TRANSPORT RESEARCH LABORATORY

Evaluation of low-floor bus trials in London and North Tyneside

Prepared for Mobility Unit, Department of the Environment, Transport and the Regions (DETR), Buses and Taxis Division DETR and the Unit for Disabled Passengers, LT

I York and R J Balcombe

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CONTENTS

	Page
Executive Summary	1
1 Introduction	5
1.1 Background	5
1.2 The trial programme	5
1.3 Monitoring	5
2 The trials	5
2.1 The vehicles	5
2.2 The services	10
2.3 Infrastructure	12
2.4 Parking control near bus stops	12
3 Research methods	12
3.1 Video recordings	12
3.2 Classified passenger counts and bus stop timings	13
3.3 Bus passenger interviews	13
3.4 In-home interviews	14
3.5 Information from operators	15
3.6 Driver interviews	15
4 Passenger characteristics	16
4.1 Age and sex	16
4.2 Age and disability	16
4.3 Proportions of disabled passengers	16
4.4 Pushchair users	18
4.5 Difficulties in using buses	18
5 Ease of access	19
5.1 Passenger assessment	19
5.2 Analysis of video recordings	19
5.2.1 Difficulties boarding and alighting for ambulant disabled passengers	19
5.2.2 Passengers with pushchairs	21
5.3 Boarding and alighting times	21
6 Difficulties in using low-floor buses	22
6.1 Boarding and alighting	22
6.1.1 Failure to stop near kerb	22
6.1.2 Failure to kneel	22
6.1.3 Failure to deploy ramp	23
6.1.4 Handrails	23

Page

6.2 Moving and standing in the vehicle 23
6.2.1 Overcrowding 23
6.2.2 Standing 24
6.2.3 Handrails 24
6.2.4 Ride quality 25
6.3 Service characteristics 25

7 Passenger preferences and evaluation 25

7.1 Preferred bus type 25
7.2 Route preference 27
7.3 Advantages of low-floor buses for less mobile people 27
7.3.1 Ambulant disabled passengers 28
7.3.2 Wheelchair users 28
7.3.3 Passengers with pushchairs 29
7.4 User evaluation of low-floor buses 29
7.4.1 Sample sizes 29
7.4.2 Valuation of the low-floor bus 30

8 Patronage 30

8.1 Patronage statistics from operators 31
8.2 Reported changes in bus use 31

9 Operational implications 32

9.1 Bus stop timing surveys 32
9.2 Alighting and boarding time analysis 33
9.2.1 Alighting times 33
9.2.2 Boarding times 33
9.2.3 Dead times 35
9.3 Effects on journey times 35
9.3.1 North Tyneside 36
9.3.2 London 36

10 Operating costs 36

10.1 Fuel consumption 37
10.2 Average cost of repairs 37
10.3 Extra cost of running low-floor buses 38
10.4 Capacity considerations 38

11 Discussion 39

12 Conclusions 39

13 References 40

Notes 40

Abstract 41

Related publications 41

Executive Summary

A substantial number of existing public transport passengers have some degree of mobility impairment and consequently experience difficulties in using conventional bus and rail services. One of the main problems is negotiating steps at the entrance and exit of a bus or the gap between the platform and train. This is impossible for wheelchair users, some ambulant disabled people and many who are simply elderly and frail and therefore cannot use mainstream services. Difficulties are also encountered on almost all types of bus by those with small children, who have to be removed from their pushchairs which must then be folded before being carried aboard, often together with some shopping.

Low-floor buses can overcome these problems and make the services on which they operate more accessible. As there are no steps to negotiate at the doorway, the low-floor bus makes it possible for pushchairs to be simply wheeled on or off without the need to fold them and, with the addition of a retractable ramp to bridge both horizontal and vertical gaps between the bus and kerb, people in wheelchairs can also board and alight. Such vehicles clearly had the potential to increase the market for bus services and therefore started to generate interest among British operators and manufacturers.

In 1993 London Transport decided to set up a demonstration project to assess low-floor buses in trial service in the Capital, and the Department of Transport agreed to promote a similar demonstration in a provincial city. In London, five routes were selected and a total of sixty-eight single deck buses were introduced between January and November 1994 in place of standard one-person operated double deck vehicles. North Tyneside was selected for the other trial, with six low-floor buses entering service in October 1994.

The new vehicles were built by Dennis Specialist Vehicles, Scania and Wrights of Ballymena. Three of the London routes and the one in North Tyneside used Dennis Lance SLF chassis bodied by Wrights, whilst the two remaining London routes were allocated Scania N113 CRL vehicles, also with Wrights' 'Pathfinder 320' bodywork. The London vehicles had both a front door and a centre door, where an underfloor wheelchair access ramp was installed. Those for North Tyneside were fitted with a single front door at which a powered ramp was also fitted. All the buses featured a rear-facing wheelchair space with a padded backrest and strategically-placed handrails to act as a restraint in the event of sharp braking. Safety interlocks between the kneeling suspension, powered ramps and braking systems were devised, and the Department of Transport initially required the entrance door to remain closed whilst the vehicles' suspension was lowered. This led to unacceptably long stop dwell times on the first two routes to be converted in London, and it was subsequently agreed that kneeling/raising the vehicle could take place simultaneously with door opening/closing though separate controls were still required. In addition, a full handbrake application was required on the low-floor buses before the doors could be opened, which was not the case with the double-deck vehicles they replaced.

Experience with the low-floor concept elsewhere demonstrated the importance of achieving a better interface between the bus and the kerb at the stops, so as to minimise the initial step height and the ramp gradient where wheelchair users are boarding and alighting. North Tyneside District Council introduced a number of infrastructure improvements along the low-floor route in its area, costing £6,000 to design and £60,000 to implement. Most of these involved enhancement of kerb heights and specific marking of the stopping place to assist both passengers and bus drivers, and the installation of new high-visibility stop signs incorporating timetable information to improve the image of the service. Action was also taken to enforce parking restrictions at bus stops. In London, similar support was received from some of the relevant Borough Councils - including the installation of 'Kassel Kerbs', into which the wheels of the bus may be safely driven in order to minimise the horizontal gap at stops, and 'bus boarders' which project the stop out into the traffic flow to ensure that the bus can pull up parallel to the kerb.

The trials of low-floor buses in London and North Tyneside were closely monitored by the Transport Research Laboratory and various surveys were performed in both areas.

- *Video recordings*. Cameras on board the buses recorded passengers boarding and alighting before and after the introduction of low-floor buses. Analysis indicated the ease of access of the two types of buses surveyed, and changes in boarding/alighting practices of people with pushchairs.
- *Classified passenger counts and passenger timings*. Observers classified all alighters according to mobility and encumberment, and boarders by the same categories and by their method of payment. Average boarding and alighting times for different types of passenger were estimated by relating these counts to the time the bus was at the stop. Operational implications resulting from changes to time spent at stops could then be predicted.
- *Bus passenger interviews*. Passengers travelling on the low-floor buses were invited to take part in this survey, though the sample was purposefully biased towards those with mobility problems in order to gain a sufficient sample of their views. Information collected included (i) the type of passenger being interviewed (whether they had a physical disability, were carrying a child, or were encumbered with a pushchair or other item(s)), (ii) which bus type was easier to use, (iii) their preferred vehicle, (iv) alterations in their trip-making behaviour since the introduction of low-floor buses and (v) their reasons for any changes.
- *In-home interviews*. Three categories of people were most likely to benefit from low-floor buses: People in wheelchairs could not use the previous double deck

service, ambulant disabled passengers needed to negotiate two or three steps at the entrance/exit and people with pushchairs had to remove their child, fold the pushchair and carry both on board. Interviews were conducted with people from these groups at their homes so they could give their considered opinions. Three survey forms (one for each respondent type) ascertained (i) the circumstances of the respondent (equipment used to aid mobility or number of small children), (ii) whether they had heard of, used and were continuing to use the low-floor services, (iii) alterations in their trip making behaviour since the introduction of the low-floor buses and the reasons for the change, (iv) which bus parents with pushchairs preferred, (v) details of any improvements which would encourage them to use the service more and (vi) the extent to which they valued low-floor buses via a stated preference exercise.

- *Information from operators*. All operators of the trial routes were contacted and asked for details of scheduled and actual mileage operated, fuel consumption, cost of maintaining systems only found on low-floor buses, patronage and revenue information for a year before and after the introduction of the low-floor buses on the low-floor and a comparison route. Operational implications and the economics of running such buses were inferred from this information.
- *Discussions with drivers*. A selection of drivers from each of the routes took part in a semi-structured interview asking about the cab and layout of the controls, the driving and handling of the bus compared with other types, their views on the kneeling mechanism, their observations of boarding and alighting problems encountered by passengers and any conflicts which had occurred over the use of the wheelchair/ pushchair space.

Some of the main findings were:

- Numbers of pensioners in the sample were greater than would be expected in a random sample. In the interviews on board buses 60.3% of respondents in London and 55.8% in North Tyneside were aged over 65. Interviewers needed to introduce this bias in order to gain a sufficient sample of mobility impaired respondents. In contrast, only 30.2% of passengers in London and 42.2% in North Tyneside were classified as elderly in the classified passenger counts.
- Females were over-represented in the interviews on-board buses (compared to the National Travel Survey): 79.5% of interviewees in London and 81.7% in North Tyneside.
- As with earlier studies, many passengers judged as mobile by the interviewers considered themselves to be mobility impaired. Interviewers tend to identify more severely impaired people, in order to explore their problems. There was a clear correlation between age and disability.
- Low-floor buses were used by significant proportions of ambulant disabled passengers and wheelchair users living in the catchment areas of the trial services.
- Most categories of passengers found low-floor buses easier to use than double-deck vehicles. The improvement in accessibility, generally associated with boarding and alighting, was mainly noticed by mobility impaired passengers (over 68% found them easier), those with infants in pushchairs (over 90% found them easier), and by people in wheelchairs. Over 90% of all those finding low-floor buses easier gave the absence of steps (or the ease of getting on and off) as a reason.
- The principal advantage of low-floor buses is the reduced step height at the entrance, and if the bus does not kneel this can be lost. Substantial variations in the incidence of kneeling was found, ranging from less than 40% on one route in London to nearly 100% in North Tyneside. A reasonable correlation existed between this factor and the percentage of passengers finding low-floor buses easier to use.
- Passengers with pushchairs particularly benefit from low-floor buses. On the previous double deck buses they all needed to remove their child, fold the pushchair and carry both on board, whilst they are generally able to push the child in the pushchair onto a low-floor bus. All pushchairs observed on the low-floor buses in video surveys in North Tyneside were unfolded, and 78.9% of them in London.
- The majority of *all* passengers had no difficulty boarding, alighting or moving in *any* of the buses. Of the rest, the most common problem was getting on and off, and particularly getting on.
- Difficulties found in using low-floor buses were associated with the location of handrails (too close together for wheelchair, too far apart for those moving between doors and seats), overcrowding, pushchairs blocking the gangway, buses not kneeling at stops, and gaps between buses and kerbs (often because of illegally parked vehicles).
- Ambulant disabled passengers needed to use handrails less when boarding and alighting low-floor buses than the previous double deck buses. In London the percentage using them to board decreased from 77 to 23% and in North Tyneside from 88 to 44%.
- Most categories of passengers preferred low-floor buses. In London, 42% of mobile adults, 95% of people with pushchairs and 61% of ambulant disabled people preferred them. In North Tyneside the preference was even stronger with 75% of mobile adults, 97% of people with pushchairs and 92% of ambulant disabled people preferring them.
- Low-floor buses provide some wheelchair users with more opportunities to go out, providing a useful alternative form of transport, and in some cases reducing their need for help from others. Wheelchair passengers particularly appreciated the ability to use the same means of transport as other members of the public.
- Ambulant disabled passengers in London are used to free travel, which possibly explains their valuation of low-floor buses at only one penny more per trip than double deckers. In North Tyneside they pay a flat fare of

15 pence (for a single stage journey) and valued the low-floor buses at 57 pence more per trip than double deckers. Only a few people with pushchairs took part in the stated preference exercise used to value the low-floor buses, so the results have to be treated with caution. However, those that did valued them at 7.4 pence per trip more than double deck buses.

- Low-floor buses attracted more passengers than standard vehicles, mainly from less mobile sections of the population, particularly people with pushchairs. Overall increases in patronage on the trial services (compared with changes on 'control' routes) ranged between -1 and +12 per cent.
- Interviewees on board the buses reported changes in their trip making behaviour since the introduction of the low-floor buses. 2.5% and 1.8% of all interviewees had reduced and 14.7% and 19.5% increased the number of trips they made in London and North Tyneside respectively. Substantial numbers of people with pushchairs had increased the number of trips they made: 49% in London and 66% in North Tyneside. In many cases the change was due to personal reasons, but significant numbers attributed it to the new type of bus.
- Marginal boarding and alighting times are slightly shorter on low-floor buses for fully mobile passengers, and substantially shorter for ambulant disabled passengers (1.3 seconds faster to board with a pass in London). People with pushchairs were quicker, through not having to fold the pushchair, taking 7.6 seconds less to alight in London. These gains can be offset by increases in 'dead time' at stops associated with kneeling and its interaction with door operation, which can take up to 3 seconds more at each stop. However, overall changes in total time spent at stops along the length of a typical bus route amount to less than one minute.
- Operating costs are slightly higher for low-floor buses than for conventional vehicles, as there are additional mechanisms and parts to maintain or replace, fuel consumption is a little higher, and capital costs are higher. It is estimated that with the current price differential between low-floor and other buses (which has fallen substantially since these trials began) the difference in overall operating costs per vehicle kilometre lies between one and four per cent.

1 Introduction

1.1 Background

Most buses currently in service in Great Britain have floors so high above ground level as to require passengers to mount two or three steps on entry, and descend two or three steps on alighting. While this causes little difficulty for the majority of passengers, a substantial minority, who are elderly, mobility impaired, carrying luggage or travelling with small children, find bus steps a considerable obstacle which take time and effort to overcome. Steps render buses completely inaccessible to wheelchair users, unless vehicles are equipped with lifts.

As the population ages, the proportion of potential bus passengers with mobility problems is likely to increase, and bus operators are beginning to realise that provision of more accessible bus services may be in their commercial interest. At the same time there is growing concern to eliminate discrimination against disabled people, stimulating efforts to provide a viable solution to the problem of making buses accessible to wheelchair users. Furthermore, the Disability Discrimination Act 1995 gives the Secretary of State power to make regulations requiring all new buses introduced after some future date to be accessible.

In response to these demands, manufacturers have begun the development of a new design of bus, incorporating a floor which is much closer to ground level. By lowering the vehicle (‘kneeling’) when it is stationary at a stop, the level of the floor can be reduced virtually to that of the kerb, effectively eliminating the step. For wheelchair users, the horizontal gap between the kerb and the bus floor (and any residual vertical step) can be bridged by the use of some form of ramp, which is simpler and quicker to operate than a lift, easier to accommodate within the vehicle, and cheaper.

1.2 The trial programme

Before committing themselves to replacing whole bus fleets with new vehicle types, operators need to satisfy themselves, and authorities who subsidise some services, that the new design meets their requirements. It is customary for operators to run trials, in which new vehicles are allocated to particular routes and all aspects of their performance are evaluated over a set period.

Two major trials of low-floor buses began in 1994, shortly after the first such vehicles appeared on the British market. London Transport, through its Unit for Disabled Passengers, assisted five London bus operating companies to deploy a total of 68 low-floor vehicles on five different routes. The second trial area was chosen in order to test low-floor buses in operating conditions which would typify urban bus services outside London. The service selected by the Department of Transport was in North Tyneside, where five low-floor vehicles were introduced by CoastLine, a subsidiary company of the Go-Ahead Group.

The trial services and the areas in which they operate are described in some detail in Section 2 of this report.

1.3 Monitoring

In London, monitoring and evaluation of the trials was financed jointly by London Transport and the Department of Transport, who commissioned the Transport Research Laboratory (TRL) to undertake the work. TRL assumed similar responsibilities, funded by the Department of Transport, for the trial in North Tyneside.

