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The demand for public transport: The effects of fares, quality of service, income and car ownership

Neil Paulley [a,*], Richard Balcombe [a], Roger Mackett [b], Helena Titheridge [b], John Preston [c], Mark Wardman [d], Jeremy Shires [d], Peter White [e]

[a] *TRL, Crowthorne House, Nine Mile Ride, Wokingham, Berkshire RG40 3GA, UK*
[b] *Centre for Transport Studies, University College London, London, UK*
[c] *Transportation Research Group, University of Southampton, Southampton, UK*
[d] *Institute for Transport Studies, University of Leeds, Leeds, UK*
[e] *Transport Studies Group, University of Westminster, London, UK*

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Abstract

This paper reports on key findings from 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. Whilst a wide range of factors was examined in the study, the paper concentrates on the findings regarding the influence of fares, quality of service and income and car ownership. The results are a distillation and synthesis of identified published and unpublished information on the factors affecting public transport demand. The context is principally that of urban surface transport in Great Britain, but extensive use was made in the study of international sources and examples.
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1. Introduction

This paper reports on the key findings 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 was made of international sources and examples.

While a wide range of factors was examined in the study, the findings relating to fares, quality of service and car ownership are the most significant and this paper concentrates on these. However, as Balcombe et al. (2004) make clear, in practice the factors cannot be treated either in isolation from each other or in isolation from many other direct and indirect influences on public transport demand. The main 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.

1.1. Background

In 1980, the then Transport and Road Research Laboratory, now the Transport Research Laboratory (TRL), 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

* Corresponding author. Tel.: +44 134 477 3131; fax: +44 134 477 0356.
E-mail address: npaulley@trl.co.uk (N. Paulley).

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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. The new collaborative study, of which the results in this paper are a part, was therefore set up to take account of another 20 years' worth of public transport information, and more recent advances in transport research techniques. 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.

1.2. The scope of the paper

The results presented in this paper are a distillation and synthesis of identified published and unpublished evidence on the influencing factors drawn from three key areas:

- Fundamental principles relating to transport demand.
- Evidence from research carried out since publication of the 1980 report.
- Empirical results for a range of modes.

Where possible, this paper looks at changes in response parameters since the 1980 study.

The data for the study mainly came from existing studies and literature identified through searches for relevant literature in publication databases, material supplied by public transport operators and local authorities and contacts with researchers engaged in analysis in the field. The information was collected, assessed for relevance and, as far as was possible, quality, and an analysis and synthesis made of implications of the overall body of evidence; a meta-analysis of fares elasticities was also conducted. In assessing the evidence it was recognised that fares elasticities, for instance, 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. All of these approaches have their advantages and disadvantages, depending on the context in which the original research was conducted. The various methodological approaches were noted during the information gathering exercise to ensure that the outcomes did not contain unwanted bias.

Most findings reviewed relate to the urban and regional market, with some references to rural areas. The inter-city, long-distance market as such is not covered, and hence 'long' distances refer to about 30 km, as in the original study of 1980.

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 0 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.[1]

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 12–15 (although sometimes as many as 20) years, while medium run is usually around 5–7 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 Table 1 and Fig. 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. There is

[1] 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.

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

	Current study				1980 Study
	Mean	Range of values reported		Number of studies	
		From	To		
Public transport—UK and outside the UK—short run	−0.41	−0.07	−1.02	99	
Public transport—UK—short run	−0.44	−0.07	−1.02	68	
Public transport—outside the UK—short run	−0.35	−0.09	−0.86	31	
Bus—UK and outside the UK—short run	−0.41	−0.07	−0.86	44	
Bus—UK—short run	−0.42	−0.07	−0.86	33	−0.30
Bus—outside the UK—short run	−0.38	−0.23	−0.58	11	
Metro—UK and outside the UK—short run	−0.29	−0.13	−0.86	24	
Metro—UK—short run	−0.30	−0.15	−0.55	15	−0.15
Metro—outside the UK—short run	−0.29	−0.13	−0.86	9	
Suburban rail—UK and outside the UK—short run	−0.50	−0.09	−1.02	31	
Suburban rail—UK—short run	−0.58	−0.10	−1.02	20	−0.50
Suburban rail—outside the UK—short run	−0.37	−0.09	−0.78	11	
Bus—UK—medium run	−0.56	−0.51	−0.61	2	
Bus—UK—long run	−1.01	−0.85	−1.32	3	
Metro—UK—long run	−0.65	−0.61	−0.69	2	
Bus—London—short run	−0.43	−0.14	−0.84	15	−0.44
Bus—outside London—short run	−0.44	−0.07	−0.86	14	
Suburban rail—SE England—short run	−0.61	−0.10	−0.95	13	
Suburban rail—outside SE England—short run	−0.55	−0.15	−1.02	11	
Bus—UK—peak—short run	−0.26	0.00	−0.42	9	
Bus—UK—off-peak—short run	−0.48	−0.14	−1.00	10	
Metro—UK—peak—short run	−0.26	−0.15	−0.35	6	
Metro—UK—off-peak—short run	−0.42	−0.23	−0.63	5	
Suburban rail—UK—peak—short run	−0.34	−0.27	−0.50	4	
Suburban rail—UK—off-peak—short run	−0.79	−0.58	−1.50	5	

