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THE DEMAND FOR PUBLIC TRANSPORT

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Abstract

This paper reports on the outcome of a collaborative study whose objective 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 were examined in the study; this paper summarises the study methodology but concentrates on the results regarding the influence of fares, quality of service and income and car ownership.

Keywords: Public transport, fares, transport demand

Topic area: SIG10

1 Introduction

This paper reports on the outcome of a collaborative study undertaken by the Universities of Leeds, Oxford and Westminster, University College London and TRL Limited (Balcombe et al, 2004). 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 in the UK. The overall direction of the project was the responsibility of a steering group which included UK transport consultants, representatives from local and central government, bus and rail operators, other researchers from the UK and outside, as well as members of the working group.

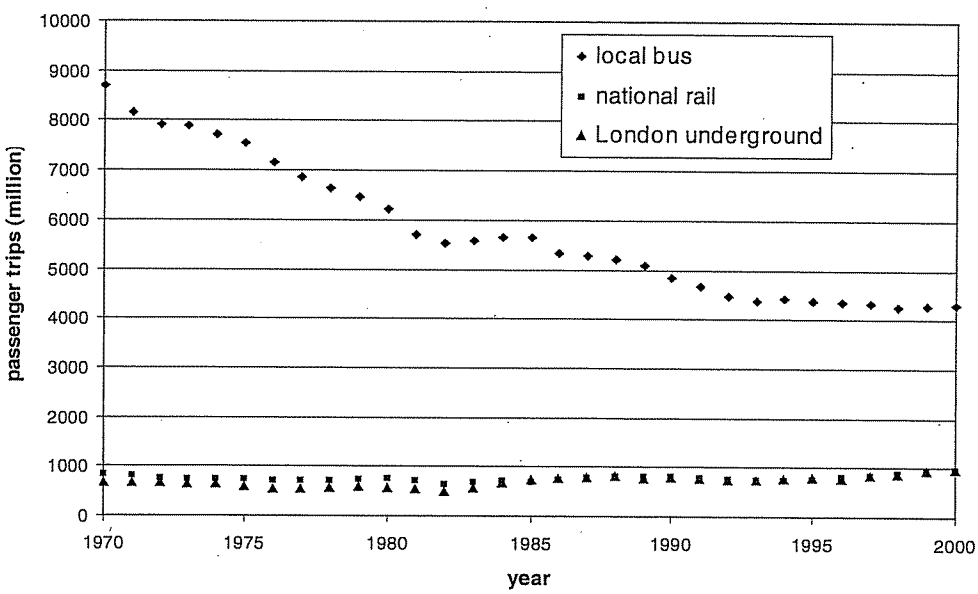
1.1 The need for a new report on public transport demand.

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 was 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 in 1980 at a time when overall demand for public transport in Britain was falling very rapidly (Figure 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.

Figure 1: Trends in public transport demand in Great Britain 1970-2000



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 UK 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 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 The scope of the study

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. In the study it was convenient to separate demand factors into a number of groups, as follows:

- Attributes of public transport services: fares, journey times, service frequency, reliability, comfort etc
- Attributes of competing or alternative public transport services: fares, journey times, service frequency, reliability, comfort etc
- Attributes of private transport: car availability, motoring costs, journey times etc
- Traveller characteristics: age, sex, income, journey purpose etc
- Land use: settlement size, population density, distribution of homes and employment, journey lengths.

While recognition of these factors is relatively straightforward, estimation of their effects on demand is much more difficult and 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

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[1] Including public transport support, concessionary fare reimbursement and Fuel Duty Grant

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 overall objectives of the study were therefore 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.

Analysis and research by using primary and secondary data sources on the factors influencing the demand for public transport were pursued to produce a document that assists in identifying cost-effective schemes for improving services.

This paper concentrates on the results from the study regarding the influence of fares, quality of service and income and car ownership. However, the study also considered 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 also looked 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.

2 The effects of fares

2.1 Summary of overall findings

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. 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[2].

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- 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-elasticities, estimating the demand elasticity for a competing mode with respect to the change in the given mode.

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 In the study, elasticity values from many sources were 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 2 and Table 1. It can be seen that, 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 the 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.

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 proportions of journeys of different types 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 increased rate of market turnover, insofar as potential new users may 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. Interestingly suburban rail short run fare elasticity has changed very little, remaining at about -0.5.