The same methods, described in Section 3 of this report, were used to monitor the trials in the two areas, to facilitate comparisons between the results. Broadly, the monitoring was divided between assessment of the impact of the new vehicles on passengers, and the implications for bus companies in terms of operations, reliability, maintenance problems and costs. The economic assessment combines both these aspects.

The main topics covered by the monitoring programme were:

- characteristics of bus users and potential bus users;
- ease of access to low-floor buses;
- difficulties experienced in using low-floor buses;
- passenger evaluation;
- changes in patronage;
- operational, maintenance and cost considerations;
- economic assessment.

These subjects are discussed in detail in Sections 4 to 10, followed by a general discussion and conclusions in Sections 11 and 12.

2 The trials

2.1 The vehicles

The buses used in the trials were single-deck ‘Pathfinder 320’ vehicles built by Robert Wright and Son on Dennis Lance SLF and (on two London routes) Scania N113CRL chassis. Details of two of the bus types used in the trials are shown in Figures 1 and 2. The front two-thirds of the floor area is flat, and the step at the entrance is normally 320 mm above ground level. When the bus stops, it can be made to ‘kneel’, by lowering the suspension, reducing the step height to 240 mm (see Figure 3a and 3b). A wheelchair access ramp can be extended from beneath the floor down to the kerb (see Figure 4a and 4b), or to ground level if the bus cannot stop close to a kerb.

The North Tyneside buses have one door at the front, equipped with a ramp. The London vehicles conform to the standard London practice of using the front door for boarding and the centre door for alighting passengers, but wheelchair users enter and leave by a ramp placed at the centre door. Both types of vehicle provide a space for one (or two) backward-facing wheelchair passengers, equipped with a bulkhead to restrain the chair during sudden stops, suitably placed handholds, and a bell push to inform the driver when the ramp needs to be deployed for wheelchair users to leave the bus. Figure 5a and 5b shows the wheelchair space, and Figure 6 an internal view of the bus.

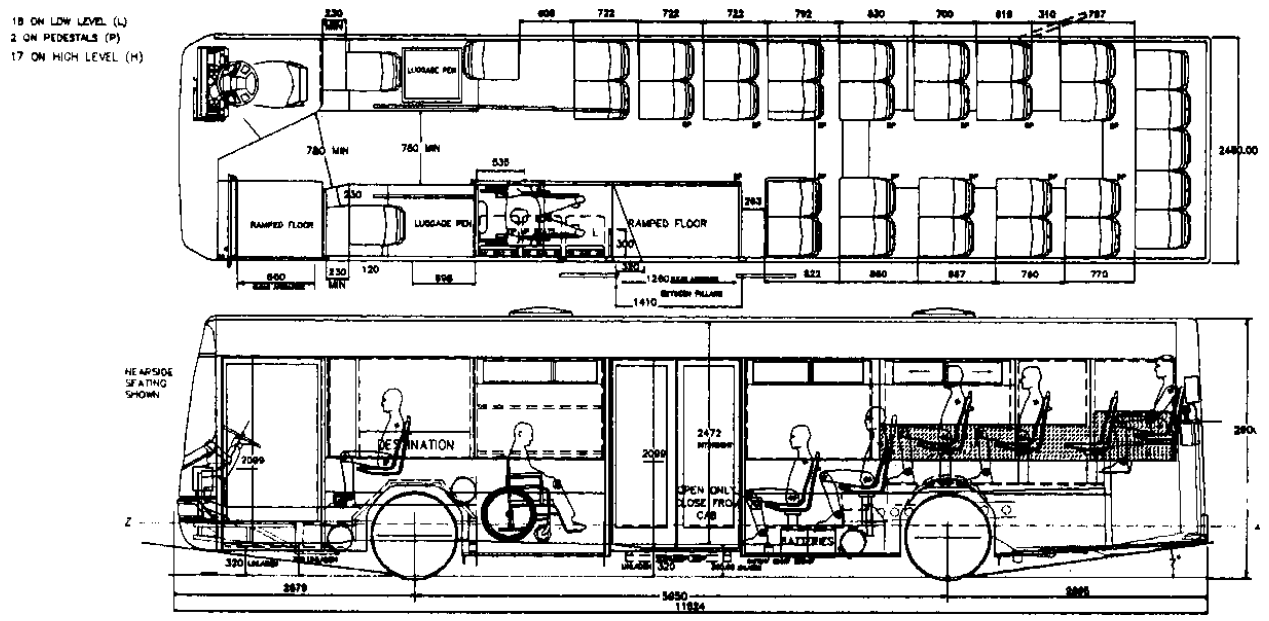

Figure 1 Two door low-floor bus (London)

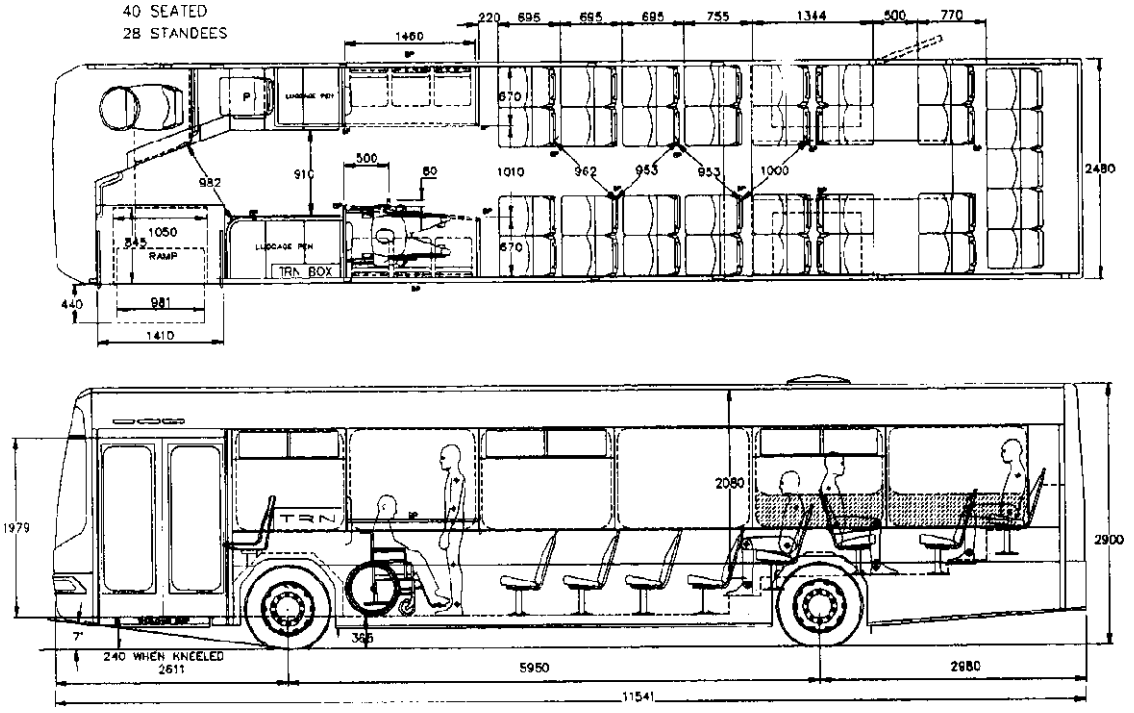

Figure 2 One door low-floor bus (North Tyneside)

Figure 3a The low step (North Tyneside)

Figure 3b The low step (London)

Figure 4a The wheelchair ramp (single doorwary, North Tyneside)

Figure 4b The wheelchair ramp (two door, London)

Figure 5a Wheelchair space (North Tyneside)

Figure 5b Wheelchair space (London)

Figure 6 Internal view (North Tyneside)

During the early stages of the trials several different arrangements of the handbrake/door-opening/kneeling interlocking system were used. There are potentially conflicting requirements here: safety and minimisation of time spent at bus stops. Because of the concern that, in the event of the bus partly running somebody over and the victim being more severely injured as the bus kneels, the DOT Vehicle Inspectorate decided that control of the doors and kneeling must depend on the driver taking positive action after the handbrake is applied. The initial arrangement on the first two London low-floor routes was for the doors to open only after the bus knelt. This was found to cause excessively long stop dwell times (see Section 9), and was eventually replaced with an arrangement whereby the doors opened as the bus knelt. A further variation, tried on one London route, was to allow the front door to open when the speed of the bus approaching a stop fell below 5 km per hour (3 miles per hour) which reduced stop times by a couple of seconds.

The buses were also fitted, in accordance with Department of Transport requirements, with a sensitive strip below the front doorway to detect any obstacle under the front overhang during the kneeling process and automatically reverse the lowering of the suspension.

The wheelchair access ramps were of two different types, both manufactured in Germany. Those on the London vehicles extend telescopically from beneath the second door whilst the design used on the North Tyneside buses involves the lowering, by a few degrees, of the front doorway floor and the subsequent extension of the ramp platform. In both cases operation of the ramp is controlled by the driver and may be initiated before or after kneeling of the bus, dependent on the kerb height at the stop. In cases where the vehicle is unable to get within reasonable reach of the kerb the ramp may be deployed down to street level, though the much steeper gradient then encountered would result in almost all wheelchair users requiring assistance - either from other passengers or the driver - to board or alight. Drivers were trained to continue for a few yards beyond a stop obstructed by parked vehicles if necessary, in order to get close enough to the kerb to deploy the ramp with a reasonable gradient.

2.2 The services

In London, the five routes were selected for the trials prior to privatisation of the bus companies then owned by London Transport whilst the North Tyneside route was commercially provided by the CoastLine subsidiary of the Go-Ahead Group.

Details of the six services are given in Table 1, and their locations are shown in the maps in Figure 7 (London) and Figure 8 (North Tyneside). The London services, mostly in Outer London, run in both directions on straightforward linear routes, The North Tyneside service is circular, with different route numbers distinguishing clockwise and anti-clockwise directions.

The London routes serve densely populated areas, with a representative cross-section of population. Buses are often heavily loaded, and have to contend with congested traffic conditions.

North Tyneside, although in a metropolitan area, is less densely developed. The route serves a mixture of areas: industrial, public sector housing and seaside resort/ retirement areas. Car ownership is low compared with the national average, and demand for buses quite high. Elderly people, who are most likely to benefit from low-floor

Table 1 Trial low-floor bus services

Route number	*Operator*	*Route*	*Service frequency*	*Date of introduction*
120	London United Busways Ltd	Hounslow - Southall - Northolt	15 mins	29.01.94
222	Centrewest London Buses Ltd	Hounslow - West Drayton -Uxbridge	15 mins	12.03.94
186	Metroline Travel Ltd	Brent Cross - Edgware -Harrow - Northwick Park Hospital	10 mins	25.06.94
144	Leaside Buses Limited	Muswell Hill - Wood Green - Edmonton Green	10 mins	17.09.94
101	East London Bus and Coach Company Ltd	North Woolwich - East Ham - Wanstead	7–8 mins	05.11.94
325/326	CoastLine	North Shields - Whitley Bay - Tynemouth	30 mins	22.10.94

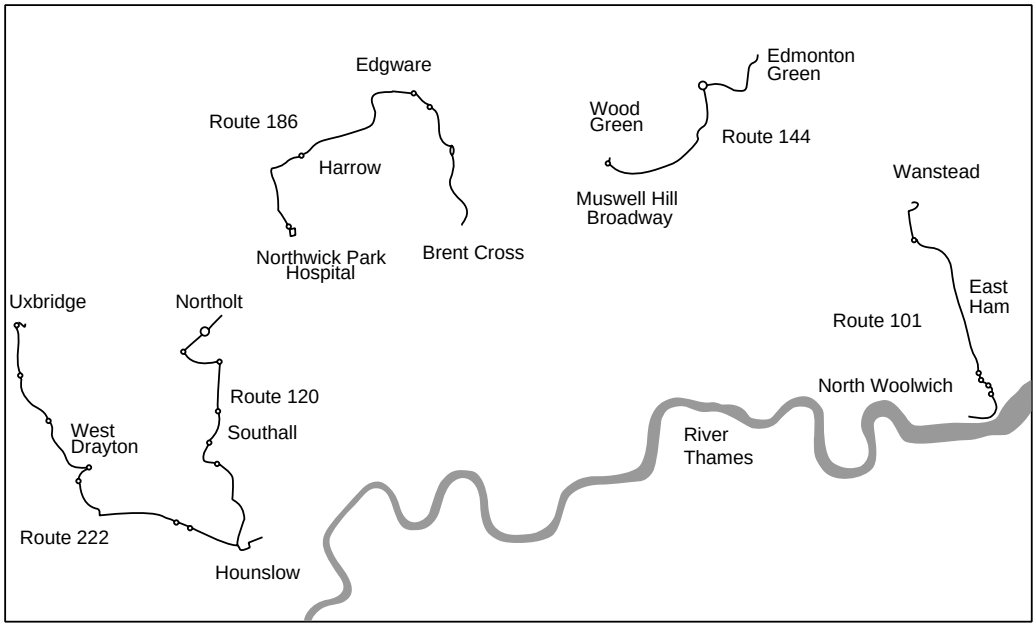

Figure 7 London routes

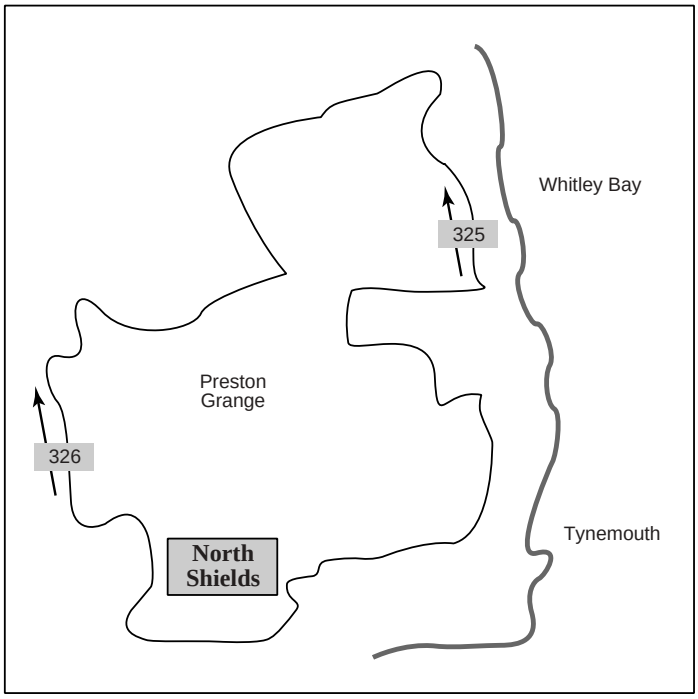

Figure 8 Route 325/326, Tyne & Wear

services, form a substantial part of the population. Traffic is much less congested than in London. As a result, the service is significantly more reliable.

2.3 Infrastructure

North Tyneside District Council made considerable efforts to improve the infrastructure on the low-floor route. Most of this work, which is listed in Table 2, took the form of improvements at bus stops, following a survey of 120 of them.

Table 2 North Tyneside infrastructure improvements

Change	*Number implemented*
High visibility kerb tape (or paint in areas prone to vandalism)	54
City stops (bus stops with timetables)	25
Footway works where existing kerb 80 to 100 mm	22
Footway works where existing kerb less than 80 mm	32
Replace shelter panel with vision panel	10
Modify entrance/exit of existing shelter	6
Relocate shelter	6
Renew shelter	4
Remove shelter	3
Repair shelter	Ongoing
Paint existing shelter in maroon/grey corporate colours (excluding Adshel and those in Whitley Bay town centre)	All
Remove bus stop poles	24
Relocate/renew bus stop pole (3 m pole)	11
Repair tarmac, concrete and flags.	10
Highway works to levels at Coach Lane, Saville Street roundabout to allow low-floor buses access.	1

The objectives were to provide:

- unimpeded access (especially by wheelchairs) to stops;
- a minimum kerb height of 100 mm, to ensure a moderate ramp slope;
- a maximum kerb height of 125 mm, to avoid contact with the underside of the bus.

The work was largely devoted to marking stop positions (to help drivers and passengers to position themselves correctly), modifying kerb heights, and relocating shelters and bus stop poles so as not to impede wheelchair access. At the same time new 'City Stop' poles were erected in some places, as part of a more general campaign to enhance the image of bus services in the area, and more particularly to draw attention to the low-floor service. Some highway works were necessary to prevent low-floor buses from grounding at one location. The infrastructure improvements cost some £6,000 to plan and design, and £60,000 to implement.