evidence for this in Dargay and Hanly (1999), Gilbert and Jalilian (1991).

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.

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 Table 1 and Fig. 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. There is evidence of this from modelling of rail fares in South-east England by Mackett and Bird (1989). The differences are greatest for long run elasticities. Fare elasticity is also affected by the current

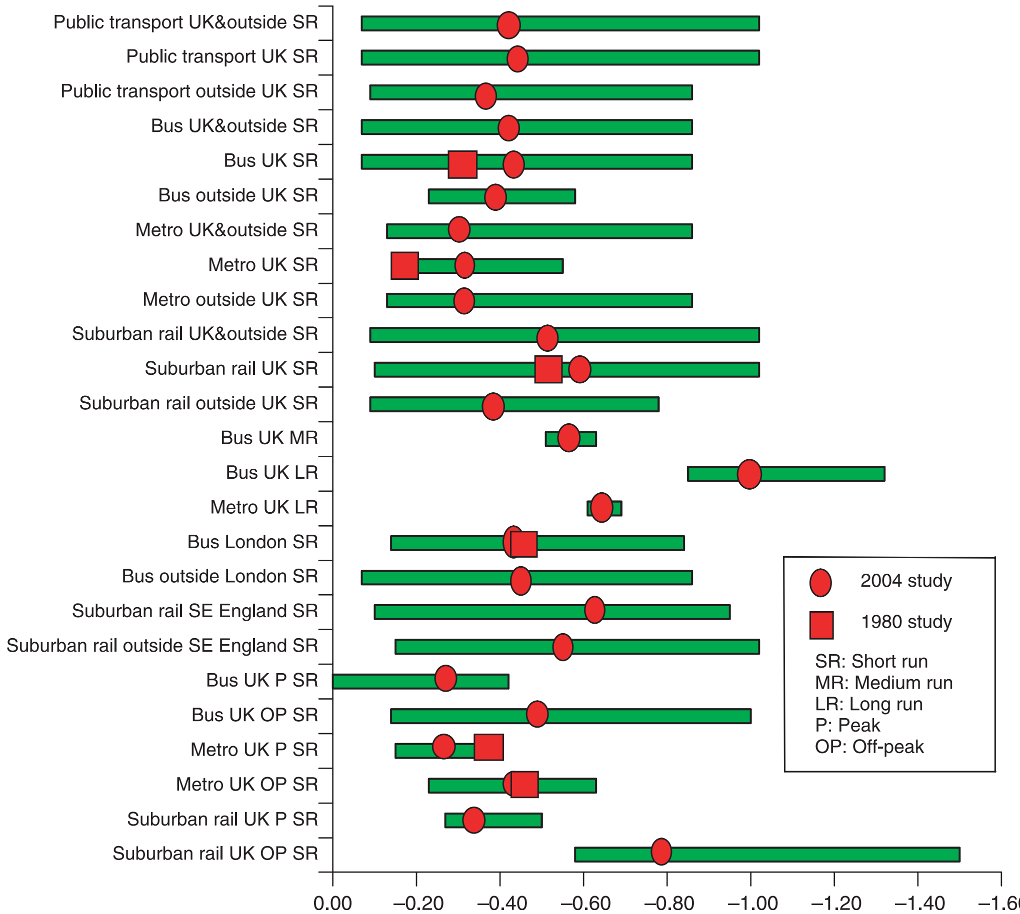

Fig. 1. Summary of mean values and ranges of fare elasticities.

level of the fare relative to people's income. This can be illustrated by the results for London buses. When fares were 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 (Collins, 1982). Elasticity values have also been found to increase with fare levels for short distance (≤32 km) rail journeys outside London (Association of Train Operating Companies, 2002).

