2002). Of the passengers on superoute 66 23% were former car users and 2.8% were newly generated (Enoch, 1998).

A number of stated preference studies were carried out by Steer Davies Gleave in the early 1990s. These studies found that car users reaction to guided bus expressed in terms of generalised minutes ranged from -12 to -26 depending on the details of the scheme. This compares with a range of -21 to -29 for bus, -5 to -15 for light rail and -8 to -22 for light rail (Kilvington, 1992).

12.4 Park and Ride

According to Parkhurst (1996) Park and Ride (P&R) usually has one or more of three aims:

- To maintain or increase the number of economically desirable trips to the city centre.
- To avoid using valuable city centre land for car parks and access roads.
- To reduce congestion and noise pollution.

Hitherto P&R has usually been implemented for economic rather than environmental reasons. Research generally focuses on short-range P&R, which is usually bus-based, as opposed to the traditional long-range rail-based P&R. The pioneers of short-range P&R tend to be historic towns and cities. One of the problems with research into P&R is that it tends to start on a small scale and has expanded incrementally. For example, between 1997 and 2001 P&R use increased by 16% per annum (Menzies, 2002). New P&R sites will often attract passengers from existing P&R sites and from bus services. For example, monitoring of the introduction of Oxford's second P&R site, (admittedly only 7 months after inauguration) found that a quarter of the users had already been travelling by P&R, half of those (an eighth overall) had switched from Oxford's 1st P&R site, and the other half (other eighth) 'had been practising ad hoc park and ride from the suburbs using scheduled bus services; perhaps an early indicator that what matters for the success of park and ride are not so much its intrinsic qualities, but the perceived alternatives'. There is a problem with P&R's poor ability to attract patronage in early years, thus its efficiency appears poor, and has to be subsidised by local taxpayers. Oxford's fourth P&R site (Thornhill) opened in 1985. It was found that due to its location it attracts users from the conventional bus services, taking advantage of cheaper fares. Around 40% are accessing the site on foot.

Cooper (1993) carried out a survey in York which found that a number of P&R users who had not previously considered using public transport would now do so. 60% of respondents had previously driven and 19% had used the local bus, now 35% said they would use bus if P&R became unavailable. It was found that 22% did not access the P&R site by driving to it (2% travelled by bicycle, 15% walked, and 5% were going the 'wrong' way). It was also found that 12% had not travelled to York before P&R became available.

Similarly, 20% of P&R users in Oxford on a Saturday felt they would not come to Oxford at all in the absence of P&R. By introducing P&R it is easier to resist pressure to retain or increase parking capacity in city centre. It was found that as the area of a journey's origin becomes more rural public transport is likely to become a less acceptable alternative to P&R. Parkhurst (1996) believes that 'Park and ride evolved as part of a strategy which sought to preserve accessibility. It has been successful in doing this, but by improving vehicle occupancy, not reducing congestion. Perhaps if the sole aim of park and ride had been reducing congestion, it would have been abandoned long ago.' P&R has tended to limit the increase in car trips into the centre of city, it does not usually diminish the actual number of car trips. P&R, however, may contribute to loss of patronage on services just outside the city, which in already marginal cases could destroy their profitability.

Use of P&R tends to increase over time, as new sites open. Some of this increase may well be attributable to rising car ownership, and also the generation of trips that were previously suppressed due to the road congestion before P&R (Parkhurst, 1998). One of the causes of resistance to P&R use is concern about site security, and personal safety, particularly when returning after dark. Sometimes the reduced travel cost for P&R can make travelling to a particular area more attractive, and result in a revival of that area's economic fortunes. In the plans for the pedestrianisation of the centre of Oxford, some retailers cited the provision of P&R as an important element of the future viability of the centre.

For P&R's decongestion benefits to be realised it is important that:

i The provision of P&R sites should not lead to an overall increase in parking space supply in the city.

ii Other users should not be attracted to the vacated road space.

To aid the latter, road restriction measures might be introduced as soon as possible after the P&R is provided, preferably at the same time, before potential users have adjusted to any increased capacity.

Politically, there can be a noticeable resistance to a new transport initiative if the measures that restrict use occur first. For example, the building work to introduce bus priority measures and light rail schemes can cause a lot of disruption to existing services and road use, which can increase people's hostility to the scheme, as in the case of Sheffield Supertram (WS Atkins and ESRC TSU, 2000).

WS Atkins (1998) present data on P&R in 8 cities. For the 47% of users who said they would otherwise drive all the way, they found their journeys by private car shortened by 2km. Distance of site from City Centre was an influence here, the maximum possible was 4km on average. It was found that 63% (range 55% to 66%) of users had previously driven, 17% (range 10% to 28%) came from conventional public transport. It should be noted that a proportion of respondents reported 'other'.

Parkhurst (1999a) notes that the net saving per car parked is 1.7km. Unfortunately, bus based P&R, tends to intercept motorists rather later in the journey (covering on average about 25% of the overall journey). On average around 62% (range 52% to 71%) of P&R users are in the target group (those who travelled to the town centre by car before P&R was introduced). Around 17% (range 8% to 40%) previously used conventional buses and trains. Around 50% said that in the absence of P&R they would drive to the city centre. Around 27% (range 18% to 41%) said they would revert to or choose public transport if P&R became unavailable. It is thought that around 12% of P&R trips are extra trips generated by the P&R. Earlier work had suggested that trips to the city following the introduction of P&R increased by between 2 to 11%. Some delegates at the English Historic Towns forum of 1998 suggested that P&R might in time be viewed as an interim phase 'filling a breech' until longer-distance public transport services can be revitalised. Other people think it might lead to an outer ring for a city.

Due to inter-centre competition, it is not often possible to set P&R charges at a price that does not undercut public transport. In other words in order to attract users to P&R it may be necessary to charge less than the costs of providing it, but that may mean that P&R costs less to use then the conventional local public transport. Sometimes P&R is introduced, because of: a temporary reduction in city centre parking (for example on market day), or increased demand due to a festival attracting extra visitors from outside, or to compete with out of town shopping centres a certain times (e.g. Christmas).

It is suggested that small scale P&R sites should be introduced far from the urban area, so that cars could be intercepted earlier, people could also access services by walking or shared taxi, and several sites could be arranged like stations along a railway line so the same P&R bus could pick up passengers from several sites.

WS Atkins (1998) found that 16% would not have made their journey in the absence of P&R. Trip generation as a result of P&R is particularly high in Brighton, Coventry, and, Reading about 18%, 21% and 18% respectively. In the other 5 cities trip generation was between 7 to 14%.

Parkhurst (1999b) uses the same calculations as WS Atkins to calculate P&R ridership, i.e. those who arrive at the P&R site who would otherwise have driven all the way. Hence this does not consider people:

- mode-switching from longer-distance conventional public transport to P&R use;
- travelling to other places instead of using P&R to the same city;
- not travelling instead of using P&R;
- travelling short-range to a P&R site by car rather than walking to a more local bus service;
- travelling by car to the centre instead of using a mode other than car (cycle, walk) to access the P&R bus service (where permitted).

This means that only 47% of the WS Atkins sample fell in the category considered, 53% did not.

Parkhurst's model used the estimated daily cost in distance travelled (weekday km) of providing a dedicated P&R bus services to 18 sites in 8 cities. (1 each in Brighton (200 spaces), Coventry (450 spaces) and Reading (625 spaces), 2 in Plymouth (120 spaces), 3 each in Norwich (1530 spaces), Shrewsbury (1750 spaces) and York (2000 spaces), and 4 in Cambridge (1700 spaces). This was factored by 3 possible equivalent passenger-car units (PCUs) for bus (as Bus km x PCU). If the value of 3 is applied then the distance travelled by buses to each site is between 873 to 2,844 km per weekday, if the value 2 is applied the distance is between 582 to 1,896 km per weekday. These figures (for each site) were then divided by the number of users who avoided car use by interchanging at the site (this was derived from patronage data). The car km saved for each car parked was calculated on average for each city. The car km saved, average car-equivalent km travelled by buses per car parked, and the different between the two were all presented in a table, below. The difference was calculated as car equivalent bus km-car km saved, so if it is negative then there is a net reduction in vehicle km as a result of P&R, but if it is positive then the impact of the bus services is greater than the reduction in car-km (Table 12.20).

Table 12.20 Comparison of car-km saved per car parked

City	*Car-km saved per car parked*	*Car-equivalent km travelled by buses per car parked*	*Difference in car-equivalent km per car parked*
Brighton	-4.02	+1.80	-2.22
Cambridge	-1.50	+2.52	+1.02
Coventry	-1.66	+3.42	+1.76
Norwich	-3.46	+3.68	+0.22
Plymouth	-4.70	+2.16	-2.54
Reading	-8.54	+2.03	-6.51
Shrewsbury	-5.12	+1.35	-3.77
York	-3.26	+2.18	-1.08

Source: Parkhurst (1999b)

It has been found that around 67% of the annualised cost of providing P&R is the cost of providing the bus service, 20% is the site operating costs and 13% is the notional capital cost of provision. Table 12.21 gives the costs and benefits of P&R excluding provision costs. Table 12.22 includes provision costs.

In order to make bus-based park & ride attractive, it is necessary to offer an adequate frequency throughout the day. Where a route's demand arises only from P&R sites, then a problem may arise if a site fills up in the morning peak, since little off-peak ridership will be found. This is more likely to be seen where constraints on site provision restrict total spaces that can be provided. Winchester can be seen as an example of this. It may be noted that bus-based P&R provision in Britain is atypical of P&R provision elsewhere, which is often rail-based (for example, on new light rail systems) and hence the service level and ridership are not solely dependent on P&R demand, even where special stations may be provided for P&R traffic.

There is a question over whether non-motorists should use the bus service or not. In some cases people using the buses the 'wrong way' (i.e. coming from the city centre first and are likely to be non-motorists) are required to pay a higher fare or prevented from using the bus by means of the ticketing arrangements. While this means that only the 'intended' market is actually served, it also means that local taxpayers, whether motorists or not are subsidising motorists. However, if the planners decide to make the scheme socially inclusive by allowing non-motorists to use the services for the same fare means that the P&R scheme may be in direct competition with the local conventional bus service, which can have a detrimental effect on the

Table 12.21 Costs and benefits of park and ride schemes per day excluding site provision costs

					Ticket receipts per weekday (£)		*Net operating cost (£)*		*Reduction in vehicle-km per £, spent*	
City	*Cars parked per weekday*	*Net vehicle-km per car parked per weekday*	*Total net change in vehicle-km per weekday*	*Operational costs per weekday (£)*	*Car arrivers*	*All users*	*Car arrivers*	*All users*	*Car arrivers*	*All users*
Brighton	590	-2.22	-1.313	732	833	1,282	-101	-550	Surplus	Surplus
Cambridge	1,910	1.02	1,950	3,709	1,927	2,190	1,782	1,519	Net inc	Net inc
Coventry	230	1.76	406	690	230	242	460	448	Net inc	Net inc
Norwich	1,335	0.22	300	3,690	2,377	3,105	1,315	585	Net inc	Net inc
Plymouth	1,492	-3.17	-4.735	1,907	1,265	1,405	642	502	4.16	5.35
Reading	1,145	-6.51	-7,454	1,696	2,000	2,174	-303	-477	Surplus	Surplus
Shrewsbury	3,046	-3.77	-11,472	3,319	2,332	2,455	987	865	11.62	13.27
York	1,950	-1.08	-2,097	3,006	2,656	3,405	351	-398	2.83	Surplus

Source: Parkhurst (1999b)

Table 12.22 Costs and benefits of park and ride schemes per day including site provision costs

					Ticket receipts per weekday (£)		*Net operating cost (£)*		*Reduction in vehicle-km per £, spent*	
City	*Cars parked per weekday*	*Net vehicle-km per car parked per weekday*	*Total net change in vehicle-km per weekday*	*Operational costs per weekday (£)*	*Car arrivers*	*All users*	*Car arrivers*	*All users*	*Car arrivers*	*All users*
Brighton	590	-2.22	-1.313	794	833	1,282	-39	-488	Surplus	Surplus
Cambridge	1,910	1.02	1,950	4,234	1,927	2,190	2,307	2,044	Net inc	Net inc
Coventry	230	1.76	406	828	230	242	599	587	Net inc	Net inc
Norwich	1,335	0.22	300	4,162	2,377	3,105	1,786	1,057	Net inc	Net inc
Plymouth	1,492	-3.17	-4.735	2,252	1,265	1,405	988	847	2.71	3.15
Reading	1,145	-6.51	-7,454	1,889	2,000	2,174	-110	-284	Surplus	Surplus
Shrewsbury	3,046	-3.77	-11,472	3,859	2,332	2,455	1,527	1,405	7.51	8.17
York	1,950	-1.08	-2,097	3,624	2,656	3,405	968	219	2.17	9.57

Source: Parkhurst (1999b).

existing local services. It also means that the P&R service ceases to become exclusive and dedicated. Possible ways round this include: operating the P&R service only in the peak; if the site lies on an existing bus route combine the two (as in Reading); and, carefully consider location of future sites so that they can be combined with existing services. This still leaves unresolved the question about whether P&R consumes resources that might otherwise be used to improve local public transport in general.

Parkhurst (2001) cites the English Historic Towns Forum (1993). Providing P&R and bus lanes may reduce road congestion and improve bus journey reliability making the conventional bus service more attractive to car users. It may also encourage car users who would not previously have considered using public transport to do so, as it presents them with a positive image of it. To achieve this latter aim some providers of P&R have tried to provide a high quality service, superior to that of the local bus service. Table 12.23 gives the redistribution of passenger km between public transport and a dedicated P&R service.

Table 12.23 Redistribution of passenger-km between PT services due to the provision of dedicated P&R

P&R scheme	*Total passenger-km travelled on P&R buses per weekday*	*Passenger-km abstracted from conventional PT services*	*Net change in passenger-km*
Brighton	8,547	-2,808	5,739
Cambridge	17,895	-5,536	12,359
Coventry	1,343	-674	669
Norwich	14,420	-17,133	-2,714*
Plymouth	8,186	-3,835	4,351
Reading	9,845	-5,844	4,001
Shrewsbury	27,590	-15,297	12,293
York	21,809	-16,234	5,575

** The negative value is correct, it is due to a high trip rate.*
Source: English Historic Towns Forum (1993).

12.5 Forecasting demand for new services

The methodology used for forecasting the impact of new services or new stations is very different to that used in for forecasting the effects of changes in rail fares or rail frequency. The framework for the latter is incremental, whilst for the former an approach that forecasts the absolute number of rail trips is required. The key parameters to be identified in forecasting demand for new rail services are the generating potential of the origin station and the attracting potential of the destination station, in addition to the generalised costs of travel between stations.

12.5.1 Forecasting models

Four modelling approaches are put forward in the PDFH:

- Trip rate models.
- Trip end models.
- Direct demand models.
- Mode choice models.

Trip Rate Models

These models are mainly used to forecast the demand associated with a new rail station. The models assume that rail demand is a function of the local population surrounding the new station and the forecasts are based on patronage at stations in 'similar' areas to the proposed new stadium. The methodology is simple but takes no account of the attractiveness of the destinations to be served. It is crucial therefore that the stations used to estimate trip rates are as similar as possible to the planned station. Some typical trip rates for new stations in various circumstances are outlined in Table 12.24.

Table 12.24 Typical trip rates for new stations in different circumstances

	Daily trips per thousand population: 0-800m from station	*Daily trips per thousand population: 800m -2km from station*	*% of popu -lation from beyond 2km*
Prime commuter belt on outskirts of urban centre	100	10	1
Village areas surrounding urban centre	25	6	20
Built-up areas close to urban centre	12	3	10
Free-standing town	10	3	40

Source: ATOC (2002)

Trip rates for new local rail services are shown in Table 12.25 and are based upon evidence taken from five new services. The services are low frequency (hourly) and the fares do not allow access onto other public transport modes. For areas such as London and PTEs these condition are unlikely and higher trip rates would be expected.

Table 12.25 Typical trip rates for new services in different circumstances

	Daily trips per thousand population within 2km of station
Inner suburban	10
Intermediate / industrial	15
Outer suburban	30

Source: ATOC, 2002

Trip end models

These models represent an improvement in the trip rate models with the consideration of other key explanatory variables. The PDFH quotes the example of a model developed for a route within Greater Manchester (Bury, Altrincham and Oldham/Rochdale services). The model took the following form:

$$V_i = 90.92\exp(0.00004P_i - 14.3SV_i$$
$$+0.0137RS_i - 0.0000024BS_i)$$

where:

V_i is the volume of rail travel from station i made by people walking to the station (daily boardings).
P_i is the usually resident population within 2

kilometres of station i, adjusting for overlapping station catchment areas.

SV_i is the proportion of population in social class V (head of household economically active and in an unskilled occupation. In 2000 only 2% of the population were in this category).

RS_i is the number of rail departures per day from station *i*.

BS_i is the number of bus departures on roads adjacent to station *i*.

It is noted that the since this model was developed (1987/88) regional rail demand has increased by 45% (2000/01). In order to uplift the forecasts by this amount the constant needs to be changed to 131.83. These types of models are context specific and the PDFH recommends that specialist advice is sought when developing them.

Gravity or direct demand model

These models combine the observed aspects of travel decision making (generation, distribution and mode choice) into a single direct model. The PDFH quotes a model that was developed for local services within West Yorkshire and based on data for around 100 flows for 1981/2. The model took the following form:

$$V_{ij} = 243.72 P1_i^{0.38} P2_i^{0.16} P1I/II_i^{0.02} D_j^{0.27} GTR_{ij}^{-1.24} GTO_{ij}^{-1.34}$$

Where:

V_{ij} is the number of single rail trips between *i* and *j* and between *j* and *i* on an average autumn weekday.

$P1_i$ is the usually resident population within a straight line distance of 800 metres of station i.

$P2_i$ is the usually resident population within a straight line distance of 800 metres and 2 kilometres of station i (adjusted for overlapping catchments).

$P1I/II_i$ is the proportion of population in $P1_i$ in social classes I and II (managerial and professional).

D_j is the number of workplaces within 800 metres of the destination station divided by the number of economically active residents.

GTR_{ij} is the Generalised Time of Rail (in minutes) = 2 (walk and wait time) + In-Vehicle Time + Fare/ Value of Time.

GTO_{ij} is the Generalised Time of Rail/(generalised time of rail + generalised time of Bus + Generalised Time of Car.

The growth in regional railways passengers between 1982 to 2000/01 (67%) means that the constant in the model should be increased to 407.01. Once again the PDFH recommends that specialist help is sought when developing such models.

Mode choice models

Most of these models take the form of a binary logit mode choice model that analyse separately choices between rail and bus and between rail and car. Other models examine the three modes simultaneously using hierarchical logit. The variables used within the modes typically consist of in-vehicle time, cost, access and egress time and service headway for each mode being examined. Whilst they take explicit account of accessibility to the rail network, they do not usually allow choices between stations and between access modes to change the overall demand for rail.

The main weaknesses of these models is their inability to account for newly generated trips (principally in the leisure market) and the necessity to possess estimates of demand levels by other modes on the flows for which rail forecasts are required. The PDFH does not recommend a specific set of parameters. Instead it recommends that a reasonably up-to-date model, estimated to broadly comparable circumstances, is used for forecasting.

The PDFH recommends that specialist advice is sought when constructing these models and that for large scale schemes (re-opening of a new line with several stations for example) a fresh mode choice study is conducted for the purpose of forecasting demand.

13 Effects of other transport policies

The aim of this chapter is to assess the impact of a range of transport policies not covered in detail elsewhere in this guide. We start by considering transport policy objectives which are broader than just focusing on demand issues. We then examine different transport policy instruments with respect to these objectives, before looking at the specific impact of these instruments on public transport demand.

13.1 The objectives of transport policies

There are a number of possible objectives of transport policies. The main objectives described by May (1997) are summarised below (but see also www.elsevier.com/gej-ng/29/29/Konsult to see how these objectives have been used in the knowledge base on Sustainable Urban Land Use and Transport, KonSULT).

Economic efficiency

This objective seeks to maximise net economic benefit. With respect to public transport, it is normally defined to consider revenue and costs to transport operators and the costs and travel times of transport users (including reliability). This definition assumes that there are no effects external to the transport sector. A wider definition would include the additional costs and benefits of environmental protection, safety, accessibility, economic regeneration, sustainability, equity and integration, many of which are considered below.

Environmental protection

This involves reducing the impact of transport facilities, and their use, on the environment of both users and non-users. Impacts of concern are listed in the Design Manual for Roads and Bridges and include noise, atmospheric pollution, vibration, visual intrusion, severance, fear and intimidation, and loss of valuable objects e.g. flora and fauna, monuments (Department of Transport, 1993). An updated list in the

New Approach to Appraisal highlights CO_2 emissions, local air quality, landscape, biodiversity, heritage and water (Price, 1999). It is often argued that public transport has environmental advantages over car based travel (see, for example, TEST, 1991 and CPT, 2002).

Safety
This considers reduction of loss of life, injuries and damage to property. Statistics indicate that public transport has safety advantages over car based transport. (CPT, 2002).

Accessibility
This can be defined as the ease of reaching facilities and can be contrasted with mobility which is the ease of movement. The New Approach to Appraisal highlights the role of access to public transport, community severance and the impact on pedestrians and others. Improved accessibility is often associated with the promotion of social inclusion. It is often argued that public transport has important benefits over car based travel in terms of accessibility. (CPT, 2002).

Sustainability
This can be defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It has become usual to consider sustainability, as consisting of three elements: economic, social, and environmental. As such sustainability might be thought of as a high level objective.

Economic regeneration
This might be seen as re-inforcing land-use plans of the area by promoting economic development in particular locations. In certain circumstances, improved transport provision may have benefits to the economy over and above those measured by the economic efficiency of the transport sector alone. This might be because transport improvements increase competition in imperfect markets, either for final products or for factors of production (particularly labour and land). Alternatively, transport improvements might promote economies of scale in production thus leading to reductions in production costs. The main impacts of public transport improvements are likely to be on the markets for labour and land. With respect to the latter, an important recent report is that of RICS Policy Unit (2002). In additional to objectives, it is also important to recognise the role of constraints.

Equity
This means ensuring that benefits are equally distributed or targeted to those with special needs. This may involve a social element, such as concessionary fares for the elderly and disabled, and/or a spatial element, such as subsidy for rural services.

Finance
Certain schemes may achieve policy objectives but are precluded because they require high levels of capital finance or on-going revenue support.

Practicability
Certain schemes may achieve policy objectives but may not be practicable because of lack of public support and/or technological barriers.

In the rest of this section, we examine five broad policy instruments (land-use planning, infrastructure provision, infrastructure management, information provision and pricing) with respect to four objectives (efficiency, environment, safety and accessibility) and three constraints (equity, finance and practicability). An illustrative assessment is based on a nine point scale but should not be taken as definitive. In particular, with assessments of this type there is a danger of double counting. For example, a reduction in public transport journey time may be seen as a benefit in terms of both economic efficiency and accessibility. More up-to-date assessments will be provided by the KONSULT database (see above).

These objectives can be pursued through a number of transport planning instruments:

Land-use measures
Most land-use measures are designed to encourage use of public transport, cycling and walking. Types of measure include: development densities, developments within transport corridors, development mix, travel reduction ordinances and parking standards (see also Section 11.3).

The possible impacts of land-use measures are shown in Table 13.1.

Infrastructure provision
This includes provision for the car e.g. new road construction, new car parks, provision for public transport e.g. conventional rail, guided bus, light rail, park and ride, provision for cyclists and pedestrians e.g. cycle routes, pedestrian areas, and provision for freight e.g. lorry parks, transhipment facilities, encouragement of other modes. Possible impacts are shown by Table 13.2.

Management of infrastructure
Provision for the car includes: conventional traffic management, urban traffic control, advanced transport telematics, accident remedial measures, traffic calming measures, physical restrictions on car use, regulatory restrictions on car use, parking controls, car sharing. Provision for public transport includes: bus priorities, high occupancy vehicle lanes, bus and rail service levels, bus service management measures. Provision for cyclists and pedestrians includes: cycle lanes and priorities, cycle parking, pedestrian crossing facilities. Provision for freight includes lorry routes and bans. Possible impacts are shown in Table 13.3.

Information provision
Provision for the car includes conventional direction signing, variable message signs, real-time driver information systems and route guidance, parking information systems, telecommunications, public awareness campaigns. Provision for public transport includes service information, real-time

Table 13.1 Performance of land use measures

Objective measure	*Efficiency*	*Environment*	*Safety*	*Accessibility*	*Equity*	*Finance*	*Practicability*	*Net*
Density	?	?	?	✓	0	0	×	0
Corridors	✓?	✓?	?	✓✓	0	0	×	✓✓
Mix	?	?	?	✓	0	0	×	0
Developer contributions	0	0	0	0	✓	✓	×	✓
Commuted payments	✓	0	0	0	✓	✓	×	✓✓
Travel reduction	?	?	?	?	0	0	××	××
Parking standards	✓	✓	?	✓/×	0	0	×	✓

Key

✓	✓✓	✓✓✓	*Positive impact on increasing scale.*
×	××	×××	*Negative impact on increasing scale.*
✓/×			*Both positive and negative impacts.*
?			*Uncertain impact.*
0			*No significant impact.*

Table 13.2 Performance of infrastructure measures

Objective measure	*Efficiency*	*Environment*	*Safety*	*Accessibility*	*Equity*	*Finance*	*Practicability*	*Net*
New roads	✓?	✓/x	✓✓	✓?	××	×××	×	×××
Parking supply	✓?	✓	✓	✓?	×	×	×	0
Rail	✓✓	✓✓	✓✓	✓✓	✓	××	××	✓✓✓✓✓
Light rail	✓✓	✓✓/×	✓✓	✓✓✓	✓	××	××	✓✓✓✓✓
Guided bus	✓?	✓?	✓	✓✓?	✓✓	×	×?	✓✓✓✓
Park and ride	✓	✓	✓	✓	0	×	0	✓✓✓
Terminals	✓/×	✓	✓	✓/×	0	××	×	×
Cycle routes	0	0	✓✓	✓	✓	×	0	✓✓✓
Pedestrian areas	×	✓✓/×	✓✓	××	✓	××	×	××
Lorry parks	0	✓	✓	0	0	×	0	✓
Trans-shipment	?	?	0	?	0	×?	××	××
Other freight modes	0	?	?	?	0	××	×××	×××××

Key: See Table 13.1.

Table 13.3 Performance of management measures

Objective measure	*Efficiency*	*Environment*	*Safety*	*Accessibility*	*Equity*	*Finance*	*Practicability*	*Net*
Traffic manage-ment	✓✓?	✓/×	✓✓	✓/×	✓/×	0	0	✓✓✓
Urban traffic control	✓✓	✓	✓	✓	0	××	0	✓✓✓
ATT	?	?	?	?	?	?	?	?
Accident remedial	0	0	✓✓✓	0	0	0	0	✓✓✓
Traffic calming	×	✓✓/×	✓✓	×?	✓/×	××	0	0
Physical restrictions	××?	×?	✓?	×?	?	0	×?	×××
Regulatory restrictions	✓?	✓✓	✓✓	✓✓/××	✓/×	×	××	✓
Parking controls	✓	✓	✓✓	✓/×	✓/×	0	×	✓✓✓✓
Car sharing	0	0	0	✓	0	0	×	0
Bus priorities	✓✓	?	✓	✓/×	✓	0	×	✓✓✓
HOV lanes	✓?	?	✓	✓/×	✓	0	×	✓
Service levels	✓	✓	✓	✓✓	✓	××	×	✓✓✓
Service manage-ment	✓✓	0	0	✓✓	✓	×	××	✓✓
Cycle lanes	0	0	✓✓	✓/×	✓	0	0	✓✓✓
Cycle parking	0	✓?	✓?	✓?	✓	0	0	✓
Pedestrian crossings	✓	?	✓✓	✓	✓	0	0	✓✓✓✓
Lorry routes, bans	×	✓/×	✓	×	✓/×	0	×	×××

Key: See Table 13.1.

passenger information, operation information systems. Provision for cyclists and pedestrians includes static direction signs, tactile paving. Provision for freight includes fleet management systems. Possible impacts are shown in Table 13.4.