In London, the operating companies carried out detailed surveys of each bus stop on the five routes and sought the co-operation of the relevant Borough Councils to achieve improvements in the most severe cases. A positive response was achieved in some instances though the problem of parking at bus stops, despite the widespread use of Clearway Orders and other restrictions, remains the most serious issue impeding the effective use of low-floor buses in the Capital. A series of seminars for the highway authorities was arranged by London Transport's Unit for Disabled Passengers to emphasise this point.

Some local authorities in London also made efforts to upgrade the infrastructure along the low-floor routes, which included fitting Kassel kerbs, into which the nearside wheels of a bus may be safely driven, in order to achieve a minimum horizontal gap between the doors of the bus and the edge of the footway. Bus 'boarders' (projections of the footway into the carriageway, where buses can stop adjacent to the kerb without deviating from the main traffic stream) have also been provided at some locations on the low-floor routes in London.

2.4 Parking control near bus stops

Parking and loading of other vehicles at or near bus stops prevents low-floor buses from drawing close to the kerb, increasing the step height or ramp gradient.

In North Tyneside, advisory bus stop boxes, 19 m in length and 2 m beyond the platforms to allow the bus to manoeuvre, were used. Initially, the combination of yellow bus stop boxes and a Traffic Regulation Order (Prohibition of waiting, loading and unloading) appeared to be the most effective way of discouraging inconsiderate motorists. Advice from the legal section of the corporate services function of the Council resulted in standard Bus Stop Clearway orders being extended from 0700 until 1900 to 0600 until 0000, with the permission of the Department of Transport. This approach was adopted because it was considered impractical to prevent local shop deliveries all day. In addition a traffic warden was provided with a free bus pass, and travelled the route ticketing any illegally parked vehicles.

No specific additional initiatives were taken to discourage parking at bus stops along the London routes, although many were already covered by Clearway orders or double yellow line restrictions.

3 Research methods

Several different techniques were used to obtain the information required to assess all the aspects of low-floor bus performance covered in this study. In some cases, data produced by one method was used for a number of purposes, as indicated in Table 3. The following sub-sections describe each of the methods employed.

3.1 Video recordings

A video survey was conducted in London and North Tyneside both before and after the introduction of the low-floor buses. Cameras recorded boarding and alighting movements of over 500 passengers in each area before the change, and over 800 after. This provided adequate samples of ambulant disabled passengers, and of people with children in pushchairs.

On the first pass through the film, a note was made of all ambulant disabled passengers boarding and alighting the buses. The second pass was used to examine these passengers in more depth and develop a method of judging the degree of difficulty encountered. Passengers were classified as disabled if they used/carried mobility aids or

Table 3 Data collection methods

Source of information	*Information used to assess*					
	Ease of access	*Passenger preference*	*Passenger difficulties*	*Patronage effects*	*Operational implications*	*Operating economics*
Video recording of boarding and alighting passengers	●		●			
Classified passenger counts and stop time observations	●				●	
Bus passenger interviews	●	●	●	●		●
In-home interviews	●	●	●	●		
Operator information				●		●
Discussions with drivers					●	

appeared to have difficulties walking (usually indicated by a short shuffling gait).

In the next pass the total number of passengers boarding and alighting from the buses were counted, and the pushchairs were classified as unfolded or folded.

In the final pass all identified disabled passengers, people with pushchairs, and other encumbered passengers were examined. For each passenger, a note was made of any handrails they used, and whether they rested on them or used them to assist their movements.

3.2 Classified passenger counts and bus stop timings

These surveys were conducted on each route shortly before the introduction of low-floor buses, and around seven months afterwards, when it was expected that any transitional effects would have ceased. The surveyors (two on dual door buses, and one on the single door buses), used Psion hand-held computers to record their observations, travelling on the bus during five working days between approximately 0800 and 1700. Where possible, data from different routes has been pooled in order to obtain more accurate values of boarding and alighting times for sub-categories of passengers.

Observers noted:

- the times at which the bus stopped and left the stop;
- the number of passengers alighting and boarding in each of the categories shown in Table 4 and, for boarding passengers, the payment method that they used (also shown in Table 4);
- whether the ramp was deployed (if applicable);
- whether the bus knelt (if applicable);
- any abnormal occurrences that affected the stop dwell time;
- and on two-door buses whether boarding or alighting took longer.

Further, observers noted encumbrances in the form of shopping trolleys, or pushchairs (folded or unfolded). They also noted passengers who were temporarily disabled, or used guide dogs or Zimmer frames.

The data from these surveys was down-loaded from the Psion hand held computers, and processed to create a data base for use in subsequent analysis. The data base contained details of over 1000 bus stopping events in North Tyneside, during which around 2000 passengers were counted boarding and alighting, in both the before and after surveys,

Table 4 Passenger and payment categories used

Boarding/alighting categories
Ordinary adult
Ordinary elderly passenger
Encumbered adult
Person with child (London only)
Encumbered elderly passenger
Ambulant disabled (adult)
Ambulant disabled (elderly)
Wheelchair passengers
Possible methods of payment
Pass
Pass & fare (North Tyneside only)
Pass, fare & change (North Tyneside only)
Exact fare
Fare & change
Smart Card (London only)
Return ticket (North Tyneside only)

and about 1000 stopping events on each of the five London routes, with about 10000 people boarding and alighting during the before survey, and over 8000 people after.

The primary use of these observations was to compare bus stop times for the two kinds of vehicle (qv Section 9), but by comparing boarding and alighting times for different categories of passenger, it is also possible to make quantitative deductions about ease of access, which supplements other observations. The classified passenger counts also provide useful information about populations of bus passengers.

3.3 Bus passenger interviews

Samples of passengers were interviewed as they rode on low-floor buses, in order to discover what differences were perceived between the old and new buses, particularly with regard to ease of access, and whether introduction of the new vehicles had affected demand. The original intention was to allow three months between the introduction of low-floor vehicles and the passenger surveys. However, a number of teething problems occurred on the first low-floor vehicles in service (on London routes 120 and 222). These led to unacceptably long stop dwell times and overcrowding, which also resulted in unfavourable passenger reaction. These problems were eventually solved by changing the configuration of the buses so that they could kneel and open their doors at the same time, and re-

introducing some double-deck buses during peak times to increase passenger handling capacity. It was considered prudent to delay the first passenger surveys (including the pilot survey) until the remedial action was complete, and for passengers to have grown accustomed to low-floor services running according to plan. Some twelve months therefore elapsed between the first low-floor buses going into service in London, and the first passenger surveys. This interval was reduced to about nine months for the London services introduced later in 1994.

In North Tyneside, where the low-floor services started late in 1994, just before the pilot survey in London, the interval before the passenger survey was less than six months.

On each route interviews were conducted for approximately ten weekdays, on the bus or at bus stops, each day between 0830 and 1700. Interviewees were generally selected randomly. However all apparently disabled passengers and people with pushchairs or prams were approached. It was necessary to introduce this bias in the sample to obtain an adequate sample of such people and deduce meaningful results. Details collected in these surveys are summarised below:

- Whether the respondent appeared to have a physical disability, to be encumbered with a pushchair, or to be carrying a child or a large amount of luggage.
- Details of any impairment to mobility declared by the interviewee, together with the reasons for any difficulties experienced when using the buses.
- Purpose and duration of the interviewees' current trip. Current average weekly use of the service for different trip purposes, and corresponding information about their use, if any, of the previous double-deck bus service.
- Details of and reasons for any changes in trip-making behaviour since the introduction of the low-floor buses.
- Whether some buses were easier to use than others, and if so which and why.
- If a choice of bus routes was available, reasons for choice of the low-floor service for the current trip.
- Bus type preference and reasons for it.
- How often overcrowding prevented the interviewee boarding.
- Tickets used, sex, age and any other comments.

Some 400 people were interviewed in North Tyneside, and nearly 1400 on the London routes.

The results of these surveys were used in the assessment of comparative ease of use of low-floor buses, to provide feedback on difficulties caused by vehicle design faults or operational shortcomings, and to assess passenger preferences and the extent to which bus use was generated by low-floor services. They also provided further information on passenger characteristics.

3.4 In-home interviews

Three categories of passenger are likely to gain the most benefit from low-floor buses. People in wheelchairs were unable to use the double deck buses, but many now have access to a new mode of transport. Ambulant disabled passengers had to negotiate two or three steps to board and alight and can now step straight onto the bus. Lastly, people with pushchairs either felt unable to use the double deck buses or had to remove their child, fold the pushchair and then carry both on board, but can now wheel their child in the buggy straight onto the low-floor bus.

Other features of the design of low-floor buses may affect the ease with which such passengers can use them. For this reason a sample of passengers in each category was interviewed in London and North Tyneside. Home interviews were performed to allow time to obtain people's considered views about the buses and give them time to participate in a stated preference ranking exercise. The survey was performed with the aid of a lap-top computer, so answers were entered directly into analysable files without the need for coding.

Initially, a sample was collected from passengers interviewed in the general survey on board buses, ensuring all were regular users of the low-floor services and could therefore furnish valid views based on their experiences. This sample proved too small for statistical purposes and was augmented through recruiting passengers during a few days spent on routes most frequented by people with pushchairs, and through a small postal questionnaire sent out to disabled people living within a quarter of a mile of a low-floor route. The postal questionnaire ascertained:

- the extent of respondents' mobility impairment: whether they used wheelchairs or mobility aids;
- whether they had used and would continue to use the low-floor buses. Those not currently using the low-floor services were asked why. Those continuing to use the low-floor buses were asked about difficulties encountered and aspects they particularly liked or disliked;
- any improvements to the buses or service which would cause them to travel more;
- whether they were willing to take part in the full survey.

The main objective of the postal survey was to find suitable participants for the home interviews. However, the answers provided gave some insight into such passengers' views and were therefore analysed. In London 765 forms were posted and 261 returned (34.1 per cent); in North Tyneside 700 forms were posted and 220 returned (31.4 per cent).

By sampling in this fashion the following types of passenger were interviewed:

a People with impaired mobility who did not use wheelchairs (referred to as 'ambulant disabled' throughout this report). They were identified through the means described for wheelchair users, and considered separately.

b Wheelchair users, registered with a dial-a-ride service and living within a quarter of a mile of a low-floor bus route, were invited to take part in the postal questionnaire. In-depth interviews were conducted with some of the postal questionnaire respondents who stated they travelled on low-floor buses combined with those encountered during the on-board surveys.

c People with children in pushchairs who were using the low-floor service.

Three separate in-depth interviews were designed, tailoring the questions asked to the different types of passenger participating. The information obtained is summarised below:

- The circumstances of the respondent. For people with pushchairs this involved asking about the number of children they had and whether they needed to be carried onto buses. For disabled respondents (both walking and in a wheelchair) it established the type and extent of disability, including how far they were able to walk, the number of steps they could manage, and the type of wheelchair or mobility aid they used outside their homes.
- Whether they had heard of, used and were continuing to use the low-floor buses: those who were using them were asked whether they needed assistance and the distance from the stops to their home and main destination. Reasons for non-use were sought where appropriate.
- The average weekly number of trips categorised by mode of travel and purpose, before and after the introduction of low-floor buses. Details of any changes were recorded together with their reasons.
- Parents with pushchairs were asked whether they preferred low-floor or double deck buses and why.
- Details of improvements to the service which would encourage people to use it more, and any difficulties encountered whilst boarding, alighting or moving in the low-floor buses.
- A stated preference exercise (see below).
- Basic personal information: including age, sex and occupation.

Benefits for these passengers are likely to be greater than for others. People in wheelchairs now have a new mode of transport available to them, which may remove the need for a friend to travel to the shops for them. A person with a child might be able to travel rather than need a home visit. New activities may be possible with their improved mobility. The questionnaire established any advantages these people had obtained and enquired about the effect on their life, and the lives of others.

A stated preference exercise was then conducted in an attempt to determine how much value people in the various categories placed on the low-floor bus services, in order to quantify any consequential benefits.

Each of the respondents took part in a ranked order stated preference experiment. This entailed placing a set of cards in order of preference, where each card showed details of cost, waiting time and travelling time for a given mode of transport (low-floor bus or taxi for those in wheelchairs, and low-floor or double-deck bus for the other two categories of respondent). For each individual interviewed, the options were specified so as to duplicate those of the trip usually made (eg journey time, fare, etc) or to differ from them by controlled amounts. Each option differed from every other option in at least one of the values of the factors being investigated.

Analysis of such a survey estimates the relative importance of the different factors, and the extent to which people would possibly trade one off against another (eg price against being able to use a low-floor rather than a double deck bus).

The sample sizes obtained from the postal and home interview surveys are shown in Table 5. The postal survey may be biased towards those people who felt strongly enough about the survey to reply, whilst the interview survey was restricted to those who stated they had used and were using the low-floor service. The postal survey gives an overview of the general reaction of disabled people to the buses, whilst the interview survey explores the problems and reactions of users in detail.

Table 5 Numbers of respondents in postal and home-interview surveys

		Number of respondents	
Type of respondent	*Area*	*Postal (Survey 1)*	*Home interviews (Survey 2)*
Ambulant disabled (Type A)	London	128	44
	North Tyneside	132	29
Wheelchair users (Type B)	London	106	32
	North Tyneside	83	26
People with pushchairs (Type C)	London	Not included	19
	North Tyneside	Not included	25
Unknown	London	27	0
	North Tyneside	5	0

3.5 Information from operators

In order to assess operational and economic aspects of the low-floor bus services, operators were asked to supply the following types of information:

- scheduled and actual mileage operated;
- fuel consumption;
- extraordinary maintenance or repair (for items which do not apply to standard vehicles) and associated costs;
- patronage and revenue on the service before and after conversion to low-floor operation;
- patronage and revenue on a similar route operated from the same garage (to serve as a control).

To allow underlying trends, and transient effects following conversion, to be taken into account this information covered periods as long as possible both before and after conversion. Since conversion dates varied, and different companies have different archiving policies, there is some variation between routes in the periods over which comparisons can be made.

In addition to supplying quantitative information, the views of the companies on a number of issues pertinent to low-floor bus operation were sought.

3.6 Driver interviews

Semi-structured interviews were conducted with a sample of low-floor bus drivers on each trial route in London and

North Tyneside. Drivers were asked about:

- the cab and the layout of the controls and indicators;
- the driving and handling of the bus compared with other buses;
- their views on whether kneeling affects adherence to schedule;
- their observations of passengers, whether they have noticed any boarding or alighting problems, or whether there had been conflicts over the use of the wheelchair/ pushchair space;
- any other comments or observations they felt were relevant.

4 Passenger characteristics

In this study we are primarily interested in those characteristics of passengers which affect their ability to get on and off buses, and the quality of the ride in terms of comfort and safety. Our information is derived from three sources: video recordings of passengers boarding and alighting (Section 3.1); classified counts of passengers boarding and alighting (Section 3.2); and interviews with passengers (Section 3.3). The second of these sources provides the largest sample, but is most subject to observer error, since passengers had to be classified in the few seconds it took them to board or alight, and the method of payment also had to be recorded for boarding passengers. Timing observations were also required. In principle the video recordings provide a more reliable classification, as interesting events can be re-examined, but samples are smaller and observers still have to make subjective judgements of age and degree of disability.

The passenger interviews should provide reliable answers to straightforward factual questions on age, sex etc, and they provide two ways of gauging disability. First there is the interviewer's assessment, based on observation of the subject; then there is the interviewee's own perception of physical mobility problems. Both these methods are necessarily somewhat subjective. This sample is likely to contain a higher proportion of ambulant disabled passengers than in the overall population of passengers since interviewers were instructed to select as many apparently disabled people as they could. Since the passenger interviews were conducted only after conversion to low-floor bus operation, they give no indication of any shift in the composition of passengers. All three surveys were conducted between peak operating hours, so are likely to contain lower proportions of younger people on their way to and from work or school, and higher proportions of elderly and disabled people.