The response to a fare increase may not be equal and opposite to the response to a fare decrease; that is, they may not be symmetrical. The evidence is however limited. Hensher and Bullock (1979) found, for rail fares in Sydney, Australia, that the fare elasticity was −0.21 when the fares were increased but −0.19 when they were decreased. However, Wardman (2000), in a review of stated preference studies, found no evidence of elasticity asymmetry, although his study did not include very many cases where the prices fell.

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) (Dargay and Hanly, 1999), 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.

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.

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

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 (based on 15 studies in London and 14 outside it). 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, with peak values for bus, metro and suburban rail of -0.26, -0.26 and -0.34, respectively, and equivalent values of -0.48, -0.42 and -0.79, respectively, for the off-peak. 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. Fares elasticities for different trip purposes

People travelling to work or to school generally have little choice of trip ends or timing of journeys. Such trips are largely the cause of the peak, which is when congestion tends to be at its greatest, making car journeys slower. Hence, elasticities tend to be lower than for other trip purposes. Evidence to demonstrate this was found in London and, for suburban rail, in South-east England. 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.

2.7. Fares elasticities for different types of traveller

Because those with access to a car have more alternatives than those without, they tend to have higher elasticity values, particularly in the long run. Males tend to have higher elasticity values than females. This may be partly because they are more likely to have a car available. The evidence for this comes from microsimulation modelling by Mackett (1990).

The evidence about age is not clear-cut, because there are several effects at work here. Many of the trips by the elderly will be discretionary, and so one would expect a high elasticity value for these trips. However, they may have low car ownership and difficulty walking which means that many of them may be captive to public transport, and so they have a low elasticity value. In many places in Britain they receive free public transport, and so they will continue to travel whatever the fare level.

Travellers with high incomes tend to have higher elasticity values because their higher car ownership levels mean that they have an alternative when fares increase.

2.8. Fares elasticities by distance travelled

For buses, there are two possible effects here: for very short trips, walking is a feasible alternative for many people, so elasticities tend to be higher (see Tyson, 1984 for example), and for 'long' trips (within the range of distances considered here) fares are a larger proportion of incomes and a wider range of alternative destinations exists (for example, for shopping), hence elasticities tend to be higher for these trips (see White, 1981 for example). Evidence was found to support the idea that elasticities are higher for very short and very long trips, and lower for medium-length ones.

For rail, fare elasticities decrease with distance (within the range considered in this paper). This may be because fares are often subject to a taper, that is the fare per unit distance decreases with increasing distance. This effect may outweigh the effects of fares for longer journeys being higher proportions of income.

2.9. Effects of ticket types and fare systems

The effects of pre-paid ticketing systems (travelcards or season tickets) are not clear and may depend on the level of discount and the conditions of use. In such cases the purchase decision relates to a 'package' of travel (for example, unlimited journeys within given zone(s) for a whole month), rather than individual single or return journeys. The user therefore may wish to consider the 'value for money' offered by such a package both relative to single and return fares on the same system (i.e. the discount within the public transport system) and other modes (notably car). When such a ticket is purchased for the first time it will influence behaviour not only by changing the average money cost per trip vis a vis previous travel patterns, but also encouraging additional trips (and interchanges) at zero money cost. This in turn may influence the renewal purchase decision at a new price level (White, 2001).

2.10. Meta-analysis

Meta-analysis involves pooling together the results from different empirical studies and developing a quantitative model that explains variations in results across studies. A meta-analysis of the British evidence on fare elasticities was conducted as part of the study (Wardman and Shires, 2003). The aim of the exercise 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.

2.11. Conclusions on fare elasticities

Fare elasticities tend to increase over time since the change of fare. For example, bus fare elasticities are about −0.4 in the short run, −0.55 in the medium run, and about −1.0 in the long run. Similarly, metro fare elasticities tend to be about −0.3 in the short run and −0.6 in the long run. Elasticities seem to be slightly higher in the UK than elsewhere. Fare elasticities have increased since the 1980 study.

Fare elasticities are affected by the time of day: off-peak values are about twice those in the peak. This partly reflects the nature of the trip purposes which dominate in each. Work and education trips, which tend to be in the peak, have lower elasticity values than discretionary trips such as shopping and leisure which tend to be during the off-peak.

Elasticity values tend to be higher in rural areas than in urban areas. This is probably because of the higher car ownership levels and may also be because fares will be higher because journeys will be longer on average. In addition, where school journeys are made on separate services (especially for pupils entitled to free travel) the market served by the 'public' network contains a very small proportion of 'peak' journeys (such as adults to work), and is dominated to a greater extent than urban services by purposes such as shopping.