Pricing

Provision for the car includes vehicle ownership taxes, fuel taxes, parking charges, congestion charging. Provision for public transport includes fare levels, fares structures, concessionary fares. These have been considered in Chapter 6. Table 13.5 shows the possible impacts.

13.2 Infrastructure management

13.2.1 Partnership between transport operators and public authorities

The bulk of this section draws heavily upon work carried out by ITS and TSU as part of a project currently in progress for the Department for Transport entitled Quality Bus Partnerships (QBPs) and Market Structure. One of the two key project aims is continually to monitor the development and performance of QBPs in the UK via a series of in-depth interviews with the relevant local authorities and operators and other parties involved. The second is to model QBPs under a number of different competition and market structure scenarios. Phases one and two of the project have been completed and along with the ongoing work by TAS (2000), who carry out a biennial survey of operators and local authorities for inclusion in their annual Bus Industry Monitor, they constitute the most up to date in-depth review of QBPs.

According to TAS (1997) QBPs can be defined as:

'An agreement (either formal or informal) between one or more local authorities and one or more bus operators for measures, to be taken up by more than one party to enhance bus services in a defined area.'

Typically, the local authority provides traffic management schemes, which assist bus services, while the bus operator offers better quality in various dimensions. The need for partnership stems from the fact that no one organisation has control over all the factors, which can improve the quality of bus service provision to the customer. For example, improvements to reliability will often be dependent on the implementation and enforcement of bus priority measures as well as ensuring the delivery of the scheduled bus service. Similarly maintenance, provision and quality of bus stops and traveller information may not be within the operators' control.

Previous studies have reported a large variety in the numbers of QBPs that exist ranging from two dozen (Hoban, 2000) to one hundred (Rye, 1999). This illustrates the problem that can exist if a definitive definition is not adopted. Many of the QBPs identified by Rye were very informal and in many cases were possibly uni-lateral, e.g. operators taking it upon themselves to introduce high quality rolling stock. To make the definition more precise TAS (1999) has outlined a number of principal elements that must exist in a QBP these are:

- The actions are designed to improve the attractiveness of bus use.
- There is agreement on the actions to be taken.
- 'Both sides' will be contributing in some way.
- The actions relate to a specific route or area.

Table 13.4 Performance of information measures

Objective measure	*Efficiency*	*Environment*	*Safety*	*Accessibility*	*Equity*	*Finance*	*Practicability*	*Net*
Direction signing	✓	0	?	0	0	×	0	0
Variable message signs	✓?	0	0	0	0	×	0	×
Driver information	✓?	0	0	✓	××	××	×	××××
Parking information	✓	?	?	✓	0	×	0	✓
Telecommunications	✓	✓✓	✓	0	0	×?	×?	✓✓✓
Public awareness	?	?	?	?	?	0	0	?
Timetables	✓	?	?	✓✓	✓✓	0	××	✓✓✓
Passenger information	✓	?	?	✓	✓	××	××	×
Operation information	✓✓	0	0	✓	✓	××	××	0
Fleet manage-ment	✓	0	0	✓	0	×	×	0

Key: See Table 13.1.

Table 13.5 Performance of pricing measures

Objective measure	*Efficiency*	*Environment*	*Safety*	*Accessibility*	*Equity*	*Finance*	*Practicability*	*Net*
Ownership taxes	×	×	0	0	✓	✓✓✓	0	✓✓
Fuel taxes	✓	✓✓	0	0	✓	✓✓✓	0	✓✓✓✓✓✓✓
Company car tax changes	✓✓	✓✓	✓✓	0	✓✓	✓✓	0	✓✓✓✓✓✓✓✓✓✓
Parking charges	✓?	✓?	✓?	✓/×	✓	✓	×	✓✓
Congestion charges	✓✓	✓✓	✓	✓✓/×	✓✓/×	✓✓✓	××	✓✓✓✓✓✓
Fare levels	✓	✓	✓	✓✓	✓✓	×××	×	✓✓✓
Fare structures	✓✓?	✓	✓	✓✓	✓✓	×	×	✓✓✓✓✓
Concessionary fares	0	0	0	✓	✓✓	××	0	✓

Key: See Table 13.1.

There is potentially a degree of tension between the Quality Partnership concept, at least in some applications, and competition law. Relevant legislation (Fair Trading Act, 1973, Restrictive Trade Practices Act, 1976 and the Competition Act, 1980) severely restricts the freedom of operators to co-operate with one another (Mackie and Preston, 1996). A report for the Office for Fair Trading (1997) provides a useful review of the effectiveness of regulatory policy towards the bus industry. The new Competition Act (1998) has clear criteria for the exemption of individual and block agreements. These must either improve production or distribution or promote technical or economic progress. Agreements must not 'impose on the undertakings concerned restrictions which are not indispensable to the attainment of these objectives or afford the undertakings concerned the possibility of eliminating competition in respect of a substantial part of the products in question' – Clause 9. Some of these tensions were meant to be rectified by the 2000 Transport Act which made provisions for statutory partnerships. However, at the time of writing there is only one statutory partnership in existence (in Birmingham). The vast majority of partnerships are informal agreements.

The first phase of the Department for Transport project included a series of interviews with the QBP partners in six case study areas. The interviews were designed to be factual in terms of identifying the financial and physical inputs and outputs (Table 13.6), organisational in terms of the organisation of QBPs (Table 13.7) and subjective (did the partners deem them a success etc).

The findings from the six case studies were brought together in the phase one report (Institute for Transport Studies and Transport Studies Unit, 2000). The key findings are summarised below:

- There is a clear preference for voluntary partnerships. It is felt that voluntary QBPs have improved relationships and enhance understanding between local authorities and operators.

Table 13.6 Quality bus partnership inputs and outputs

Inputs	Outputs
1 *Traffic Priority* – bus lanes, signal priority, bus gates, bus only roads & allowed manoeuvres, pre signals, guideways, automatic vehicle location etc.	1 Journey times. 2 Service frequencies. 3 Reliability.
2 *Information & Promotional Measures* – real time passenger info., roadside displays, joint promotional campaign, route branding etc.	4 Traveller information. 5 Comfort/accessibility. 6 Fares/interavailability.
3 *Passenger Infrastructure* – signage, shelters, at-stop facilities, interchange improvements, raised kerbs, improved pedestrian access to stops etc.	7 Entry/exit. 8 Tender market.
4 *Vehicles & Quality* – new buses, low floor, low emission standards, alternative fuels etc.	
5 *Service, Fares & Tickets* – enhanced frequency, operational standards, service & fare simplification, new ticket products etc.	

Source: Adapted from TAS (1999).

Table 13.7 Organisational features of quality bus partnerships

Organisational features
1 Parties to the partnership.
2 Period covered.
3 Status of the agreement – formal, informal etc.
4 Area the QBP is applicable to – route, area, project specific or a wider strategy.
5 Funding requirements & arrangements.

Source: Adapted from TAS (1999)

- QBPs are setting new standards for the industry.
- QBPs have encouraged bus operators to target their investment strategies and operators have contributed to infrastructure investment.
- QBPs have led to patronage growth, usually in an otherwise declining market. However, identifying the reasons for growth is difficult given a lack of detailed survey work.
- Leadership and effective project management are seen as critical to the success of QBPs. The ability to bid for management resources within the Local Transport Plan would be welcome.
- Marketing is seen as a key factor in achieving patronage growth.
- QBPs occur in conditions of mature competition, normally with one or two dominant operators.
- QBPs have been subject to limited, short-run competition in certain areas.
- There are widespread problems with enforcement of bus priorities. Although efforts have been made to include police forces, they are very much a 'missing' partner. Decriminalisation of parking offences is seen as only a partial solution, while moving offences remain the exclusive domain of the police. It is felt that the police do not have any incentive to prioritise the enforcement of bus priorities.
- A constraint on the further development of QBPs is the position of the OFT on competition in the bus industry. Further integration of services and ticketing will not occur while operators perceive the threat of legal action.

Evidence on changes in patronage was presented by Mackie (2000) in a paper given to a workshop on London's Bus Contracting Regime. The performance appears to be impressive if one considers the national backdrop of falling bus patronage (with the exception of London). The percentage rise in patronage differs across QBPs, a reflection of the different features and background trends of each QBP. For example, two of the most ambitious schemes, Line 33 and Scott Hall Road have enjoyed the largest patronage growths. Other schemes such as Brighton have been assisted by increasing population density in the city centre and parking constraints. In fact all the schemes presented in the table are located in prime bus markets, reducing the investment risks to each party (Table 13.8).

Table 13.8 Estimates of patronage change in QBPs and associated features

Quality bus partnership	*% Change in patronage*	*Time period*	*Explanatory notes*	*Associated features*
Leeds – Scott Hall Road	+60% *	1995-99	In the context of a decline city wide.	Segregated bus way; bus lanes; traffic prioritymeasures; new low floor buses; route branding; increased service frequency; increased information and publicity; driver training.
Nottinghamshire Calverton Connection	+29%	1st year.	+48% since inception in 1998.	Bus lanes; new buses; increased service frequency; driver training; route branding.
West Midlands: Line 33 (Birmingham) Bloxwich (Walsall) Primeline (Coventry)	 +30% +18% +5%	 1996-97 1998-99 91998-99	 There has also been a +8% increase on the Bloxwich corridor.	 Line 33 – Traffic priority measures; bus lanes; real time information; new low floor branding; increased passenger information and publicity; increased service frequency; driver training.Bloxwich – Bus lanes; improved passenger infrastructure; new low floor buses; increased passenger information and publicity; driver training.Primeline – Bus lanes; improved passenger infrastructure; new low floor buses; increased passenger information and publicity; driver training.
Edinburgh Greenways	+12% (First) +7% (LRT)	August 1997 onwards.	LRT increase is set against a 3% network decline.	Traffic priorities; bus lanes (greenways); increased passenger information and publicity; improved passenger infrastructure.
Cheltenham Route 2	+5%	September 1998 onwards.	In context of a 1% network decline.	Traffic priorities; bus lanes; new buses; improved passenger infrastructure – note not all of features are in place as yet.
Brighton	+5%	Per annum from 1995 onwards.		Increased passenger information and publicity; improved passenger infrastructure; new vehicles (some low floor); driver training; increased frequencies; route branding.

Source: Mackie (2000).

** Note that this figure is contested. Daugherty and Balcombe (1999) only found a demand uplift of around 6%.*

In total, Mackie (2000) finds that QBPs can increase bus usage on average by 22%, but with a range of 5% to 60%. These results are consistent with later work by LEK Consulting (2002) which found eleven urban QBP schemes had an average uplift on bus demand of 21% with a range from 4% to 92%. CPT (2002) examined seventeen examples of quality improvements with a mean passenger uplift of 33% (with a range from 10% to 72% - see Appendix to Chapter 9).

Knowles (1999) found low cost QBPs only increased demand by between 5% and 8%. Comprehensive conventional upgrade led to increase of demand of between 10% and 30%, whilst major upgrades with some guideway could increase demand by over 40%. Of the eleven schemes analysed by Knowles, the average patronage uplift was found to be 20%.

13.2.2 Restricted access zones

United Kingdom examples of restricted access zones include the Nottingham zones and collar scheme and the Cambridge Core scheme. The Nottingham scheme attempted to discourage traffic entering the centre of Nottingham through signal delays. Signals at all junctions around the central area were set with long wait times and short go times for traffic entering the area. The scheme ran between 1975 and 1976. No significant changes were observed in the mode of transport used by residents and use of the park and ride scheme provided for visitors to the city was low (Cairns *et al.,* 1998).

The Cambridge core scheme has gradually restricted its central area to traffic by closure of three through routes. Phase 1 (closure of Magdalene St., Bridge St., and Jesus Lane) was implemented in January 1997. WS Atkins carried out before and after surveys of traffic counts, journey speeds and journey times in June/July 1996 and 1997 (Cairns *et al.,* 1998). Traffic within the city fell by approximately 10%, and by 44-48% along the affected route. Traffic on the ring road increased by 10%. A modelling exercise carried out using SATURN to forecast the impacts of the scheme suggested a 3-10% reduction in traffic in the central area.

In Oxford bus patronage has increased over the last 10 years by 40% (Cairns *et al.,* 1998). However, Oxford has implemented a mixture of policies ranging from the closure to traffic of several streets within the centre, parking restrictions and introduction of bus lanes and park and ride.

Rome introduced a limited access zone (LTZ) in 1994 in combination with parking fees (Sta spa, 2000). Residents of the LTZ were given free permits to both move and park within the zone. Authorised non-residents have been required to pay for permits since 1998. In 2001 approximately 70,000 permits were distributed (30% to residents, 30% to non-residents, 30% to disabled, and 10% to freight vehicles). Public transport use has declined between 1996 and 1999. The rate of decrease in suburban and peripheral areas was 20%, whilst only 10% for trips to/from the centre.

In September 1982 traffic restraint was introduced into central Athens. Private cars were banned from the city centre. Buses, shared taxis and motorcycles were permitted to use the restricted zone. This was accompanied by an 'alternate day' policy on car use within the central area. Odd and even number plates were permitted to enter the area on alternate days. The restriction was in force Monday to Friday 6.30 to 16.00, but was lifted for major holidays and during the summer months. Initially commuters moved to public transport modes and use of shared taxis. After one year of operation, traffic was banned totally from the inner ring, and the alternate day restriction zone was expanded outwards to cover a wider area. In 1984, bus journey times were found to have reduced by 6.2% in the morning peak, 7.1% for outbound journeys in the afternoon peak and by 1.7% off-peak. A small change was observed in bus use – a maximum increase of 5%, with bus use in the inner area making up 8.8% of mode share before the introduction of the scheme and 9.0% in 1984. Most of the displaced car journeys moved to shared taxi or motorcycle.

Other European schemes include Bologna, which introduced a traffic-limited zone in 1972. This resulted in an increase in bus patronage of between 38% and 66% depending on the route and bus speed increases of between 15 and 20%. However, the zone was implemented alongside associated parking restrictions, park and ride facilities and public transport improvements (Cairns *et al.*, 1998).

13.2.3 Road space reallocation

Road space reallocation involves changes to the types of transportation activities that can use the road space. Road space reallocation may be undertaken to smooth the flow of specific modes such as bus priority lanes, cycle lanes and HOV lanes; to improve the quality and safety of the local environment (e.g. pedestrian improvements, traffic calming). It has also been suggested that road space reallocation can be used as a traffic reduction measure. Not all the displaced traffic will divert to neighbouring streets. Other possible responses include changing mode, changing destination, trip chaining, changing journey time, not making the trip or making the trip less frequently.

Cairns *et al.* (2002) examined the evidence from a number of case studies where roadspace had been reallocated, for a variety of planned permanent, planned temporary and unplanned reasons. They found vehicle flows changed by between +25% and -146%. In some cases traffic disappeared both from the altered route but also from the alternative routes. This may be a result of the cumulative effect of a number of traffic policies. The median reduction was 10.9% (mean = 21.9%).

Evidence from Chapter 9 suggests that in urban areas over 70% of this suppressed demand might switch to public transport, reducing to 50% for inter urban travel. In both cases, these abstraction rates are net of re-routing and re-timing effects.

13.2.4 High Occupancy Vehicle lanes

High occupancy vehicle (HOV) lanes restrict traffic using these lanes to vehicles with an occupancy of two or more (in some cases higher). Some HOV schemes allow single occupancy vehicles to use the HOV lanes on payment of a toll; these are sometimes referred to as high occupancy toll (HOT) lanes. High occupancy vehicle lanes can affect public transport in several ways:

1 Increase traffic speeds, giving improved journey times and thus reduced generalised costs of travel by public transport compared with single occupancy vehicles, which could result in increased patronage.

2 In order to be able to make use of the HOV lanes, car drivers may offer lifts to people who previously used public transport. The extent to which this will occur will depend on the time savings available from using the HOV lane compared with the delay incurred in stopping to pick up passengers.

A study conducted by the University of Pennsylvania (Vukic, 1995) comparing different lane priority configurations found that bus patronage increased the most when a lane on a road without HOV or transit priority lanes, was converted for exclusive bus use. The worst-case scenario for public transport was to add a HOV lane on a route which already had a bus only lane. This finding is supported by evidence from the El Monte busway in Los Angeles. The El Monte busway was opened in 1973 for transit only. It was later opened additionally to carpools (3 plus persons). Although the additional vehicles using the lane have not had an adverse effect on the running time of the buses, ridership levels have declined (Silver, 1995). Silver attributes this to the price of parking, length of commute and other factors which have made carpooling more attractive to many commuters than taking the bus.

UK experience of HOV lanes is limited. Evidence from the introduction of a HOV lane during peak hours on a section of the A647 in Leeds suggests a slight increase in bus patronage 5 months after the scheme was introduced (Leeds City Council, 1999). The number of scheduled buses running in the morning peak has also increased.

13.2.5. Bus priority measures

Slinn (1993) lists the following bus priority measures:

- With flow bus lanes.
- Contraflow bus lanes.
- Busways.
- Bus only roads.
- Selected banned turns.
- Oneway streets/street closures.
- Signal rephasing (passive priority).
- Selective vehicle detection at signals (active priority).
- Queue relocation.
- Pre-signals advance bus areas.
- Waiting and loading restrictions/priority route treatment (e.g. Red routes).
- Bus stop treatments/bus boarders.

Introducing a bus priority scheme in north east London (Route 43) along with a red route scheme, which aims to keep traffic moving by restricting parking and stopping, resulted in journey time savings and improvements in reliability of Route 43. Patronage on the route increased by 8.8% to 8700 passenger journeys per week (Thompson, 1993). Over the same period London-wide bus patronage decreased by 2%.

Daugherty *et al.* (1999) examined a number of bus priority schemes including Aberdeen and Brighton. They found no correlation between the bus priority scheme length and bus journey timesavings. The savings were more likely to depend on the number and severity of the bottlenecks along the length of the scheme, rather than the overall scheme length. The patronage data Daugherty *et al.* managed to obtain was 'sketchy', so the authors were unable to draw any definite conclusions (but see also Chapter 7). However, the journey time improvements achieved by the schemes reviewed were of less than 5 minutes, which is small compared with overall journey times. Therefore, the authors felt that bus priority schemes would have limited impact on bus patronage levels. However, perception maybe important; the image of a bus overtaking queuing traffic may help stem or reverse a declining patronage. For example, the Brighton scheme resulted in a 16% increase in patronage as a result of a combination of things: the introduction of a flat fare, the enhanced image of the buses and priority measures. The Aberdeen scheme generated a 1.4% increase in patronage, from a combination of new travellers and increased trip rates of previous travellers. However, this figure has a wide margin of error due to the small sample size, i.e. one can be 95% confident of a true patronage increase of between 0.5% and 4.5%.

Other studies give higher trip generation values still. During the first year of operation super route 66 in Ipswich saw a 20% increase in bus services along the corridor. The route includes 200m of guided busway and a number of other bus priority measures including a bus gate which permitted more direct routing through a large residential area. The project also included promotion of the super route and new buses (Handsley and Butterwick, 1999). By the fourth year of operation passenger numbers were 75% above those of the first year of operation.

13.3 Employer subsidies

In the US there is a growing trend to try and persuade employers to subsidise their employees' use of public transport, just as they do private transport, and in both Britain and the US there have been moves to try and restrict employer subsidisation of private transport. In 1992 the National Energy Policy Act restricted US employers to a maximum of $155 in parking subsidies. In New York alone employees were getting free parking worth an average of $200 a year.

One method for encouraging employer subsidisation of public transport use is the provision of environmental travelcards, such as RTD Denver's Eco Pass, (Trommer *et al.*, 1995) an environmental travelcard purchased by employers on behalf of their employees. There is a group discount varying with the number of passes purchased in a manner similar to health insurance. It is up to the employers whether they then charge their employees for the pass; they may charge from nothing up to the full cost of the pass.

Another, more popular method, for encouraging employer subsidisation of public transport use, especially among smaller employers for whom a pass from a specific operator is both prohibitively expensive, and not really suitable, is a scheme such as TransitChek, (US Department of Transportation, 1995), where the employer purchases vouchers from the appropriate organisation (TransitCentre in New York, DVRPC (Delaware Valley Regional Planning Commission) in Philadelphia), which they pass on to their employee's as a tax free-benefit (neither employer or employee pays any tax on it. The employer may give the vouchers to all employees with their payslips, or only to those that sign-up for it (some employers offer a choice between subsidised parking and TransitCheck), or as a bonus or reward for good performance or attendance. TransitChek type options have only become a realistic possibility in the United States since the 1984 Deficit Reduction Act, which allowed employers to provide vouchers towards the cost of travel up to $15 month ($180 a year) as a de minimus fringe benefit (that is one that is too small to warrant taxation or associated record keeping). Cost of living expenses meant this allowance was increased from 1 July 1991 to $21 a month ($252 a year), and The National Energy Policy Act increased it to $60 a month ($720 a year) from 1 January 1993. The employee then uses the vouchers towards the cost of purchasing a pre-paid ticket or tokens for their commuting travel. The employer has some choice over the value of the vouchers they distribute monthly (ranging from around $15 to $60 a month). The schemes are generally too small as yet to have had a big impact on ridership overall, but they seem to be fairly popular with employees and in participating firms can go a long way towards reducing commuting by car. For example a survey among participating companies in Philadelphia found that before TransitChek was introduced 73.7% of employees used public transport, 20.3% drove alone and 3.9% drove with others. Afterwards 98.7% used public transport, 0.4% drove alone, and 0.6% drove with others.

Travel vouchers have been investigated as a way of reducing fares in Great Britain. Root (1999) speculates, on the basis of surveys in Oxfordshire, that the take-up of travel vouchers might be 3.6% of the population in urban areas but 7.2% of the population in rural areas. She notes that research in the United States suggests such vouchers can increase public transport usage by between 30% and 50%. This might suggest such a scheme could increase bus use for the journey to work by around 3% in rural areas.

13.4 Congestion charging

The idea of congestion charging has gained increasing popularity over the past decade because of growing environmental pressures to curb greenhouse gas emissions and improve local air quality, as well as economic pressures to reduce congestion; whilst the availability of key new technologies (such as smart-cards) has enabled such schemes to be implemented efficiently and effectively. It has been shown to be particularly effective where the revenue generated is ploughed back into further improvements to the public transport system. Singapore has been operating such a scheme since 1975.

During the early 1990s Norway implemented urban road pricing schemes in several of its cities: Bergen, Trondheim and Oslo – charging for access to central areas, although the official justification for the Oslo scheme was not to restrain traffic but to generate revenue to pay for major road investments (Hall, 1995). In Sweden, a toll ring was proposed for Stockholm as part of a package of transport measures – the 'Dennis Traffic Agreement' (Tegnér, 1994). The scheme was to help finance new transport infrastructure as well as restrain traffic in the inner city. (This scheme was eventually abandoned for political reasons).

The UK Government is now following suit, and introduced legislation to allow local transport authorities to charge for road use and commercial car parking space in order to reduce city centre congestion. The recent Transport Acts for England and Wales and for Scotland give local authorities the power to introduce congestion charging, while the Greater London Authority Act 1999 grants similar powers to the mayor.

There are two basic variations of road user charging: route-based schemes – charging for use of individual stretches of road; and zone-base schemes – charging users to enter a bounded zone.

13.4.1 Route based schemes

Route-based schemes involve charging tolls for the use of individual stretches of road and have already been implemented in the UK as a way of recouping construction costs for some bridges and tunnels. Until recently tolls have only been set for short stretches of the network and where alternative no-pay routes are available. The new West Midlands' Northern Relief Road is a toll-route, with charges aimed at both recouping construction costs and ensuring a free flowing route around the West Midlands. The M1-M6 route around the conurbation remains free of charge.

UK empirical evidence on the effects of road tolls on travel behaviour is limited. There have been two pilot studies (Leicester and Bristol) both aimed at reducing congestion and improving the environmental quality of the cities involved (Crawford, 1998). In the Leicester trials, which ran from August 1997 to May 1998, users were charged for time using the A47, a main arterial route into the centre of Leicester, during peak hours. The charging pilot was accompanied by the opening of a park and ride scheme on the A47 corridor and bus improvements. The toll for using the route was varied from £2 to £10 (Ingrey and Fouracre, 1999). On average (for all charge levels) 2% of participants changed from using the car to the bus, 15% shifted from the car to park and ride, 25% changed their route and 13% changed the time at which they travelled. The numbers changing their travel behaviour varied according to the charge level. For example, at a toll of £2 to £3 18% of participants in the trial changed route; this increased to 38% when the toll was raised to £10.

Trials in Stuttgart (Ingrey and Fouracre, 1999) of both corridor and cordon tolls found that a route-based scheme performed better in terms of reducing traffic levels. This was mainly due to the pricing scheme; once a user had paid to cross the cordon subsequent trips within the cordon were not influenced by the pricing scheme. A maximum of 5% of all trips transferred to public transport under the various scenarios trialled. However, each scenario was only piloted for two months, so medium to long-term effects were not realised within the trial period.

A trial charging car users to use a corridor in the suburbs of Florence, resulted in similar levels of mode shift to the two examples given above, with 5% of car users changing to public transport to avoid paying the tolls (*op. cit.*).

A recent report by the Commission for Integrated Transport (CfIT, 2002b) recommends that a national road charging scheme be implemented, with differential rates based on congestion levels. Charges would be distance-based. It was estimated that such a scheme would lead to 20% traffic reductions in central London, traffic reductions of around 12% in outer London and the metropolitan conurbations (e.g. Birmingham) and around 8% in cities such as Leicester. Traffic levels on motorways and rural areas would reduce by less than 3%.

13.4.2 Zone based schemes

There are two main variants of zone-based schemes – (1) cordon toll schemes where road users are charged to cross the zone boundary, in either one or both directions; and (2) area licensing schemes, where users purchase a licence to move within the zone. Zone based schemes can be implemented either through the display of a disc in the car window to show eligibility to enter a zone or through smart cards activated every time the car crosses the zone boundary. The London area licensing scheme implemented in February 2003 works by comparing licence plates of vehicles photographed inside the zone with a registry of vehicles that have either paid to enter the zone or are exempt from the charges.

13.4.3 Modelling studies – UK

There has been some research on the effectiveness of road charging schemes in reducing traffic and on the optimal price level to obtain maximum traffic reduction with minimum economic impact (e.g. Liu and McDonald, 1999). Most of this research has been conducted with the use of transport models employing price elasticities to determine the extent of modal switching, trip reduction and changes in destination choice. In many of the studies the effect of congestion charging is difficult to isolate as it was modelled as part of a package of transport improvements.

The MVA (1995) study on congestion charging for London is one exception. A variety of different cordon-based charging schemes with different prices for inbound and outbound traffic at different times of day were modelled. No road or public transport improvements were included. Bus trips were estimated to increase by between 1.2% and 10.1% over the base, depending on the scheme and the level of charging. Most schemes were modelled with low, medium and high levels of charging equating roughly to £2, £4 and £8 charges. The smallest increase in patronage was as a result of a scheme that charged for crossing a central London cordon in either direction, with charges ranging from 0p to £1.00 depending on the direction and time of day. The largest increase in patronage resulted from a two cordon scheme, with an additional charge for crossing a screenline of the Thames. Motorist incurred an £8 charge for entering the central London cordon and a £4 charge for crossing the Inner London cordon in peak hours. Patronage changes for rail ranged from -0.1% to 4.2%

The MVA study used an equilibrium model based on the MEPLAN-LASER model for the south east. The number of rail services was assumed to be fixed, whilst for buses the occupancy rate was assumed constant, with more buses being laid on to cope with any increase in patronage. To avoid the virtuous circle of increased services leading to decreased wait times and thus a further increase in demand, an increase in the number of buses was assumed not to affect service frequency. Buses were assumed to run in convoy. Sensitivity analysis suggests that the model tended to slightly underestimate bus patronage as a result of these assumptions.