4.1 Age and sex

The distribution of ages, by sex, of passengers who were interviewed is shown in Figures 9 and 10.

The proportion of respondents aged over 65 in the sample (60.3% in London and 55.8% in North Tyneside) was substantially higher, especially in London, than the proportion judged to be pensioners in the classified passenger counts (30.2% in London and 42.2% in North Tyneside). The reason for this difference is that interviewers were instructed to bias the interviews in favour of mobility impaired passengers, who are predominantly elderly.

The proportion of females also appears somewhat high (79.5% in London and 81.7% in North Tyneside), compared with national average bus use estimates. National Travel Survey data indicates that 62.4% of all bus journeys are made by women (Department of Transport 1988). This may have been due to the time of day that the interviews were conducted.

4.2 Age and disability

The proportions of passengers in different age groups who claimed to have some form of disability affecting their mobility are shown in Figure 11. This pattern is similar to that found in a study in Sheffield (Benwell 1983), with a clear correlation between age and disability. Rather more in each age group are affected by disability in North Tyneside than in London.

Arthritis or rheumatism were cited as the most common cause of disability in both areas, but significant numbers in London mentioned other 'limb problems' and heart or lung conditions.

4.3 Proportions of disabled passengers

Table 6 compares proportions of disabled passengers estimated from the three surveys.

Table 6 percentages of disabled passengers

	London		*North Tyneside*	
Survey	*before*	*after*	*before*	*after*
Video recording	8.5	7.3	7.3	5.3
Classified counts: alighting	6.8	4.4	1.5	4.6
Classified counts: boarding	2.1	3.0	1.2	5.6
Interviews: interviewer assessment	..	9.2	..	6.3
Interviews: passenger assessment	..	26.1	..	32.5

The most important feature of these figures is the difference, in each area, between the number of passengers who consider themselves to have some form of disability, and the number whose disabilities are apparent to interviewers: the former exceed the latter by a factor of between three and five. It is clear that observation by non-medical observers, unsupported by questions or tests, will distinguish only more severe examples of disability. However, it is arguable that these more severe cases are more likely to experience difficulties while using buses, and that, as a group, they are therefore worth consideration in this study. In any case, less severely disabled people cannot be identified in the other surveys, so it is useful to be able to distinguish them in the interview surveys. However, it should be borne in mind that any advantages or disadvantages resulting from low-floor bus operation will also affect, to a lesser degree, passengers with less severe disabilities, and any benefits or dis-benefits should, in principle, be scaled up accordingly.

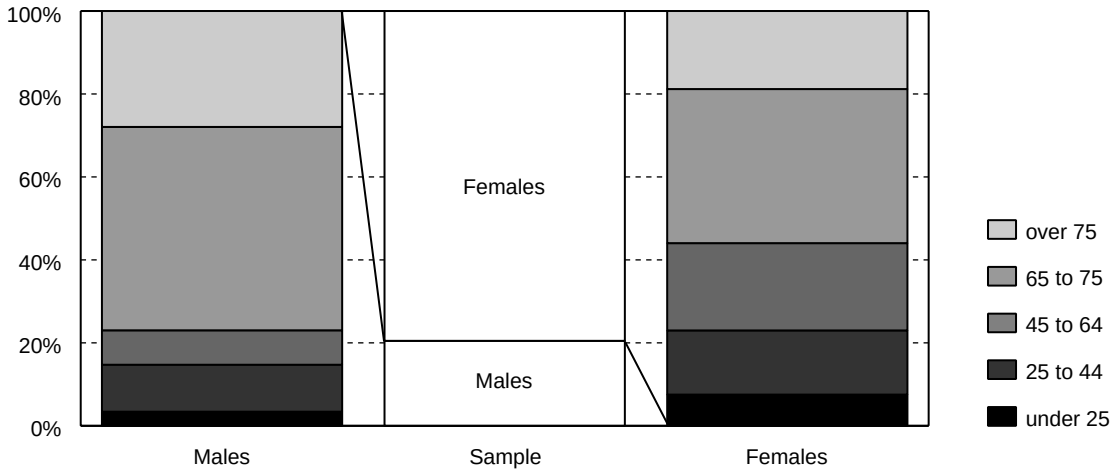

Figure 9 Proportion of males and females of different ages in the sample in London

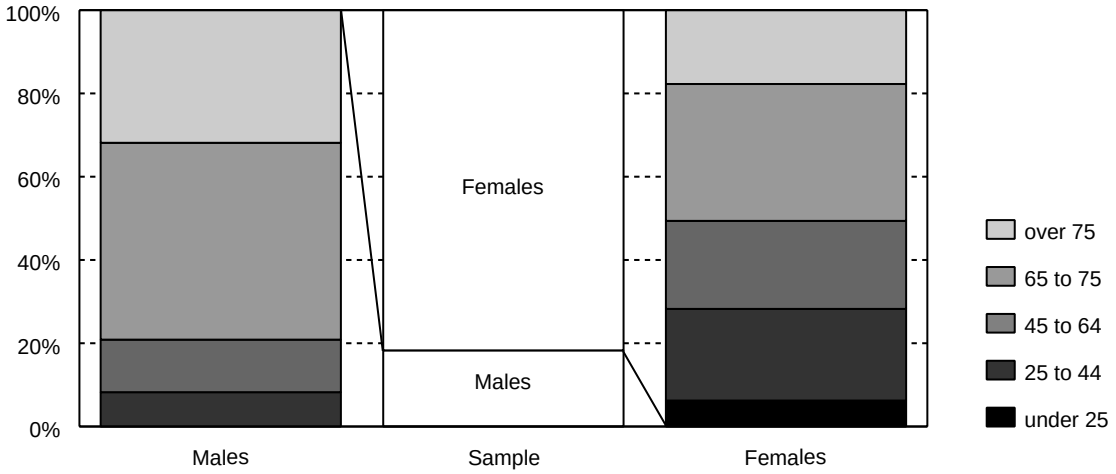

Figure 10 Proportion of males and females of different ages in the sample in North Tyneside

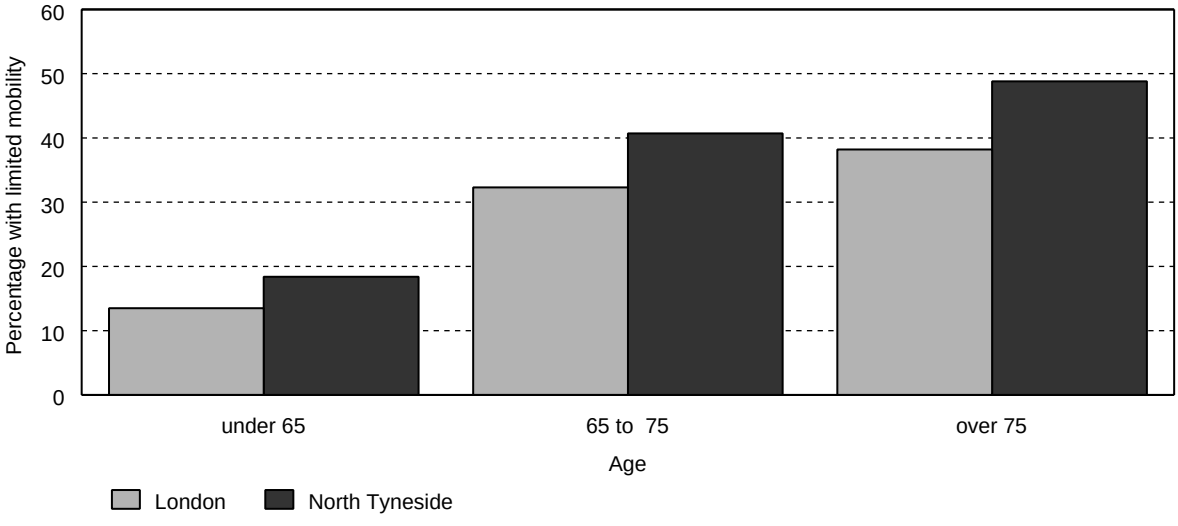

Figure 11 Effect of age on mobility

There is tolerable agreement between the proportions of disabled passengers identified by interviewers, and those detected in the video surveys. The differences are not statistically significant, but they are consistent with the expectation that the interview sample, being deliberately biased towards disabled passengers, should contain more of them.

People's mobility problems may be more noticeable when they have to negotiate steps, so that they are less likely to be classified as disabled when using low-floor buses. On the other hand, low-floor buses, by virtue of their improved accessibility, might attract a greater proportion of disabled passengers. Comparison of the video recording results (Table 6) supports the first of these hypotheses (although the differences are not statistically significant): the classified passenger counts (in which there are significant differences) lend weight to the second. However, the results of the classified passenger counts are not entirely consistent, and they produce generally lower estimates than the video surveys. This suggests that the observers employed on the classified counts had insufficient time to recognise any but the more extreme examples of disability, and that there was inconsistency between observers. Any conclusions drawn from these statistics would therefore be of doubtful validity. Unfortunately, this has implications for assessment of ease and speed of boarding, as we shall discuss later.

4.4 Pushchair users

Low-floor buses are also much more accessible to people with children in pushchairs, which can be wheeled in and out complete with child and without folding. It is therefore of interest to consider the proportions of such passengers on both types of bus in each area. The relevant statistics are shown in Figure 12.

There is better consistency between the surveys than for disabled passengers, presumably because identification of pushchairs presents no difficulty. In both areas, there was a substantial increase in the numbers of pushchairs carried.

4.5 Difficulties in using buses

In the interview survey, passengers of all types were asked about difficulties experienced in using buses in general. They were first asked whether they found boarding, alighting or moving around in any bus to be difficult. Those who found more than one of these a problem were asked which was the worst, and why it was difficult.

The majority of passengers in London and North Tyneside had no difficulties with boarding, alighting or moving in *any* of the buses. Of the rest, the most commonly cited problem was getting on and off, and particularly getting on the bus (Table 7). A higher percentage of passengers in North Tyneside compared with London found some aspect of using the bus to be difficult. This may be indicative of a higher percentage of less mobile adults in the bus passenger population. In both areas most passengers who normally travel with children in pushchairs stated they had no difficulties boarding and alighting buses, but these passengers were almost certainly referring to the ease of boarding and alighting when they are without the pushchair.

Table 7 also shows the effect of mobility impairment on passenger problems. Only small minorities of apparently mobile passengers (some of whom, as we have seen, consider themselves to be disabled) but a larger majority of less mobile passengers, experience difficulties.

Most people with pushchairs had no difficulty in using any bus type, possibly because they were judging the difficulty of boarding and alighting without a pushchair.

In most cases the problems associated with using buses are due to disability. Steps seem to present most difficulties, and problems of movement in the bus are relatively common among mobile passengers. Those passengers who found moving in the bus difficult usually cited problems with the handrails or blocking of the gangway when the bus is crowded.

Problems experienced by mobile and less mobile passengers are correlated with age. Older passengers are more likely to have mobility problems, and so have greater

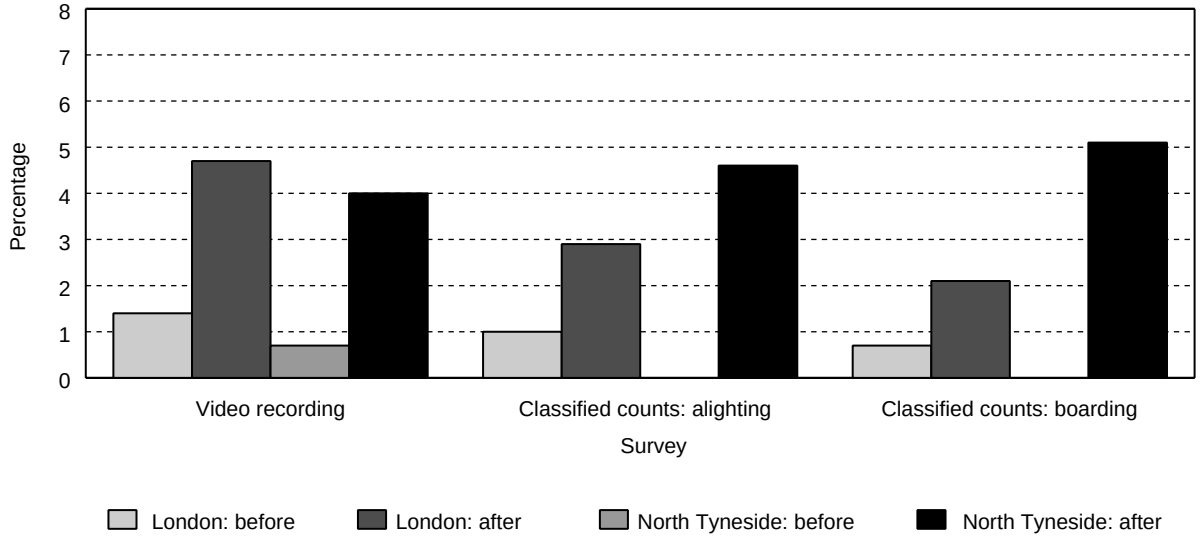

Figure 12 Percentage of passengers with pushchairs

Table 7 Most difficult act on all bus types (all passengers)

Passenger type (as assessed by interviewer)	*Getting on bus*	*Getting off bus*	*Getting on & off bus*	*Moving in bus*	*All as bad (Could not differentiate)*	*No difficulty*
London						
Fully mobile	6.2%	3.6%	5.3%	2.4%	0.9%	81.5%
With pushchair	2.3%	1.7%	0.6%	1.7%	0.0%	93.7%
Encumbered (other)	9.0%	3.9%	5.4%	2.4%	3.0%	76.2%
Ambulant disabled	17.3%	18.1%	31.5%	4.7%	15.0%	18.1%
Other	13.0%	10.1%	18.8%	2.9%	29.0%	26.1%
All passengers	7.8%	5.1%	7.8%	2.5%	3.6%	73.1%
North Tyneside						
Fully mobile	13.8%	9.6%	7.5%	2.9%	0.8%	65.3%
With pushchair	1.4%	2.8%	2.8%	4.2%	0.0%	88.9%
Encumbered (other)	14.3%	4.8%	11.9%	2.4%	4.8%	61.9%
Ambulant disabled	38.0%	20.0%	4.0%	12.0%	16.0%	20.0%
Other	0.0%	18.8%	25.0%	6.3%	18.8%	31.3%
All passengers	11.9%	8.9%	7.6%	3.8%	2.8%	65.0%

difficulty getting up and down the bus steps: in contrast a greater proportion of the more mobile younger passengers find difficulties moving about in the buses.

5 Ease of access

We have employed four methods to determine the extent to which people of various types found the low-floor buses easier to use than the previous ones: analysis of video recordings, boarding and alighting time measurements, on-board interviews with passengers, and home interviews with selected users or potential users. In this section we first discuss the results of the on-board interviews, which give a qualitative indication of passenger's perceptions. We then discuss the semi quantitative findings from the video analysis and the boarding and alighting times. Finally we present opinions of home interviews with ambulant and wheelchair using disabled people, and parents who use pushchairs.

5.1 Passenger assessment

Figure 13 shows how passengers judged the comparative ease of use of the two types of bus. Perceptions depended strongly on passenger type: those with no apparent disability, most of whom do not experience difficulties in using buses (Table 7), seemed to gain the least advantage from the new buses. In London they were most likely to find both bus types as easy to use, but a sizeable minority found low-floor easier. In North Tyneside, however, the majority found low-floor buses easier. Nearly three quarters of ambulant disabled passengers[1] in London, and all of them in North Tyneside, found low-floor buses easier to use. In both areas the great majority of passengers with pushchairs found low-floor buses easier.

For those who found low-floor buses easier to use, the overwhelming reason is the absence of steps, as Figure 14 shows.

The reasons given by the minority (nearly all in London) who find double-deck buses easier to use are more varied, and include ease of movement inside the bus, the position or spacing of handrails, a smoother ride, and better availability of seats.

5.2 Analysis of video recordings

5.2.1 Difficulties boarding and alighting for ambulant disabled passengers

Having identified ambulant disabled passengers, it was necessary to devise an assessment framework in order to compare ease of access to the two types of bus. For this purpose, each handrail at the entrance or exit of the bus was assigned a label, and occasionally the front and back of a handrail were assigned different labels. For each passenger, a note was made of which, if any, handrails they used, and whether they rested on them or used them to assist their movements.