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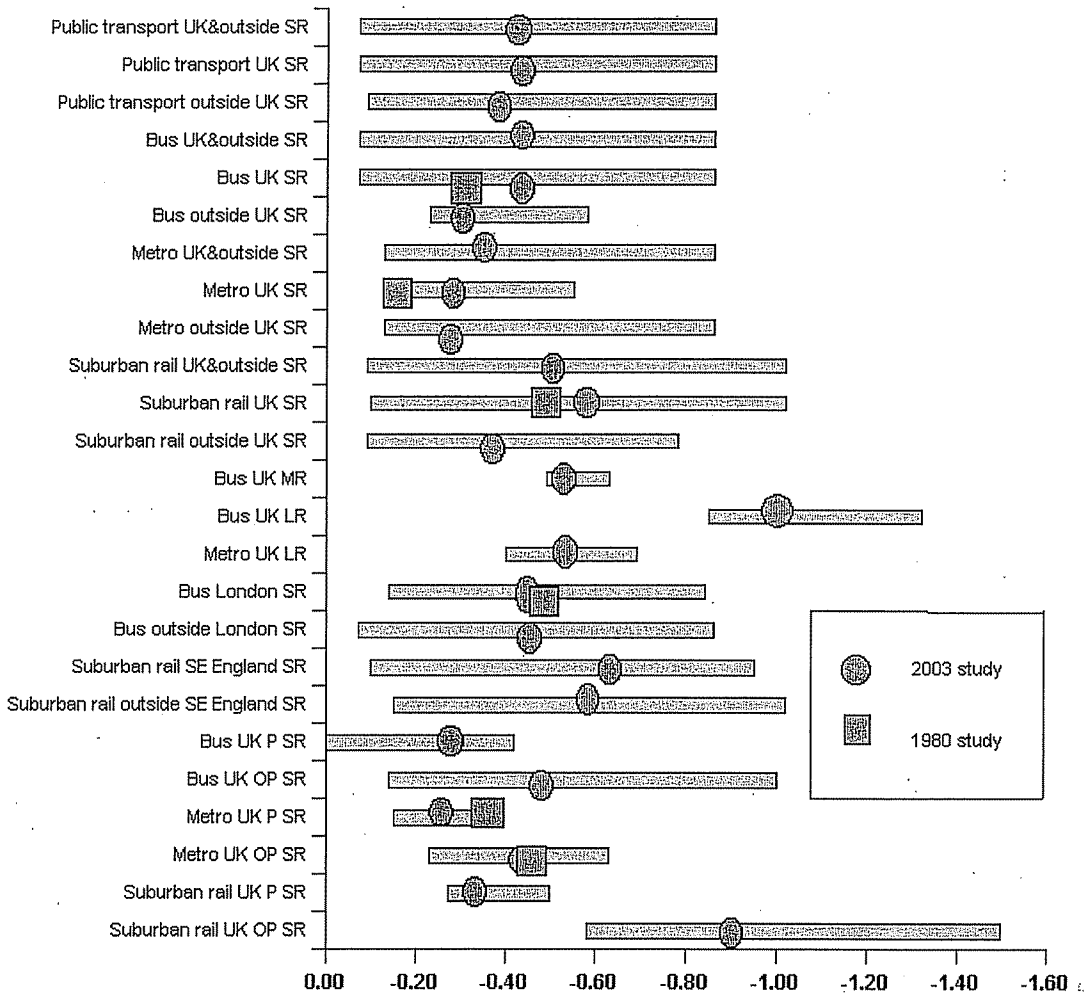
2 To avoid confusion in comparisons of elasticities, many of which are negative, the terms "increase" and "decrease" will always in this paper refer to the change in the magnitude (the numerical part) of the elasticity. Thus an elasticity which changes from -0.5 to -0.7 is said to have increased

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.

Table 1 Comparison of fare elasticities from the current study and the 1980 Black Book