Table 3
Fare 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

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 because changes in these attributes are often accompanied by changes in other attributes, particularly fare and journey time. Valuations of such attributes are often derived from stated preference (SP) models, based on hypothetical behaviour, as distinct from the revealed preference (RP) methods, based on actual behaviour, reviewed earlier in this paper to illustrate aggregate price elasticities, and later in this section to derive aggregate service level (frequency) elasticities. Although there is a body of evidence that suggests RP and SP approaches are comparable in terms of attribute valuation, there is also evidence to suggest that SP approaches may give biased elasticity results (Louviere et al., 2000). In practice emphasis continued to be placed on RP estimated elasticities but where these were absent the results from SP attribute valuation were used. For example, 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 min 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/journey times and used, together with an appropriate fare/journey time elasticity, to estimate effects on demand.

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 SP, rather than RP, techniques (Wardman, 2001).

Weightings for walking times to and from bus stops and stations range between about 1.4 and 2.0 units of in-vehicle time (based on 183 observations), 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 (1.3–2.1—based on 52 observations).

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.

A number of studies have estimated the elasticity of bus demand with respect to vehicle kilometres. As shown in Table 4, this is approximately 0.4 in the short run, and 0.7 in the long run. For rail services, the short run elasticity is somewhat greater (about 0.75), but this is based on only three measurements and no long run elasticity appears to have been estimated.

Service elasticities for buses have been found to be considerably greater on Sundays and in the evenings, when service levels are generally lower (Preston, 1998). Similarly, elasticities tend to be higher in rural than in metropolitan areas, where service levels are higher (Dargay and Hanly, 1999). There is some evidence, however, that bus demand is shown to be more service elastic in big cities (with populations of over 500,000) 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 (European Commission, 1997).

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 (Preston and James, 2000). 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 (Pratt et al., 2000).

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 (both based on 11 observations—see Wardman, 2001).

Table 4
Bus and rail service elasticities

	Bus	No. of obs	Rail	No. of obs
Short run	0.38	27	0.75	3
Long run	0.66	23	–	–

3.4. Time spent on board the vehicle

There is limited evidence on bus elasticities with respect to in-vehicle time (IVT), possibly because the options for improving bus speeds are somewhat limited, especially in urban areas. In addition, for short journeys, IVT may be only a relatively small part of the total journey time.

The review suggests that IVT elasticities appear to be roughly in the range −0.4 to −0.6 (based on three studies), while those for urban or regional rail range between −0.4 and −0.9 (based on five studies). Small and Winston (1999) suggest greater values for longer interurban journeys (−2.1 for bus, −1.6 for rail).

There is also some 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 (Halcrow Fox et al., 1993).

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 6 p per trip (subject to a limiting cap of around 26 p on the total—Steer Davies Gleave, 1996), or up to 2 min of in-vehicle time per trip (Wardman et al., 2001).

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 that are easy to get on and off, but the relative importance of such factors is difficult to determine. SP techniques have therefore commonly been used, sometimes in conjunction with RP approaches, to obtain quantifiable measurements.

Studies using SP 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 (Accent, 2002). Evidence from bus operators suggests a passenger growth of about 5% on low-floor conversion, arising not only from wheelchair users but also categories such as those with heavy shopping or children in buggies. If considered as an effective reduction in monetary fare, the SP valuation produces a similar percentage growth when a typical short run fares elasticity is applied.

Research for rail has estimated the effects of replacing old with new rolling stock, using a combination of RP and SP methods (Wardman and Whelan, 2001). 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. 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 min IVT on a bus trip (based on six observations), and 37 min IVT on a rail trip (based on 13 observations—Wardman, 2001). 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 broadly equivalent to the standard deviation multiplied by the corresponding value of waiting or in-vehicle time (WS Atkins and Polak, 1997). For example if the mean waiting time is 5 min, with a standard deviation of 2.5 min, then the effective waiting time is 7.5 min.

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 that 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. Evidence from Countdown in London (Steer Davies Gleave, 1996) and similar systems elsewhere (Accent, 2002) suggests a valuation somewhere between 4 p and 20 p per trip.

Service information available at home, through printed timetables, bus maps, telephone enquiry services, etc. seems to be valued at between 2 p and 6 p per trip (based on four observations), and similar information at bus stops at between about 4 p and 10 p per trip (based on 43 observations).