A value for the overall difficulty boarding and alighting was calculated for each passenger. The value was set at 0 if no handrail was used, 1 if handrails were used but only for resting on, and 2 if a passenger applied force to any handrail in the process of boarding or alighting. For passengers who need the handrails to board or alight the average difficulty will be close to two: for those who rarely need them it will be close to 0. The average values on the two types of bus in both survey areas are shown in Figure 15.

Ambulant disabled passengers evidently found low-floor buses easier to board and alight from than double-deck buses in both of the survey areas: they were having to rely much less on the handrails to assist them.

The proportions of ambulant disabled passengers using at least one handrail to help them board or alight (ie those who scored 2) are shown in Figure 16.

Figure 16 possibly understates the difference between the two types of bus, as a smaller proportion of ambulant disabled passengers may have been so classified in the 'after' surveys (see Section 4.3). However, Figure 16 clearly demonstrates that ambulant disabled passengers are able to board and alight from low-floor buses with significantly less effort than the previous double deck buses.

Most of those needing to use handrails to board or alight from double deck buses used those in the centre of the doorway. Similar handrails were unavailable on the low-floor buses, to allow wheelchair and pushchair access. Instead those needing assistance in London used the

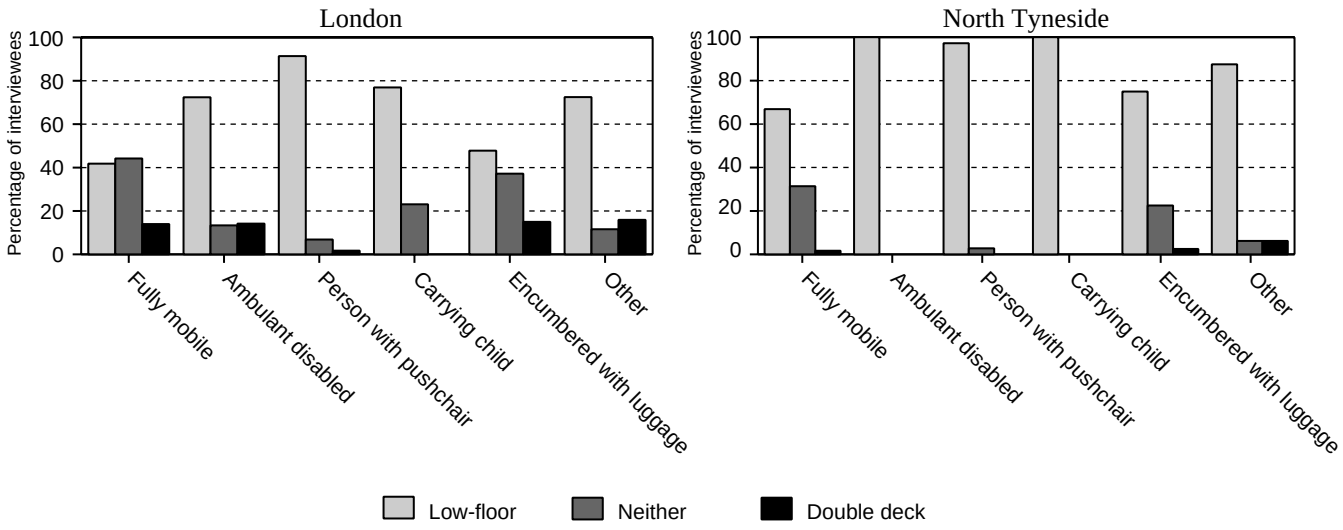

Figure 13 Which bus is easier to use

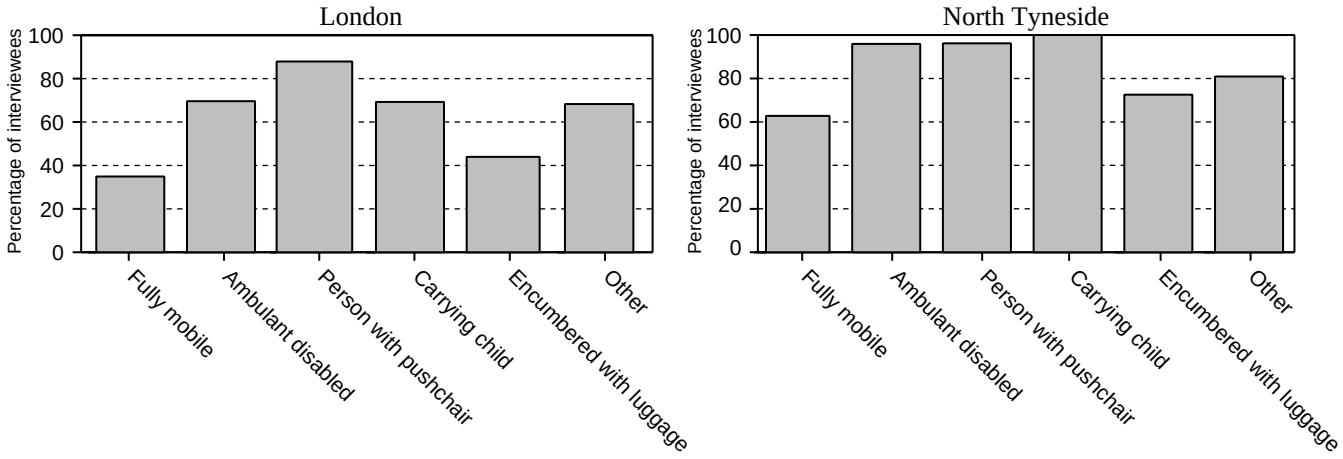

Figure 14 Passengers finding low-floor buses easier to use because of the low step

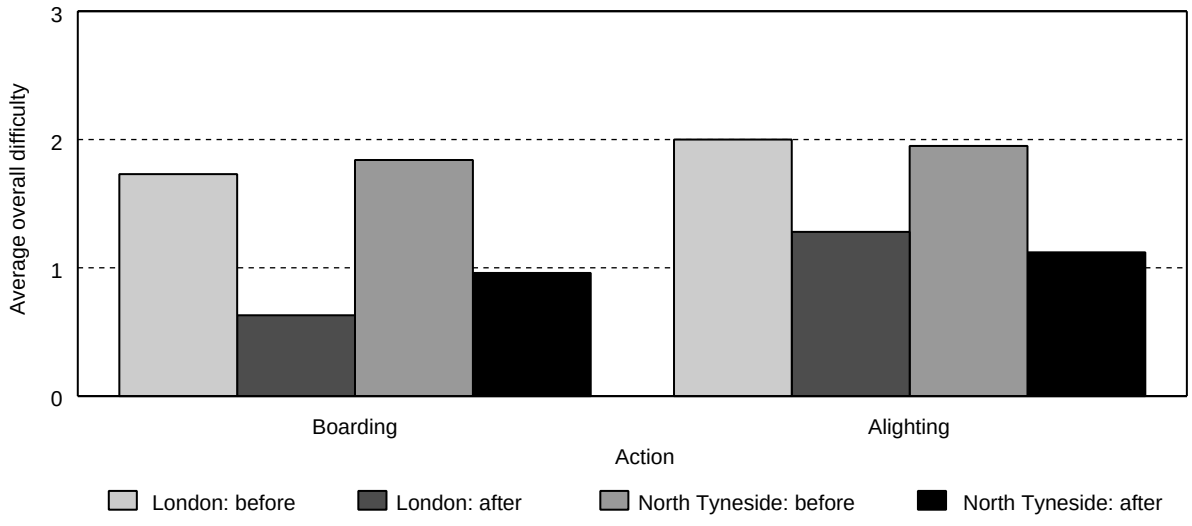

Figure 15 Difficulty boarding and alighting

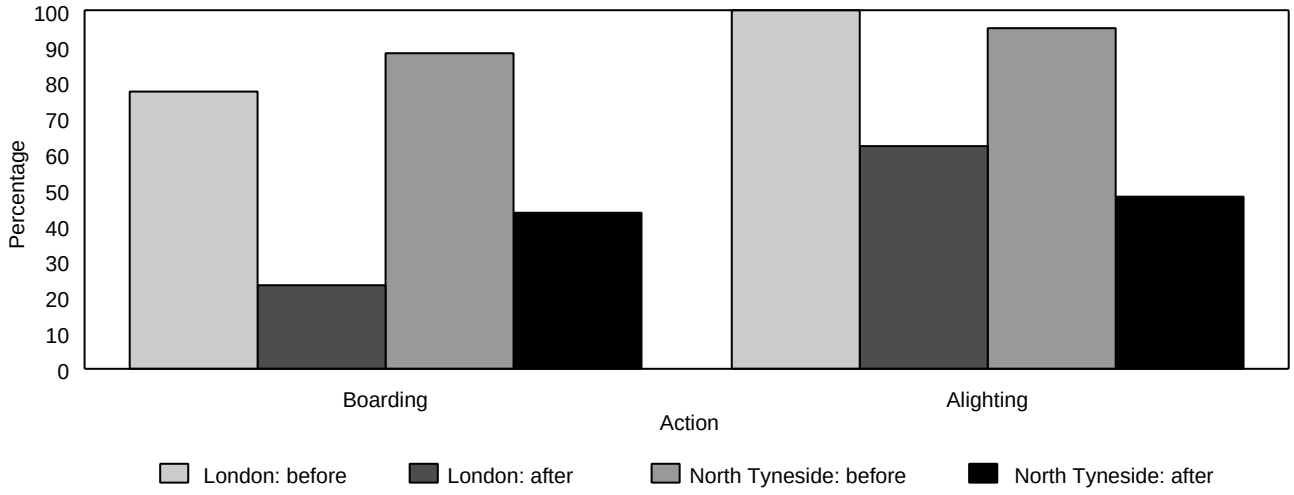

Figure 16 Percentage of ambulant disabled passengers needing to use handrails

horizontal handrail on the right hand side to board, possibly because it is fixed to the bodywork rather than the door, and the handrails at the exit door to step down onto the pavement. In North Tyneside they used the handrails that were at a slight angle to the horizontal on the door leaves to step up and down.

5.2.2 Passengers with pushchairs

The statistics in Figure 12 show a substantial increase in bus use by people with pushchairs, which seems attributable to improved access to the low-floor buses. The qualitative evidence from the video recordings is that it is much easier to wheel a pushchair, complete with occupant, onto a low-floor bus, than to remove the child, fold the pushchair and carry both up the steps of a double-deck bus. The quantitative evidence is that whereas all pushchairs carried on double-deck buses in both London and North Tyneside were folded, all of those on low-floor buses in North Tyneside and 78.9 per cent in London were unfolded.

5.3 Boarding and alighting times

Another measure of the relative ease of access to the two types of bus is, in principle, provided by comparison of boarding and alighting times for different classes of passenger: if an action is made easier then it is likely that people will perform it more quickly.

Analysis of the times buses are stationary at stops, together with counts of different types of passengers, provides an indication of the marginal boarding or alighting time of each category of passenger. This is discussed in more detail in Section 9.

For our present purpose we note that in London marginal boarding times for all passengers (ie without distinguishing different passenger types) were somewhat lower on the low-floor buses, except for passengers requiring change. Marginal alighting times were very similar. In North Tyneside however, both boarding and alighting times appeared longer on the low-floor buses.

Marginal boarding and alighting times for the major categories of London passengers are shown in Table 8. Since we are interested in the physical difficulties of access, we have included only those passengers using some form of pass, which requires no action by the driver.

There appear to be reductions in boarding times for all categories, although the only one which is statistically significant (at the 5 per cent confidence level) is that for mobile adults. This change is small in absolute terms, but it represents a reduction of nearly 8 per cent and applies to the largest group of passengers. Although the reduction for elderly disabled passengers appears greater, it is not statistically significant since the sample sizes (even when all the London observations are combined) are relatively small.

There appear to be small changes in alighting times for mobile passengers, but they are not statistically significant. The apparent increase in alighting times for elderly disabled

Table 8 marginal boarding and alighting times in London (seconds)

	Boarding		*Alighting*	
Passenger type	*Double-deck*	*Low-floor*	*Double-deck*	*Low-floor*
Mobile adult	2.61±0.07	2.41±0.07	1.12±0.03	1.05±0.04
Mobile elderly	3.06±0.14	3.02±0.16	1.58±0.08	1.53±0.08
Mobility impaired elderly	6.20±0.54	4.90±0.47	2.75±0.16	3.40±0.24
With folded pushchair	11.06±1.17	5.64±0.40	7.14±0.69	3.19±0.32
With unfolded pushchair	not available	5.64±0.40	12.00±1.53	4.37±0.55

± *indicates standard error*

passengers is significant, but inconsistent with the finding that the majority of such passengers consider that low-floor buses are easier to use (Figure 13). This discrepancy may stem from the variability in the classification of ambulant disabled passengers (qv Section 4.3). Less severely disabled passengers were perhaps more likely to be missed in the 'after' surveys so that those that were counted would have been somewhat slower, producing an exaggerated estimate of the average alighting time.

The results for passengers with pushchairs (where there are sufficient observations to make valid comparisons) clearly support the finding that pushchairs are much more easily handled on low-floor buses.

The North Tyneside results seem to defy rational explanation. Greater proportions of passengers of all types found the low-floor buses easier to use, yet, where samples are large enough for valid statistical comparison, boarding times are longer (see Table 23).

Table 9 Improvements to low-floor bus services suggested by interviewees (per cent*)

	Ambulant disabled		*Wheelchair users*	
	London	*North Tyneside*	*London*	*North Tyneside*
More low-floor bus routes	55	48	84	47
Less crowding	45	7	47	33
Greater frequency	45	30	37	24
More reliable	42	0	53	0
More comfortable seats	37	4	0	0
Better handrails	40	30	26	0
Stops nearer home/destination	34	22	21	19
More comfortable ride	29	0	5	9
Better safety	26	15	0	0
More seats	18	0	0	0
Easier to board and alight	3	4	11	24
Other	29	26	68	29
Number interviewed	(38)	(27)	(19)	(21)

**Many interviewees suggested several improvements, so the figures in these columns total more than 100 per cent*

6 Difficulties in using low-floor buses

The majority of passengers interviewed on buses report no particular difficulties in using buses in general (Table 7), but a significant minority find getting on or off buses difficult, and a smaller number have problems moving around inside buses. These difficulties are naturally more common among less mobile passengers, and are correlated with age.

The more detailed interviews with less mobile people in their homes therefore provided a means to explore problems of accessibility to low-floor buses in greater depth. These people generally cited the same kind of problems as those experienced by passengers on the buses, but to a greater extent.

In this section it is therefore convenient to discuss each general type of problem in turn, but making reference to interactions where appropriate. The discussion is largely qualitative in view of the relatively small numbers of respondents experiencing difficulties, the occurrence of multiple responses and the lack of an objective measure of difficulty. It is however useful to make occasional reference to Table 9, which lists improvements suggested by ambulant disabled people and wheelchair users interviewed at home.

6.1 Boarding and alighting

Although, as was indicated in Section 5, the low-floor buses have generally proved easier to board and alight, there are some residual problems arising from a number of causes. Not surprisingly, wheelchair users were more likely to suggest improvements to arrangements for boarding and alighting, and against the general trend in Table 9, the proportion suggesting such improvements was greater in North Tyneside than in London, possibly an indication that centre door entrances are more convenient for wheelchair access.

6.1.1 Failure to stop near kerb

When there is a horizontal gap of more than about 250 mm between the edge of the floor at the entrance (or exit) and the kerb, less mobile passengers have to make an intermediate step on the carriageway, and the effective step height (when the bus is kneeling) is approximately doubled and much of the low-floor advantage is lost. This increases difficulties for both ambulant disabled passengers and those with pushchairs.

The most common cause of this problem was parking of other vehicles at or near bus stops, denying buses proper access to the kerb. Since enforcement of parking regulations was more effective in North Tyneside, this problem was less common there than on the London routes.

In some case the drivers may be at fault through lack of commitment, pressure to adhere to schedule, inadequate skill or fear of damaging the sensitive edge beneath the door (see Section 2.1). Staff selection and training are important ingredients of successful low-floor bus operation, and there is scope for further development of devices (such as the 'Kassel Kerb') to facilitate the correct positioning of buses at stops.