	Current study			1980 Study
	Mean	Range of values reported		
		from	To	
Public transport - UK and outside the UK – short run	-0.41	-0.07	-0.86	
Public transport - UK – short run	-0.44	-0.07	-0.86	
Public transport – outside the UK – short run	-0.35	-0.09	-0.86	
Bus - UK and outside the UK – short run	-0.42	-0.07	-0.86	
Bus - UK – short run	-0.43	-0.07	-0.86	-0.30
Bus - outside the UK – short run	-0.37	-0.23	-0.58	
Metro - UK and outside the UK – short run	-0.29	-0.13	-0.86	
Metro – UK – short run	-0.29	-0.15	-0.55	-0.15
Metro - outside the UK – short run	-0.29	-0.13	-0.86	
Suburban rail – UK and outside the UK – short run	-0.50	-0.09	-1.02	
Suburban rail – UK – short run	-0.58	-0.10	-1.02	-0.50
Suburban rail – outside the UK – short run	-0.37	-0.09	-0.78	
Bus – UK – medium run	-0.56	-0.49	-0.63	
Bus – UK – long run	-1.01	-0.85	-1.32	
Metro – UK – long run	-0.56	-0.40	-0.69	
Bus – London – short run	-0.42	-0.14	-0.84	-0.44
Bus – outside London – short run	-0.44	-0.07	-0.86	
Suburban rail – SE England – short run	-0.61	-0.10	-0.95	
Suburban rail – outside SE England – short run	-0.59	-0.15	-1.02	
Bus – UK – peak – short run	-0.26	0.00	-0.42	
Bus – UK – off- peak – short run	-0.48	-0.14	-1.00	
Metro – UK – peak – short run	-0.26	-0.15	-0.35	-0.38?
Metro – UK – off- peak - short run	-0.42	-0.23	-0.63	-0.45?
Suburban rail – UK – peak - short run	-0.34	-0.27	-0.50	
Suburban rail – UK – off- peak - short run	-0.92	-0.58	-1.50	

Figure 2: Summary of mean values and ranges of fare elasticities



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 Table 1 and Figure 1 reflect variation in methods of estimation, as well as variation between studies in a number of other factors influencing demand and elasticity. A few of the more significant disaggregations are considered below.

2.2 Effect of types of fare change

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

2.3 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 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.

In Great Britain, elasticity values are much higher in the shire counties than in metropolitan areas (Table 2), 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 2 Bus fare elasticities in Great Britain by type of area

	Metropolitan areas	Shire counties
Short run	-0.21	-0.51
Long run	-0.43	-0.70
	London	Outside London
Short run	-0.42	-0.43

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

2.4 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 conurbation, levels of congestion and the extent of public transport networks, but also because of the degree of regulation that still obtains in London. As shown in Table 2, in the short run, at least, bus fare elasticity is marginally higher outside London than inside 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.

2.5 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.

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.

2.6 Meta-analysis

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 (Wardman and Shires, 2003). 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 – such as the estimation of elasticities over a wide range of circumstances and the influence of the methodological approaches used in the individual studies reported.

The analysis took the form of a regression model, estimated using 902 public transport fare elasticities obtained from 104 studies conducted in Britain between 1951 and 2002. The markets covered were inter-urban rail travel, suburban rail travel, urban bus travel and London underground. A number of interesting findings emerged and the models can be used to 'predict' fare elasticities for a range of situations.

The elasticities predicted by the resulting model, for various types of modes, journeys and travellers are shown in Table 3. There is a good degree of consistency between these results and those from the individual studies reported above, 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.

3 The effects of quality of service

3.1 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 various bus specific factors) are more problematical, and need to be treated indirectly.

Such indications are often derived from stated preference (SP) models, as distinct from the Revealed Preference (RP) methods reviewed earlier in this paper to illustrate aggregate price elasticities, and later in this section to derive aggregate service level (frequency) elasticities. Some care may need to be taken in comparing the elasticities and values derived from the two methods

Table 3 Elasticities derived from the meta-analysis

	Elasticities
Bus - UK – short run	-0.36
Metro – UK – short run	-0.37
Suburban rail – UK – short run	-0.52
Bus – UK – long run	-0.70
Metro – UK – long run	-0.54
Bus – London – short run	-0.37
Bus – outside London – short run	-0.36
Suburban rail – SE England – short run	-0.50
Suburban rail – outside SE England – short run	-0.60
Bus – UK – peak – short run	-0.30
Bus – UK – off- peak – short run	-0.40
Metro – UK – peak – short run	-0.30
Metro – UK – off- peak - short run	-0.44
Suburban rail – UK – peak - short run	-0.42
Suburban rail – UK – off- peak - short run	-0.65

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 minutes. 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 monetary 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 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 these studies were based on the 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).

3.3 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 operated. This has an inverse, but generally inexact, relationship with service headways.

The elasticity of bus demand with respect to vehicle kilometres, shown in Table 4, 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.

Table 4 Bus and rail service elasticities

	Bus	Rail
Short run	0.38	0.75
Long run	0.66	-

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 bus demand is shown to be more service elastic in big cities (with populations of over 50000) than small towns 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 corresponding value for rail is 1.2.