More recently, the ROCOL (2000) report on road charging options for London, modelled the effect of introducing an £5 area licensing scheme for the central area of the capital. With no public transport improvements, public transport patronage increased by 7% during the morning peak. This was composed of a 3% increase in rail patronage, 1% increase in underground use and a 2% increase in bus use.

Cooper *et al.* (2001) used a traditional four-stage transport model to test a variety of different transport policy scenarios for Belfast, several of which included the introduction of a toll cordon. One of the scenarios modelled the impact of the toll cordon if introduced unaccompanied by supporting land use and transport infrastructure improvements. This resulted in a 6% increase in transit passenger mileage compared with the do-nothing scenario. When the toll cordon was combined with densification along major transport routes and implementation of a number of high-quality public transport schemes, it resulted in a reduction in transit passenger mileage. With the addition of a city-centre parking levy, public transport passenger mileage rose by 12% compared with the do-nothing case.

13.4.4 Modelling studies – international

A study (Johansson and Mattsson, 1995) of the effect of implementing the Dennis Agreement in Stockholm, which included increased rail track capacity, construction of a light rail scheme and bus service improvements; as well as completion of a ring road. The charging scheme was to take the form of a toll ring, with traffic charged for using the ring road or entering into inner Stockholm. A network-based equilibrium model (EMME/2) was used. The study found that under conditions of moderate economic growth the number of trips made during the morning peak by public transport increased by 8% over 1990 levels. In the reference case (no road tolls and only a modicum of public transport improvements), public transport trips increased by 6%.

As already noted in Section 13.2.2, Rome introduced a limited access zone (LTZ) in 1994 in combination with parking fees (Sta spa, 2000). The city is considering implementing road pricing for the LTZ. In preparation for this several different road pricing schemes have been modelled, including road pricing replacing access restriction, charging residents an annual fee, and charging moped users. Most of the scenarios also considered some public transport improvements. The largest increase in public transport use was as a result of introducing a charge for mopeds. 10% of car users switched to public transport when a per trip fee of €3 rather than current flat annual fee of €300 was charged. The amount of switching doubled when the per trip fee doubled. Seven percent of residents switched to public transport when a €300 residents annual fee was introduced – currently residents are exempt from any fees. Sta spa found that if road pricing is to replace the access restrictions, €32 would need to be charged to achieve the same mode split of 20% public transport.

Oslo is also considering moving from an urban toll to congestion pricing (Sorlie, 2002) when the 15 year toll period ceases. The Municipality of Oslo has undertaken a study focussed on the design of the charging system. The assumption was that the present toll ring is kept. One of the systems modelled as part of the study involved charging an increased toll during the morning and evening peaks (over double the current rate). The between-peak period would be charged for at the current rate, and during low-traffic periods the charge would be zero. It was assumed that public transport capacity would be increased to handle more traffic. This scenario resulted in an increase in the annual demand for public transport of 9.7% during the morning peak, 10.5% during the evening peak, 3% between peaks and -0.6% during low-traffic periods; giving a total annual increase of 5.3%.

Calthrop *et al.* (2000) modelled a series of congestion charging/parking tax options for Brussels. They found that introducing a cordon toll to enter the CBD would increase the share of peak hour trips made by public transport from 20% to 24%, with no discernable effect on off-peak trips.

13.4.5 Before and after studies

There is little UK evidence of the effect of congestion charging on mode split. Durham’s cordon-based scheme with a £2 entry fee to the penisula section of the city has reduced traffic by 90% (Parking Review, 2002). In London, six months after the introduction of the cordon charge, the number of motor vehicles entering the zone during charging times has dropped by 16%, and traffic delays due to congestion have fallen by around 30%. Bus capacity has been increased to accommodate 15,000 extra bus passengers travelling to the zone in the morning peak period (Transport for London, 2003). Otherwise there have been a few trial route-based schemes. However, as already mentioned there are a number of schemes internationally that are in operation.

Ramjerdi (1995) estimates that the Oslo cordon toll scheme resulted in a growth in public transport patronage of 5%. This estimate was based on a before-and-after study; the before study took place in October/November 1989, and the follow up study a year later. The toll scheme came into force in February 1990. The results of the survey showed a 6% decrease in the number of public transport trips reported. However, the survey as a whole showed an 11% decrease in trips. Ramjerdi suggests that the reduction in trips was a result of significant under-reporting in the second survey. In addition the results are likely to be affected by a period of recession that had been affecting the region since 1987, producing downward trends in employment, petrol sales and car ownership. There were also reductions in the levels of various car travel subsidies between the 1989 and 1990 surveys. Ramjerdi compared her results with those from two other studies on the Oslo toll scheme, which reported a 0% increase in public transport trips between Apr 1990 and April 1991, and a 0% to 3% increase in public transport use based on ticket sales (Vibe, 1991; Nordheim and Sælensminde, 1991; both cited in Ramjerdi, 1995).

Ramjerdi went on to estimate mode choice elasticities with respect to toll costs for different travel purposes using logit models (Table 13.9).

Table 13.9 Public Transport choice elasticities with respect to toll costs

	All journeys	*Journeys crossing toll cordon*
Journey to work	0.03	0.04
Other travel purposes	0.02	0.05

Source: Ramjerdi (1995).
[Compare with cross elasticities in Chapter 8]

Introducing peak period entry fees in central Milan, resulted in a 50% reduction in peak period car trips into the city centre. Forty-six percent of those drivers switched to using public transport (Orski, 1992).

The Singapore area licensing scheme was introduced in 1975, initially only charging for entry into the restricted zone during the morning peak. Chin (1996) reports that the journey to work mode split before the scheme was introduced was 56% car, 33% bus; afterwards this changed to 46% for both modes. This change was not duplicated in the evening peak. One of the reasons for this was that the cars that were left at home in the morning were being used by other household members to pick up individuals from the central area at the end of the working day.

13.5 Parking

There are a number of ways in which parking policy could be used as a traffic demand management tool. These include limiting the number of available spaces, increasing the price paid for parking and changing the mix of short and long term parking spaces available.

Kuzmyak and Schreffler (1990) found, from an analysis of 9 US cities, that parking fees and restrictions were the most effective components of the cities' adopted traffic management schemes. A study of workplace parking provision in the East Midlands (Valleley *et al.*, 1997) found that parking cost and availability at the workplace clearly influenced mode choice of employees. Employees were surveyed from 37 organisations across the region. Of the 100 respondents who travelled to work by bus, 65% said that the cost of parking or lack of available space was the main reason for using the bus.

However, parking policies are not always effective traffic demand management tools. Strict enforcement is required as the tendency for evasion is high (Button, 1993).

13.5.1 Restriction of parking space

McSheen and Tweedale (1993) investigated the effect of a parking restraint policy for St. Albans using the SATURN model with elastic assignment of trips, based on responses from 350 stated preference questionnaires from city centre employees who drive to work. The traffic management policy modelled included reduced levels of offstreet parking through planning permissions – resulting in a rise from 33% of commuters without a private parking space provided to 40-45% of total commuter demand. The policy modelled also included provision of 5 park and ride sites, and improvement of bus services along four corridors leading into the town centre. Between 475 and 495 morning peak trips were transferred to bus in the short term (1996), rising to 540-620 trips in the long term (2006).

13.5.2 Parking pricing

TRACE (1999) provides detailed cross-elasticity estimates between parking price and public transport demand for various trip purpose, based on numerous European studies. The key finding is summarised in Table 13.10.

Table 13.10 Cross-elasticity between parking price and demand for public transport

Journey purpose	*Number of trips*	*Kilometres*
Commuting	+0.02	+0.01
Business	+0.01	+0.00
Education	+0.00	+0.00
Other	+0.04	+0.02
Total	+0.02	+0.01

Source: TRACE (1999), Table 8 and Table 9.

Clark and Allsop (1993) estimated the effect of the workplace parking charges on mode split using a logit model based on data from a stated preference survey of staff at a central London university site. Introducing a daily rate which guaranteed a parking space, as opposed to the system in place of a £10 annual fee but with no space guarantee, would reduce the demand for parking bays and increase public transport use (Table 13.11).

Table 13.11 Mode split and parking bay demand elasticities with respect to parking costs

Daily rate	*Car (%)*	*Public transport (%)*	*Demand for parking*	*Demand elasticity*
50p	62	38	144	-0.13
£2.50	40	60	93	-1.00
£4.50	20	80	46	-2.40
£9.50	1	99	3	-6.22

Source: Clark and Allsop (1993).

Shoup and Willson (1992) estimated the cross-elasticity between the price of parking and the demand for public transport to be 0.35. This was estimated using a multinomial logit model of employees travel behaviour in Los Angeles central business district.

Shoup (1997) has examined 'cashing-out' parking provision in California. This is a legal requirement for large employers (50 employees plus) to offer employees the option of a cash payment in lieu of subsidised parking spaces. The legislation, in existence since 1992, only applies to areas which fail to meet clean air standards. Case studies of large employers found that the number of solo drivers fell by 17% and transit ridership increased by 50%.

Miller and Everett (1982) found that introducing parking charges for government employees in Ottawa, Canada at 70% of commercial rates resulted in a 7% shift from car to transit. Similarly for Federal sites in Washington USA, introducing or increasing parking charges to a level approximately half that of commercial rates, resulted in between -3 to 11% switching to public transport. This compares with a 0 to 6% reduction for sites where parking charges were not increased. The level of change was dependent on the locality of the site, availability of alternatives to the car and the amount of street parking available. Higgins (1992) found that parking price accounted for up to 80% of the variation in employee mode split between six hospitals in San Francisco. In Los Angeles, the percent of employees for a computer company driving alone to work fell from 42% to just 8% after free employee parking was eliminated (Higgins, 1992).

Matsoukis (1993) carried out a before-and-after comparison of parking pricing policy in Patras. The implemented policy set up different zones within the city centre for no parking, short stay and long stay parking. Unfortunately no public transport data were collected but parking densities (average number of parked cars) dropped by 25% in the morning peak and 17% in the evening peak. The number of people parking for shopping dropped by 25%, whilst number of people parking for work has dropped by 45%. Traffic flows in main corridors have eased, with number of delays reduced. Public transport movements also been made easier due to reduced numbers of turning vehicles at urban intersections.

VTPI (2001) have collated evidence from a number of studies in North America to assess the impact of parking charges on commuter car trips. Some key results are shown by Table 13.12. this suggests that, for example, introduction of a parking charge of $1.30 in a low density suburb will reduce commute vehicle trips by 6.5%. Evidence from Chapter 9 suggests that up to 70% of this suppressed demand might be abstracted by public transport. This would suggest an increase in transit share from 7% to 11.6%. However, in this instance we suspect that the public transport abstraction rate might be too high as it fails to take into account rideshare as an alternative. Table 13.12 assumes that rideshare has a similar base share of commuter trips as transit.

Table 13.12 Reduction in commuter car vehicle trips as a result of parking charges

		% Reduction in vehicle trips if parking charge				
	Transit share	*$0*	*$1.30*	*$2.60*	*$4.00*	*$5.20*
Low density suburb	7%	0.0	6.5	15.1	25.3	36.1
Activity centre	16%	0.0	12.3	25.1	37.0	46.8
Regional CBD/corridor	30%	0.0	17.5	31.8	42.6	50.0

Source: Comsis (1993), VTPI (2001).

13.5.3 Parking levies

Local transport authorities in England and Wales have the power to tax employers for commercial car parking space provision through the workplace parking levy. The levy became law through the Transport Act 2000 (no similar powers exist in Scotland). Introducing a workplace-parking levy should reduce the number of employee parking spaces provided by employers, discouraging car use and thus reduce city centre congestion. As yet no local authority within the UK has made use of these powers but a number of studies have been carried out which give some indication of the effects of the tax.

Wang and Sharples (1999) found that 30% of firms indicated that they would reduce the number of parking spaces if a levy was introduced. Twenty percent of those firms that expressed a choice (8% of all responses) would pass on the costs to employees. A further 30% would pass a proportion of the costs on to employees with the remainder being met by the company and/or customers.

The ROCOL study on road user charging in London (ROCOL, 2000) found that between 75% and 85% of existing parking spaces would be registered if a workplace parking levy were introduced in London, i.e. 25% of spaces would be decommissioned. Through a modelling exercise the study found that the introduction of a workplace-parking levy would result in relatively small changes in public transport use (1%), when compared with mode split changes brought about by road user charging.

As decribed in Section 13.4.3, Cooper *et al.* (2001) modelled a variety of different transport policy scenarios for Belfast. One of these included the introduction of a parking levy. This scenario, which included densification along major transport routes, introduction of advance transit and a toll cordon, resulted in an increase in passenger transport mileage of 19% compared with a scenario which included all the elements listed except the parking levy.

Calthrop *et al.* (2000) modelled a series of congestion charging/parking tax options for Brussels. They modelled the effect of three different parking tax options: (1) a tax on parking charges, (2) resource cost pricing for parking, and (3) optimal second best (one price across all parking markets) pricing of spaces. The percent of trips made by public transport increased under all three options compared with the reference case of 20% of peak trips and 8% of off-peak trips. Peak trips increased to between 21% and 27% of total trip demand depending on pricing structure. Off-peak trips increased to between 10% and 16%.

The effect of a workplace parking levy on travel patterns changes according to location. Willson and Shoup (1990) examined changes to travel choices for employees from a variety of locations within Los Angeles as a result of a reduction in the level of parking subsidy received. Sites in the central business district saw the largest switch to public transport (with up 21% of employees switching to public transit from the car), whilst in the suburban site examined no employees moved to transit as a result of reduced parking subsidy. Interestingly, they found that the proportion of employees travelling to work by public transport decreased from 38% to 28% when parking subsidies were reduced for one site near the CBD. This was as a result of transit users switching to car share; a car share scheme was introduced at the same time as the parking charges.

13.6 Land use planning

Full details of the inter-relationships between public transport and land use are given in Chapter 11.

Table 13.13 indicates how various land use design features are estimated to reduce per capita vehicle trip generation compared with conventional development that lacks these features. This information could again be used with diversion rates to determine the impact on public transport demand.

Table 13.13 Travel impacts of land use design features

Design feature	*Reduced vehicle travel*
Residential development around transit centres.	10%
Commercial development around transit centres.	15%
Residential development along transit corridor.	5%
Commercial development along transit corridor.	7%
Residential mixed-use development around transit centres.	15%
Commercial mixed-use development around transit centres.	20%
Residential mixed-use development along transit corridors.	7%
Commercial mixed-use development along transit corridors.	10%
Residential mixed-use development.	5%
Commercial mixed-use development.	7%

Source: Dagang (1995) (from VTPI, 2001).

Related to land-use is the issue of how activity patterns might change in the light of the increased use of information technology. A recent report for DfT (Department for Transport, 2002a) suggests that teleworking could reduce car commuting by 6% by 2015 and videoconferencing could reduce car based business traffic by 5% by 2015. Similar impacts on public transport demand might be expected.

13.7 Transport policy integration

An important issue is how packages of policy instruments might be put together in a complementary manner. For example, increasing parking controls and charges will increase the demand for public transport and hence the case for public transport infrastructure (Table 13.14). Conversely, provision of additional public transport infrastructure is likely to increase public acceptability of parking control and charges, particularly where the two policies are linked financially through hypothecation (e.g. tram construction and Work Place Parking Levies in Nottingham). Considerable empirical modelling work has been undertaken in order to quantify these synergistic effects.

Some early work in this respect is that of May and Gardner (1990) in London. Table 13.15 shows some indicative results. Scenario 1, a do-minimum investment strategy, would result in bus use decreasing by 30% and rail use by 5% between 1986 and 2001. Scenario 2 involved increasing investment in rail, combined with charging for car use in central London (2a) or halving public transport subsidy (2b). Although rail use would be stable or increase, bus use would continue to show large falls. Scenario 3 involved additional investment on orbital roads with charging for use in central London (3a) or environmental highway management (3b). Public transport use continues to show a decrease. Scenario 4 involved pricing for car use in central London and a peak surcharge for public transport use. Scenario 4a involved extending charging to inner London whilst 4b involved holding public transport fares constant and increasing rail frequencies. Bus use continues to show a decrease but rail use is up. Moreover, comparing scenario 4a with scenario 1, bus use is up 18 percentage points and rail use is up 13 percentage points.

Work of this type has also been undertaken at the European level (May *et al.,* 2000). In a study of nine cities, the optimal transport strategy included public transport fare reductions in six cities and public transport service increases in six cities. By contrast, road pricing was suggested for three cities (see Table 13.16).

13.8 Concluding remarks

This has been a wide ranging chapter that has covered the broad objectives of public transport policy and the associated policy instruments. Five groups of instruments have been examined: infrastructure and new vehicle provision; infrastructure management; pricing; information, promotion, marketing; and land use planning. The way that these groups of instruments may be brought together in a synergistic manner has been considered under the heading of transport policy integration.

With respect to infrastructure and vehicle provision, this chapter has focused on the role of accessible vehicles and bus based based park and ride. Corresponding details for for suburban rail and light rail are given in Chapter 12. Our key finding in terms of accessible vehicles is that low floor buses: can lead to an average 7% public transport demand uplift (range -4% to +17%). Demand responsive services may lead to substantial uplifts in certain circumstances. Similarly, bus based park and ride may lead to substantial patronage uplifts in certain circumstances. For example, extensive park and ride services in Oxford account for around 16% of bus passengers arriving in the central area (Preston, 2002). This might be interpreted as increasing bus demand on these flows by almost 20% but this would assume that all park and ride demand is new to public transport. In fact, surveys of park and ride users suggest that 63% come from car, 17% come from public transport and 14% are generated (with the balance coming from other modes).

With respect to infrastructure management, this chapter examined Quality Bus Partnerships, Restricted Access Zones and Bus Priority. It was acknowledged that some of

Table 13.14 Interaction between measures

	Highways	*PT infra -structure*	*Park & ride*	*Parking supply*	*Traffic manage -ment*	*Bus priorities*	*Traffic calming*	*Parking control*	*PT service levels*	*Infor -mation systems*	*Parking charges*	*Road pricing*	*Fuel prices*	*PT fares*	*Develop -ment control*
Highways						C	C					C			C
PT infrastructure								C/P			C/P	C/P	C/P		C
Park & Ride		C						C			C	C			
Parking supply							C	C							C
Traffic management						C	C		C	C		C			C
Bus priorities					C		C		C						
Traffic calming	C							C/P			C/P	C/P	C/P		
Parking control		C	C	C		C			C	C					C
PT service levels			C								C/P	C/P	C/P		C
Information systems			C		C		C	C/P	C		C	C			
Parking charges		C/F	C/F	C/F	C		C	C	C/F					C/F	
Road pricing	F	C/F	C/F	F		C	C		C/F	C				C/F	
Fuel prices	F	C/F	F	F					C/F						
PT fares		C/F	C/F	C			C	C	C		C/P	C/P			
Development control	C	C							C		C	C			

Measures in the left-hand column can reinforce the measure in the appropriate column by:

C Complementing it.

F Providing finance for it.

P Making it more publicly acceptable.

Table 13.15 London performance indicators 2001 relative to 1986

Scenario	*1*	*2*	*2A*	*2B*	*3*	*3A*	*3B*	*4*	*4A*	*4B*
Car use	+21%	+18%	+15%	+20%	+22%	+22%	+19%	+18%	+11%	+15%
Bus use	-30%	-16%	-12%	-29%	-29%	-29%	-20%	-20%	+12	-16%
Rail use	-5%	+5%	+11%	Same	-5%	-5%	+3%	+3%	+8%	+6%
Central speeds	-35%	-13%	+18%	-22%	-37%	-37%	+12%	+12%	+15%	+15%
Inner speeds	-15%	-9%	-5%	-11%	-7%	-10%	-3%	-7%	+4%	-3%
Bus fares	+85%	Same	Same	+41%	+81%	+82%	+64%	+46%	+42%	Same
Rail fares	+63%	Same	Same	+36%	+64%	+64%	+60%	+13%	+8%	Same
Environment	–	–	++	–	–	–	+	++	+++	++
Equity	–	–	+	–	–	–	+	++	+++	+
Accidents	+15%	+11%	+7%	+13%	+14%	+14%	+10%	+11%	+7%	+6%

Source: May and Gardner (1990).

Table 13.16 Benchmark objective function - optimal strategies

Measures *Cities*	*Infrastructure investment - high, medium or no*	*Road capacity*	*PT frequency†*	*PT fares†*	*Road pricing† (Euro)*	*Parking charges@*
Edinburgh	Medium	10%	85% (70%)	-90% (-35%)	1.6 (1.6)	~ (300%)
Merseyside	Medium	10%	50% (-40%)	-100% (-100%)	0 (0)	-100% (100%)
Vienna	No	-10%	0%	77%	0	0% (2.45%)
Eisenstadt	-	-15%	-50%	-50%	0	-50% (115%)
Tromsø	-	10%	46% (0%)	-100% (-50%)	2.0 (1.6)	-100%
Oslo	Medium	10%	-15% (0%)	-5% (-15%)	5.0 (5.0)	0%
Helsinki	No	0%	25% (13%)	-12% (-50%	0 (0	0% (0%)
Torino	No	10%	30%	100%	0	100%
Salerno	No	0%	80%	25%	0	300%

- *Not included.*
~ *Indicates irrelevant around the optimum.*
† *Off peak values are shown in ( ) for Edinburgh, Merseyside, Tromsø, Oslo, Helsinki.*
@ *Long stay; short stay values are shown in ( ) for Edinburgh, Merseyside, Vienna, Eisenstadt, Helsinki.*
Positive values signify an increase from the do-minimum.
Zero values signify no change from the do-minimum.
Negative values signify a reduction from the do-minimum.
Source: May et al. (2000).

these policies might also involve infrastructure provision and other measures. There have been a number of studies of the impacts of quality improvements on public transport demand and these are summarised in Table 13.17. Overall, this suggests that quality partnerships and similar measures might increase public transport demand on average by around 25%, but there is huge variation around this figure. Evidence on the impact of restricted access zones is more limited but suggests a maximum public transport demand uplift of 5%. Evidence on the impact of bus priority measures is mixed but suggests a 9% public transport demand uplift on average, but with a range of 1 to 16%.

With respect to pricing measures not considered in Chapter 6, we find that travel vouchers that provide employees with tax free public transport travel might lead to a possible public transport demand uplift of up to 3%. Modelling studies suggests that road pricing could lead to a public transport demand uplift of 5%, with a range of 1% to 10%. Early indications from London indicate that a 10% increase in bus use has already been achieved. With respect to parking evidence from the US indicates a cross-elasticity of public transport demand with respect to parking price of 0.35. Modelling studies in Great Britain suggest that workplace parking levies (WPPL) may lead to a public transport demand uplift of 1%.

In terms of information, promotion and marketing, conventional marketing may lead to public transport demand uplift of around 20% but an important issue is the duration of this uplift. Similarly, individualised marketing (such as the TravelSmart and Travel Blending programmes developed in Australia) can also uplift public transport demand amongst target populations by 20%. However, there is some concern that the target populations for these approaches might be quite limited. There is a growing body of evidence that the implementation of work based travel plans can lead to substantial increases in public transport use, along with increases in car sharing and cycling.

Table 13.17 The impact on public transport demand of quality partnerships and similar measures

	Average uplift(%)	*Range (%)*	*Number of observations*
Knowles, 1999	20	5 - 42	11
Mackie, 2000	22	4 - 60	9
LEK Consulting, 2002	21	4 - 92	11
CPT, 2002	33	10 - 72	17

With respect to land-use planning, it was found that such measures may reduce car travel by between 5% and 20% (see also Chapter 11), with the potential for a substantial proportion of this travel to switch to public transport. By contrast, increased adoption of teleworking and teleconferencing might reduce commuter and business travel by all modes by 5% or so, particularly if complemented by planning measures.

Lastly, a number of studies that have identified through modelling the synergistic benefits of an integrated package of policy measures have been reviewed. For example, May and Gardner (1990) found that in London combinations of infrastructure improvements and road pricing could increase bus use by 18% and rail use by 13% compared to the base. Similarly, Cooper *et al.* (2001) found that in Belfast parking levies added to densification, a new public transport system and a cordon toll could increase public transport demand by 19%.

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Notes

[1] Including public transport support, concessionary fare reimbursement and Fuel Duty Grant.

[2] This was formerly known as Fuel Duty Rebate. In effect it reimburses operators of local bus services for part of the duty paid on fuel.

[3] The mathematical formulations of various elasticity measures are given in Chapter 5.

[4] To avoid confusion in comparisons of elasticities, many of which are negative, the terms ‘increase’ and ‘decrease’ will always refer to the change in the magnitude (the numerical part) of the elasticity. Thus an elasticity which changes from -0.5 to -0.7 is said to have increased. Similarly, an elasticity of -1.5 is said to be larger than one of -0.5. This practice is retained throughout this book. Where results are quoted the negative sign will be indicated.

[5] For a brief mathematical description of the relationships between economic theory and demand models, the reader is referred to Appendix III.I. of the 1980 study (Wesbter and Bly, 1980).

[6] To be consistent with economic theory based on utility maximisation the functions must fulfIl the so-called integrability conditions and be homogeneous of degree zero in prices and incomes (so that they remain unaffected if both prices and incomes are changed in the same proportion) – see Bruzelius (1979). However, these conditions are rather general and cannot be used to specify either the functional form or the explanatory variables which should be included.

[7] The relationship between economic theory and different demand models, in particular demand models expressed in terms of generalised costs, is considered in greater detail in Appendix III.1 xzof the original study.

[8] As has been indicated, fares elasticities take on negative values. To avoid confusion the terms ‘increase’ and ‘decrease’ will always refer to the change in the numerical value of the elasticity so that an elasticity which changes from -0.5 to -0.7 is said to have increased. Similarly an elasticity of -1.5 is said to be larger than one of -0.5. This practice will be retained throughout this Report. Where results are quoted the negative sign will, of course, be indicated.

[9] A convex function varies less strongly with fares as fares are increased, or, in mathematical terms, $\partial^2 y/\partial x_i^2 > 0$.

[10] It is assumed that $k>O$ and $a_i<O$.

[11] If the growth were attributed wholly to increased frequency, this is consistent with a +0.4 short-run elasticity, and +0.6 two-year elasticity.

[12] See Chapter 5 for the definition of cross-elasticity and explanation of its use.

[13] How aggregate trip rates vary across income levels for a given level car ownership could also have been examined. Section 6.6 reports more disaggregate analysis of the effects of both income and car ownership on individuals’ trip rates.

[14] We would expect a lesser impact here for all trips than the leisure trips reported above.

[15] Indeed, we could estimate trip rates as a function of income and other variables for separate levels of household car ownership, thereby isolating the direct income effect from the car ownership effect.

[16] Urban areas as defined by OPCS are areas with continuous urban land of at least 20 hectares; areas with a minimum populations of approximately 1000; areas in close proximity are joined to form one urban area; urban agglomerations are sub-divided into parts to provide more useful statistics.

[17] A new edition of this seminal publication was published in 1999.