6.1.2 Failure to kneel

Much of the advantage of the low-floor design is lost when the bus does not kneel, whether it is correctly positioned near the kerb or otherwise (when the problems discussed above are compounded). There was substantial variation between services in the incidence of kneeling, ranging from under 40 per cent on one London route to nearly 100 per cent in North Tyneside. The apparently unhelpful attitude of some London drivers may result from experience with the prototype interlocking system (Section 2.1) leading to the perception that kneeling was too slow a process to be tolerated when trying to adhere to schedule.

Some drivers seem to kneel only when they are aware that a waiting passenger is likely to have a disability, but as our surveys (Section 4.3) reveal, appearances can be very deceptive. Figure 17 indicates a reasonable correlation between relative ease of use of low-floor buses by mobile passengers ($R^2 = 0.42$) and those with mobility impairment ($R^2 = 0.53$) but not by those with pushchairs, and the proportion of stops at which buses kneel. There is a strong case for ensuring that buses kneel at every stop.

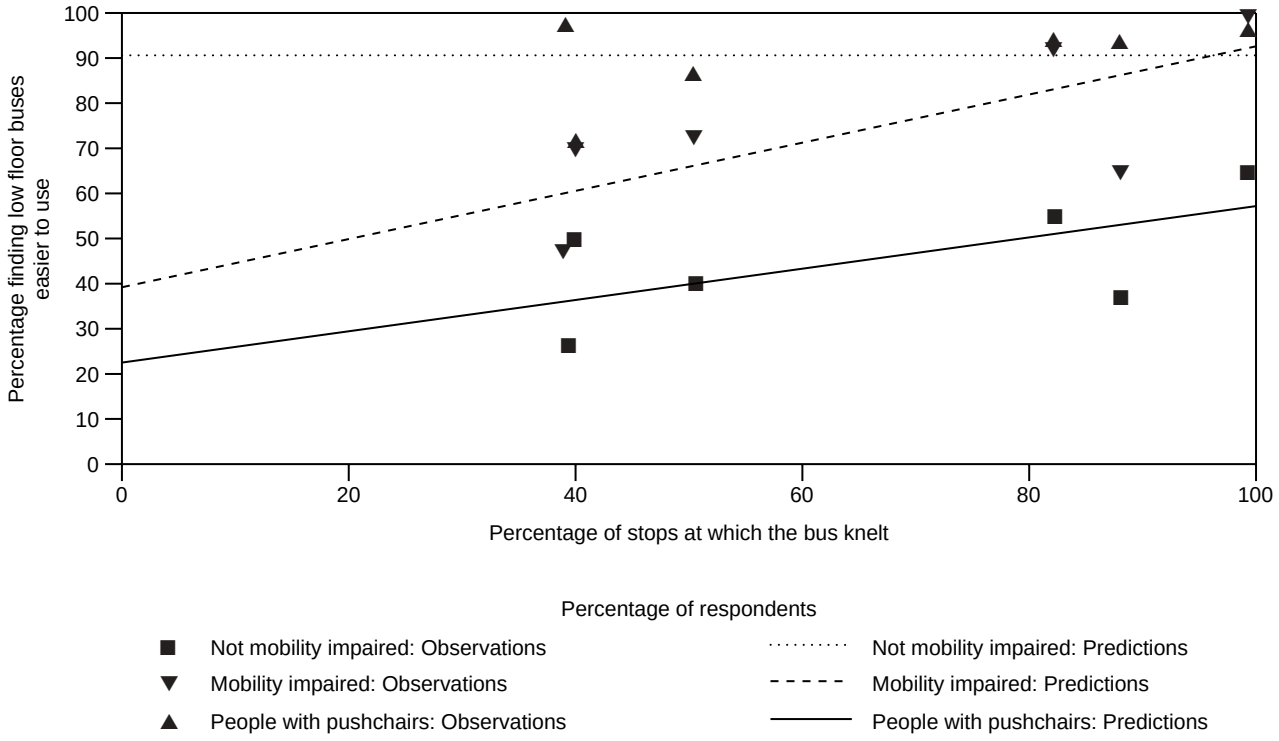

Figure 17 The effect of kneeling on finding low floor buses easier to use

6.1.3 Failure to deploy ramp

There were some complaints from wheelchair users that the ramp did not always work when required, effectively denying them access to the bus. Although there is no firm indication of the frequency of such occurrences, the fact that they are remembered at all presents a psychological barrier to wheelchair users, which is clearly unsatisfactory. More attention should be given to ramp design (reliability and ease of maintenance) and driver training (in some cases drivers seemed to be unable to remember how to operate ramps).

Whilst a small number of ambulant disabled people complained that drivers did not deploy the ramp for them it would appear reasonable to assume that such a boarding aid is only a requirement for wheelchair users. In the case of the London vehicles the ramp is located at the second door to avoid delays caused by passengers having to wait whilst a wheelchair user alights through the front door before they can board. On the North Tyneside vehicles, with only one door, use of the ramp for passengers not in wheelchairs would be bound to cause some delay but this is probably a matter best left to the drivers' discretion.

Such guidance should also apply to pushchair users, a few of whom complained about ramp unavailability. These are a relatively numerous category of passenger, most of who seem to have little difficulty (Section 5.2.2) getting pushchairs in and out of low-floor buses without using ramps. Unnecessary use of ramps would add considerably to bus journey times, delaying other passengers and increasing operating costs.

6.1.4 Handrails

While many interviewees found that some handrails on low-floor buses were less useful than those on double-deck vehicles, most of the complaints were associated with problems of moving inside buses (from entrance to seat, or seat to exit) or, for standing passengers, the need for support while the bus is in motion. We cannot be sure however that every passenger perceives the same demarcations between the acts of getting on or off and moving inside the bus, so that interpretation of survey results is somewhat problematical.

The results reported in Section 5 suggest that the categories of passenger most likely to complain about handrails (ambulant disabled people and those with pushchairs) are the passengers who perceive the greatest improvement in ease of access. This seems consistent with the hypothesis that people have less need of handrails when getting on or off low-floor vehicles, rather than that the less frequent use of handrails is because handrails at entrances and exits are less useful.

However, the interior handrails serve a different purpose from those at the doors: the relative merits of interior handrails on the two vehicle types is discussed in Section 6.2.3.

6.2 Moving and standing in the vehicle

6.2.1 Overcrowding

In this study, the London services proved to be much busier and liable to crowding than those in North Tyneside. Proportions of passengers interviewed who were unable to board the first bus to arrive because it was full are shown in Figure 18. The problem was exacerbated on some routes (particularly route 144) by the improved accessibility for pushchairs which greatly increased the numbers carried. There is room on the buses for two or

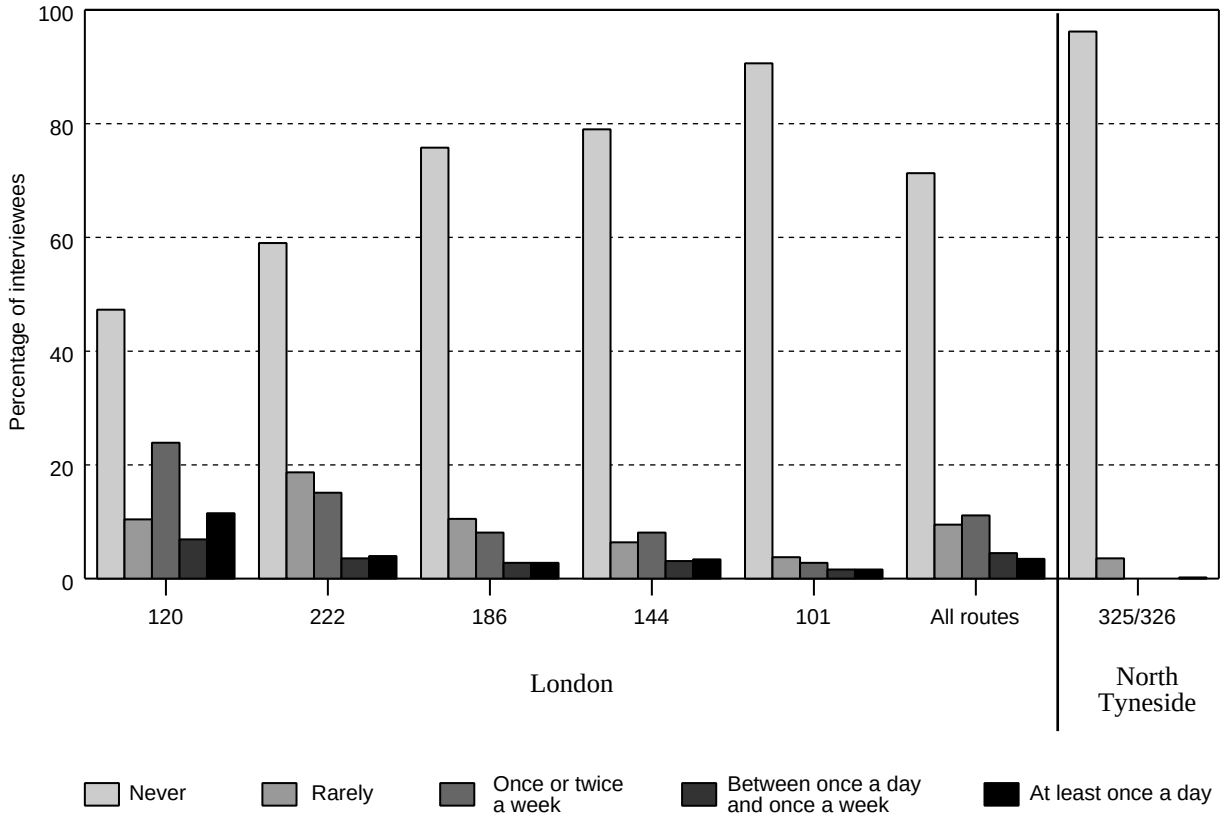

Figure 18 How often are passengers affected by overcrowding

sometimes three pushchairs, provided that other passengers on the tip-up seats move elsewhere in the buses. However, some passengers are reluctant to give up these seats, which is understandable if they are old or less mobile, in order to try and find a seat further down the bus. Also it is fairly common for too many passengers with unfolded pushchairs to try and board the bus, especially when one or more have double pushchairs. A combination of these factors leads to the front section of the bus becoming overcrowded and causes other passengers difficulties in getting through to the back of the bus where there may be free seats, which is why some passengers find the double-deck buses easier to use.

Some interviewees complained specifically about overcrowding, while others mentioned problems which may have been the result of, or intensified by, overcrowding. This in turn leads to more complaints about the London buses than those in North Tyneside.

6.2.2 Standing

Prior to the introduction of low-floor vehicles, passengers were generally only permitted to stand in the gangway on buses in the UK with the result that, for most people, standing was an unpleasant or uncomfortable experience, though not necessarily a cause of difficulty. For people with physical disabilities, however, standing may be painful as well as uncomfortable and maintaining their balance may be difficult. Failure to do so could be dangerous. Standing passengers are more likely to be sensitive to acceleration and braking and will feel a greater need for support from well-placed handrails.

If buses are more crowded there is less chance of finding a vacant seat, and, even if seats are available, they may not be accessible for the reasons described above (Section 6.2.1). So on more crowded buses there is a strong correlation between complaints about overcrowding, lack of seats, a jerky ride, safety, and people are more likely to find difficulties in moving about the vehicle.

6.2.3 Handrails

The carriage of passengers in wheelchairs necessitates a new arrangement of the bus interior: there must be adequate space for at least one wheelchair and its occupant to be safely positioned while the bus is in motion, and there must be clear passageways between door and wheelchair space(s). This is achieved by fitting fewer fixed seats than in a conventional bus, and by increasing horizontal distances between handrails, and possibly relying more on high level handrails.

This inevitably reduces the availability of handrails (to those standing or moving between their seats and the doors) in the entrance/exit area and the space required for a wheelchair-user to manoeuvre into place. Interviewers reported that some passengers had difficulties negotiating the front part of the low-floor buses because of the lack of handrails. Various pieces of evidence support this observation. Some passengers said that double-deck vehicles were easier to use, and a significant minority cited inferior handrail provision on low-floor buses (possibly the

lack of a centre handrail in the door area) as a reason. Ambulant disabled people elicited the same reaction during the household surveys.

A minority (26 per cent) of wheelchair users interviewed in London also expressed a need for more and better handrails. Conversely, some of those interviewed in North Tyneside found handrails an obstacle when trying to manoeuvre their wheelchairs.

Generally, dissatisfaction with handrail provision was more common in London than in North Tyneside; this was almost certainly a consequence of the more frequent occurrence of overcrowding on the five London routes.

6.2.4 Ride quality

The most common reason for low-floor buses being more difficult to use is that they are perceived to provide a jerky, rather than a smooth, ride (12.6% in London and 1.5% in North Tyneside of passengers interviewed found double deck buses easier to use). Discussions with drivers gave no indication that low-floor buses are less smooth than others: possibly passengers are more sensitive to the effects of acceleration because they are more frequently standing on the low-floor buses due to the reduced seating capacity.

6.3 Service characteristics

The ability to get on and off buses is a necessary, but not sufficient condition to satisfy a potential passenger's needs. The service is useful only if it connects the desired origin and destination of a trip, and runs at convenient times, and walking or wheeling distances to and from bus stops are not too great. People in our study areas who can only use low-floor buses have a choice of just one bus route, even if they can get to it and can tolerate waiting at the stops.

Consequently complaints most commonly voiced by less mobile people were about aspects of the services rather than the vehicles, as indicated by Table 9 which lists improvements to low-floor services suggested by wheelchair users. The most popular request is simply for more low-floor routes, offering people more opportunity to go where they wish. The demands for more frequent, more reliable services echo general opinions of bus users everywhere. The need for bus stops to be nearer homes and destinations can be better appreciated if walking or wheeling ability is taken into account. Only about 40 per cent of ambulant disabled people interviewed in London could walk more than 200 yards (183 m), and only about 30 per cent in North Tyneside. By contrast, nearly 70 per cent of wheelchair users in London, and over 95 per cent in North Tyneside, were able to travel more than a mile (1.6 km) in their wheelchairs, provided they were accompanied by an escort.

There is no easy solution to this problem. Bus stops could be brought nearer to people's homes and destinations, by increasing the density of the service network but, unless overall vehicle mileage is increased, this would imply frequency reductions on some existing routes. The balance between network density and service frequency is normally derived assuming reasonable walking distances for able-bodied passengers. As a result of the Disability Discrimination Act, all conventional public transport will become wheelchair accessible over time, although it will be unable to meet the needs of the total population of disabled people at an economic cost, this requirement will help to focus door-to-door transport services on people who cannot get to the bus stop rather than those who cannot get on the bus..

About 20 per cent of ambulant disabled interviewees in each area felt that bus stops would be improved by the provision of seats. In North Tyneside some 30 per cent of ambulant disabled people, and 60 per cent of wheelchair users perceived a need for more shelters at stops.

7 Passenger preferences and evaluation

The evidence presented in Section 5 showed that the majority of passengers found low-floor buses easier to use, but that in Section 6 indicated that significant minorities experienced difficulties. People's attitudes to the new services will depend on how they are affected on balance by the various factors discussed and possibly on other factors, for example comfort. In this section we therefore present survey results revealing people's overall assessment of the low-floor buses compared with the older vehicle types.

We also present the results of attempts to determine whether the low-floor services produce any measurable benefits to passengers.

7.1 Preferred bus type

During interviews on buses, passengers were asked which bus type they would prefer for the journey they were making at the time. The replies are summarised in Figure 19. Just over half the London passengers (in all categories) prefer low-floor buses compared with nearly three-quarters in North Tyneside.

In both areas the preference for low-floor buses is significant among mobile unencumbered passengers, stronger among less mobile passengers, and almost universal among passengers with pushchairs.

There is a strong correlation between preference and ease of use. In London passengers who found both types of bus equally easy to use tend to have no preference, or to prefer double deckers. In North Tyneside more are indifferent but fewer prefer double deckers. Passengers finding one bus type easier to use are much more strongly in favour of low-floor buses, more so in North Tyneside than in London.