3.4 Time spent on board the vehicle

There is limited evidence on elasticities with respect to in-vehicle time (IVT), possibly because the options for 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 -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 cost 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 rail. These ranges incorporate variations with journey purposes and income.

3.5 The waiting environment

Passengers who have to wait for buses or trains prefer to do so in conditions of comfort, cleanliness, safety and 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.

3.6 Effect of vehicle or rolling stock characteristics

The attributes of public transport vehicles are largely unquantifiable and they are too many and various for 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. Stated Preference (SP) techniques have therefore commonly been used, sometimes in conjunction with revealed preference approaches, to obtain quantifiable measurements.

Studies using these methods have suggested that 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. Similar research on demand for rail 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.

Refurbishment which changes the level of train seating layout, ride quality, ventilation, ambience, noise and seating comfort from levels associated with old 'slam door' stock to new air conditioned stock in South East England was worth around 2.5% of the fare (Wardman and Whelan (2001). However, most refurbishments would be worth somewhat less than this, with 1.5% being a representative figure.

3.7 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 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.

3.8 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 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.

3.9 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 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 metro stations displaying the predicted arrival times of relevant buses or trains. Such systems seem to be valued somewhere between 4p and 20p per trip.

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

4 Demand interactions: effects of fare changes on competing modes

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 (see Table 5).

Table 5 Matrix of cross elasticities for London

	Bus use	Under-ground 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/A
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)

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 (Table 6). This reflects differences in market shares of public and private transport: a small percentage shift from car travel can amount to a large percentage increase in public transport use. This observation also applies to inter-urban travel (Table 7), where 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.

Table 6 Urban 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 7 Interurban cross elasticities

	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).

5 Effects of income and car ownership

5.1 Introduction

Traditionally income and car ownership 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 since 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. This is consistent with evidence from the National Travel Survey that bus use (both in trips and person-km) falls substantially as car ownership per household rises. However, for rail the position is more mixed - while trips per person decline with rising household car ownership, person-km shows little variation, as average trip length becomes higher. 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, associated with growth in employment levels in that area.

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 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.

5.2 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 8 illustrates the growth 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%).

Table 8 Changes in demand for rail, and fare levels

Change 1991/92 to 2001/02 (%)	National rail	London Underground	Other rail systems
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 (2002)

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 rail business trips will include longer distance journeys.

5.3 Effect of income on public transport demand

The empirical evidence from Britain 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 (Table 9). 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.

Table 9 Bus income elasticities (Great Britain)

	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

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 UK National Travel Survey (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.

5.4 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 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 external factors on public transport demand indicate that the impact on bus travel in Britain is negative (see also Section 5.1 above).

5.5 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 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 UK 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.

6 Impacts of overall awareness campaigns

Stimulating ridership through some of the instruments identified above is often unlikely to be financially worthwhile to the operator in the short run, given the observed elasticities for real fares and service levels, for example. However, awareness of public transport services is often poor, and substantial growth in ridership has resulted from awareness campaigns and personalised travel planning – as in some of the schemes undertaken through the Travelsmart™ programme in Australia.

7 Concluding remarks

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 it must always be recognised that the results may be subject to a considerable degree of uncertainty. Further research which aims to extend understanding of responses to public transport improvements will help reduce these areas of uncertainty.

It has also been made clear by the study that there are major gaps in evidence to provide much-needed understanding and knowledge. While the impacts of fares, journey times and frequency have been quite widely studied and analysed, the same is not true of other important factors, such as quality of service, information provision or perceived personal safety. Such measures are increasingly central elements of transport policy, and understanding their impact is crucial if policies are to be properly formulated and implemented.

One of the problems encountered during the study was in determining the context under which some of the reported experiments and studies had been conducted. This was especially marked with regard to separating short and long run effects. This whole issue would benefit from further investigation.

The project collected substantial amounts of information from published sources abroad, and received comment and input from non-UK experts. However, we are aware that there is undoubtedly a much wider body of evidence that is not in the published domain. In the UK, such material was accessed through contact with the project Steering Group members and others; with greater resources, similar activity outside the UK could provide significant extra information.

Demand responsive services are of growing importance. Whilst so far confined mainly to low-density rural areas, they are now being introduced in urban areas, in some cases as an alternative to conventional fixed-route operations. As greater experience is obtained, conclusions may be drawn about their impact on ridership from a given catchment area.

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The results reported in this paper are drawn from a wide number of reports and articles that had been published or were otherwise made available to the authors. A complete bibliography is not included here, but may be found in the full report of the study (Balcombe et al, 2004).

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