Glossary of Terms

ATOC	Association of train operating companies (see TOC).
Black Book	The forerunner of this work, published as Webster VF and Bly PH (editors). The Demand for Public Transport. Transport and Road Research Laboratory, Crowthorne, 1980.
BSO	Bus Service Operator Grant: a partial reimbursement of duty on fuel used in operating local bus services. (Formerly known as Fuel Duty Rebate).
Bus lane	A part of the highway for the exclusive use of buses (and in some cases taxis and bicycles) at certain times of day.
Bus priority schemes	Traffic management systems typically including bus lanes and signalling modifications giving buses priority over other traffic at junctions.
CAPRI	UK National railway's computerised ticket sales recording system.
CBD	Central Business District.
CfIT	Commission for Integrated Transport.
Concessionary fares	Discounted fares available to certain passenger categories, including elderly and disabled passengers (see Section 6.11).
Concessionary Fare Reimbursement	Payment by a local authority to an operator to make up the difference in revenue between charging the ordinary cash fare and the concessionary fare, taking into account the fact that the lower concessionary fare will generate some additional trips.
CPT	Confederation of Passenger Transport UK.
Cross-elasticity	A measure of the effect on demand for one transport mode of a change in attributes (eg fares, journey times) of a competing transport mode (see Chapter 5).
Cross-sectional studies	Studies using surveys of cross-sections of the population to relate differences in travel behaviour, demand, mode choice etc to differences in traveller category.
Demand curve	Graphical representation of demand function (qv).
Demand function	Mathematical relationship between demand for a service and its attributes (eg fare, journey time) (see Chapter 5).
DETR	Department of the Environment and Transport and the Regions (see DfT).
DfT	Department for Transport; UK Government Department with overall transport responsibilities. Was preceded, at various times, by DTp, DETR, DTLR, DoE.
Disaggregate studies	Studies which explore how various factors affect travel behaviour of individuals.
Diversion factor	The fraction of demand for one transport mode which transfers to another as a result of changes in fares, service levels etc.
DoE	Department of the Environment (see DfT).
DTLR	Department of Transport, Local Government and the Regions (see DfT).
DTp	Department of Transport (see DfT).
ECU	European currency unit (forerunner of the Euro).
Elasticity	A measure of the effect on demand for a transport mode of a change in attributes (eg fares, journey times) (see Chapter 5 for detailed explanation of several forms of elasticity).
ETM	Electronic ticket machine.
FDR	Fuel Duty Rebate (see BSO).
GC	Generalised cost - A means of representing the total cost of a journey in monetary terms. It usually consists of: the monetary cost, the value of time spent on the journey, and other factors.

GDP	Gross domestic product: often used as an indicator of income levels.
GJT	Generalised journey time: as generalised cost but expressed in units of time instead of money.
GLBPS	Greater London Bus Passenger Survey.
Guided busway	A segregated section of the highway, exclusively for buses, which are steered automatically (see Section 12.3).
HOV	High occupancy vehicle: vehicle carrying at least a specified minimum number of passengers, allowed to use exclusive 'HOV lanes' on the highway.
Interchange penalty	The disutility of interchange over and above the actual interchange time. This figure is usually given in time units.
IVT	In-vehicle time.
LATS	London Area Transport Study.
Light rail	Local rail systems (or tramways) using smaller vehicles than metros; parts may share roads with other traffic, parts my be segregated from road traffic (see Chapter 12).
Linked trip	A journey in more than one vehicle, with interchanging between modes (eg from train to bus), or within the same mode (eg from one train line to another, or from one bus route to another).
Longitudinal studies	Studies in which the same or similar individuals are surveyed at different periods over time. It enables turnover rates and trends in transport markets to be determined.
Metro	Common term used for local rail services, often with major underground sections.
NTS	National Travel Survey: the regular travel diary survey of structured samples of individuals commissioned by DfT and its predecessors.
O&D	(or OD): origin and destination of a journey.
P&R	Park and Ride: out -of-town parking facilities, connected to town centres by dedicated bus services (see Section 12.4).
PDFH	Passenger demand forecasting handbook. Based on research commissioned by ATOC, provides guidance on forecasting demand for rail services.
PHV	Private Hire Vehicle (known as 'minicab' in some areas): licensed vehicle with no more than 8 seats, available for hire when arrangements are made in advance (usually by telephone) but, unlike a taxi, it may not 'ply for hire'.
PTAL	Public transport accessibility level.
PTE	Passenger Transport Executive: public bodies with responsibilities for planning and supporting public transport services in Metropolitan Areas.
QBP	Quality bus partnership: joint initiative by bus operator and local authority to improve bus services.
RP	Revealed preference - Surveys where preferences are inferred from observed aggregate data. This is in contrast to Stated Preference surveys (qv), where individuals are asked about how they would respond to some proposed changes.
RPI	Retail Price Index: used to take monetary inflation into account.
Service intervals	The time between successive arrivals or departures of a public transport service.
SP	Stated preference analysis and surveys - A method of estimating demand for new or radically modified services. Based on questionnaires in which respondents indicate preferences between various journey options (which may include hypothetical transport modes) with different journey times, services frequencies, fares etc.

SRA	Strategic Rail Authority: public body with responsibilities for planning and franchising rail services.
Taxi	(or Hackney Carriage): a licensed vehicle with no more than 8 passengers seats, available for hire. It is allowed to ‘ply for hire’, with journeys being initiated at taxi ranks or by on-street hailing.
TfL	Transport for London: public body with overall responsibility for transport in Greater London, including planning and supporting public transport services.
TOC	Train Operating Company: one of some 15 companies franchised (by the SRA qv) to operate parts of the former British Rail network of services since rail privatisation (in 1994).
Travelcard	A card allowing unlimited use of public transport within a specified area and time period (see Section 6.2).
Trip generation factor	The ratio of the number of concessionary journeys (see concessionary fares) to the number which would be made if no concessions were available.
UG	The London Underground rail system.
VTPI	Victoria Transport Policy Institute.

Comparisons of data from operators and the National Travel Survey (NTS)

Use has been made in this report of data derived both from that collected by operators, and that from comprehensive household surveys such as the National Travel Survey (NTS). Examples below are drawn from Britain, but broadly similar issues may arise when similar data sources are used in other countries.

In principle, very similar results should be obtained from the two types of source, but a number of differences in definition affect this, notably:

1 Public transport operators have traditionally counted ‘trips’, associated with sales of a tickets each time a vehicle is boarded. Where there is no integration between operators, or transferable single tickets within the same operator or mode, each boarding of a vehicle thus results in the issue of a ticket, and is counted as a ‘journey’.

2 Within rail systems run by the same operator, this problem has been less common, due to through ticketing and to provision of interchange between lines within the same network, such as the London Underground. Through single tickets have been offered and counted as one-way ‘trips’.

3 Where tickets permitting multiple rides have been sold, varying assumptions have been made as to the number of ‘trips’ resulting. For a return ticket, this is obviously two, and for multi-ride tickets it is normally assumed that trips made are equal to rides sold (e.g. for a 10-ride ticket). However, for longer-period seasons assumptions may be made by operators based on sample surveys, or cruder data sources. Over time, the number of journeys per ticket may change (e.g. reduce on an annual season as fewer days are worked per year), but this may not necessarily be adopted in operators’ assumptions.

4 There may be difficulty in collecting data from some operators, especially smaller business. In the British case, smaller local bus operators are sampled each year. No ridership data are collected from taxi operators. Where small operators represent a substantial share of the market, this may result in year-to-year fluctuations arising from sampling procedures and response rates, rather than real changes in the volume of travel.

5 In the case of household surveys, such as the NTS, a more consistent definition is usually obtained, but the number of trips recorded will generally be fewer than in operator data. The problem of double-counting arising from interchange is avoided, but unless care is taken to identify the level of interchange en route, it will be difficult to harmonise operator and NTS data. Most published NTS data in Britain are in the form of ‘stages’, i.e. sections of a journey using one specific mode of transport, excluding very short walks. Where data are published for modes used for the ‘main stage’ only, the role of subsidiary modes will be understated (e.g. where a bus feeder trip to a rail route is much shorter than the rail stage). Data showing all stages should be used for comparison with operator data. In addition, the NTS does gather data on ‘boardings’, i.e. where successive rides within the same mode are made on the same ticket. This is usually unpublished, but does enable some estimates to be made of interchange effects.

6 A greater difference may arise from the types of household included in surveys such as NTS. These generally exclude student halls of residence or other communal accommodation. There may be particular difficulties in covering multi-occupied dwellings. Hotels and other accommodation used by tourists are excluded. One might thus expect greater differences between operator and NTS data where such categories form a greater part of the users of a transport system, for example in London.

In the case of the NTS in Britain, data are normally averaged over three-year periods, formed from calendar years (for example 1999 to 2001 inclusive), due to sample size limitations in taking a single year. Operator data are usually gathered for financial years (running to 31 March), and hence the nearest equivalent years have to be compared (e.g. financial years 1999/2000 to 2001/02) or adjustments made directly for the quarters concerned. Since the NTS data are in the form of a sample of households, it is necessary to gross-up the totals by reference to the national population.

As part of this study, comparisons were made for the most recent applicable three year period (as defined above), with the following ratios of boardings to stages being derived:

Local buses outside London	1.15
Local buses in London	1.81
London Underground	2.34
National railways	1.42

(NTS data derived from Bulletin SB(02)22 Table 3.2. (showing ‘trips’), and operator data derived from Tables 5 and 10 in Statistics Bulletin SB(25)02)

It should be noted that NTS figures have been grossed up from average trips per person expressed as a whole number, which may result in some distortion. Nonetheless, very marked differences are clear.

One might expect such differences to be less marked if total passenger-kilometres were used as the measure, since this should eliminate the ‘double counting’ problems where interchange takes place. However, local bus operators do not produce such estimates themselves, so such comparisons are only possible for local buses in London, London Underground and national railways.

As part of this work, comparisons were also made over a longer period of time., from 1986 to 2000 (using one-year data for 1986), with the following broad results obtained (excluding outliers).

Operator trips per NTS stage

Local buses	1.12 to 1.23 fairly consistent over time
Of which, non-London	1.04 to 1.15 consistent over time.
London	1.42 to 1.68 possibly a slight decrease over time.

For rail the differences are more clearly defined, the ratios (excluding outliers) varying as follows:

All railways	1.30 to 1.67 broadly increasing over time.
National railways	1.18 to 1.36 broadly increasing over time .
London Underground	1.54 to 1.73 varies from year to year.

For the National Railways the 1986 ratio was particularly low 1.02, while 1997 and 1998 were particularly high 1.54 and 1.42 respectively. For London Underground in the latter half of the 1990s the data ranged from 1.63 to 1.73, prior to that it had been in the 1.54 to 1.59 range (which is where the 2000 figure lies).

Passenger kilometres on rail systems

For rail, the ratios (excluding outliers) obtained were as follows:

All railways	1.14 to 1.23
National railways	1.09 to 1.17
London Underground	1.24 to 1.42

If one were to allow an uplift to the NTS figures to take into account the fact that 9% of London Underground patronage is tourists the ratios would range from 1.13 to 1.29.

Appendicies to Chapter 6

Preface

The data and sources in the tables in this appendix to Chapter 6 are described in following form:

Description – A broad outline, if possible, of the main points of how the data are derived. If the sample size is known (which, in general, it is not) it is stated in this column.

Elasticity – The elasticity value, or range of values given in the source document.

Reference - The reference to the documentary source from which the elasticity came.

Designation – This outlines the kind of data presented. Each data value can have up to three sets of code letters to denote its country, methodology and whether or not it includes London. The possible designations are as follows:

Country

AD – UK aggregate data.

DD – UK disaggregate data.

UD – UK data.

FD – Non-UK data.

Methodology

SP – Stated preference surveys.

RPCS – Revealed preference, single mode, change over time (Own elasticities).

RPCE – Revealed preference, all modes, change over time (Conditional elasticities).

RPM – Cross-sectional modelling.

RPU – Not stated preference, but it is unclear whether it is cross-sectional modelling or revealed preference, change over time. Has been grouped with RPCE.

RPCU – Revealed preference, change over time, but it is unclear whether it is just a single mode change or all the modes change. Has been grouped with RPCE.

AP – Average of various studies, mixture of types of study. Has been grouped with RPCE.

UP – Classification not clear. Has been grouped with RPCE.

London (NB this only applies to UK data)

L – In London only.

N – Not in London at all.

M – Includes London but not exclusively.

For the suburban rail values the term ‘London’ is actually used to denote whether the source includes data for the ‘south east’ instead of just ‘London’.

Rows in tables that are given in grey denote a case where a reference gave several elasticity values for a particular situation, such as from a model applied under different assumptions. To prevent bias towards such situations, a representative value (sometimes an average) is used. This is given in the row below.

Appendix to Section 6.1

The various methods used to estimate elasticities can be found in Meurs, Van Eijk and Goodwin (1990) (p371 to p375). They are summarised as follows:

If:
D = Demand.
F = Fare.
E = Elasticity.

Simple case:

$$D = f(F) \qquad E = \frac{dD}{dF} \bullet \frac{F}{D}$$

Before and after studies:

$$E = \frac{\text{\% change in D}}{\text{\% change in F}}$$

Examples: Blase (1985), Collins (1983), and Smith (1982)

Unlagged time series:

$$D_t = a\,F^b{}_t X^c{}_t.$$

In this case, X is used to represent one of the many other factors to be taken into account, and E = b.

Examples: Cervero (1985), Doi and Allen (1986), Grimshaw (1984), Oldfield (1979), and Tyson (1984).

Lagged time series:

$$D_t = a\,F^b{}_{t-1}\,X^c{}_{t-1}.$$

Examples: Fairhurst *et al.* (1987), Goodwin (1987), and McKenzie and Goodwin (1986).

Equilibrium models
See Chapter 5. These can be rather complicated. Examples include Smith (1982), Mackett (1984), Ryder (1982).

Appendix to Section 6.2

Below is a list of the common types of ticketing arrangements:

Cash fares: On boarding a particular mode, the traveller pays a fare, normally in cash (for longer distances by rail they might pay by cheque, credit or debit card), to make that particular single trip. Used for all modes of public transport.

Through-ticketing: Before boarding the first public transport mode of the trip the traveller purchases a ticket for the entire journey. This can be used for intramodal transfer, and is particularly common in the rail industry. However where providers of different modes are willing it is possible to use it for intermodal transfer too. Privatisation has made this method less common than it used to be. However, it is popular among passengers, because it reduces the necessity to purchase more than one ticket. In some cases, it may also be cheaper than buying several.

Return fares: Usually used for rail, but not generally used for bus. The traveller buys a ticket, usually just before boarding the mode, for both their outward journey, using that mode, and their return journey. It is often possible to combine this with through-ticketing.

Flat fares: The traveller pays a cash fare of a set value no matter how long the journey is. Sometimes this might be combined with multiple ticket booklets.

Multiple ticket booklets, or Pre-paid coupons: A method of ticketing more common on the Continent of Europe (for examples include urban transport networks in: Berlin, Stockholm, Paris), than in Britain. Traveller purchase books or strips of tickets or coupons and then give up one for each appropriate journey they make, until they have used up all the tickets. Then they buy another book. In some cases (if combined with a zonal system), for longer journeys, more than one token has to be given up.

Zones: Within a particular zone passengers pay the same amount to travel anywhere within that zone. This may be for a particular trip, or on several modes.

Journey-specific season ticket: Travellers buy pre-paid season ticket (usually in conjunction with a photocard), entitling them to make a particular journey any number of times over the duration of that 'season'. The period involved can by anything from 1 week to 1 year. Usually it is for so many weeks or so many months. Usually used by adults commuting to work, and by school children. In London it has largely been replaced by the more flexible zonal travelcard.

Zonal travelcard: Very popular, for example in areas around Greater London. Travellers pay a set fee (according to the zones and duration) which then entitles them to unlimited travel within those zones for that duration. Some are mode specific, while others are for several modes. In London a One-day Travelcard may be purchased, by any traveller, after 9:30 am giving unlimited travel within the zones specified for the rest of that day. In London Travelcards covering a 'season' having a duration of between 1 week to 1 year may be purchased with a photocard. They offer the flexibility to make other trips easily at zero marginal cost to the passenger. They also offer flexibility in terms of route and mode.

APEX and similar: A rail ticket, purchased in advance (i.e. one day or more before the outward journey), for travel on specific days. Allows the traveller to travel to their destination on one day, and return on another day, provided the return journey is made within a set period after the outward journey. The day of the outward journey (and possibly the return journey too) must be specified when the ticket is bought. Can be used in conjunction with some concessionary cards (such as Young Persons Railcard).

Concessionary fares: Certain groups of people such as children, pensioners, sometimes disabled people, and occasionally even unemployed people, are usually entitled to discounted, in some cases zero, fares on most forms of public transport. In the bus industry, the local authority pays the bus company the difference, as CFR (Concessionary Fare Rebate).

Concessionary cards: In the rail industry in particular, certain groups of people may, if they wish, purchase a card, once a year, that entitles them a discount on any tickets purchased (this usually only applies to tickets for travelling at certain times in the day). Examples include: Young Persons Railcard (bought by a person aged 16 to 25, it entitles them to one third off, anywhere on the national railway network), Family Railcard (bought by an adult, entitles them and one other named adult and up to two additional adults travelling with them to a discount, and any children in the group to travel at a flat fare, anywhere on the national railway network), NetworkCard (bought by an adult, covers the south-east of England.

Appendix to Section 6.3

Below are given the actual elasticity values and their study sources, used to derive the elasticity values presented in Tables 6.1, 6.4, 6.10 and 6.11. (Note: here and in subsequent tables SD indicates standard deviation.)

Bus short run – UK *(used to derive Tables 6.1, 6.4, 6.10 and 6.11)*

Table A6.1 Revealed preference, fare changes over time for the single mode (own elasticity) (*Used to derive Table A6.3 and its successors, Tables 6.1, 6.4, 6.10 and 6.11)*

Description	*Elasticity*	*Source*	*Designation*
Bus, short term	-0.34	Frerk, Lindsey and Fairhurst (1981)	AD, RPCS, L
Bus, Morpeth, all day	-0.70	White (1981)	AD, RPCS, N
Bus, long distance, Sheffield to Doncaster	-0.80	White (1981)	AD, RPCS, N
Bus, medium distance, Doncaster to Rotherham	-0.40	White (1981)	AD, RPCS, N
London Bus, between October 1981 and March 1982	-0.30 to -0.33	Collins (1983)	AD, RPCS, L
Bus, 1-2 years	-0.36	McKenzie and Goodwin (1986)	AD, RPCS, N
Bus, short run	-0.42	Fairhurst, Lindsay and Singha (1987)	AD, RPCS, L
Bus	-0.2 to -0.6	Fowkes, Sherwood, and Nash (1992)	DD, RPCS, L
Bus, own price, short to medium term,	-0.62	London Transport (1993)	AD, RPCS, L
Bus, short run	-0.4	Survey of values currently in use in Dargay and Hanly (1999)	AD, RPCS, M
Bus, short run, county level	-0.4	Dargay and Hanly (1999)	AD, RPCS, M
Bus	-0.6	Goodwin (1975)	AD, RPCS, L
Bus, short run	-0.49	Goodwin (1987)	AD, RPCS, N
Bus, 5 scenarios	-0.371, -0.335, -0.447, -0.370, -0.396 (5 scenarios)	Goodwin (1987)	AD, RPCS, N
Bus, 23 towns	-0.30	Preston and James (2000)	AD, RPCS, N
Average	-0.46 (SD = 0.15)	15 cases	UD, RPCS

Table A6.2 Revealed preference, fare changes over time for all public transport fares (conditional elasticity) *(Used to derive Table A6.3, and its successors, Tables 6.1, 6.4, 6.10 and 6.11)*

Description	*Elasticity*	*Source*	*Designation*
Bus, short run	-0.41 ±0.05	Oldfield (1979)	AD, RPCE, M
Bus, short term	-0.53	Frerk, Lindsey and Fairhurst (1981)	AD, RPCE, L
LT Bus, conditional	-0.28	Ryder (1982)	AD, RPCE, L
Bus, other analysis	-0.43 with 95% confidence interval -0.22 to -0.64	National Bus Company (1984)	AD, RPCE, M
Bus	-0.3	Tyson (1984),	AD, RPCE, N
Bus with respect to London Transport (LT) fares	-0.07 to -0.20	Blase (1985)	AD, RPCE, L
Bus	-0.3, range: -0.1 to –0.6	Goodwin and Williams (1985)	AD, RPCE, M
Bus, short run, conditional	-0.27	Fairhurst, Lindsay and Singha (1987)	AD, RPCE,L
Bus, LT's scenario model	-0.31	Halcrow Fox *et al.* (1993)	AD, RPCE, L
Bus, conditional, short to medium term	-0.35	London Transport (1993)	AD, RPCE, L
Bus, travelcard, demand data PTE Area A	-0.12 to -0.47	Preston (1998)	AD, RPCE, N
Bus, travelcard, demand data PTE Area B	-0.86	Preston (1998)	AD, RPCE, N
Bus, full fare, short run, Greater London	-0.408	Clark (1997)	AD, RPCE, L
Bus, full fare, short run, English met areas	-0.581	Clark (1997)	AD, RPCE, N
Bus, full fare, short run, English non-met areas	-0.066	Clark (1997)	AD, RPCE, N
Bus, full fare, short run, Wales	-0.341	Clark (1997)	AD, RPCE, N
Bus, full fare, short run, Scotland	-0.336	Clark (1997)	AD, RPCE, N
Bus, short run, no long run symmetry	-0.839	Gilbert and Jalilian (1991)	AD, RPCE, L
Average	-0.39 (SD = 0.21)	18 cases	UD, RPCE

Table A6.3 Bus fare elasticities by data type - UK data - short run *(Used to derive Tables 6.1, 6.4, 6.10 and 6.11)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Own elasticity	-0.46	-0.30 to -0.80	0.15	15
Conditional elasticity	-0.39	-0.07 to -0.86	0.21	18
Cross-sectional modelling				
Average	-0.42	-0.07 to -0.86	0.18	33

For data and sources see Tables A6.1 and A6.2.

Bus short run – international *(used to derive Tables 6.1, 6.10 and 6.12)*

Table A6.4 Revealed preference, changes over time for the single mode (own elasticity) *(Used to derive Table A6.7 and its successors, Tables 6.1, 6.10 and 6.12)*

Description	*Elasticity*	*Reference*	*Designation*
Urban bus, Dallas, US 1985-87	-0.35	Pratt *et al.* (2000) citing Allen (1991)	FD, RPCS
Suburban express bus Dallas US 1985-87	-0.26	Pratt *et al.* (2000) citing Allen (1991)	FD, RPCS
Suburban local bus, Dallas US 1985-87	-0.25	Pratt *et al.* (2000) citing Allen (1991)	FD, RPCS
Bus, Dallas, US, 1985-87	-0.29	Pratt *et al.* (1999) citing Allen (1991)	FD, RPCS
Average	-0.29	1 case	FD, RPCS

Table A6.5 Revealed preference, fare changes over time for all public transport modes (conditional elasticity) *(Used to derive Table A6.7 and its successors, Tables 6.1, 6.10 and 6.12)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, short run	-0.252, range -0.23 to -0.27	Benham (1982)	FD, RPCE
Single mode, bus, partially recognising inter-modal competition.	-0.522 (SD 0.257)	Hamberger and Chatterjee (1987)	FD, RPCE
Bus, Chicago, for fare increases January 1981, July 1981 and February 1986	-0.40, range -0.20 to -0.66	Cummings, Fairhurst, Labelle and Stuart (1989)	FD, RPCE
Bus, Australia, short run	-0.29	Bureau of Transport Economics (2003) citing Luk and Hepburn (1993)	FD, RPCU
Bus, Chicago, US, 1981-86	-0.43	Pratt *et al.* (2000) citing LTI Consultants Inc. and E A France and Associates (1988)	FD, UP
Bus, New York, US, 1995	-0.36	Pratt *et al.* (2000) citing Charles River Associates (1997)	FD, UP
Houston bus services, based on 1980-1990 data	-0.23	O'Fallon and Sullivan (2000) citing Kain and Lui (1999)	FD, UP
Fixed route PT (bus and rail) - consistent results for 4 cities: San Diego, Atlanta, Portland Oregon, Ottawa - several independent studies	-0.48	O'Fallon and Sullivan (2000) citing Kain and Lui (1999)	FD, UP
Bus	-0.32	Victoria Transport Policy Institute (2001) citing Kain and Liu (1999)	FD, UP
Average	-0.36 (SD = 0.10)	9 cases	FD

Table A6.6 Cross-sectional modelling *(Used to derive Table A6.7 and its successors, Tables 6.1, 6.10 and 6.12)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, short run, immediately following the introduction of the BART metro system when that was not yet fully operational	-0.58	McFadden (1974)	FD, RPM
Average	-0.58	1 case	FD, RPM

Table A6.7 Bus fare elasticities by data type - international data - short run *(Used to derive Tables 6.1, 6.10 and 6.12)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Own elasticity	-0.29	-0.29 to -0.29	n/a	1
Conditional elasticity	-0.36	-0.23 to -0.52	0.10	9
Cross-sectional modelling	-0.58	-0.58 to -0.58	n/a	1
Average	-0.38	-0.23 to -0.58	0.12	11

For data and sources see Tables A6.4, A6.5 and A6.6

Bus medium run - UK *(used to derive Table 6.4)*

Table A6.8 Revealed preference, fare changes over time for the single mode (own elasticity) *(Used to derive Table A6.10 and its successor, Table 6.4)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, adult single, after 4 years	-0.67	McKenzie and Goodwin (1986)	AD, RPCS, N
Bus, travelcard, after 4 years	-0.55	McKenzie and Goodwin (1986)	AD, RPCS, N
Bus, after 4 years	-0.61	McKenzie and Goodwin (1986)	AD, RPCS, N
Average	-0.61	1 case	UD, UD, RPCS, N

Table A6.9 Revealed preference, fare changes over time for all public transport modes (conditional elasticity) *(Used to derive Table A6.10 and its successor, Table 6.4)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, adults, cash fare, medium term,	-0.28 (±0.12)	Preston (1998)	AD, RPCE, N
Bus, adults, pre-paid ticket, medium term,	-0.74 (±0.39)	Preston (1998)	AD, RPCE, N
Bus, adults, medium term	-0.51	Preston (1998)	AD, RPCE, N
Average	-0.51	1 case	UD, AD, RPCE, N

Table A6.10 Bus fare elasticities by data type - UK data - medium run (Used to derive Table 6.4)

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Own elasticity	-0.61	-0.61 to -0.61	n/a	1
Conditional elasticity	-0.51	-0.51 to -0.51	n/a	1
Cross-sectional modelling				
Average	-0.56	-0.51 to -0.61	0.07	2

For data and sources see Tables A6.8 and A6.9.

Bus long run - UK *(used to derive Table 6.4)*

Table A6.11 Revealed preference, fare changes over time for the single mode (own elasticity) *(Used to derive Table A6.13 and its successor, Table 6.4)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, long run	-0.9	Dargay and Hanly (1999)	AD, RPCS, M
Bus, long run, county-level model	-0.7 to -0.9	Dargay and Hanly (1999)	AD, RPCS, M
Bus, long run	-0.85	Dargay and Hanly (1999)	AD, RPCS, M
Bus, long run	-0.87	Goodwin (1987)	AD, RPCS, N
Average	-0.86 (SD = 0.01)	2 cases	UD, RPCS, N

Table A6.12 Revealed preference, fare changes over time for all public transport modes (conditional elasticity) *(Used to derive Table A6.13 and its successor, Table 6.4)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, long run, without long run symmetry	-1.318	Gilbert and Jalilian (1991)	AD, RPCE, L
Average	-1.318	1 case	UD, RPCE, L

Table A6.13 Bus fare elasticities by data type - UK data - long run *(Used to derive Table 6.4)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Own elasticity	-0.86	-0.85 to -0.87	0.01	2
Conditional elasticity	-1.32	-1.32 to -1.32	n/a	1
Cross-sectional modelling				
Average	-1.01	-0.85 to -1.32	0.26	3

For data and sources see Tables A6.11 and A6.12.

Appendix to Section 6.4

Below are given the actual elasticity values and their study sources, used to derive the elasticity values presented in Tables 6.5 to 6.10, 6.11 and 6.12.