Respondents who had expressed a preference were asked to indicate the reasons they preferred the chosen bus type. The most frequently quoted reasons are shown in Tables 10 and 11. (Note that the percentages do not total 100 because respondents were allowed to give up to five reasons each).

Less mobile passengers and those with pushchairs who prefer the low-floor buses do so mainly because of the ease with which they can board and alight. Further, people with pushchairs particularly like the amount of space on the

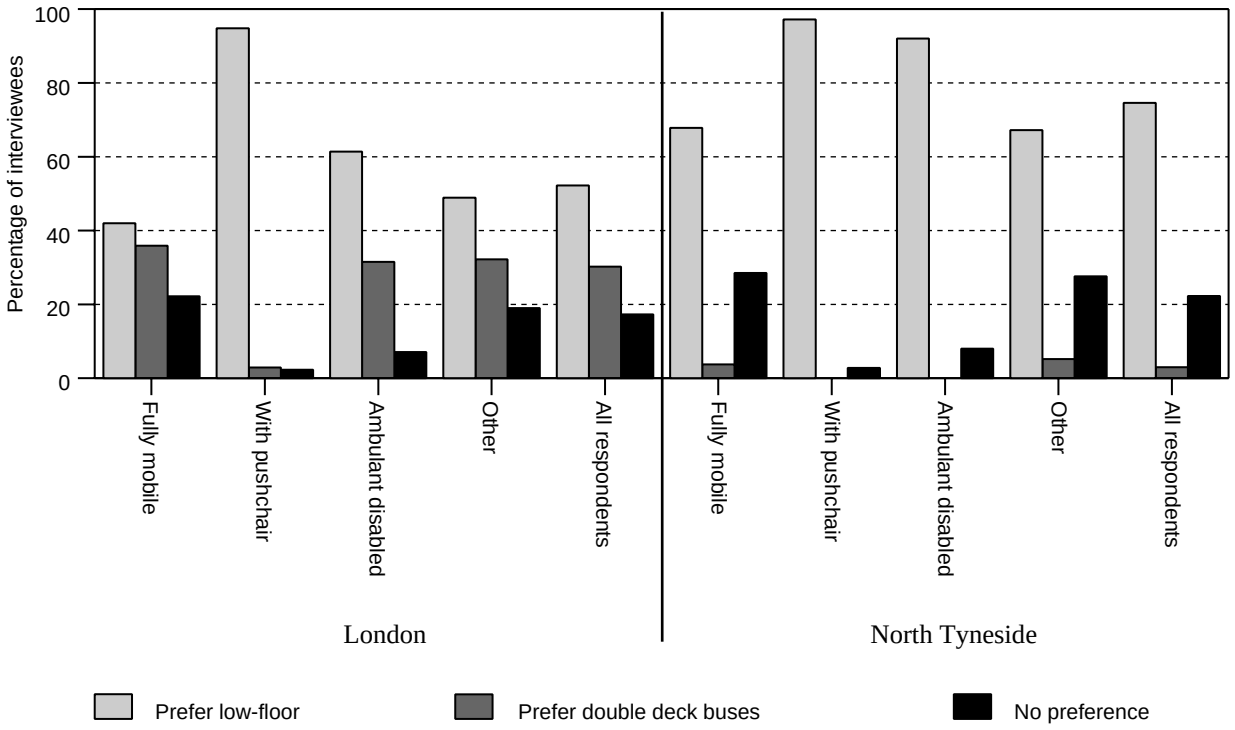

Figure 19 Bus type preference

Table 10 Reasons for preferring the low-floor buses (percentage of respondents who expressed a preference for low-floor buses)

Passenger category (sample size)	*Getting on/off*	*Comfort/ Smooth ride*	*Amount of space*	*Steps*	*Temperature*
London					
Finding one bus type easier to use than the other (620)	88	15	41	8	2
Finding both bus types equally easy to use (101)	45	18	30	6	2
Fully mobile (282)	71	21	32	7	3
With pushchair (165)	94	9	61	7	1
Ambulant disabled (78)	87	15	28	10	1
North Tyneside					
Finding one bus type easier to use than the other (268)	95	24	30	6	18
Finding both bus types equally easy to use (26)	58	35	19	0	8
Fully mobile (162)	87	30	27	6	20
With pushchair (70)	99	13	37	1	11
Ambulant disabled (23)	100	13	26	9	9

Table 11 Reasons for preference of double-deck buses in London (percentage of respondents who expressed a preference)

Passenger category (sample size)	*Comfort/ smooth ride*	*Number of seats*	*Amount of space*	*Extent crowded*	*Hand-rails*	*Seat size*	*Safety*	*Getting to seat*
Finding one bus type easier to use (246)	50	32	28	9	31	13	21	16
Finding both bus types equally easy to use (169)	45	43	25	14	10	12	12	8
Fully mobile (241)	47	38	27	39	14	12	15	11
Ambulant disabled (40)	55	30	28	10	10	10	23	20

bus. The absence of steps at doorways allows them to board without folding their pushchairs and they can park them in the tip-up seat space. Unencumbered mobile passengers are generally influenced by the same factors.

The responses of those who find some buses easier to use and those who do not emphasises the differences: passengers can find some buses easier to use because of disability or encumbrance (including pushchairs); those finding some buses easier to use prefer the low-floor buses because of the ease with which they can board and alight, and approve of the amount of space, to a greater extent than other passengers.

Although newer buses have been introduced in both areas, this has had only a small effect on passenger perception of the buses. Fewer than three per cent of passengers who preferred the low-floor buses stated it was because they were newer. This is confirmed by passenger surveys on route 300 in North Tyneside where new DPTAC standard single deckers replaced older double-deck buses. On that route, passengers were less likely to have a bus type preference, more likely to prefer double-deck buses and those preferring the single deckers often did so because of an aspect of comfort rather than the ease of use.

In North Tyneside too few passengers preferred the double-deck buses (12 out of 394) to permit analysis of their reasons. In London those preferring double-deck buses did so primarily because of the greater number of seats, or the experience of a smoother, more comfortable, ride (Table 11). Newer buses tend to be capable of rapid acceleration and have more powerful brakes which may, if used immoderately, lead to a less comfortable ride. The perception of a smoother ride on the double deckers could also be related to the fact that passengers have to stand more often on the low-floor buses and consequently are more susceptible to the motion of the bus. The comments made about comfort were due in part to the harder seats that were fitted on the low-floor buses.

Otherwise, the reasons for preferring double-deck buses are consistent with the difficulties encountered in using low-floor buses discussed in Section 6.

7.2 Route preference

People were asked whether they could have used an alternative bus service for the journeys they were making when interviewed. In each area roughly one half (London 45 per cent, North Tyneside 52 per cent) knew of alternatives. These passengers were asked why they had chosen to travel by low-floor bus rather than the alternative service. The most common reasons are shown in Table 12.

In both areas mobile passengers were most likely to be using the low-floor route because it was the first bus to arrive, stopped nearer to their home or destination, was quicker or had a more direct route. Less mobile passengers were only slightly less influenced by these factors and slightly more likely to use it because it was a low-floor bus. By contrast, the people with pushchairs have been highly influenced by the introduction of the low-floor buses. These passengers are significantly more likely to use the low-floor route because of the bus type than mobile unencumbered passengers.

This finding is consistent with the fact that people who find one type of bus easier to use are much more likely to choose low-floor services because of vehicle type. Those who find all buses as easy to use generally choose the route because it is the first bus to arrive, the bus is quicker or the route is more direct. The difference in opinion of passengers finding some buses easier to use compared with those who do not is mainly due to the opinions of people with pushchairs.

The percentage of passengers choosing the low-floor bus route because of the bus type is consistently greater in North Tyneside than in London.

7.3 Advantages of low-floor buses for less mobile people

The evidence presented in Section 5 clearly indicates that less mobile passengers, including those encumbered with pushchairs, find low-floor buses easier to use than conventional bus types. Low-floor buses are also accessible to most wheelchair users, albeit with varying degrees of difficulty, whereas the older buses were completely inaccessible.

Table 12 Why passengers with a choice of route chose this one (percentages of respondents)

Passenger category (sample size)	*First to arrive*	*Nearer home/ destination*	*Quicker/ more direct*	*Need only one bus*	*Bus type*	*No steps*	*More frequent*
London							
Fully mobile (303)	37	21	42	5	9	1	4
With pushchair (83)	5	8	18	6	77	6	6
Ambulant disabled (44)	32	18	36	7	21	0	0
Finding one bus type easier to use (405)	31	18	36	6	30	3	6
Finding both bus types equally easy to use (214)	41	27	36	4	4	1	3
North Tyneside							
Fully mobile (123)	26	50	7	1	23	3	2
With pushchair (37)	3	5	5	0	89	5	0
Ambulant disabled (12)	25	33	0	0	67	0	0
Finding one bus type easier to use (160)	20	36	6	1	48	4	1
Finding both bus types equally easy to use (46)	39	50	7	1	7	2	2

Names and addresses provided by a local authority, and a special transport provider, were used to contact a random sample of disabled people living within a quarter of a mile of some low-floor bus routes. Though the questionnaire primarily aimed to find willing participants in the home interviews, it also gave some indication of these people's knowledge and opinions of low-floor buses, see Table 13. Many of these people knew of the service and used it.

Parts of the surveys of less mobile people in their homes were designed to discover whether the availability of low-floor bus services had in fact provided people with new travel opportunities, and what, if any, were the resulting advantages. The responses from the three groups of interviewees are discussed in turn in the following sections.

Table 13 Knowledge and use of low-floor services. Percentage mobility impaired people living within a quarter of a mile

	London		*North Tyneside*	
	Ambulant disabled	*Wheel -chair users*	*Ambulant disabled*	*Wheel -chair users*
Had heard of low-floor buses	87.8	84.9	86.4	91.6
Continuing to use low-floor buses (Percentage of those who had heard of them)	60.7	27.8	63.2	48.7

7.3.1 Ambulant disabled passengers

Many respondents gained no advantage from low-floor bus services (see Table 14). Those that did generally needed less assistance from others (probably while boarding and alighting) or considered them a useful alternative mode.

Further questions were asked of people who enjoyed certain advantages. These revealed that two of the three respondents in London who were less reliant on a lift with a friend or relative, and all four in North Tyneside, still make the same number of trips with them. The other respondent had reduced the frequency of such trips by no more than once per month. Respondents appeared to appreciate that they are able to make trips by the bus if necessary but possibly still preferred the convenience and company of making the trip with their friend.

Table 14 Low-floor bus advantages experienced by ambulant disabled passengers* (numbers of respondents giving response)

	London	*North Tyneside*
Useful alternative mode	9	0
Less need for assistance from others	8	15
Can get out more	6	6
Able to change from different mode	5	0
Not reliant on lift with friend/relative	3	4
Able to undertake new activities	3	0
Able to go out when they want	3	7
Less help by friend/relative required	2	3
None/no answer	19	10
(Sample size)	38	27

**Respondents could give more than one answer, so columns do not add up to the sample size*

Five respondents in the two survey areas said a friend or relative was now required to help less, but in three cases their helper still made the same number of trips for them. Again, the buses appear to be a useful alternative when necessary, and not a replacement. One person in North Tyneside no longer needs their friend/relative to make one errand per week, and a respondent in London no longer needs them to make at least four errands per week by bus.

Four of the five London respondents who were able to change from a different mode had not altered their trip making behaviour, the other now makes two trips a week by low-floor bus instead of by taxi.

Overall, ambulant disabled respondents appeared to appreciate the extra mobility afforded by the low-floor buses, but until more low-floor services become available they were seen as an occasional useful alternative and not as a replacement.

7.3.2 Wheelchair users

People in wheelchairs found the greatest advantages to be the ability to use the same transport as others, and to get out more (see Table 15). In London they also considered low-floor buses a useful alternative mode, which had allowed them to switch from other modes of transport. The ability to undertake new activities and not rely on dial-a-ride services also appealed to the respondents in London.

Table 15 Low-floor bus advantages experienced by wheelchair users* (number of respondents giving response)

	London	*North Tyneside*
Can use same transport as others	12	13
Can get out more	13	8
Useful alternative mode	10	4
Able to change from different mode	9	1
Able to undertake new activities	7	2
Less reliant on dial-a-ride	6	1
Able to go out when they want	5	2
Less help by friend/relative required	3	0
Not reliant on lift with friend/relative	2	0
Other	4	1
None/no answer	6	1
(Sample size)	19	21

**Respondents could give more than one answer, so columns do not add up to the sample size*

Further questioning indicated that the one person in North Tyneside who was able to change from a different mode now makes up to one trip a month by low-floor bus rather than using the metro. In London nine respondents were able to change from a different mode: 4 changed from car, 3 from taxi and 2 from propelling themselves over short distances. Seven of these claimed not to have altered the number of trips they make by other modes possibly because the changes were too irregular to be counted. The other two both make two fewer trips a week by other means.

Two respondents in London are now less reliant on a lift with a friend or relative, but still made the same number of

trips with them. They, like ambulant disabled respondents, appeared to appreciate that they are able to make trips by the bus if necessary but possibly still preferred the convenience and company of making the trip with a friend.

Three respondents in London claimed a friend or relative needed to help less, but their helper still made the same number of errands for them. Again the buses may be seen as a useful alternative when necessary, and not a replacement. However, more advantages could become apparent as user confidence grows and a more comprehensive network of accessible bus services becomes available.

7.3.3 Passengers with pushchairs

Most important to people with pushchairs is the ability to get out more, and the reduced need for assistance from others, including help from other passengers when boarding or alighting (see Table 16). This is consistent with the almost universal view that low-floor buses are easier to use (Section 5.1).

Table 16 Low-floor bus advantages experienced by passengers with pushchairs* (number of respondents giving response)

	London	*North Tyneside*
Can get out more	10	4
Less need for assistance from others	7	8
Less need for home visits for child	7	0
Easier to use	4	18
Able to go out when they want	4	2
Less need for baby sitters	5	0
Not reliant on lift with friend/relative	4	0
Able to change from different mode	4	0
Cheaper than a taxi	0	4
Able to undertake new activities	3	1
Useful alternative mode	2	0
Less help by friend/relative required	2	0
(Sample size)	19	25

**Respondents could give more than one answer, so columns do not add up to the sample size*

In London, some people are able to take children out to clinics etc, reducing the need for home visits. Four of the London respondents gave details of the reduced number of home visits they required, two by four or more a week, one by one a week and one by less than once a month. Two respondents needed fewer errands made on their behalf: in one case the reduction was between once per fortnight and once per month.

7.4 User evaluation of low-floor buses

The evidence presented so far in this section clearly indicates that, individually, less mobile passengers benefit from the opportunity to use low-floor bus services. An attempt was made to quantify these benefits in economic terms. In principle, all that is required is to ask people how much extra they would be prepared to pay to use low-floor buses rather than alternatives. In practice, responses to such hypothetical questions have been found very unreliable, and 'stated preference' surveys have been developed to overcome some of the problems.

In this study, stated preference experiments were conducted with ambulant disabled passengers, wheelchair users and people who travelled with pushchairs. Each of the respondents took part in a ranked order stated preference experiment. A number of transport options were described upon a set of cards, each of which showed details of cost, waiting time and travelling time for one option (low-floor bus or taxi for those in a wheelchairs, and low-floor or double deck bus for the other two categories of respondents). For each individual interviewed, the options were specified so as to duplicate those of the trip usually made (eg journey time, fare, etc) or to differ from them by controlled amounts. Each option differed from every other option in at least one of the values of the factors being investigated. Respondents were asked to arrange all the cards in order of preference.

Generally in stated preference, if there are n factors (parameters associated with the trip) being investigated, each of which can take m values, the number of different options is m^n .In practice many people have difficulty logically ranking more than a dozen options, limiting the number of factors which can be investigated, and the number of values each can take. Experimental design can be used to chose a sub-set of all the options, which presents interviewees with a manageable number of cards to rank but still allows statistical interpretation.