3.10. Conclusions on quality of service

There is generally less evidence on the demand impacts of service quality variables than that of fares. The main body of evidence on elasticities relates to bus service levels, although there is also some elasticity evidence on the impact of IVT. There is a large body of evidence on attribute values, particularly for walk and wait time, IVT and information provision, based largely on SP studies. In combination with a knowledge of fare elasticity, the fare level and the level of the service attribute (all derived from RP studies), the valuation of the service attribute can be used to infer a service attribute elasticity. For example, at 2000 prices it was found that the mean value of time for commuting by urban bus was 4.2p/min (based on 17 observations), whilst the value of leisure travel was 2.6p/min (based on 17 observations—Wardman, 2001). This in turn implies an elasticity of bus demand with respect to IVT of around -0.4, which is consistent with the range given in Section 3.4. There is likely to be further scope for combining SP and RP evidence in this way. However, more evidence is also needed on the demand impacts of service improvements, particularly in terms of IVT, the waiting environment, vehicle characteristics, interchange, reliability and pre-trip information. There are other areas, such as personal security, where there have been very few quantifiable results to date.

4. Demand interactions: effects of fare changes on competing modes

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).

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.

Table 5
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/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 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.

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 UK National Travel Survey that bus use (both in trips and person-kilometre) 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-kilometre 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.

Table 6
Urban cross elasticities

	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).

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 and are not comparable with income elasticities that are estimated alongside car ownership terms. 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-kilometre has risen at around 1–2% 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%).

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 kilometres 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 of trip length with respect to income lie in the range 0.09–0.21 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 as is clear in 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.

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. Unlike the bus market, there are many segments in the rail market where car ownership has saturated or where car availability is sufficiently high that the growth rate and its negative impact on demand is low. 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. Conclusions on income and car ownership effects

Income and car ownership growth are fundamental to the underlying demand for public transport. There has been almost continual decline in the demand for bus travel over the past 25 years, although rail travel has recently experienced something of a renaissance. To a lesser extent than for car travel, the average trip length by public transport has increased with income, with elasticities of trip length to income in the range 0.1–0.2. The income elasticity of bus demand, including the indirect car ownership effect, is large and is in the range −0.5 to −1.0 in the long run. This can be expected to fall as the car ownership growth induced by income growth slows as saturation is approached. Rail income elasticities are somewhat

Table 8
Growth in public transport use: European Union countries 1990–1999

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

Table 9
Bus income elasticities (Great Britain)

	Short run	Long run
National data (journeys)	0	−0.45 to −0.80
National data (pass-kilometres)	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

larger, in part because car ownership levels are much higher in the rail market, and can be as high as 2.

6. Concluding remarks

This paper reports on key findings from 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. While a wide range of factors was examined in the study, the paper concentrates on the findings regarding the influence of fares, quality of service and income and car ownership.

Fare elasticities tend to increase over time since the change of fare, with bus fare elasticities being about −0.4 in the short run, −0.55 in the medium run, and about −1.0 in the long run. Similarly, metro fare elasticities tend to be about −0.3 in the short run and −0.6 in the long run. For quality of service, the mean value of time for commuting by urban bus was 4.2p/min, whilst the value of leisure travel was 2.6p/min (at 2000 prices), implying an an elasticity of bus demand with respect to in-vehicle time of around −0.4. As incomes increase over time, trip lengths increase. The impact varies across journey purposes, but with elasticities in the range 0.1–0.2 the long run impact on passenger kilometres, if maintained, will be significant. Income has a positive impact on public transport demand, but with an offsetting negative impact, particularly in the bus market, through its effects on car ownership. As car ownership growth slows and reaches saturation, these negative effects will diminish.

As has been shown, a substantial body of evidence exists with respect to fare elasticities and, to a lesser extent, service and income elasticities, with important distinctions made between the short run and the long run. There is also a sizeable evidence base on the valuation of key attributes such as walk time, wait time, IVT and some aspects of information provision. However, there is more limited evidence on the impacts of reliability, vehicle characteristics, the waiting environment, interchange, personal security, and marketing and awareness campaigns. Such attributes are increasingly central elements of transport policy, and understanding their impact is crucial if policies are to be properly formulated and implemented.

Whilst there can be little doubt that a wide range of factors influences the demand for public transport, and 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, it must always be recognised that the results may be subject to a considerable degree of uncertainty. 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, particularly to ascertain whether attribute valuations refer to the short- or the long run.

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