Metro - short run - UK *(used to derive Tables 6.5 to 6.8, 6.10 and 6.12)*

Table A6.14 Revealed preference, fare changes over time for the single mode (own elasticity) *(Used to derive Table A6.16 and its successors, Tables 6.5 to 6.8, 6.10 and 6.11)*

Description	*Elasticity*	*Reference*	*Designation*
Underground, short term, own elasticity	-0.19	Frerk, Lindsey and Fairhurst (1981)	AD, RPCS, L
LT Underground, own	-0.37	Ryder (1982)	AD, RPCS, L
Underground, between October 1981 and March 1982	-0.14 to -0.16	Collins (1983)	AD, RPCS, L
Underground, short run, own	-0.55	Fairhurst, Lindsay and Singha (1987)	AD, RPCS, L
Underground, own	-0.1 to -0.7	Fowkes, Sherwood, and Nash (1992)	DD, RPCS, L
Underground, own price, short to medium term	-0.43	London Transport (1993)	AD, RPCS, L
Average	-0.35 (SD= 0.15)	6 cases	UD, RPCS, L

Table A6.15 Revealed preference, fare changes over time for all public transport modes (conditional elasticity) *(Used to derive Table A6.16 and its successors, Tables 6.5 to 6.8, 6.10 and 6.11)*

Description	*Elasticity*	*Reference*	*Designation*
Underground, short term, conditional	-0.41	Frerk, Lindsey and Fairhurst (1981)	AD, RPCE, L
LT Underground, conditional	-0.15	Ryder (1982)	AD, RPCE, L
Underground, with respect to London Transport fares	-0.17 to -0.50	Blase (1985)	AD, RPCE, L
London, rail	-0.12 to -0.23	Goodwin and Williams (1985)	AD, RPCE, L
Underground, short run	-0.16	Fairhurst, Lindsay and Singha (1987)	AD, RPCE, L
Underground, conditional, short run	-0.43	Goulcher (1990)	AD, RPCE, L
Underground, London Transport's scenario model	-0.17	Halcrow Fox *et al.* (1993)	AD, RPCE, L
Underground, conditional, short to medium term	-0.17	London Transport (1993)	AD, RPCE, L
Rail, short run, without Slutsky symmetry	-0.355	Gilbert and Jalilian (1991)	AD, RPCE, L
Average	-0.26 (SD= 0.12)	9 cases	UD, RPCE, L

Table A6.16 Metro fare elasticities by data type - UK data - short run *(Used to derive Tables 6.5 to 6.8, 6.10 and 6.11)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Own elasticity	-0.35	-0.15 to -0.55	0.15	6
Conditional elasticity	-0.26	-0.15 to -0.43	0.12	9
Cross-sectional modelling				
Average	-0.30	-0.15 to -0.55	0.13	15

For data and sources see Tables A6.14, and A6.15.

Metro - short run - international *(used to derive Tables 6.5, 6.7, 6.10 and 6.12)*

Table A6.17 Revealed preference, fare changes over time for all public transport modes (conditional elasticity) *(Used to derive Table A6.19 and its successors, Tables 6.5, 6.7, 6.10 and 6.12)*

Description	*Elasticity*	*Reference*	*Designation*
Linear model, rapid transit line	-0.233	Doi and Allen (1986)	FD, RPCE
Log-linear model, rapid transit line	-0.245	Doi and Allen (1986)	FD, RPCE
Rapid transit line	-0.24	Doi and Allen (1986)	FD, RPCE
Metro, Chicago, for fare increases in January 1981, July 1981 and February 1986	-0.34	Cummings, Fairhurst, Labelle and Stuart (1989)	FD, RPCE
Metro, Chicago 1981-1986	-0.18	Pratt *et al.* (2000) citing LTI Consultants Inc. and E A France and Associates (1988)	FD, UP
Metro, New York 1948-1977	-0.16	Pratt *et al.* (2000) citing Mayworm, Lago and McEnroe (1980)	FD, UP
Metro, New York, 1970-1995	-0.10 to -0.15	Pratt *et al.* (2000) citing Jordan (1998)	FD, UP
Metro, New York 1995	-0.15	Pratt *et al.* (2000) citing Charles River Assoc (1997)	FD, UP
BART metro, San Francisco	-0.31	Pratt *et al.* (2000) citing Reinke (1988)	FD, UP
New York Metro North	-0.20	Pratt *et al.* (2000) citing Charles River Associates (1997)	FD, UP
Average	-0.21 (SD= 0.08)	8 cases	FD

Table A6.18 Cross-sectional modelling *(Used to derive Table A6.19 and its successors, Tables 6.5, 6.7, 6.10 and 6.12)*

Description	*Elasticity*	*Reference*	*Designation*
Metro - specifically BART immediately following its introduction when it was not yet fully operational	-0.86	McFadden (1974)	FD, RPM
Average	-0.86	1 case	FD, RPM

Table A6.19 Metro fare elasticities by data type - international data - short run *(Data used to derive Tables 6.5, 6.7, 6.10 and 6.12)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Own elasticity				
Conditional elasticity	-0.21	-0.13 to -0.34	0.08	8
Cross-sectional modelling	-0.86	-0.86 to -0.86	n/a	1
Average	-0.29	-0.13 to -0.86	0.23	9

For data and sources see Tables A6.17 and A6.18.

Metro - long run - UK *(used to derive Tables 6.6 and 6.8)*

Table A6.20 Revealed preference, fare changes over time for all public transport modes (conditional elasticity) *(Used to derive Table A6.21 and its successors, Tables 6.6 and 6.8)*

Description	*Elasticity*	*Reference*	*Designation*
Underground only conditional, long run	-0.61	Goulcher (1990)	AD, RPCE, L
Rail, long run, no long run symmetry	-0.688	Gilbert and Jalilian (1991)	AD, RPCE, L
Average	-0.65 (SD = 0.06)	2 cases	UD, RPCE, L

Table A6.21 Metro fare elasticities by data type - UK data - long run *(Data used to derive Tables 6.6 and 6.8)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Revealed preference single mode				
Revealed preference all modes	-0.65	-0.61 to -0.69	0.06	2
Cross-sectional modelling				
Average	-0.65	-0.61 to -0.69	0.02	2

For data and sources see Table A6.20.

Suburban rail - short run - UK *(used to derive Tables 6.5, 6.6, 6.9, 6.10 and 6.11)*

Table A6.22 Revealed preference, fare changes over time for the single mode (own elasticity) *(Used to derive Table A6.25 and its successors, Tables 6.5, 6.6, 6.9, 6.10 and 6.11)*

Description	*Elasticity*	*Reference*	*Designation*
Suburban rail (20 to 120 km), full fare	-0.75	Hughes (1980)	AD, RPCS, L
Rail elasticities for work and school trips, if only rail fares changed	-0.46 or -0.53	Bamford (1984)	AD, RPCS, N
Suburban rail	-0.4 to -1.5	Fowkes, Sherwood, and Nash (1992)	DD, RPCS, L
BR's own figure for the provincial sector	-0.9	Goodwin (1992)	AD, RPCS, N
Rail, single market hierarchical logit model (work-trips only)	-0.34	Preston (1991)	AD, RPCS , N
Rail	-0.8611 to -0.8670	Fowkes, Nash and Whiteing (1985)	AD, RPCS, L
Rail, total rail travel	-0.55	Wardman (1992b)	DD, RPCS, L
Average	-0.69 (SD= 0.23)	7 cases	UD, RPCS

Table A6.23 Revealed preference, fare changes over time for all public transport modes (conditional elasticity) *(Used to derive Table A6.25 and its successors, Tables 6.5, 6.6, 6.9, 6.10 and 6.11)*

Description	*Elasticity*	*Reference*	*Designation*
Medium distance rail, full fare ticket	-0.20 ±0.04	Oldfield and Tyler (1981)	AD, RPCE, L
Rail short term	-0.5 ±0.07	Oldfield and Tyler (1981)	AD, RPCE, L
Rail	-0.35	Oldfield and Tyler (1981)	AD, RPCE, L
Rail	-0.64, range -0.6 to -0.8	Jones and Nicols (1983)	RPCE, L
West Midlands BR ridership price elasticity, before and after surveys	-0.18	Godward (1984) cited in Goodwin *et al.* (1992)	RPCE, N
Rail, Glasgow	-0.44 to –0.49	Goodwin and Williams (1985)	AD, RPCE, N
Rail, log linear model	-0.83	Preston (1991)	AD , RPCE, N
Rail, semi-log model	-0.65	Preston (1991)	AD, RPCE, N
Rail	-0.74	Preston (1991)	AD, RPCE, N
London Transport's scenario model, BR,	-0.1	Halcrow Fox *et al.* (1993)	AD, RPCE, L
Rail, short run, Network SouthEast	-0.395	Clark (1997)	AD, RPCE, L
Rail, short run, Regional Railways	-0.299	Clark (1997)	AD, RPCE, N
Rail, short run	-0.35	Clark (1997)	AD, RPCE, N
Rail, demand data PTE Area C, travelcard	-1.02	Preston (1998)	AD, RPCE, N
Rail, short run, PTE Area A	-0.15	Preston (1998)	AD, RPCE, N
Bedford to London	-0.74	Glaister (1983)	AD, RPCE, L
Rail, High Wycombe to London	-0.77 to -0.90 (depending on method)	Glaister (1983)	AD, RPCE, L
Average	-0.49 (SD = 0.32)	10 cases	UD, RPCE

Table A6.24 Cross-sectional modelling *(Used to derive Table A6.25 and its successors, Tables 6.5, 6.6, 6.9, 6.10 and 6.11)*

Description	*Elasticity*	*Reference*	*Designation*
Journeys to work	-0.7	Mackett (1985)	AD, RPM, L
Local Rail, W Yorks, cross-sectional model, run not stated	-0.825	Preston (1987)	AD, RPM, N
Rail, all trips, short run,	-0.31	Mackett and Nash (1991)	AD, RPM, L
Average	-0.61 (SD = 0.27)	3 cases	UD, RPM

Table A6.25 Suburban rail fare elasticities by data type - UK data - short run *(Data used to derive Tables 6.5, 6.6, 6.9, 6.10 and 6.11)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Own elasticity	-0.69	-0.34 to -0.95	0.23	7
Conditional elasticity	-0.51	-0.10 to -1.02	0.32	10
Cross-sectional modelling	-0.61	-0.31 to -0.83	0.27	3
Average	-0.58	-0.10 to -1.02	0.29	20

For data and sources see Tables A6.22, A6.23, and A6.24.

Suburban rail - short run - international *(used to derive Tables 6.5, 6.9, 6.10 and 6.12)*

Table A6.26 Revealed preference, fare changes over time for the single mode (own elasticity) *(Used to derive Table A6.28 and its successors, Tables 6.5, 6.9, 6.10 and 6.12)*

Description	*Elasticity*	*Reference*	*Designation*
Rail, Sydney, Australia, commuting from outer suburban areas	-0.48	Hensher and Bullock (1979)	FD, RPCS
US rail services, 1986	-0.444	Hsing (1994)	FD, RPCS
US rail services, 1987	-0.640	Hsing (1994)	FD, RPCS
US rail services, 1988	-0.775	Hsing (1994)	FD, RPCS
US rail services, 1989	-0.911	Hsing (1994)	FD, RPCS
US rail services, 1990	-1.057	Hsing (1994)	FD, RPCS
US rail services	-0.78	Hsing (1994)	FD, RPCS
Average	-0.63 (SD = 0.21)	2 cases	FD, RPCS

Table A6.27 Revealed preference fare changes over time for all public transport modes (conditional elasticity) *(Used to derive Table A6.28 and its successors, Tables 6.5, 6.9, 6.10 and 6.12)*

Description	*Elasticity*	*Reference*	*Designation*
Rail, Australia	-0.18	Pratt *et al.* (2000), citing Hensher and Bullock (1977)	FD, UP
Rail, Boston, US	-0.09	Pratt *et al.* (2000), citing Pratt and Copple (1981)	FD, UP
Suburban rail	-0.084 to -0.751	Johnson and Hensher (1982)	FD, RPCE
Rail, average fare	-0.36, range -0.17 to -0.41	Kyte, Stoner, and Cryer (1988)	FD, RPCE
Rail, Australia, short run	-0.35	Bureau of Transport Economics (2003) citing Luk and Hepburn (1993)	FD, UP
Rail, New York/Long Island Rail Road	-0.22	Pratt *et al.* (2000) citing Charles River Associates (1997)	FD, UP
11 cities, suburban rail, Spain, short run	-0.33	Arsenio (2000)	FD, RPU
Rail, Wellington, 1970-85	-0.3 to -0.4	Bureau of Transport Economics (2003) citing Wallis and Yates (1990)	FD, AP
Fixed route public transport (bus and rail) - consistent results for 4 cities: San Diego, Atlanta, Portland Oregon, Ottawa - several independent studies	-0.48	O'Fallon & Sullivan (2000) citing Kain and Lui (1999)	FD, UP
Average	-0.31 (SD = 0.12)	9 cases	FD

Table A6.28 Suburban rail fare elasticities by data type - international data - short run *(Data used to derive Tables 6.5, 6.9, 6.10 and 6.12)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Own elasticity	-0.63	-0.48 to -0.78	0.21	2
Conditional elasticity	-0.31	-0.09 to -0.48	0.12	9
Cross-sectional modelling				
Average	-0.37	-0.09 to -0.78	0.18	11

For data and sources see Tables A6.26, A6.27.

Appendix to Section 6.7.3

Bus short run – London *(used to derive Table 6.23)*

Table A6.29 Revealed preference, fare changes over time for the single mode (own elasticity) *(Used to derive Table A6.31 and its successor, Table 6.23)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, short term	-0.34	Frerk, Lindsey and Fairhurst (1981)	AD, RPCS, L
LT Bus, own	-0.47	Ryder (1982)	AD, RPCS, L
London Bus, between October 1981 and March 1982	-0.30 to -0.33	Collins (1983)	AD, RPCS, L
Bus, short run	-0.42	Fairhurst, Lindsay and Singha (1987)	AD, RPCS L
Bus	-0.2 to -0.6	Fowkes, Sherwood, and Nash (1992)	DD, RPCS, L
Bus, own price, short to medium term	-0.62	London Transport (1993)	AD, RPCS, L
Bus	-0.6	Goodwin (1975)	AD, RPCS, L
Average	-0.45 (SD=0.12)	7 cases	UD, RPCS, L

Table A6.30 Revealed preference, fare changes over time for all public transport modes (conditional elasticity) *(Used to derive Table A6.31 and its successor, Table 6.23)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, short term	-0.53	Frerk, Lindsey and Fairhurst (1981)	AD, RPCE, L
LT Bus, conditional	-0.28	Ryder (1982)	AD, RPCE, L
Bus with respect to London Transport fares	-0.07 to -0.20	Blase (1985)	AD, RPCE, L
Bus, short run	-0.27	Fairhurst, Lindsay and Singha (1987)	AD, RPCE, L
Bus, LT's scenario model	-0.31	Halcrow Fox *et al.* (1993)	AD, RPCE, L
Bus, conditional, short to medium term	-0.35	London Transport (1993)	AD, RPCE, L
Bus, full fare, short run, Greater London	-0.408	Clark (1997)	AD, RPCE, L
Bus, short run, no long run symmetry	-0.839	Gilbert and Jalilian (1991)	AD, RPCE, L
Average	-0.39 (SD= 0.21)	8 cases	UD, RPCE, L

Table A6.31 Bus fare elasticities by data type - UK - London data - short run *(Used to derive Table 6.23)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Own elasticity	-0.45	-0.32 to -0.62	0.12	7
Conditional elasticity	-0.39	-0.14 to -0.84	0.21	8
Average	-0.42	-0.14 to -0.84	0.17	15

For data and sources see Tables A6.29, A6.30.

Bus short run – not London *(used to derive Table 6.23)*

Table A6.32 Revealed preference, fare changes over time for the single mode (own elasticity) *(Used to derive Table A6.34 and its successor Table 6.23)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, Morpeth, all day	-0.70	White (1981)	AD, RPCS, N
Bus, long distance, Sheffield to Doncaster	-0.80	White (1981)	AD, RPCS, N
Bus, medium distance, Doncaster to Rotherham	-0.40	White (1981)	AD, RPCS, N
Bus, 1-2 years	-0.36	McKenzie and Goodwin (1986)	AD, RPCS, N
Bus 23 towns	-0.30	Preston and James (2000)	AD, RPCS, N
Bus (5 scenarios)	-0.371, -0.335, -0.447, -0.370, -0.396	Goodwin (1987)	AD, RPCS, N
Bus, English counties, short run	-0.3 to -0.4	Dargay and Hanly (1999)	AD, RPCS, N
Average	-0.47 (SD= 0.20)	7 cases	UD, RPCS, N

Table A6.33 Revealed preference, fare changes over time for all public transport modes (conditional elasticity) *(Used to derive Table A6.34 and its successor Table 6.23)*

Description	*Elasticity*	*Reference*	*Designation*
Bus	-0.3	Tyson (1984)	AD, RPCE, N
Demand data PTE Area A, bus, travelcard,	-0.12 to -0.47	Preston (1998)	AD, RPCE, N
Demand data PTE Area B, Bus, travelcard,	-0.86	Preston (1998)	AD, RPCE, N
Bus, full fare, short run, English metropolitan areas,	-0.581	Clark (1997)	AD, RPCE, N
Bus, full fare, short run, English non-metropolitan areas	-0.066	Clark (1997)	AD, RPCE, N
Bus, full fare, short run, Wales	-0.341	Clark (1997)	AD, RPCE, N
Bus, full fare, short run, Scotland	-0.336	Clark (1997)	AD, RPCE, N
Average	-0.40 (SD= 0.25)	7 cases	UD, RPCE, N

Table A6.34 Bus fare elasticities by data type - UK - non-London data - short run *(Used to derive Table 6.23)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Own elasticity	-0.47	-0.30 to -0.80	0.20	7
Conditional elasticity	-0.40	-0.07 to -0.86	0.25	7
Cross-sectional modelling				
Average	-0.44	-0.07 to -0.86	0.22	14

For data and sources see Tables A6.32, A6.33.

Appendix to Section 6.7.4

Suburban rail - short run - UK - south east *(data used to derive Table 6.24)*

Table A6.35 Revealed preference fare changes over time for the single mode (own elasticity) *(Data used to derive Table A6.38 and its successor, Table 6.24)*

Description	*Elasticity*	*Reference*	*Designation*
Suburban rail (20 to 120 km), full fare	-0.75 (SD 0.07)	Hughes (1980)	AD, RPCS, L
Suburban rail	-0.4 to -1.5	Fowkes, Sherwood, and Nash (1992)	DD, RPCS, L
Bedford to London, all tickets change	-0.74	Glaister (1983)	AD, RPCS, L
Rail, High Wycombe to London, total trips all fares	-0.77 to -0.90	Glaister (1983)	AD, RPCS, L
Rail	-0.8611 to -0.8670	Fowkes, Nash and Whiteing (1985)	AD, RPCS, L
Rail, total rail travel	-0.55	Wardman (1992b)	DD, RPCS, L
Average	-0.78 (SD = 0.14)	6 cases	RPCS, L

Table A6.36 Revealed preference, fare changes over time for all public transport modes (conditional elasticity) *(Data used to derive Table A6.38 and its successor Table 6.24)*

Description	*Elasticity*	*Reference*	*Designation*
Medium distance rail, full fare ticket	-0.20 ±0.04	Oldfield and Tyler (1981)	AD, RPCE, L
Rail, short term	-0.5 ±0.07	Oldfield and Tyler (1981)	AD, RPCE, L
Rail	-0.35	Oldfield and Tyler (1981)	AD, RPCE, L
Suburban rail, ave 75 studies, all London based	-0.79	Goodwin (1988)	AP, L
Suburban rail, ave 3 studies, London based commuting	-0.31	Goodwin (1988)	AP, L
Suburban rail, London based	-0.55	Goodwin (1988)	AP, L
London Transport's scenario model, BR	-0.1	Halcrow Fox *et al.* (1993)	AD, RPCE, L
Rail short run, Network SouthEast	-0.395	Clark (1997)	AD, RPCE, L
Average	-0.35 (SD = 0.19)	4 cases	UD, L

Table A6.37 Cross-sectional modelling *(Data used to derive Table A6.38 and its successor, Table 6.24)*

Description	*Elasticity*	*Reference*	*Designation*
Journeys to work overall	-0.7	Mackett (1985)	AD, RPM, L
Local Rail, W Yorkshire, cross-sectional model, run not stated	-0.825	Preston (1987)	AD, RPM, N
Rail, all trips, short run	-0.31	Mackett and Nash (1991)	AD, RPM, L
Average	-0.61 (SD = 0.27)	3 cases	UD, RPM

Table A6.38 Suburban rail fare elasticities by data type - UK - South east data - short run *(Data used to derive Table 6.24)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Revealed preference single mode	-0.78	-0.55 to -0.95	0.14	6
Revealed preference all modes	-0.35	-0.10 to -0.55	0.19	4
Cross-sectional modelling	-0.61	-0.31 to -0.83	0.27	3
Average	-0.61	-0.10 to -0.95	0.26	13

For data and sources see Tables A6.35, A6.36 and A6.37.

Suburban rail - short Run - UK - not-south-east *(used to derive Table 6.24)*

Table A6.39 Revealed preference fare changes over time for the single mode (own elasticity) *(Data used to derive Table A6.42 and its successor, Table 6.24)*

Description	*Elasticity*	*Reference*	*Designation*
Rail elasticities for work and school trips, if only rail fares changed,	-0.46 or -0.53	Bamford (1984)	AD, RPCS, N
BR's own figure for the provincial sector	-0.9	Goodwin (1992)	AD, RPCS, N
Rail, single market hierarchical logit model (work-trips only)	-0.34	Preston (1991)	AD, RPCS, N
Average	-0.58 (SD = 0.29)	3 cases	UD, RPCS, N

Table A6.40 Revealed preference, fare changes over time for all public transport modes (conditional elasticity) *(Data used to derive Table A6.42 and its successor Table 6.24)*

Description	*Elasticity*	*Reference*	*Designation*
West Midlands BR ridership price elasticity, before and after surveys	-0.18	Goodwin *et al.* (1992) citing Godward (1984)	AD, RPCE, N
Glasgow, rail	-0.44 to -0.49	Goodwin and Williams (1985)	AD, RPCE, N
Suburban rail, average of 2 studies, non-London	-0.67	Goodwin (1988)	AP, RPCE, N
Rail, log linear model	-0.83	Preston (1991)	AD, RPCE, N
Rail, semi-log model	-0.65	Preston (1991)	AD, RPCE, N
Rail	-0.74	Preston (1991)	AD, RPCE, N
Rail short run, Regional Railways	-0.299	Clark (1997)	AD, RPCE, N
Demand Data PTE Area C, Rail, travelcard	-1.02	Preston (1998)	AD, RPCE, N
Rail, short run, PTE Area A	-0.15	Preston (1998)	AD, RPCE, N
Average	-0.50 (SD = 0.32)	7 cases	UD, RPCE, N

Table A6.41 Cross-sectional modelling *(Data used to derive Table A6.42 and its successor Table 6.24)*

Description	*Elasticity*	*Reference*	*Designation*
Local Rail, W Yorks, cross-sectional model, run not stated	-0.825	Preston (1987)	AD, RPM, N
Average	-0.83	1 case	UD, RPM, N

Table A6.42 Suburban rail fare elasticities by data type - UK - non south east data - short run *(Data used to derive Table 6.24)*

Run	*Elasticity*	*Range*	*Standard deviation*	*Number of cases*
Revealed preference single mode	-0.58	-0.34 to -0.90	0.29	3
Revealed preference all modes	-0.50	-0.15 to -1.02	0.32	7
Cross-sectional modelling	-0.83	-0.83 to -0.83	n/a	1
Average	-0.55	-0.15 to -1.02	0.30	11

For data and sources see Tables A6.39, A6.40, and A6.41.

Appendix to Section 6.8

Below are given the actual elasticity values and their study sources, used to derive the elasticity values presented in Table 6.24.

Peak travel/work trips - UK

Table A6.43 Bus *(Used to derive Table 6.26)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, peak,	-0.42	Fowkes, Sherwood and Nash (1992) citing Hallam (1978)	RPCE, L
Bus, short term, peak	-0.28	Frerk, Lindsey and Fairhurst (1981)	AD, RPCS, L
Bus, short term, peak,	-0.47	Frerk, Lindsey and Fairhurst (1981)	AD, RPCE, L
Bus, short term, peak	-0.375	Frerk, Lindsey and Fairhurst (1981)	AD, RPCE, L
Bus, Morpeth, peak,	0.00	White (1981)	AD, RPCS,N
Bus, peak, London	-0.28	London Transport (1984)	AD, RPCE, L
Bus, business and commuting	-0.3	Fowkes, Sherwood and Nash (1992)	DD,RPCS, L
Bus, am peak, fixed	-0.24	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM
Bus, peak, equilibrated	-0.18	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM
Bus, am peak	-0.21	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM
Bus, short run, peak	-0.20 to -0.30	Literature review in Halcrow Fox *et al.* (1993)	AP
Bus, medium run, peak	-0.28	Literature review in Halcrow Fox *et al.* (1993)	AP
Bus, peak	-0.265	Literature review in Halcrow Fox *et al.* (1993)	AP
Bus, 23 towns, peak, town centre	-0.38	Preston and James (2000)	AD, RPCS, N
Bus, 23 towns, peak, other areas	-0.08	Preston and James (2000)	AD, RPCS, N
Average	-0.26 (SD = 0.14)	9 cases	UD

Table A6.44 Metro *(Used to derive Table 6.26)*

Description	*Elasticity*	*Reference*	*Designation*
Underground, London, peak	-0.35	Fowkes, Sherwood and Nash (1992) citing Hallam (1978)	AD, RPCE, L
Underground, short term, peak	-0.15	Frerk, Lindsey and Fairhurst (1981)	AD, RPCS, L
Underground, short term, peak	-0.37	Frerk, Lindsey and Fairhurst (1981)	AD, RPCE, L
Underground, short term, peak	-0.26	Frerk, Lindsey and Fairhurst (1981)	AD, L
Underground, peak	-0.15	London Transport (1984)	AD, RPCE, L
Metro, business and commuting,	-0.3	Fowkes, Sherwood, and Nash (1992)	DD, RPCS, L
Metro, am peak, fixed	-0.29	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM
Metro am peak, equilibrated	-0.22	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM
Metro am peak	-0.255	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM
Underground, short run, peak	-0.20 to -0.29	Literature review in Halcrow Fox *et al.* (1993)	AP
Average	-0.26 (SD=0.07)	6 cases	UD

Table A6.45 Suburban rail *(Used to derive Table 6.26)*

Description	*Elasticity*	*Reference*	*Designation*
Rail, single market hierarchical logit model (work-trips only)	-0.34	Preston (1991)	AD, RPCS
Suburban rail, business and commuting	-0.5	Fowkes, Sherwood, and Nash (1992)	DD, RPCS, L
Rail, am peak, fixed, BR	-0.33	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM
Rail, am peak, equilibrated, BR	-0.20	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM
Rail am peak, BR	-0.265	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM
Rail, short run, peak, BR	-0.20 to -0.33	Literature review in Halcrow Fox *et al.* (1993)	AP
Average	-0.34 (SD = 0.11)	4 cases	UD

Peak travel/work trips - international

Table A6.46 Bus *(Used in Section 6.8.1)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, Trenton, New Jersey, peak	-0.15	Hamberger and Chatterjee (1987) citing Mayworm, Lago and McEnroe (1980)	FD
Unlagged time series regression of transit ridership in Cincinnati, 1980-1983, peak	-0.31	Cervero (1985)	FD
Bus, Spokane, Washington, peak	-0.32	Linsalata and Pham (1991)	FD
Bus, Grand Rapids, Michigan, peak	-0.29	Linsalata and Pham (1991)	FD
Bus, Portland, Oregon, peak	-0.20	Linsalata and Pham (1991)	FD
Bus, San Francisco, California, peak	-0.14	Linsalata and Pham (1991)	FD
Bus, Los Angeles, California, peak	-0.21	Linsalata and Pham 1991)	FD
Bus, Dublin, peak	-0.267	O'Mahony *et al.* (1995)	FD, RPCS
Average	-0.24 (SD = 0.07)	8 cases	FD

Off-peak travel and weekend/leisure trips - UK

Table A6.47 Bus *(Used to derive Table 6.26)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, off-peak	-0.68	Fowkes, Sherwood and Nash (1992) citing Hallam (1978)	AD, RPCE, L
Bus, short term, off-peak	-0.38	Frerk, Lindsey and Fairhurst (1981)	AD, RPCS, L
Bus, short term, off-peak	-0.57	Frerk, Lindsey and Fairhurst (1981)	AD, RPCE, L
Bus, short term, off-peak	-0.48	Frerk, Lindsey and Fairhurst (1981)	AD, L
Bus, Morpeth, off peak, inter-urban	-1.00	White (1981)	AD, N
Bus, off-peak	-0.38	London Transport (1984)	AD, RPCE, L
Bus, Greater Manchester, off-peak	-0.6	Tyson (1984)	AD, RPCE, N
Bus, leisure	-0.6	Fowkes, Sherwood and Nash (1992)	DD, RPCS
All public transport, interpeak, equilibrated,	-0.14	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM, L
Bus, short run, off-peak	-0.14	Literature review in Halcrow Fox *et al.* (1993)	AP
Bus, 23 towns, off-peak, town centre	-0.43	Preston and James (2000)	AD, RPCS, N
Bus, 23 towns, off-peak, other	-0.38	Preston and James (2000)	AD, RPCS, N
Average	-0.48 (SD = 0.26)	10 cases	UD

Table A6.48 Metro *(Used to derive Table 6.26)*

Description	*Elasticity*	*Reference*	*Designation*
Underground, London off-peak	-0.63	Fowkes, Sherwood and Nash (1992) citing Hallam (1978)	AD, RPCE, L
Underground, short term, off-peak	-0.26	Frerk, Lindsey and Fairhurst (1981)	AD, RPCS, L
Underground, short term, off-Peak	-0.48	Frerk, Lindsey and Fairhurst (1981)	AD, RPCE, L
Underground, short term, off-peak	-0.37	Frerk, Lindsey and Fairhurst (1981)	AD, L
Underground, off-peak,	-0.26	London Transport (1984)	AD, RPCE, L
Metro, leisure	-0.6	Fowkes, Sherwood, and Nash (1992)	DD, RPCS, L
Underground, London, inter peak, equilibrated	-0.23	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM, L
Average	-0.42 (SD = 0.19)	5 cases	UD, L

Table A6.49 Suburban rail *(Used to derive Table 6.26)*

Description	*Elasticity*	*Reference*	*Designation*
Rail short term, season ticket	-0.7 ±0.03	Oldfield and Tyler (1981)	AD, RPCE, L
Suburban rail, leisure	-1.5	Fowkes, Sherwood, and Nash (1992)	DD, RPCS, L
Rail, interpeak, equilibrated, all PT	-0.58	Halcrow Fox *et al.* (1993) citing MVA (1992)	AD, RPM, L
Suburban rail, short run, off peak	-0.58	Literature review in Halcrow Fox *et al.* (1993)	AP
Rail, railcard up to 60 miles, leisure and shopping	-0.60	Steer Davies Gleave (1993)	UD
Rail, non-railcard, leisure and shopping	-0.58	Steer Davies Gleave (1993)	UD
Rail, leisure and shopping	-0.59	Steer Davies Gleave (1993)	UD
Average	-0.79 (SD = 0.40)	5 cases	UD

Off-peak travel and weekend/leisure trips - International

Table A6.50 Bus *(Used in Section 6.8.1)*

Description	*Elasticity*	*Reference*	*Designation*
Bus, off-peak	-0.29	Hamberger and Chatterjee (1987) citing Mayworm, Lago and McEnroe (1980)	FD, AP
Bus, off-peak, Cincinnati, unlagged time series regression of transit ridership, 1980-1983	-0.69	Cervero (1985)	FD
Bus, off-peak, Spokane Washington	-0.73	Linsalata and Pham (1991)	FD
Bus, off-peak, Grand Rapids, Michigan	-0.49	Linsalata and Pham (1991)	FD
Bus, off-peak Portland, Oregon	-0.58	Linsalata and Pham (1991)	FD
Bus, off-peak San Francisco, California	-0.31	Linsalata and Pham (1991)	FD
Bus, off-peak, Los Angeles, California	-0.29	Linsalata and Pham (1991)	FD
Bus, off-peak, Dublin	-0.724	O'Mahony *et al.* (1995)	FD, RPCS
Average	-0.51 (SD = 0.20)	8 cases	FD

Appendix to Section 6.14

Review of British evidence on fares elasticities (by Mark Wardman and Jeremy Shires)

A6.14.1 Introduction

Empirical analysis of the behavioural impact of a wide range of travel variables has been conducted extensively in Britain over the past forty years or so. With the likely exception of the value of travel time (Wardman, 2001), the most widely estimated parameters have been price elasticities of demand and in particular public transport fare elasticities. The wealth of available evidence provides an excellent opportunity to obtain greater insights into fare elasticities and their determinants.

There have been numerous notable reviews of price elasticities (Bly, 1976; TRRL, 1980; Goodwin and Williams, 1985; Goodwin, 1992; Oum *et al.*, 1992; Halcrow Fox *et al.*, 1993; Wardman, 1997b; Nijkamp and Pepping, 1998; Pratt, 2000; De Jong and Gunn, 2001; Graham and Glaister, 2002; VTPI, 2003). The unique features of this study are that it covers a much larger amount of public transport evidence and a broader range of issues than previous reviews and, more significantly, it has developed a model to explain variations in fare elasticities across studies.

This review covers 902 public transport fare elasticities obtained from 104 studies conducted in Britain between 1951 and 2002. The markets covered are inter-urban rail travel, suburban rail travel, urban bus travel and London Underground. The research was specifically undertaken to input to the updating of this document.

A6.14.2 Purpose

Whilst assembling the wealth of empirical evidence and attempting to explain variations in fare elasticities across studies has its limitations, such as an inability to examine detailed issues such as how fare elasticities vary with the level of fare charged or socio-economic characteristics, and reliance on the use of proxy variables, it does have a number of significant attractions:

- As a result of drawing together a wealth of evidence on fare elasticities, conclusions can be drawn about the preferred elasticity values to be used in a range of different circumstances. This is particularly useful where it is not otherwise possible to obtain independent fare elasticity estimates. It is also generally preferable to base recommended values on the results of a number of studies rather than a few or a single one.
- Insights can be obtained into methodological issues, such as fare elasticity estimates varying according to the type of data upon which they are estimated.
- It is possible to draw conclusions that are often beyond the scope of a single study. For example, collecting together evidence from numerous studies is particularly useful in indicating how elasticities vary over time. Similarly, few studies estimate elasticities across a wide range of circumstances whereas pooling elasticities estimates allows more detailed analysis of cross-sectional variations in elasticities according to, for example, area or distance and insights to be obtained into the relationship between ordinary and mode choice elasticities and between conditional and non-conditional elasticities.
- Results which would not otherwise be in the public domain, primarily due to commercial confidentiality, can be exploited because the means of analysis maintains their anonymity.
- The development of models to explain variations in elasticities is useful where there is conflicting evidence across studies and provides a means of appraising current recommendations and conventions and of interpreting the results of a single empirical study in the light of a large amount of previous evidence.
- Traditional reviews tend to focus on mean values rather than the variation. As such, there is always the risk that a comparison of means is distorted by confounding effects. For example, cross-sectional data is more common in older evidence and stated preference data is more common in recent years and this may give a misleading effect of elasticity variation over time.

A6.14.3 Data assembly

The elasticities in the studies reviewed cover the period 1951 to 2002, although the publication dates of the studies range between 1968 and 2002. The number of studies and fare elasticities broken down by time period are given in Table A6.51. As can be seen, there is a good temporal spread of data. We have only made use of elasticity figures which have been reported in studies; there has been no attempt to deduce elasticities from estimated parameters.

Table A6.51 Studies and elasticities by time period

Elasticity time period			*Publication date*		
Years	*Studies*	*Elasticities*	*Years*	*Studies*	*Elasticities*
1951-1955	1	2	1968-1972	5	10
1956-1960	0	3	1973-1977	8	65
1961-1965	3	24	1978-1982	11	90
1966-1970	7	31	1983-1987	16	235
1971-1975	9	99	1988-1992	28	166
1976-1980	18	235	1993-1997	22	74
1981-1985	14	49	1998-2002	14	262
1986-1990	32	224			
1991-1995	15	194			
1996-2002	5	41			

The time period relates to that for which the elasticity was estimated. In the case of time series data, the midpoint is used.

The numbers of elasticities and studies covering each mode are given in Table A6.52. Bus and inter-urban rail are particularly well represented, but even the smallest category of 42 for underground is significant by comparison with many review studies.

Table A6.52 Modal coverage

Mode	*Studies*	*Values*
Bus	41	305
Underground	12	42
Suburban rail	28	99
Inter urban rail	57	456

This study differs from previous reviews in its sourcing of elasticity values. Oum *et al.* (1992) concentrated on material published in academic journals. Goodwin (1992) widened the net to include reports produced by government agencies, transport operators or the research organisation responsible but which were 'unambiguously in the public domain'. We have here made extensive use of consultancy reports and working papers which are not in the public domain but nonetheless reported serious research and credible results. As is clear from Table A6.53, this allowed us to amass a much larger data set than would otherwise be possible.

Table A6.53 Sources of elasticity evidence

Source	*Studies*	*Elasticities*
Journal/book	12 (12%)	137 (15%)
Conference paper	2 (2%)	54 (6%)
Review study	4 (4%)	39 (4%)
Published report	16 (15%)	200 (22%)
Unpublished operator commissioned report	34 (33%)	309 (34%)
Unpublished Government commissioned report	4 (4%)	22 (2%)
Unpublished academic report	12 (12%)	57 (6%)
Unpublished 'In house' report	20 (19%)	84 (10%)

A review study might be published as, say, a journal article, but material that is not the author's own and therefore where we have not accessed the primary material is here separately identified. Published reports include TRL and LGORU reports and other publicly available documents such as University Working Papers and final reports published by operators or government agencies. Unpublished academic reports includes PhD and Masters dissertations.

The elasticities can be regarded as largely independent pieces of information. Separate elasticities were collected from a single study if they represented different modes, journey purposes, types of data, routes or areas, ticket types, distances, or market segments, or if they distinguished between short-run and long-run effects, mode choice and ordinary elasticity, and conditional and non-conditional elasticity. The distribution of elasticities per study is given in Table A6.54. Those studies which yielded a large number of elasticities tended to distinguish between short run and long run and estimated separate elasticities by route or type of data (Owen and Phillips, 1987; Phillips, 1987; Dargay and Hanly, 1999). The average number of elasticities per study is 8.6, with 54% of studies providing 5 or fewer elasticities and 90% providing 15 or fewer.

Table A6.54 Number of elasticities per study

η	*Studies*	*η*	*Studies*	*η*	*Studies*
1	26	6	10	11-15	12
2	15	7	4	16-20	3
3	5	8	3	21-30	3
4	7	9	1	31-50	2
5	4	10	6	51+	3

A wide range of information has been collected to explain variations in fare elasticities across studies:

- Whether the elasticity was estimated to aggregate revealed preference (RP) data, with a further distinction between time series and cross sectional data, disaggregate RP data, before-and-after data, stated preference (SP) data or stated intention data.
- Whether a time series fare elasticity estimate related to the short run, long run or whether no distinction was made between the two.
- Whether the elasticity was estimated at national, regional, district or route level and, where appropriate, the area to which the elasticity related.
- The year to which the elasticity estimate relates, and the associated gross domestic product (GDP) per capita in that period.
- Whether the elasticity was conditional or not. Two types of conditional elasticity were examined. One related to the competition between different ticket types in the inter-urban market and the other related to competition between different modes in the urban market
- The mode to which the elasticity was estimated.
- Whether the elasticity relates to urban or inter-urban rail travel and the average distance involved.
- Journey purpose, including combinations of purposes where clear distinctions were not made.
- The ticket type used, covering season tickets, multi-modal tickets, other prepaid tickets and cash fares for urban travel and first class, standard class unrestricted and standard class restricted for inter-urban rail travel.
- The market segment, and in particular whether the elasticity related to elderly or child concessionary fares.
- Whether the elasticity was an ordinary or mode choice elasticity.
- The source of the data used to estimate the model.
- Whether the elasticity was arc or point and whether the estimated function was constant elasticity, proportional elasticity, a logit function or some other variable elasticity form.
- Where possible, the sample size upon which the model was estimated.
- Where available, a confidence interval for the elasticity estimate.

A full list of the studies covered and a detailed description of the data set assembled are contained in Wardman and Shires (2003).

A6.14.4 Results

The main aim of this study is to explain variations in fare elasticities across a large number of British studies and regression analysis provides a means of achieving this.

The regression model explaining fare elasticity variation as a function of variations in a range of explanatory variables could take several forms. The main two contenders are a multiplicative form or an additive form. The multiplicative model takes the form:

$$\eta = \tau \prod_{i=1}^{n} X_i^{\alpha_i} e^{\sum_{j=1}^{p} \sum_{k=1}^{q=1} \beta_{jk} Z_{jk}} \quad (1)$$

There are n continuous variables (X_i) and the a_i denote elasticities of the fare elasticity with respect these variables. Thus if X were distance, its coefficient would indicate the proportionate change in the fare elasticity resulting from a proportionate change in distance. The Z_{jk} are dummy variables representing the p categorical variables. We can specify q-1 dummy variables for a categorical variable of q levels and their coefficient estimates (b_{jk}) are interpreted relative to the arbitrarily omitted level. The exponential of β_{jk} denotes the proportionate effect on the fare elasticity of level k of the j'th categorical variable relative to its omitted category. Thus if a dummy variable is specified for inter-urban travel, the exponential of its coefficient indicates the proportionate impact on the fare elasticity of a journey being inter-urban rather than urban.

A logarithmic transformation of the multiplicative model allows the estimation of its parameters by ordinary least squares[1]. The additive form of the model is represented as:

$$\eta = \mu + \sum_{i=1}^{n} \alpha_i X_i + \sum_{j=1}^{p} \sum_{k=1}^{q=1} \beta_{jk} Z_{jk} \quad (2)$$

Here the α_i represent the marginal effect of a change in X_i on the fare elasticity whilst the β_{jk} denote the additive effect on the fare elasticity of a particular level of a categorical variable relative to its base level.

After making appropriate adjustments for the different dependent variables, the multiplicative model was found to achieve a somewhat better fit and is that reported.

The estimated model is reported in Table A6.55. It contains all but six of the 902 elasticity values collected. The six elasticities identified as outliers all related to inter-urban rail trips and were less than -0.15. The goodness of fit at 0.52 seems quite respectable given the disparate nature of the studies, the inherent inability of this type of approach to examine detailed variations in elasticities, and the sampling distribution surrounding any individual fare elasticity estimate.

Collinearity is not a problem to any great extent. Coefficient estimates with correlations in excess of 0.5 were non commuting and all purposes (0.61), commuting outside the south east and all purposes (0.59), conditional first class and non commuting (0.58), and commuting within the south east and all purposes (0.54).

[1] *The elasticities are therefore specified in absolute form prior to taking logarithms.*

Table A6.55 Regression model results

	Coeff (t)	*Effect*
Intercept	-0.335 (4.0)	*0.715
Distance - inter urban rail	0.086 (4.4)	
Rail	Base	
Bus	-0.375 (6.3)	-31%
UG	-0.345 (3.1)	-29%
Short term/neither/before and after	Base	
Long run rail	0.386 (7.1)	+47%
Long run bus	0.670 (9.8)	+95%
Cross sectional - urban	0.169 (1.9)	+18%
Cross sectional - inter urban rail	0.671 (2.0)	+96%
SP-rail	0.193 (2.3)	+21%
Stated intention	0.464 (6.0)	+59%
Ordinary elasticity	Base	
Mode choice leisure	-0.451 (3.9)	-36%
Urban and inter urban London	Base	
Inter urban non London	-0.118 (2.3)	-11%
Leisure	Base	
Business rail	-0.620 (4.7)	-46%
Business UG	-1.845 (3.9)	-84%
Business bus	-0.199 (1.9)	-18%
Commute south east	-0.530 (5.5)	-41%
Commute not south east	-0.413 (4.6)	-34%
All purposes	-0.278 (3.9)	-24%
Not commute	-0.293 (4.2)	-25%
No concessions	Base	
Elderly full	0.226 (2.1)	+25%
Elderly concession	-0.718 (5.6)	-51%
Child	0.125 (1.7)	+13%
Non PTE and non rural	Base	
PTE	-0.142 (2.6)	-13%
Rural bus	0.473 (4.7)	+60%
Rural rail	-0.348 (2.2)	-29%
Std and 1st rail/non conditional full	Base	
Conditional 1st	-0.484 (5.2)	-38%
Conditional full	-0.216 (1.9)	-19%
Conditional reduced	0.130 (2.2)	+14%
Non conditional 1st	-0.407 (2.5)	-33%
Non conditional reduced	0.402 (3.3)	+50%
Non conditional bus	Base	
Conditional bus	-0.214 (2.1)	-19%
Non conditional UG	Base	
Conditional UG1	-0.815 (4.5)	-56%
Conditional UG2	-1.007 (5.6)	-64%
Non conditional rail	Base	
Conditional rail	-0.072 (1.1)	-7%
Adjusted R^2	0.52	
Observations	896	

Excluded variables

In general, interaction terms were specified to explore whether the incremental effects varied across modes in particular but according to other factors, such as area or journey purpose where there was reason to expect elasticity variation. The reported model contains only those distinctions that were statistically significantly or which were of sufficient important to merit retention.

A number of variables did not have a statistically significant influence on the fare elasticity. Of particular interest was the testing of whether the fare elasticity increased over time. This was specified in relation to both a time trend term and GDP per capita and separate effects were allowed for each mode as well as pooled terms across modes. Despite the view that at least in the bus market the fare elasticity has increased over time, we found not the slightest evidence to support inter-temporal variations in fare elasticities for any mode. The coefficients on both GDP and the time trend and their associated t statistics were to all intents and purposes zero. We return to this issue below.

Nor were there any significant effects attributable to the type of elasticity function estimated, the spatial aggregation of the estimated model, the source of the data for model estimation or ticket type for urban journeys.

Distance

We cannot take distance as a proxy for fare level because of distance tapers whilst in any event the fare elasticity might depend not only on the absolute fare but also, as a measure of value for money, on the fare per mile. However, we might expect the fare elasticity to vary with distance since a given proportionate change implies a larger absolute change at longer distances but offsetting this is that public transport tends to achieve higher shares as distance increases. Any distance effect must be included to allow transferability of the results, and causal inspection of only a few rail studies soon reveals that fare elasticities are clearly larger for longer distance journeys.

Separate distance terms were specified for each mode. However, we did not anticipate an effect for urban journeys both because the range of distances is small and because of the approximations introduced in estimating a representative distance for urban journeys where none was reported. The results confirmed our expectations and no distance effects were apparent for bus, suburban rail, or underground.

Within inter-urban rail journeys, a statistically significant effect from distance on the fare elasticity was discerned. However, the distance elasticity of 0.086 is not particularly strong. For inter-urban rail, the majority of evidence relates to analysis of ticket sales and only limited allowance for journey purpose effects can be made by segmenting by ticket type. The distance effect may therefore also reflect a larger proportion of more elastic leisure travel at longer distances as well as any absolute fare variation effects.

Mode

The base category is rail, with no distinction necessary between suburban and inter-urban rail. The results show that, other things equal, the bus and underground fare elasticities are respectively 31% and 29% lower than rail fare elasticities.

Data type and time period

This is an area where meta-analysis can provide valuable insights of a methodological nature as well as drawing together evidence from a range of sources to obtain a collective value for dynamic effects.

The base category was specified as elasticities estimated to time series data which were explicitly short term in nature. In addition, as a result of their effects being far from statistically significant, the base also include those fare elasticities obtained from time series models where no distinction was made between short and long run and also those estimated in before and after studies.

There was no evidence to allow a distinction between long run and short run underground fare elasticities. For rail travel, the incremental effect of the long run was similar for inter-urban and suburban rail (0.42 and 0.38) and hence a single term was specified. For bus, the variation between long run and short run elasticities is somewhat larger.

The long-run rail elasticities are 47% larger than the short run elasticities whilst for bus the figure is 95%. Presumably, in the long run the number of alternative courses of action are greater for bus than for rail. The bus evidence will relate to commuting trips, where lagged home and employment location decisions are relevant, much more than for rail. The figure estimated for bus is very consistent with the conclusions of Dargay and Hanly (2002) who state that, 'The evidence suggests that the long-run elasticities are about twice the short-run elasticities'.

Given that there was not a great deal of cross-sectional evidence for urban travel, and the figures for bus and suburban rail of 0.14 and 0.24 are broadly in line, a single figure was estimated. This indicates that cross-sectional urban values are 18% higher than short-run time series values. In contrast, the figure for cross-sectional inter-urban rail indicates the fare elasticity to be 96% larger than the short run time series value.

Those fare elasticities here denoted as cross-sectional were estimated to spatial variations in aggregate data. Although they are often regarded as representing longer term effects, and the results here would to some extent support this, they can suffer from specification errors associated with cross-sectional models, such as adequate specification of catchment areas and 'size' effects and a failure to distinguish between cause and effect. This may have contributed to the lack of consistency between the long-run time series and cross-sectional effects.

Terms were specified to denote whether the fare elasticity was obtained from disaggregate RP choice data or from SP data. No significant effect was detected in the case of the former but some interesting finding emerged with respect to SP data.

Our data set contains only a small amount of SP-based evidence for underground and bus and the SP coefficient was far from significant for these modes separately or together. In contrast, most evidence comes from rail studies and the coefficient estimate indicates that SP-based elasticities are on average 21% higher than the base.

The fare elasticity for a public transport mode X (η_x) implied by a logit model, which is that by far most commonly estimated, and for the almost universally estimated linear-additive utility function, would be:

$$\eta_X = \beta_X F_X (1 - p_X)$$

where β_X is the marginal utility of variations in the cost of X, F_X is the fare of X and P_X is the probability of choosing X.

The coefficients and hence forecast choice probabilities of discrete choice models are estimated in units of residual variation. If, as we might reasonably expect, the amount of random error in an SP model is greater than is consistent with actual decision making, then β_X will be too low. Given that the public transport mode will be the minor mode in most of the instances covered, since it is was compared with car, P_X will then be too large and will also operate to reduce the fare elasticity.

It is therefore of some concern that the SP effect denotes a higher elasticity when we would expect it to be lower and given that allowance has been made in the leisure market for SP models covering only part of the behavioural response. In any event, a failure of SP choice models to cover all aspects of choice relevant to the overall elasticity would again lead to lower elasticities than otherwise.

A possible, and we believe very likely, explanation of the high elasticities obtained from SP data is that the stated sensitivity to cost is much higher than it should be as a result of protest response. Public transport fares are a sensitive issue and are often perceived to be very much in the control of the operators such that there is an incentive to send a signal that increases would not be tolerated but reductions would very much be appreciated.

It is not clear whether SP models can be regarded as providing short-run or long-run effects. To the extent that individuals evaluate hypothetical scenarios in the context of a specific journey, the responses will not include long-run effects associated with moving house or job. However, they cannot be regarded as short-term effects to the extent that the presentation of information and the requirement to make decisions overcome issues of misperception and habit which are barriers to behavioural change. Nonetheless, even in the long run the demand forecast by SP based parameters may not materialise because of remaining issues of misperception.

Whilst it has often been claimed that stated intention data will produce demand forecasts which over-predict behavioural response to changes in fare and other attributes, quantitative evidence on the degree of inaccuracy is both sparse and potentially valuable as a correction factor for what is otherwise a very straightforward technique.

The stated intention evidence was almost entirely obtained from studies of inter-urban rail travel. The results indicate that such elasticities are 59% larger than the short-run rail elasticity. Thus regardless of whether stated intention data reflects short- or long-run effects, it would produce higher elasticities. However, the uncertainty of the extent to which it is short or long run means that unfortunately correction factors cannot be derived with any great degree of confidence.

Mode choice elasticity

In their review of price elasticities, Oum *et al.* (1992) recognised the key area of disaggregate choice modelling and its potential to provide evidence. However, given the absence of trip generation effects from the implied elasticities, they concluded, 'Consequently, it is virtually impossible to draw on the extensive mode-choice literature to help establish values of ordinary demand elasticities'.

We would expect the mode choice elasticity to provide a reasonably accurate account of the ordinary elasticity for commuting and business trips where mode choice will provide the vast majority of the change in demand for any public transport mode. For leisure travel, there will be a trip generation effect and thus the mode choice elasticity will underestimate the ordinary elasticity.

We therefore specified a term to denote those elasticities which were based on the output of disaggregate choice models, estimated to either RP or SP data, and which related to leisure travel. A statistically significant effect was detected, indicating quite plausibly that the mode choice elasticity for leisure travel is 36% less than the ordinary elasticity.

Not only is this a useful parameter in allowing us to make use of the other information context of the mode choice elasticities alongside the ordinary elasticities, but it provides a measure which is potentially useful to those using disaggregate models to convert from mode choice to ordinary elasticities.

Analysis was conducted to determine variation in the effect across modes but none was apparent. The small number of observations when split by mode may well have contributed to this finding.

Inter-urban non London rail travel

One of the most consistent findings across studies of which we are aware is an estimated fare elasticity of around -0.9 on non London inter-urban rail flows. This elasticity is lower than is typically obtained on London based flows at least for tickets where, as on non London flows, leisure travel dominates.

The result indicates that the fare elasticity is 11% lower on non London than London inter-urban flows. This is presumably the result of the lower fares typically charged on the former.

Journey purpose

A wide variety of distinctions by journey purpose are made across studies. Within urban travel market, a distinction often made is between peak and off-peak travel. For the purposes of this study, values estimated for peak travel have been subsumed within commuting whilst off-peak values are included within leisure travel.

For the rail market, a large proportion of the fare elasticity evidence is obtained from analysis of ticket sales where segmentation by journey purpose is not always straightforward. In such cases, season tickets are also indicated as commuting trips whilst non London inter-urban flows are assigned to the leisure category. First class rail trips are assigned to a journey purpose of first class business alongside such evidence obtained from other forms of data.

Elasticities estimated to non-season ticket sales data on suburban services are assigned to a category which indicates all journey purposes whilst full, reduced and combined Standard class ticket types on London inter-urban flows are denoted as non commuting trips as far as journey purpose is concerned.

Business travellers generally have, as expected, the least sensitivity to cost. The differential is small for bus but there will be few in this category. No additional effect was apparent for the first class business travelers.

Commuters are also somewhat less sensitive to fare than are leisure travellers. This is to be expected given that public transport has higher shares in the commuting than leisure market, although the generally higher fares in the peak can be expected to have had a dampening effect. The higher impact in the south east may stem from public transport's particularly strong position in that area whilst the generally higher incomes in the south east may also have contributed. No significant differences in the commuting elasticity according to mode were apparent.

The remaining two significant categories relate to all purposes and to non-commuting purposes. Given that all purposes contains leisure travel, the effect is consistent with the relative fare elasticities for business travel, commuting and leisure, lying as it does broadly between the leisure and commuting effect. Given that business trips will form a larger proportion of the non commuting trips than the all purposes trips, the non commuting effect is, as expected, larger than the all purposes effect.

Concessionary travel

Elderly travellers paying full fares have higher elasticities than other adults. This is presumably because they have lower incomes and because the journeys largely relate to discretionary travel. However, where concessionary fares apply, the fare elasticity for the elderly is somewhat lower. There was insufficient data to examine variations by mode.

For child fare elasticities, there were too few observations to split by concession or not, but most relate to concessionary travel. Even at the lower fares, the elasticity is a little higher than for adults, again presumably reflecting income effects.

Area

Few significant variations by area were apparent. In addition to different commuting elasticities between the south east and elsewhere, Passenger Transport Executive (PTE) areas exhibit lower elasticities. This is presumably because in these areas public transport has a relatively high share and fares tend to be lower. For quite the reverse reasons, the bus fare elasticities are 60% higher in rural areas.

The rail fare elasticity is somewhat lower for rural travel. This may be because those who do use such rail services are highly dependent upon it, although it should be pointed out that there are few observations.

Conditional and non-conditional ticket type elasticities

These relate solely to different ticket types in the inter-urban travel market. The data distinguishes between whether a conditional or non-conditional elasticity was estimated.

The ticket type distinctions were: first class; standard class tickets where there are no restrictions on travel, which are termed full fare tickets; standard class tickets where there are restrictions on times of travel, which are termed reduced tickets; standard class tickets, where the elasticity makes no distinction between different standard class tickets; and cases where no distinction was made between first and standard class tickets.

What is termed a conditional elasticity is obtained if the fares of competing tickets are changed in the same proportion as the ticket of interest. This will be lower than the non-conditional elasticity since the fare increase on competing tickets means that there will be some switching from those tickets to the ticket of interest.

The non-conditional elasticity is obtained when the fare of a ticket is varied and this is not correlated with the fares of competing tickets.

The conditional elasticity for a particular ticket is simply the sum of its non-conditional elasticity and cross-elasticities with respect to the prices of competing tickets.

The base was initially chosen as the full-fare non-conditional elasticity. However, the base also subsequently contained the fare elasticities for standard class and for first and standard class combined which were not significantly different from the full-fare non-conditional elasticity. There were too few inter-urban season tickets to distinguish this from the other commuting evidence.

The results split by ticket type generally appear plausible. The conditional elasticities for first, full and reduced tickets are all less than their non-conditional elasticities whilst, as expected, the first class largely business travel tickets have the lowest elasticities and the reduced tickets which are dominated by leisure travel have the highest elasticities. The difference between the conditional and non-conditional elasticities indicates low cross elasticities between ticket types, suggesting that the railways are effectively segmenting their different markets. The cross elasticities between first and the other tickets are lowest, not unreasonably indicating that first class is a quite distinctly different market. There are insufficient data to reliably distinguish distance effects by ticket type.

Conditional and non-conditional mode choice elasticities

These relate entirely to urban trips where there can sometimes be close links between the fare variations for different public transport modes as a result of local authorities having close control over the fares charged. However, there is no such link for inter-urban rail journeys.

The conditional elasticity is the sum of the non-conditional elasticity and relevant mode-choice cross-price elasticities. For all three modes, the conditional elasticity is, as expected, lower than the non-conditional elasticity. The effect is largest for underground. Here two conditional elasticities are specified. UG1 denotes the underground elasticity conditional on competing bus fares varying in the same proportion as the underground fares whilst UG2 denotes the conditional elasticity where additionally the rail mainline fares are also varied in the same proportion. Given that bus provides more extensive competition to underground than does rail, it is not surprising that the largest effect comes from UG1.

The difference between the conditional and non-conditional elasticities is greater for bus than for rail presumably because rail provides stronger competition to bus than does bus to rail.

A6.14.5 Implied fare elasticities and comparison with tabulations

Fare elasticities implied by the estimated model for a range of situations are provided for inter-urban travel in Table A6.56 and urban travel in Table A6.57.

To assist with the interpretation of the results, suppose that a long run non-conditional fare elasticity is required for urban bus leisure journeys within a PTE area by adults receiving no concessions. Given a preference for elasticities estimated to revealed preference data, the elasticity would be:

$$\eta = -e^{-0.335-0.375+0.670-0.142} = -0.84$$

The fare elasticity has been scaled to convert from the absolute units in which the equation was estimated to their natural units.

The variations in elasticities discussed in preceding sections are apparent in the elasticities reported in Tables A6.56 and A6.57 and thus further discussion is not required. However, one issue warrants further attention both because of the implications of the numbers quoted and as an illustration of one of the key shortcomings of meta-analysis.

It will be seen in Table A6.57 that the figures for the long-term elasticity for elderly bus travel, both concessionary and full fare, suggested as results of the meta-analysis are substantially greater than those suggested in the fare chapter, and by Goodwin (2003). We should point out that this is not because there is any source evidence of such high elasticities. In fact the average value of elasticity for elderly bus travellers, entered as data into the meta-analysis, was -0.5 for full fare payers and -0.29 for concessionary travellers, based on 38 elasticities drawn from six separate studies. The higher figures in Table A6.62 are an artefact of the meta-analysis, and stem from the use of the relationship between short run and long run estimated for other groups of bus users. For practical use, we would favour the use of figures actually drawn from studies of concessionary travellers, in preference over such extrapolated results based on other groups, until further information is available.

Table A6.56 Illustrative elasticities: inter-urban rail

	50 miles	100 miles	150 miles	200 miles	250 miles	300 miles
London first						
SR-NC	-0.67	-0.71	-0.73	-0.75	-0.77	-0.78
SR-C	-0.62	-0.65	-0.68	-0.70	-0.71	-0.72
LR-NC	-0.98	-1.04	-1.08	-1.10	-1.13	-1.14
London full						
SR-NC	-0.75	-0.79	-0.82	-0.84	-0.86	-0.87
SR-C	-0.60	-0.64	-0.66	-0.68	-0.69	-0.70
LR-NC	-1.10	-1.17	-1.21	-1.24	-1.26	-1.28
London reduced						
SR-NC	-1.12	-1.18	-1.23	-1.26	-1.28	-1.30
SR-C	-0.85	-0.90	-0.93	-0.96	-0.98	-0.99
LR-NC	-1.64	-1.74	-1.80	-1.85	-1.89	-1.92
London business						
SR	-0.54	-0.57	-0.59	-0.61	-0.62	-0.63
LR	-0.79	-0.84	-0.87	-0.89	-0.91	-0.92
London leisure						
SR	-1.00	-1.06	-1.10	-1.13	-1.15	-1.17
LR	-1.47	-1.56	-1.62	-1.66	-1.69	-1.72
Non London business						
SR	-0.48	-0.51	-0.53	-0.54	-0.55	-0.56
LR	-0.70	-0.75	-0.77	-0.79	-0.81	-0.82
Non London leisure						
SR	-0.89	-0.94	-0.98	-1.00	-1.02	-1.04
LR	-1.31	-1.39	-1.44	-1.47	-1.50	-1.53

SR and LR denote short and long run. C and NC denote conditional and non-conditional elasticities

Table A6.57 Illustrative elasticities: urban travel

	Bus			*Suburban Rail*			*Underground*			
	SR-NC	*SR-C*	*LR-NC*	*SR-NC*	*SR-C*	*LR-NC*	*SR-NC*	*SR-C1*	*SR-C2*	*LR-NC*
Leisure no concessions PTE	-0.43	-0.34	-0.83	-0.62	-0.58	-0.91	–	–	–	–
Leisure no concessions rural	-0.79	-0.64	-1.54	-0.51	-0.47	-0.74	–	–	–	–
Leisure no concessions	-0.49	-0.40	-0.96	-0.72	-0.67	-1.05	-0.51	-0.22	-0.18	-0.75
Leisure elderly full	-0.62	-0.50	-1.20	-0.90	-0.83	-1.32	-0.64	-0.28	-0.23	-0.95
Leisure elderly concession	-0.24	-0.19	-0.47	-0.35	-0.32	-0.51	-0.25	-0.11	-0.09	-0.36
Leisure child	-0.56	-0.45	-1.09	-0.81	-0.75	-1.19	-0.57	-0.25	-0.21	-0.84
Commute no concessions south east	-0.29	-0.23	-0.57	-0.42	-0.39	-0.62	-0.30	-0.13	-0.11	-0.44
Commute no concessions not south east	-0.33	-0.26	-0.64	-0.47	-0.44	-0.70	–	–	–	–
Commute no concessions not south east PTE	-0.28	-0.23	-0.55	-0.41	-0.38	-0.60	–	–	–	–
Commute no concessions not south east rural	-0.52	-0.42	-1.02	-0.33	-0.31	-0.49	–	–	–	–
Commute elderly full not south east	-0.41	-0.33	-0.80	-0.59	-0.55	-0.87	–	–	–	–
Commute elderly concession not south east	-0.16	-0.13	-0.31	-0.23	-0.21	-0.34	–	–	–	–
Commute child not south east	-0.37	-0.30	-0.72	-0.54	-0.50	-0.79	–	–	–	–
Business no concessions PTE	-0.35	-0.28	-0.68	-0.33	-0.31	-0.49	–	–	–	–
Business no concessions rural	-0.65	-0.52	-1.26	-0.27	-0.25	-0.40	–	–	–	–
Business no concessions	-0.40	-0.33	-0.79	-0.38	-0.36	-0.57	-0.08	-0.04	-0.03	-0.12

SR and LR denote short and long run. C and NC denote conditional and non-conditional elasticities. For underground, there are two conditional elasticities depending upon whether there are corresponding variations in just bus (C1) or both bus and rail (C2) fares.

Another issue to be covered here is the degree of correspondence between the elasticities predicted by the meta-analysis for urban travel in Table A6.57 with the mean figures of the tabulations in Chapter 6. Key values are summarised in Table 6.55 in the main body of the report. It can be seen that there is generally a close correspondence between the two values. The largest discrepancy is for the long-run bus fare elasticity and this is due in large measure to the inclusion in Table 6.55 of a very large elasticity.

A6.14.6 Variations over time

There is a widely held view that bus fare elasticities have increased over time, and this is confirmed by specific studies (Dargay and Hanley, 2002) and also the evidence summarised in Table 6.55 of the main report where the short run bus fare elasticity has increased from the -0.30 of the 1980 study to the -0.43 of this study. Against this backdrop, the development of the meta-analysis model had explicitly examined whether GDP variation or the closely correlated time trend could explain the elasticity variation, but no effect was detected. This could be because the causes of the elasticity changes over time go unaccounted for in the tabulations but are discerned by the meta-analysis model. For example, fare elasticity increases due to different data sources over time or changes in journey purpose mixes would be included in the coefficient estimates for the data source and journey purpose variables.

Table A6.58 reports both the actual elasticities in the meta-analysis data set and the elasticities that would be predicted by the estimated model for the independent variables relating to the same observations. It can be seen that, at face value, there has been an increase in the bus fare elasticity and the suburban rail fare elasticity over time.

Table A6.58 Meta-analysis actual and predicted elasticities

Period	*Actual*	*Predicted*	*Cases*
Bus			
Up to 1980	-0.35 (0.015)	-0.34 (0.006)	71
1981-1990	-0.39 (0.026)	-0.36 (0.013)	56
After 1990	-0.46 (0.027)	-0.40 (0.011)	112
Underground			
Up to 1980	-0.30 (0.034)	-0.29 (0.028)	22
1981-1990	-0.25 (0.070)	-0.20 (0.033)	7
After 1990	-0.29 (0.041)	-0.27 (0.029)	13
Suburban rail			
Up to 1980	-0.51 (0.050)	-0.50 (0.000)	4
1981-1990	-0.58 (0.044)	-0.51 (0.013)	61
After 1990	-0.62 (0.061)	-0.54 (0.017)	30
Interurban rail			
Up to 1980	-0.65 (0.189)	-0.69 (0.061)	3
1981-1990	-0.90 (0.032)	-0.90 (0.018)	223
After 1990	-0.74 (0.028)	-0.77 (0.014)	133

Given the large difference between short run and long run elasticities, there is potential for these to distort the inter-temporal variations and hence they have been removed from these calculations. Standard errors in brackets.

The purpose of the predicted model is to determine whether the elasticity variation can be accounted for by factors within the model. It can be seen that the model does particularly well for inter-urban rail and can predict the fall and subsequent rise in the underground elasticity. For bus and suburban rail, however, the model cannot fully explain the elasticity increase. The failure of the time trend to discern any effect may be because this residual effect is only a small annual change. However, given that there is a widespread view that it is increases in real fares that have caused a drift upwards in the elasticity, it may be that experimentation with fare indices in place of GDP or time trends would prove fruitful. Notably, the lower fare elasticities for the underground correspond with a period of relatively low underground fares.

Noticeably there have been increases in the bus and suburban rail fare elasticities whereas there is no evidence for such an effect in the inter-urban rail market. This may point to the operation of changing socio-economic characteristics within these markets. Public transport users in general, but bus users in particular, have lower incomes and levels of car ownership on average. As incomes grow over time, the more affluent of the public transport users will purchase cars and use public transport less. The public transport market will therefore become increasingly dominated by those of lower incomes and conceivably the average incomes of public transport users could actually fall even though incomes in general are rising. Those with lower incomes can be expected to be more sensitive to fare increases and as they increase in importance so the fare elasticity will increase. Insofar as the underground and inter-urban rail markets have not experienced such changes, because the former has a strong market position and the latter is often regarded a luxury good, they will not have experienced an upward trend in fare elasticity. In drawing a balance between the effects of fare increases and changing socio-economic characteristics, it is worth noting that as with bus fares there have been gradual increases in average rail fares.

A6.14.7 Caveat

This work only commenced towards the final stages of this project. It is very much work in progress and cannot be taken as our final word on this matter. It has stimulated debate and raised a number of interesting and challenging questions which need to be addressed.

In particular, further research is planned for Autumn 2003 which will explore in more detail the relationship between short-run and long-run elasticities, including the collection of additional data on the time periods used in time series analysis and segmentation by journey purpose. Other issues include the further analysis of changes over time, including the use of fare indices and car ownership data at a suitable local level.

Appendix to Chapter 7

Table A7.1 Service elasticities – short run

Description	*Elasticity*	*Source*
Short run		
Metropolitan, bus	0.150	Clark (1997)
Non-metropolitan, bus	0.103	Clark (1997)
Wales, bus	0.260	Clark (1997)
Scotland, bus	0.255	Clark (1997)
Intercity, rail	0.900	Clark (1997)
Network SouthEast, rail	0.649	Clark (1997)
Regional railways, rail	0.715	Clark (1997)
English counties, bus	0.40 to 0.50	Dargay & Hanly (1999)
Regional data, all regions, bus	0.26	Dargay & Hanly (1999)
Regional data, individual regions, bus	0.33	Dargay & Hanly (1999)
Fare per journey ex CFR, regional data, all regions, bus	0.53	Dargay & Hanly (1999)
Fare per journey ex CFR, regional data, individual regions, bus	0.46	Dargay & Hanly (1999)
Fare per journey ex CFR, regional data, average, bus	0.46	Dargay & Hanly (1999)
Fare per journey ex CFR, English met areas, all areas, bus	0.27	Dargay & Hanly (1999)
Fare per journey ex CFR, English met areas, individual areas, bus	0.29	Dargay & Hanly (1999)
Fare per journey ex CFR, English met areas, partial adjustment, all areas, bus	0.35	Dargay & Hanly (1999)
Fare per journey ex CFR, English met areas, partial adjustment, individual areas, bus	0.38	Dargay & Hanly (1999)
English counties, constant elasticity, constrained, bus	0.48	Dargay & Hanly (1999)
English counties, constant elasticity, unconstrained, bus	0.41	Dargay & Hanly (1999)
English counties, variable elasticity, constrained, bus	0.45	Dargay & Hanly (1999)
English counties, variable elasticity, unconstrained, bus	0.42	Dargay & Hanly (1999)
Regional GB data, bus	0.43	Dargay & Hanly (1999)
Shire counties, bus	0.64	Dargay & Hanly (1999)
Metropolitan areas, bus	0.35	Dargay & Hanly (1999)
All regions, bus	0.36	OXERA (2000)
London, bus	0.30	OXERA (2000)
All regions excl. London	0.41	OXERA (2000)
North east region, bus	0.34	OXERA (2000)
All regions excl. London (fares averaged over regional time series), bus	0.74	OXERA (2000)

Table A7.2 Service elasticities – long run

Description	*Elasticity*	*Source*
English counties, bus	0.80 to 1.00	Dargay & Hanly (1999)
Fare index, regional data, all regions, bus	0.36	Dargay & Hanly (1999)
Fare index, regional data, individual regions, bus	0.25	Dargay & Hanly (1999
Fare per journey ex CFR, regional data, all regions, bus	0.81	Dargay & Hanly (1999)
Fare per journey ex CFR, regional data, individual regions, bus	0.69	Dargay & Hanly (1999)
Fare per journey ex CFR, regional data, average, bus	0.74	Dargay & Hanly (1999)
Fare per journey ex CFR, English met areas, all areas, bus (significant at 10% level)	0.24	Dargay & Hanly (1999)
Fare per journey ex CFR, English met areas, individual areas, bus	0.22	Dargay & Hanly (1999)
Fare per journey ex CFR, English met areas, partial adjustment, all areas, bus	0.67	Dargay & Hanly (1999)
English counties, constant elasticity, constrained, bus	1.04	Dargay & Hanly (1999)
Fare per journey ex CFR, English met areas, partial adjustment, individual areas, bus	0.64	Dargay & Hanly (1999)
English counties, constant elasticity, unconstrained, bus	0.79	Dargay & Hanly (1999)
English counties, variable elasticity, constrained, bus	0.95	Dargay & Hanly (1999)
English counties, variable elasticity, unconstrained, bus	0.79	Dargay & Hanly (1999)
Regional GB data, bus	0.81	Dargay & Hanly (1999)
Shire counties, bus	0.87	Dargay & Hanly (1999)
Metropolitan areas, bus	0.71	Dargay & Hanly (1999
All regions, bus	0.87	OXERA (2000)
London, bus	0.26	OXERA (2000)
All regions excl. London	0.95	OXERA (2000)
North east region, bus	0.32	OXERA (2000)
All regions excl. London (fares averaged over regional time series), bus	0.30	OXERA (2000)

NB. CFR stands for ‘Concessionary Fare Reimbursement’

Table A7.3 In-vehicle time elasticities

Description	*Elasticity*	*Source*
Rail UK average	-0.6 to -0.8	Steer Davies Gleave (1999)
Bus urban passenger	-0.58	Victoria Transport Policy Institute (2001) Ref0820 on Small & Winston (1999)
Rail urban passenger	-0.86	Victoria Transport Policy Institute (2001) on Small & Winston (1999)
Rail Chiltern Line all trips, short run	-1.11	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail south east sector, short run	-0.58	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail Chiltern Line all trips, long run	-1.21	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail south east sector, long run	-0.68	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail trips to central London, Chiltern line corridor, short run	-1.29	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail trips to central London, South east sector corridor, short run	-0.50	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail trips to central London, Chiltern line corridor, long run	-1.47	Mackett & Nash (1991) Ref0520 & Mackett & Bird (1989) Ref0898
Rail trips to central London, south east sector corridor, long run	-0.62	Mackett & Nash (1991) & Mackett & Bird (1989)
All modes trips to central London, Chiltern line corridor, short run	-0.98	Mackett & Nash (1991) & Mackett & Bird (1989)
All modes trips to central London, south east sector corridor, short run	-0.26	Mackett & Nash (1991) & Mackett & Bird (1989)
All modes trips to central London, Chiltern line corridor, long run	-1.13	Mackett & Nash (1991) & Mackett & Bird (1989)
All modes trips to central London, south-east sector corridor, long run	-0.34	Mackett & Nash (1991) Ref0520 & Mackett & Bird (1989) Ref0898
Rail Chiltern Line & south east sector corridors, all trips, short run	-0.63	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail Chiltern Line & south east sector corridors, all trips, medium run	-0.66	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail Chiltern Line & south east sector corridors, all trips, long run	-0.69	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail Chiltern Line & south east sector corridors, trips to central London, short run	-0.34	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail Chiltern Line & south east sector corridors, trips to central London, medium run	-0.36	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail Chiltern Line & south east sector corridors, trips to central London, long run	-0.38	Mackett & Nash (1991) & Mackett & Bird (1989)
Rail in general	-0.63 to -0.7	Mackett & Nash (1991) & Mackett & Bird (1989)

Appendix to Chapter 9

Excerpts from the Confederation of Passenger Transport UK's Better Buses (June 2002)

Birmingham: 40% growth on Line 33 after 18 months; 18% initial growth on SuperLine

Brighton & Hove: 5% growth per annum since 1994 across the whole network.

Cambridge: 25% increase in the city network in the first four months (from launch in November 2001).
Edinburgh: 10% growth on Greenways bus corridors since 1997.

Fife: Ferrytoll Park and Ride generating 7000 passengers per week since 500 space site opened in November 2000.

Hertfordshire: 20% growth on Elstree and Borehamwood Network; initial growth of 20% on Lea Valley Green Route.

Ipswich: 63% increase in first five years (1995 to 2000) on Superoute 66, which includes guided busways and bus lanes; in 2000 33% of passengers said they would otherwise have used the car.

Leeds: 75% increase in first five years (September 1995 to October 2000) on Scott Hall Road Superbus Quality Corridor, which includes guided busways and bus lanes; in the first 18 months 20% of new passengers said they had previously used a car.

Nottingham: 48% growth after two years on Calverton Connection; 15% growth after two years on Cotgrave Connection.

Oxford: 52% increase in patronage in city (all operators, inner cordon) between 1991 and 2001.

Portsmouth: 25% increase on Portsmouth to Leigh Park service in first 15 months (from launch in November 2000)

Rotherham: 17% increase on Rotherham to Maltby services between 1998 (launch of Quality Bus Corridor) and 2002.

Sheffield: nearly 50% growth on X33 to Bradford in first two years (from quality upgrade in 2000)

Telford: 46% growth on redline in the first two years (2000 and 2001); 12% growth on blueline in the first year (2001).

Woking: 22% growth on route 91 in first two years, 1.5% growth in third year.

Apppedix to Chapter 10

Income and journey length

This section reports the linear regression models that were estimated to determine how income, amongst a range of other variables, affects the dependent variable, journey length. The models were estimated to NTS data for the period 1985 to 1997 in order to explain variations in trip length over time and across individuals in terms of socio-economic and demographic characteristics. Tables A10.1 to A10.6 report the estimated models segmented by four modes (car driver, car passenger, bus and train) and three journey purposes (commuting, business and leisure). The independent variables are either continuous (C) or categorical, represented by a dummy variable and denoted by D.

Table A10.1 Models of journey length for commuter travel

*Variable**	*Interpretation*	*Car*	*Passenger*	*Bus*	*Train*
Dependent variable: Log of mean trip length					
Intercept		-0.21 (1.3)	0.19 (0.6)	0.68 (2.8)	3.17 (37.7)
Region (Base = Non metropolitan)					
London	D	-0.18 (-5.0)	-0.24 (2.5)	-0.32 (4.8)	-1.08 (28.7)
South east	D	0.13 (7.3)			
Metropolitan	D			-0.06 (2.2)	-0.39 (5.2)
Scotland	D	-0.04 (-1.6)			-0.51 (6.1)
Log density	C	-0.10 (14.2)	-0.06 (4.2)	-0.11 (7.1)	-0.06 (3.0)
Log income	C	0.21 (13.6)	0.16 (4.6)	0.11 (4.5)	
Work location (Base = Rural)					
London central	D	0.25 (4.1)	0.65 (4.2)	0.29 (3.5)	0.06 (1.6)
London outer	D	0.09 (2.1)	0.22 (1.8)	0.13 (1.7)	-0.32 (3.5)
Conurb central	D	0.28 (4.2)	0.52 (4.0)	0.33 (6.1)	-0.31 (2.6)
Conurb outer	D	0.04 (1.2)		-0.18 (5.3)	-0.23 (3.7)
Urban central	D	-0.20 (-9.9)	-0.10 (2.4)	-0.11 (3.2)	-0.38 (5.3)
Urban outer	D	-0.09 (-5.1)			
Gender (Base = Female)					
Male	D	0.17 (5.9)	0.36 (9.1)		
Age group (Base = 17-20)					
Age 21-29	D	0.22 (8.5)			
Age 30-39	D	0.11 (4.0)			
Age 40-49	D		-0.10 (2.3)		
Age 50-64	D		-0.15 (3.3)		
Household structure (Base = Single)					
2 people	D				0.10 (2.7)
3+ people with kids	D	-0.05 (-3.1)	-0.16 (3.9)		0.12 (3.2)
3+ people no kids	D	-0.07 (-3.5)	-0.19 (4.6)		
Work status (Base = Full Time)					
Part time	D	-0.32 (13.9)	-0.19 (4.2)	-0.21 (7.2)	-0.41 (6.5)
SEG (Base = Prof/Mgr)					
Clerical	D	-0.08 (-3.9)	-0.10 (2.4)		
Skilled	D	-0.21 (10.3)			
Semi	D	-0.34 (12.7)	-0.13 (2.9)		
Car status (Base = No Support)					
Free fuel	D	0.24 (7.3)			
No free fuel	D	0.32 (8.8)			
Comp contribution	D	0.19 (5.7)			
Used for work	D	0.13 (4.9)			
Gender age interactions					
Male age 30-39	D	0.26 (6.7)			
Male age 40-49	D	0.26 (7.9)			
Male age 50-64	D	0.20 (6.1)			
Obs		19,472	3,333	3,791	1,936
R^2		0.13	0.10	0.09	0.36

D Categorical variable.

C Continuous and can be interpreted as an elasticity.

** A full definition of the variables appears at the end of appendix 10.1.*

All coefficient values have been reported to two decimal figures.

Table A10.2 Models of journey length for business travel

*Variable**	*Interpretation*	*Car*	*Passenger*	*Bus*	*Train*
Dependent Variable: Log of mean trip length					
Intercept		+0.40 (1.6)	+1.93 (17.4)	-0.94 (-1.3)	+2.89 (2.8)
Region (Base = Non metropolitan)					
London	D	-0.28 (-6.8)	-0.13 (-1.4)	-0.28 (-2.7)	-1.63 (-13.6)
South east	D				-0.87 (-7.6)
Metropolitan	D	-0.11 (-3.5)	-0.19 (-2.5)	-0.21 (-2.0)	-0.38 (-2.3)
Scotland	D		-0.18 (-1.9)		-1.07 (-5.0)
Log density	C	-0.05 (-5.1)	-0.06 (-2.3)	-0.09 (-2.4)	
Log income	C	+0.15 (6.3)		+0.26 (3.75)	+0.21 (2.5)
Log cost	C				-0.45 (-2.3)
Work place (Base = Same)					
Diff	D	+0.60 (19.2)	+0.42 (5.3)		-0.27 (-2.4)
Work location (Base = Rural)					
London central	D	0.32 (4.23)		-0.41 (-3.6)	-0.36 (-3.8)
London outer	D			-0.28 (-1.9)	-0.20 (-1.6)
Conurb central	D				-0.97 (-3.5)
Conurb outer	D		+0.42 (2.7)		
Urban central	D		+0.22 (2.9)		
Urban outer	D	-0.10 (-3.7)	+0.14 (2.1)		
Gender (Base = Female)					
Male	D	+0.50 (17.6)	+0.18 (2.8)	+0.44 (5.9)	
Age group (Base = 17-20)					
Age 30-39	D				+0.13 (1.5)
Age 40-49	D				+0.23 (2.3)
Age 50-64	D				+0.40 (3.8)
Work status (Base = Full time)					
Part time	D	-0.21 (-5.8)	-0.25 (-3.1)		
SEG (Base = Prof/Mgr)					
Clerical	D	-0.26 (-9.0)	-0.37 (-6.0)		
Skilled	D	-0.36 (-11.4)			
Semi	D	-0.54 (-10.1)	-0.44 (-5.7)		-0.76 (-3.1)
Car status (Base = No support)					
Free fuel	D	+0.28 (6.8)			
No free fuel	D	+0.54 (11.4)			
Comp contribution	D	+0.19 (3.7)			
Car availability (Base = No car)					
All car	D		+0.26 (4.2)		
Some male	D		+0.28 (3.3)		
Obs		9,857	2,612	998	903
R^2		0.17	0.09	0.11	0.33

D Categorical variable.

C Continuous and can be interpreted as an elasticity

** A full definition of the variables appears at the end of Appendix 10.1.*

All coefficient values have been reported to two decimal figures.

Table A10.3 Models of journey length for leisure travel

*Variable**	*Interpretation*	*Car*	*Passenger*	*Bus*	*Train*
Dependent variable: Log of mean trip length					
Intercept		1.54 (13.4)	0.74 (7.7)	0.10 (0.53)	4.85 (10.7)
Region (Base = Non metropolitan)					
London	D	-0.12 (-7.6)	-0.14 (8.6)	-0.24 (-12.7)	-1.10 (16.1)
South east	D		0.02 (1.4)		-0.52 (-10.1)
Metropolitan	D	-0.14 (-11.1)	-0.19 (-14.6)	-0.09 (-5.6)	-0.79 (-14.0)
Scotland	D		-0.04 (2.3)		-0.54 (-8.3)
Wales	D		0.06 (2.7)		-0.67 (-6.8)
Log density	C	-0.08 (-18.1)	-0.08 (17.4)	-0.11 (-17.7)	-0.07 (3.7)
Log income	C	+0.09 (9.4)	0.15 (17.3)	0.18 (14.3)	+0.05 (1.9)
Log cost	C	-0.12 (-3.4)	-0.20 (-7.1)	-0.02 (-0.4)	-0.68 (5.2)
Log trips	C	-0.07 (-12.5)			
Gender (Base = Female)					
Males	D	+0.33 (28.3)		0.08 (6.4)	
Age group (Base = 17-20)					
Age 21-29	D		0.05 (2.5)		
Age 30-39	D		0.05 (3.0)		
Age 40-49	D		0.04 (2.4)		
Age 50-64	D	-0.06 (-4.5)	0.09 (4.6)		0.10 (1.9)
Age 65+	D	-0.18 (-7.9)	-0.08 (-4.3)		0.20 (2.7)
Household structure (Base = Single)					
2+ people	D	-0.11 (-6.3)	0.13 (11.0)		
2+ people with kids	D	-0.33 (-17.9)		-0.04 (2.9)	-0.15 (-3.6)
3+ people + no kids	D	-0.18 (-9.4)		-0.06 (2.9)	-0.09 (2.0)
SEG (Base = Prof/Mgr)					
Clerical	D	-0.12 (-9.9)	-0.07 (-4.0)		
Skilled	D	-0.16 (-12.5)	-0.14 (-6.9)		
Semi	D	-0.20 (-12.5)	-0.16 (-8.8)	-0.05 (4.2)	-0.12 (-3.4)
Work status (Base = Full time)					
Part time	D	-0.11 (-7.2)	0.05 (3.0)		
Student	D		0.09 (3.0)	0.11 (3.2)	0.14 (2.1)
Retired	D	-0.08 (-3.8)		-0.05 (-2.9)	-0.15 (-2.1)
Non-work	D	-0.05 (-3.2)	0.06 (4.5)	-0.06 (-3.4)	-0.09 (-2.0)
Car status (Base = No support)					
Comp contribution	D	+0.04 (1.6)	0.09 (4.0)		
Com12	D	+0.13 (7.5)	0.16 (8.8)		
Obs		37,548	53,379	28,763	5,132
R^2		0.09	0.04	0.04	0.19

D Categorical variable.

C Continuous and can be interpreted as an elasticity.

** A full definition of the variables appears at the end of appendix 10.1.*

All coefficient values have been reported to two decimal figures.

Table A10.4 Stripped down models of journey length for business travel

*Variable**	*Interpretation*	*Car*	*Passenger*	*Bus*	*Train*
Dependent variable: Log of mean trip length					
Intercept		-0.48 (-1.9)	+0.20 (0.4)	-1.55 (-2.2)	+1.30 (1.5)
Region (Base = Non metropolitan)					
London	D	-0.31 (-7.1)		-0.45 (-5.4)	-1.73 (-18.3)
Metropolitan	D	-0.12 (-3.5)			
Scotland	D				-0.76 (-4.1)
Log density	C	-0.03 (-2.9)	-0.06 (-2.6)	-0.12 (-3.1)	
Log income	C	+0.27 (10.9)	+0.19 (3.8)	+0.35 (5.2)	+0.23 (2.7)
Work location (Base = Rural)					
London central	D	-0.31 (-7.1)			
Conurb central	D				-1.06 (-3.8)
Urban outer	D	-0.29 (-10.7)			
Obs		9,858	2,613	999	904
R^2		0.03	0.00	0.07	0.29

D Categorical variable.
C Continuous and can be interpreted as an elasticity.
** A full definition of the variables appears at the end of appendix 10.1.*
All coefficient values have been reported to two decimal figures.

Table A10.5 Stripped down models of journey length for commuter travel

*Variable**	*Interpretation*	*Car*	*Passenger*	*Bus*	*Train*
Dependent variable: Log of mean trip length					
Intercept		-1.06 (7.0)	-0.03 (-0.1)	+0.28 (1.19)	+1.89 (5.5)
Region (Base = Non metropolitan)					
London	D	-0.14 (4.9)		-0.17 (-4.3)	-1.11 (-30.7)
South east	D	+0.13 (7.1)			
Metropolitan	D				-0.49 (-6.9)
Scotland	D				-0.59 (-7.4)
Log density	C	-0.08 (-11.3)	-0.07 (-4.5)	-0.11 (-7.1)	
Log income	C	+0.31 (20.7)	+0.17 (5.1)	+0.14 (6.0)	+0.11 (3.4)
Work location (Base = Rural)					
London central	D	+0.33 (5.5)	+0.49 (3.5)	+0.24 (3.8)	
Conurb central	D	+0.36 (5.3)	+0.47 (3.5)	0.39 (7.1)	-0.28 (-3.2)
Urban central	D	-0.21 (-10.4)	-0.16 (-4.0)	-0.15 (-5.7)	-0.25 (-4.5)
Urban outer	D	-0.11 (-6.6)			-0.37 (-5.6)
Obs		19,472	3,332	3,790	1,935
R^2		0.04	0.03	0.05	0.34

D Categorical variable.
C Continuous and can be inferred as an elasticity
** A full definition of the variables appears at the end of appendix 10.1.*
All coefficient values have been reported to two decimal figures.

Table A10.6 Stripped down models of journey length for leisure passengers

*Variable**	*Interpretation*	*Car*	*Passenger*	*Bus*	*Train*
Dependent variable: Log of mean trip length					
Intercept		+0.82 (9.7)	+1.0 (5.5)	-0.12 (-1.2)	+4.54 (10.3)
Region (Base = Non Metropolitan)					
London	D	-0.11 (-7.0)	-0.163 (-10.2)	-0.23 (-13.3)	-1.12 (-16.1)
South east	D				-0.53 (-10.2)
Metropolitan	D	-0.13 (-10.2)	-0.21 (-17.2)	-0.09 (-6.4)	-0.80 (-14.2)
Scotland	D		-0.07 (-4.2)		-0.56 (-8.7)
Wales	D				-0.71 (-7.2)
Log density	C	-0.08 (-18.1)	-0.08 (-17.7)	-0.11 (-17.8)	-0.05 (-2.6)
Log income	C	+0.13 (15.6)	+0.19 (24.1)	+0.19 (18.1)	+0.05 (2.0)
Log cost	C		-0.66 (-5.2)		-0.63 (-7.8)
Log trips	C	-0.08 (-14.6)			
Obs		37,548	53,379	28,763	5,132
R^2		0.03	0.03	0.03	0.18

D Categorical variable.
C Continuous and can be interpreted as an elasticity.
** A full definition of the variables appears at the end of appendix 10.1.*
All coefficient values have been reported to two decimal figures.

Table A10.7 NTS modelling outputs defined

Variable	*Description*
Region	(Base = Non metropolitan)
London	London
South east	South east
Metropolitan	Metropolitan area
Scotland	Scotland
Wales	Wales
Density	Urban population density (persons per hectare)
Log density	Density logged
Income	Personal income (£s) – 1997 Prices
Log income	Income logged
Cost	Cost per trip (£s)- 1997 Prices
Log cost	Cost logged
Work place	Base = Same
Diff	Work in diff locations
Work location	Base = Rural
London central	Central London
London outer	Outer London
Conurb central	Non-London central conurbations
Conurb outer	Non-London outer conurbations
Urban central	Non-London central urban areas
Urban outer	Non-London outer urban areas
Gender	Base = Female
Male	Male
Age group	Base = 17-20
Age 21-29	Aged 21-29
Age 30-39	Aged 30-39
Age 40-49	Aged 40-49
Age 50-64	Aged 50-64
Household structure	Base = Single
2+ people	2 adults + no kids household
3+ people with kids	3 adults + kids household
3+ people no kids	3 adults + no kids household
Work status	Base = Full time
Part time	Part time worker
Student	Student
Retired	Retired
Non-work	Not working
Some male	
Gender interaction	Base = Male 17-20
Male age 30-39	Male aged 30-39
Male age 40-49	Male aged 40-49
Male age 50-64	Male aged 50-64
Car availability	Base = No Car
All car	Everyone has a car available
Some male	Some males have a car available
Car status	Base = No support
Comp. contribution	Employer contributes some of the cost of a car.
No free fuel	Company car but no free fuel
Used for work	Company car for work purposes only
Comp12	Company car for work with and without free fuel
Free Fuel	Company car with free fuel
SEG	Base = Prof/Mgr
Semi	Semi skilled worker
Other	Other type of worker
Clerical	Clerical worker
Skilled	Skilled worker

Re-estimated car availability model

In this section we present the re-estimated car availability model based upon the original car availability model that was estimated by Wardman and Preston (2001).The choice set of whether a car is available for the journey to work is analysed using a logit model fitted to NTS data from 1985 through to 1997. The key difference between the two models is that in the re-estimated model the time trend terms have been removed.

Table A10.8 Re-estimated car availability model

	Standard logit
ASC-available	+0.56 (1.5)
Income (£s – 1997 prices)	+0.00003 (26.1)
Distance (miles)	0.04 (20.1)
Car purchase cost index	-0.02 (4.8)
Region (Base = Non met and Wales)	
London	+0.20 (2.9)
South east	+0.15 (3.9)
Metropolitan	-0.20 (-5.4)
Scotland	-0.48 (-10.3)
Gender (Base = Female)	
Male	+0.60 (18.4)
Age (Base = 17-20)	
Age 21-29	+1.47 (27.2)
Age 30-39	+1.78 (32.9)
Age 40-49	+1.68 (31.0)
Age 50+	+1.46 (26.8)
SEG (Base = Professional)	
Clerical	-0.57 (-13.9)
Skilled	-0.62 (-13.7)
Other	-1.41 (-29.7)
Workplace (Base = Same)	
Different places	+0.69 (12.3)
Work location (Base = Rural, conurbation outer and urban outer)	
London central	-1.42 (-18.3)
London outer	-0.37 (-4.8)
Conurbation centre	-0.61 (-6.0)
Urban centre	-0.31 (-9.4)
Public transport access (minutes)	
Bus	0.02 (7.9)
Train	0.01 (9.4)
Bus frequency (Base = Less than hourly)	
At least hourly	-0.34 (-7.1)
At least half hourly	-0.46 (-11.1)
At least quarter hourly	-0.77 (-17.7)
Multiple household workers (Base = Single worker household)	
Multi-household*	+0.22 (+9.3)
Multi-not household**	-0.75 (-39.4)
Obs	37,376
r^2	0.25

* *Head of the household in a multi-worker household.*

** *Not the head of the household in a multi-worker household.*

Table A10.12 defines the coefficients.

All variables relate to utility of car availability.

Commuting mode choice

In Table A10.9 a multinomial logit model is presented which indicates the relative importance of different variables on mode choice for the journey to work. The model has been fitted to NTS data from 1985 through to 1997 and is a re-estimation of a model estimated by Wardman and Preston (2001).

Table A10.9 Car, passenger, bus and train mode choice model for the journey to work

Mode constants (Base = Car)	
Pass	-3.74 (21.8)
Bus	-3.90 (19.2)
Rail	-3.88 (20.4)
Work status (Base = Full time)	
Part time - pass	-0.20 (3.2)
Part time - rail	-0.20 (1.8)
Region (Base = Non metropolitan)	
London - pass	-0.37 (3.7)
London - rail	1.46 (11.6)
SE - bus	-0.15 (2.1)
SE - train	1.18 (11.3)
Met - pass	-0.30 (5.2)
Wales - rail	0.58 (2.7)
Scot - rail	0.47 (3.6)
Pop density (persons per hectare)	
Dens - bus	0.002 (3.2)
Gender age interactions	
Male 21-39 - pass	-0.45 (4.9)
Male 21-39 - bus	-0.28 (3.0)
Male 40+ - pass	-0.47 (5.5)
Male 40+ - rail	0.56 (4.3)
Age group (Base = 17-20)	
Age 21-29 - pass	
Age 21-29 - bus	-0.36 (-4.5)
Age 30-39 - pass	-0.44 (4.3)
Age 30-39 - bus	-0.71 (5.9)
Age 30-39 - rail	-0.45 (4.3)
Age 40-49 - pass	-0.54 (4.7)
Age 40-49 - bus	-0.88 (7.3)
Age 40-49 - rail	-1.10 (8.1)
Age 50+ - bus	-0.81 (6.6)
Age 50+ - rail	-1.15 (8.2)
Age 50+ - pass	-0.33 (2.8)
Gender (Base = Female)	
Male - rail	
ρ^2	0.52
Access to PT (minutes)	
Walk - bus	-0.02 (3.2)
Walk - rail	-0.04 (13.5)
Gender PT access interaction (minutes)	
Walk - PT - male	0.008 (2.4)
Work location (Base = Rural)	
Lon - central - pass	0.87 (4.8)
Lon - central - bus	2.33 (16.9)
Lon - central - rail	3.53 (29.5)
Lon - outer - bus	0.84 (7.3)
Lon - outer - rail	0.52 (4.2)
Con - central - pass	0.97 (4.8)
Con - central - bus	2.22 (12.4)
Con - central - rail	2.83 (15.8)
Con - outer - pass	-0.42 (4.1)
Urb - central - bus	0.69 (10.2)
Urb - outer - pass	-0.34 (3.8)
Urb - outer - bus	-0.19 (1.9)
Urb - outer - rail	-0.99 (8.1)
No car available	
No car - pass	-0.36 (4.3)
No car - rail	-0.99 (10.3)
Car status (Base = No support)	
Comp car free fuel	1.11 (6.3)
Comp car no free fuel	0.78 (4.6)
Comp contribution	0.77 (4.4)
Used for work	0.66 (5.4)
SEG (Base = Prof/Mgr)	
Clerical - bus	0.34 (5.0)
Skilled - pass	0.26 (3.5)
Skilled - rail	-0.69 (7.0)
Other - pass	0.41 (3.6)
Other - bus	0.36 (2.9)
Other - rail	-0.75 (5.0)
Personal income (£s – 1997 prices)	
Income - bus	-0.26 (6.3)
Income - rail	0.00002 (4.9)
Cost - car (£s)	-0.004 (3.8)
Cost - pass (£s)	-0.01 (3.2)
Cost - bus (£s)	-0.002 (6.5)
Cost - rail (£s)	-0.002 (3.8)
Bus frequency (Base < 60mins)	
Freq 1	0.64 (5.9)
Freq 2	1.08 (11.4)
Freq 3	1.43 (14.9)
Multi household workers (Base = No)	
Multi - bus	0.31 (5.8)
Multi - rail	0.32 (3.8)
Household structure (Base = Single)	
2 - Pass	0.34 (2.2)
2 - bus	-0.65 (4.7)
2 - rail	-0.42 (2.9)
3 + C - pass	0.30 (1.9)
3 + C - bus	-0.80 (5.7)
3 + C - rail	-0.74 (5.2)
3 + NC - pass	0.44 (2.7)
3 + NC - bus	-0.52 (3.6)
3 + NC - rail	-0.36 (2.3)
Obs	32,623

Table A10.12 defines the coefficients.

Table A10.10 presents logit models that determine whether or not a person makes a specific trip or not. The models have been fitted to NTS data for the period 1985-1997 and cover employer business and leisure trips made by rail and bus.

Table A10.10 Making or not making a trip by public transport

Variable	*EB* – rail*	*EB - bus*	*Leisure - rail*	*Leisure – bus*
Dependent variable	*Log public transport trip*	*Log public transport trip*	*Log public transport trip*	*Log public transport trip*
ASC-bustri	-5.57 (-21.3)	-4.48 (-34.1)	-1.56 (-14.0)	-0.06 (-0.9)
Gender (Base = Female)				
Male	+0.61 (+7.7)		-0.05 (-1.3)	-0.52 (-23.8)
Age group (Base = 17-20)				
Age 3	+0.71(+3.4)		-0.15 (-2.2)	-0.71 (-17.0)
Age 4	+0.69 (+3.4)		-0.47 (-6.5)	-1.04 (-24.2)
Age 5	0.51 (+2.4)	-0.14 (-2.0)	-0.64 (-8.6)	-1.05 (-24.3)
Age 6	+0.19 (+0.9)	-0.47 (-6.1)	-0.88 (-11.5)	-1.16 (-26.2)
Age 7	-1.67 (-5.2)	-2.7 (-12.2)	-1.05 (-11.5)	-1.34 (-27.0)
Income (£s) 1997 prices	+0.000038 (+13.3)	+0.000032 (+2.4)	+0.000021 (+12.9)	
Dens			+0.0007 (+1.3)	+0.001 (+5.1)
Region (Base = Non metropolitan)				
London	+1.84 (+18.5)	+1.04 (+11.2)	+1.52 (+28.8)	+0.41 (+12.5)
South east	+1.10 (+11.7)	+0.30 (+3.3)	+0.75 (+14.1)	-0.15 (-5.5)
Wales	-0.68 (-1.9)	-0.57 (-2.5)		
Scotland		+0.56 (+5.3)	+0.44 (+6.4)	+0.37 (+11.7)
Metropolitan			+0.35 (+6.1)	+0.45 (+18.2)
Access to PT (minutes)				
Walk bus	+0.021 (+3.4)	+0.0042 (+0.7)	+0.007 (+1.7)	-0.03 (-12.4)
Walk train	-0.01 (-4.0)	-0.0041 (-2.1)	-0.03 (-24.2)	0.005 (+7.9)
SEG (Base = No support)				
Cler	-0.65 (-7.7)	-0.55 (-8.3)	-0.08 (-1.6)	+0.24 (+8.0)
Skill	-1.33 (-11.4)	-1.16 (-11.7)	-0.74 (-12.1)	+0.12 (+3.6)
Semi	-3.13 (-10.1)	-1.44 (-12.7)	-0.59 (-9.7)	+0.22 (+6.8)
Work status (Base = Full time)				
Student			+0.98 (+11.1)	+0.32 (+4.9)
Part			+0.09 (+1.4)	+0.36 (+11.3)
Non work			+0.15 (+2.8)	+0.46 (+16.4)
Retired			+0.19 (+2.7)	+0.73 (+21.9)
Household structure (Base = Single)				
2+ NC			-0.15 (-3.7)	-0.14 (-6.3)
2+ C			-0.58 (-12.2)	-0.32 (-12.0)
Bus frequency (Base <60 mins)				
Freq 1				+0.56 (+15.1)
Freq 2				+0.83 (+25.6)
Freq 3				+1.10 (+32.6)
Car availability (Base = No car)				
Car 1	-0.37 (-3.5)	-0.62 (-8.3)	-0.36 (-17.2)	-1.18 (-54.8)
Car 2	-0.62 (-5.5)	-1.07 (-12.0)	-0.58 (-21.0)	-1.67 (-61.2)
Obs	921	1,346	5,135	28,841
R^2	0.22	0.11	0.16	0.17

** Employers business.*
Table 10.12 defines the doefficients.
All variables relate to utility of making a trip.

Table A10.11 outlines the regression results from a model that has estimated the number of trips made by rail and bus on employers business and for leisure trips given that the passenger chooses to travel by those modes for those purposes.

Table A10.11 Trip making if a person makes a trip by public transport

Variable	*EB – rail*	*EB - bus*	*Leisure - rail*	*Leisure – bus*
Dependent variable	*Log EB rail trips*	*Log EB bus trips*	*Log leisure rail trips*	*Log leisure bus trips*
Intercept	0.86 (1.5)	0.59 (1.55)	0.00 (0.00)	1.00 (10.07)
Log dens		0.04 (1.90)		0.02 (4.20)
Log income (£s)1997 prices	0.01 (0.18)	-0.02 (0.46)	0.10 (5.43)	-0.05 (4.72)
Access to PT (minutes)				
Log walk bus				-0.05 (6.55)
Log walk train			-0.07 (5.83)	0.06 (8.96)
Bus frequency (Base <60 mins)				
Freq 1				0.11 (5.6)
Freq 2				0.19 (11.30)
Freq 3				0.26 (14.92)
Region (Base = Non metropolitan)				
Scotland	-0.26 (2.35)		-0.09 (2.96)	0.16 (12.00)
Metropolitan				0.21 (20.46)
South east			0.15 (6.36)	
Lonondon			0.18 (8.08)	0.16 (11.37)
Gender (Base = Female)				
Male	0.11 (2.21)			-0.05 (5.31)
Age group (Base = 17-20)				
Age 3				-0.06 (4.01)
Age 4	0.13 (1.82)			-0.09 (5.71)
Age 5				-0.08 (4.94)
Age 6			-0.10 (3.82)	-0.08 (4.77)
Age 7			-0.10 (2.61)	-0.05 (2.61
Age 23	0.05 (0.92)			
Household structure (Base = Single)				
2+ NC				-0.07 (6.44)
2+ C				-0.12 (9.76)
Logcost (£s)	-0.23 (1.61)			0.16 (6.17)
Work status (Base = Full time)				
Part				0.14 (8.76)
Retired			0.19 (4.97)	0.38 (21.79)
Non work			0.12 (4.79)	0.29 (21.35)
Number of cars in household (Base = No Car)				
Veh 1		-0.04 (0.79)	-0.09 (4.51)	-0.27 (27.32)
Veh 2		-0.05 (0.82)	-0.12 (4.56)	-0.34 (23.92)
SEG (Base = Prof/Mgr)				
Skill		0.10 (1.74)		
Semi		0.16 (2.54)		
Semi-cler	-0.08 (1.59)			
Work place (Base = same)				
Diff	0.37 (5.26)	0.34 (5.65)		
Obs	921	1,346	5,135	28,841
R^2	0.06	0.04	0.06	0.18

Table A10.12 defines the doefficients.

Table A10.12 Definition of coefficients

Coefficient	*Description*
Pass	Car passenger
Bus	Bus passenger
Rail	Rail Passenger
Distance to work (Miles)	Walk - PT - male (minutes)
Dist - pass	For car passenger
Dist - rail	For bus passenger
Region (Base = Non metropolitan)	
Lon	London
London - pass	For car passenger
London - bus	For bus passenger
London - rail	For rail passenger
SE - bus	For south east bus passenger
SE - train	For south east train passenger
Met	Metropolitan
Met - pass	For metropolitan car passenger
Met - rail	For metropolitan car passenger
Wales	Wales
Wales - rail	For Welsh rail passenger
Scot	Scotland
Scot - rail	For Scottish rail passenger
Time trend	
Trend - bus	For bus passenger
Trend - rail	For rail passenger
Time trend and region interactions	
Trend - Lon - bus	For London bus passenger
Trend - Lon - rail	For London rail passenger
Trend - SE - pass	For SE car passenger
Trend - SE - bus	For SE bus passenger
Trend - Wales - bus	For Wales bus passenger
Trend - Wales - rail	For Wales rail passenger
Age group (Base = 17-20)	
Age 21-29 - pass	Car passenger. aged 21-29
Age 21-29 - bus	Bus passenger. aged 21-29
Age 30-39 - pass	Car passenger. aged 30-39
Age 30-39 - bus	Bus passenger. aged 30-39
Age 30-39 - rail	Rail passenger. aged 30-39
Age 40-49 - pass	Car passenger. aged 40-49
Age 40-49 - bus	Bus passenger. aged 40-49
Age 40-49 - rail	Rail passenger. aged 40-49
Age 50+ - bus	Bus passenger. aged 50+
Age 50+ - rail	Rail passenger. aged 50+
Age 50+ - pass	Car passenger. aged 50+
Gender (Base = Female)	
Male	Male
Male - rail	Male rail passenger

Coefficient	*Description*
Walk - bus (minutes)	Access walk time for bus passenger
Walk - rail (minutes)	Access walk time for rail passenger
Gender PT access interaction	
Access walk time for male passenger	
Work location (Base = Rural)	
Lon - central - pass	Central London + car passenger
Lon - central - bus	Central London + bus passenger
Lon - central - rail	Central London + rail passenger
Lon - outer - bus	Outer London + bus passenger
Lon - outer - rail	Outer London + rail passenger
Con - central - pass	Central conurbations + car passenger
Con - central - bus	Central conurbations + bus passenger
Con - central - rail	Central conurbations + rail passenger
Con - outer - pass	Outer conurbations + car passenger
Urb - central - bus	Central urban + bus passenger
Urb - central - rail	Central urban + rail passenger
Urb - outer - pass	Outer urban + car passenger
Urb - outer - bus	Outer urban + bus passenger
Urb - outer - rail	Outer urban + rail passenger
Number of car available (Base = No car)	
Car 1	1 car available
Car 2	2 cars available
No car - pass	No car available car passenger
No car - rail	No car available rail passenger
Car status (Base = No support)	
Comp car free fuel	Company car + free fuel
Comp car no free fuel	Company car + no free fuel
Comp contribution	Company contribution to car cost
Used for work	Company car for work journeys only
SEG (Base = Prof/Mgr)	
Clerical - bus	Clerical worker + bus passenger
Skilled - pass	Skilled worker + car passenger
Skilled - rail	Skilled worker + rail passenger
Other - pass	Other type of worker + car passenger
Other - bus	Other type of worker + bus passenger
Other - rail	Other type of worker + rail passenger
Personal income and costs (£s – 1997 prices)	
Income	Personal income
Income - bus	Personal income of bus passenger
Income - rail	Personal income of rail passenger
Cost - car	Cost of travel for car owner
Cost - pass	Cost of travel for car passenger
Cost - bus	Cost of travel for bus passenger

Continued ....

Coefficient	*Description*
Freq 1	Bus frequency greater than or equal to every 60 minutes
Freq 2	Bus frequency greater than or equal to every 30 minutes
Freq 3	Bus frequency greater than or equal to every 15 minutes
Multi household workers (Base = No)	
Multi - bus	Belongs to a multi-worker household and is a bus pass
Multi - rail	Belongs to a multi-worker household and is a rail pass
Household structure (Base = Single)	
2+ NC	Belongs to a 2 adult household
2+ C	Belongs to a 2 person household (including a child)
2 - pass	Belongs to a 2 adult household and is a car passenger
2 - bus	Belongs to a 2 adult household and is a bus passenger
2 - rail	Belongs to a 2 adult household and is a rail passenger
3+C - pass	Belongs to a 3 or more person household (including a child) and is a car passenger
3+C - bus	Belongs to a 3 or more person household (including a child) and and is a bus passenger
3+C - rail	Belongs to a 3 or more person household (including a child) and is a rail passenger
3+NC - pass	Belongs to a 3 or more adult household and is a car passenger
3+NC - bus	Belongs to a 3 or more adult household and is a bus passenger
3+NC - rail	Belongs to a 3 or more adult household
Work status (Base = Full Time)	
Part	Part time worker
Part time - pass	Part time worker who is a car passenger
Retired	Retired
Non work	Not working
Student	Student
Part time - rail	Part time worker who is a rail passenger
Work place (Base = Same)	
Diff	Work in different locations
Pop density (persons per hectare)	
Dens	Population density
Dens - bus	Population density of persons who are bus passengers
Dens - rail	Population density of persons who are rail passengers
Gender age interactions	
Male 21-39 - pass	21 to 39 yr old male who is a car passenger
Male 21-39 - bus	21 to 39 yr old male who is a bus passenger
Male 40+ - pass	40+ year old male who is a car passenger
Male 40+ - rail	40+ year old male who is a rail passenger
Cost-rail	Cost of rail
Household car ownership (Base = No car)	
Veh 1	1 Car household
Veh 2	2 Car household

Abstract

This document reports on the outcome of a collaborative study the objective of which was to produce an up-to-date guidance manual on the factors affecting the demand for public transport for use by public transport operators and planning authorities, and for academics and other researchers. The context of the study was principally that of urban surface transport in Great Britain, but extensive use is made of international sources and examples. Analysis and research by using primary and secondary data sources on the influencing factors were pursued to produce a document that assists in identifying cost-effective schemes for improving services. A wide range of factors was examined. The study has re-examined the evidence from an earlier, 1980, study on the factors affecting the demand for public transport, and has extended the coverage from that of the 1980 study to reflect the changing sociological and policy background.

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