Analysis of such a survey estimates the relative importance of the different factors, and the extent to which people would possibly trade one off against another (eg price against being able to use a low-floor rather than a double deck bus). Formally, the 'utility' of each option may be expressed as a weighted sum[2] of the factors included in the design, with the weight of each factor (which is the same for all options) being determined to produce the best fit between the model predictions and people's stated preferences.

A person should logically place the option with highest utility first, the one with the next highest second and so on. However, a probabilistic approach is required to allow for random (or unknown) influences. The probability of choosing one option rather than the other is expressed as a mathematical function of the two utilities. If one utility heavily outweighs the other, then the probability is nearly 100% that it would be chosen; if the utilities are nearly equal then the probability is close to 50%.

7.4.1 Sample sizes

People who were interviewed at home took part in the stated preference part of the survey if they had heard of, used and would continue to use the low-floor buses. This restriction was necessary to ensure that all the participants could make a valid trade between the different modes of transport. The numbers of respondents taking part are shown in Table 17 categorised according to whether they completed ranking the trade off cards, could not cope with the exercise, or did not take part in the ranking exercise because of a strong preference for a given mode.

Provided the sample size is large enough segmentation of the data by an influential variable is possible, with separate analyses being performed on each segment. It

Table 17 Participants and reasons for non-participation in stated preference exercise*

	In wheelchair			*Ambulant disabled*			*With pushchair*		
	London	*Tyne & Wear*	*Both areas*	*London*	*Tyne & Wear*	*Both areas*	*London*	*Tyne & Wear*	*Both areas*
Participated in stated preference	4	1	5	29	11	40	9	6	15
Stated preference abandoned	2	1	3	0	3	3	1	1	2
Would not pay a reasonable taxi fare	13	21	34						
Valued taxis much greater than low-floor	0	3	3						
Low-floor buses easier to use/cannot use other buses				7	13	20	7	15	22
Other reason				1	0	1	2	3	5
Total	19	26	45	37	27	64	19	25	44

**Shaded cells are used to indicate the reasons were not relevant to the choice made*

might be expected that evaluations vary in different parts of the country, and this has been tested for ambulant disabled respondents and those with a pushchair. No segmentation of wheelchair users was possible because of the small sample sizes.

7.4.2 Valuation of the low-floor bus

It was assumed in the design of the stated preference exercise that wheelchair passengers would prefer travelling by taxi rather than by low-floor bus. Initial filter questions asked participants how they would travel if given the choice between a free low-floor bus and a taxi for a small fixed fare. Contrary to expectation, many wheelchair users preferred the low-floor buses (68 per cent in London and 81 per cent in North Tyneside). Possible reasons for this are the easier access afforded by low-floor buses by comparison with taxis, and the ability to travel with other members of the public. In practice however the choice between taxis and low-floor buses is currently limited to a minority of wheelchair users living near low-floor routes.

Many ambulant disabled (31 per cent) and people with pushchairs (50 per cent) did not participate in ranking the stated preference cards because they would not use the double deck buses under any circumstances. Such people were either not able to use them, or found low-floor buses much easier to use.

Ambulant disabled passengers in London able to use both bus types only valued low-floor buses at one penny a trip more, while those in Tyne & Wear considered them worth 57 pence a trip more than double deckers. In London disabled passengers are eligible for free travel, compared with concessions available in North Tyneside where they pay a fixed (reduced) fare. An initial resistance to paying any fare would be expected from those used to free travel (see Hill and Last, 1994), and this is almost certainly reflected in these results.

Few people with pushchairs took part in the stated preference exercise, so the results obtained must be treated with caution. Those taking part valued the low-floor buses as worth between 4 and 12 pence a trip more than double deck buses, which is fairly consistent given the sample sizes: taking both areas together, low-floor buses were valued at 7.4 pence per trip more than double-deckers.

8 Patronage

Patronage is a vital measure of the performance of any bus service. For purely commercial services, patronage is directly related to profit; for subsidised services patronage can affect the magnitude of the subsidy required, and is also a measure of the social benefit which is being bought with the subsidy. Regardless of whether low-floor buses are to be assessed from a commercial or a social standpoint, it is important to know whether they attract more or fewer passengers than standard bus types.

However, measurement of the effect of a change of bus type on patronage is not straightforward: patronage is determined by a combination of many factors, including several which are external to the operation of bus services (eg demographic change, increasing car ownership). If measurements are made over short enough periods to be affected by longer-term trends, then sample sizes are likely to be too small for meaningful statistical comparison, and in the short term there may be transient effects as initial operating difficulties are overcome and passengers become accustomed to the new services.

One solution to this problem is to compare patronage of services on which new buses are introduced with ‘control’ services, which should be similar to the trial services in every way except for vehicle type. This ideal is difficult to achieve in practice since it is never possible to find perfect matches.

An alternative approach is to ask passengers whether, and if so, how much their use of services has changed as a result of the change in bus type. This enables changes due to external causes (eg change of address, place of work, school) to be discounted, and the true effects of the new bus type assessed. Ideally, this would be achieved by encoding people’s use of buses before and after the change, by means of travel diaries distributed to randomly selected households within the catchment areas of bus routes. But this method tends to be inefficient (much information is collected from non-bus users), time consuming and expensive, and was not considered appropriate for this study. An alternative is to question passengers using the buses, comparing their trip rates before and after the service change, and identifying any extraneous reasons for changes in bus use. This method

has two imperfections: it relies on people's memories, and it under-represents people whose use of buses has decreased or ceased.

8.1 Patronage statistics from operators

Each of the five London bus companies and Coastline in North Tyneside were asked for weekly patronage data for its low-floor bus route, and another similar (control) route in the area, for one year before and one year after the introduction of the low-floor buses. This sample should be sufficiently large to show the trend in patronage and allow the removal of seasonal variation by comparing data over the same times of year. By collecting data from a similar route in the area, that is one running through the same towns any local changes in patronage (for example due to the opening of a new supermarket) could be removed.

Unfortunately, these data were not always available, and those which were available received careful checking to remove anomalous values and manipulation to derive weekly averages from statistics for part weeks and other odd time periods. The resulting weekly averages are displayed in Table 18.

Patronage had increased along all but one of the low-floor routes, though the extent of the change varies considerably, from -6.7% to 17.0%. In London it is possible to compensate for external influences by assuming they were the same as on the appropriate control route. Subtraction of the percentage change on the control route from that on the low-floor route, suggests low-floor buses had affected patronage by 0.4 per cent (route 120), -1.1 per cent (route 186) and 11.8 per cent (route 144). The first two of these apparent changes are too close to zero to indicate any real effect with confidence; the third is substantial and probably indicates that on route 144 low-floor buses have generated substantial new patronage.

8.2 Reported changes in bus use

Interviewees on the buses were asked about the average number of single trips they made each week on the current low-floor service and also about the number they used to make when double-deck buses operated on the route. They were asked for details of any changes and the reasons for them. Their replies are summarised in Table 19 and Figure 20.

Table 19 Increases and decreases in trips made

	Percentage of interviewees in category					
	London			*North Tyneside*		
	Same	*More*	*Less*	*Same*	*More*	*Less*
Fully mobile	87	10	2	91	7	2
Person with pushchair	48	49	3	33	66	1
Encumbered with child	85	15	0	0	100	0
Encumbered: Other	91	6	3	90	5	5
Ambulant disabled	94	6	1	80	20	0
Other	70	29	1	75	25	0

The analysis has not weighted the data to adjust for possible bias towards the more frequent travellers, nor does it take account of those people who have stopped using the service for personal or other reasons. The sample was also biased towards ambulant disabled passengers and people with pushchairs in order obtain sufficient sample sizes in these categories. These passengers will have benefitted most from the introduction of the buses.

Since the introduction of the new vehicles, 2.5% and 1.8% of passengers in all categories had reduced and 14.7% and 19.5% increased the number of trips they made in London and North Tyneside respectively. In both survey areas substantial proportions of people with pushchairs and passengers in the 'other' category (including wheelchair passengers) have increased the number of trips they make. In North Tyneside there was a marked increase in the number of less mobile passengers making more trips. There was a lesser effect on the other categories of passenger.

Table 18 Changes in patronage*

Area	*Route*	*Number of weeks (observations)*		*Weekly patronage before low-floor introduction (,000)*	*Weekly patronage after low-floor introduction (,000)*	*Change (%)*
		Before	*After*			
London	120	38	38	45.9	48.4	5.3
	H32	20	20	51.8	54.3	4.9
	222	n/a	n/a	n/a	n/a	n/a
	U4	n/a	n/a	n/a	n/a	n/a
	186	16	16	53.5	49.9	-6.7
	182	16	16	82.3	77.8	-5.6
	144	32	32	75.8	88.6	17.0
	W3	16	16	93.2	99.0	6.2
	101	49	49	68.8	70.4	2.4
	262	49	49	37.1	41.2	11.1
North Tyneside	325/326	52	52	14.6	15.4	4.7
	315/316	n/a	n/a	n/a	n/a	n/a

Note: Shaded cells relate to a route used for comparison with the route in the row above: also routes 186 and 182 may have been affected by the trial of 'smartcard' tickets.

**Only comparable data (observed at the same time of year) was analysed for each route*

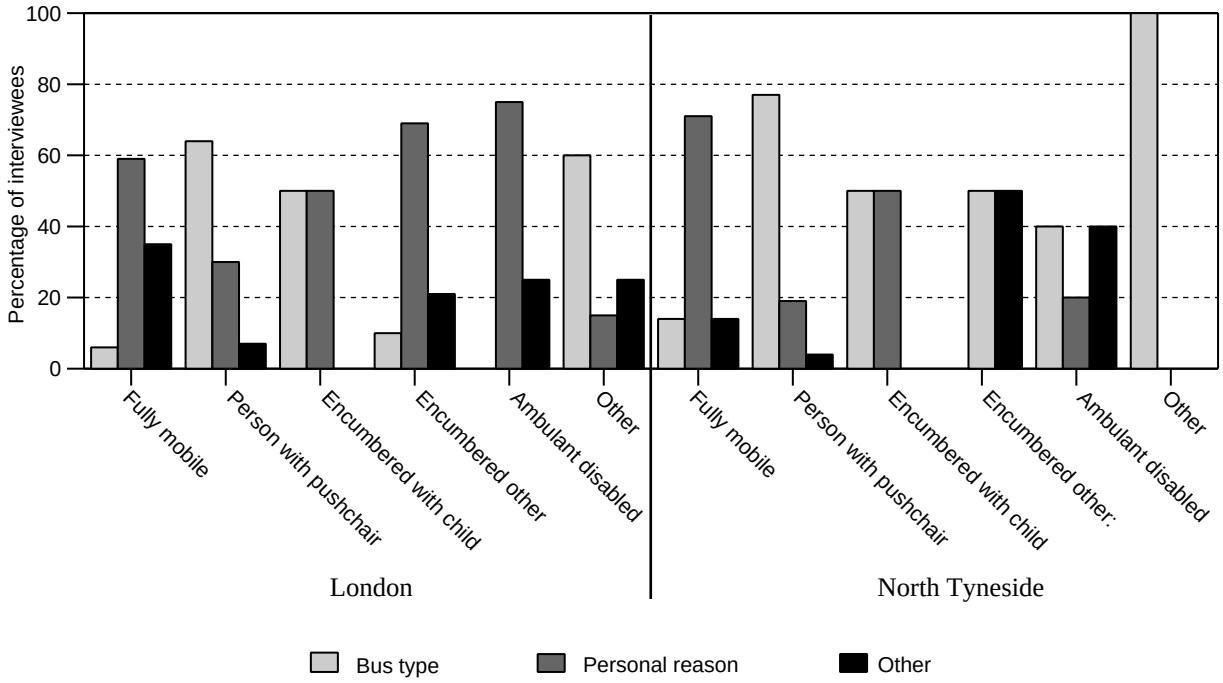

Figure 20 Reasons for changes in bus use (passengers who had altered the number of trips they made)

Reasons for changes in numbers of bus trips are given in Figure 20 (which relates only to those passengers whose trip rates had changed). In many cases travel patterns had changed for personal reasons, but significant numbers of people (especially those with pushchairs) attributed change to the new bus type.

Passengers were asked about the number of trips they make for different purposes during a typical week on the low-floor service. They were then asked about the number of trips that they used to make on the previous double-deck buses. Respondents stated that they now make on average 12.2% more trips in London and 20.8% more trips in North Tyneside. However, since it was not possible to interview any people who had ceased using the service, and the sample was also biased towards those passengers who are most likely to benefit from the new buses and consequently use them more, this statistic almost certainly overstates the net increase in bus use. However, it does not need to be discounted very much to be compatible with the overall patronage changes discussed in Section 8.1.

Although these figures are unweighted, and do not take account of any possible bias, there is an indication that low-floor buses do have a patronage generation effect. The surveys performed on route 300 in North Tyneside where the service changed from non-DPTAC double-deck to DPTAC specification single-deck operation were subject to the same biases as those on routes 325/326, yet fewer passengers had altered their trip making behaviour and the resultant increase in trips was smaller.

Those passengers (131 in London, 58 in North Tyneside) who had not used the previous double-deck service were asked if they used to use any other bus service and then asked their reason for changing. Most of those passengers who had not previously used the relevant service, 77.7% in London and 69.0% in North Tyneside, had not used any other bus route. For many of these passengers, 36.2% in London and 62.1% in North Tyneside, the reason for change was the introduction of the low floor buses.

9 Operational implications

Considerable concern has been expressed by both bus operators and drivers about difficulties with the kneeling mechanism on low-floor buses, and the interaction of the kneeling and door opening/closing processes. Inevitably, some of these difficulties were of a transient nature following the introduction of new equipment and new procedures, and proved possible to remedy. Others, like the vulnerability of the sensitive strips (see section 2.1) beneath the doors, and obstruction of bus stops by parked vehicles, preventing proper alignment of bus and kerb, have proved more persistent.

9.1 Bus stop timing surveys

However, most drivers in London seemed to believe that the kneeling process required additional time, even when it occurred in parallel with door operation, which could be ill afforded when trying to adhere to a tight operating schedule. On the other hand if, as we have shown, low-floor buses are easier for passengers to get on and off, individual boarding and alighting times are likely to be shorter, which may off-set any delay in door operation or kneeling.

This study therefore included a series of comprehensive measurements of boarding and alighting times. These were made using the method described by York (1993). One or two observers riding on a bus record the times the bus stops and restarts at each stop, and count the number of passengers boarding and alighting, and note, in each case,

the method of fare payment and the type of passenger (according to age and mobility). When sufficient data have been collected, it is possible to make statistical analyses to determine average boarding and alighting times for different types of passenger, using different payment methods.

Previous research (Cundill and Watts 1973 and York 1993) has shown that the total time spent by a single-door bus at a stop can be considered to be the sum of a 'dead' time, which represents the delays associated with door operation (and kneeling where appropriate), and the individual time taken by each boarding or alighting passenger, using the average time for each category of passenger. The estimation is slightly more complex for two-door buses. The time required at the entrance is the dead time for that door, plus the individual time for each boarding passenger; at the exit there is a dead time for that door, to which must be added all the individual alighting times. Boarding and alighting take place simultaneously, and the longer process determines how long a bus has to wait at the stop. Which process is longer depends on relative numbers of boarders and alighters, which vary from stop to stop. Some occasions are therefore classified by observers as 'boarding events', others as 'alighting events', depending on whether boarding or alighting is completed first. Two observers are needed on two-door buses: one for each door.

Surveys were conducted over five working days, between approximately 0800 and 1700, for all six services included in the study, both on the original double-deck vehicles and on the new low-floor buses. The total numbers of events recorded are shown in Table 20.

Table 20 Numbers of observations

	London		
	Boarding events	*Alighting events*	*North Tyneside*
Before survey	2563	1748	1279
After survey	2399	1303	1210

9.2 Alighting and boarding time analysis

Linear regression analysis was used to estimate average individual alighting and boarding times for different categories of passenger, using different payment methods, on double-deck and low-floor buses, in London and North Tyneside. The results are summarised in Tables 21 to 23.

9.2.1 Alighting times

The simplest results are for alighting times, as these are independent of payment methods; they are shown in Table 21.

Average alighting times per person are shown in the first part of the table; the second part shows extra times for alighting with various forms of impediment, which must be added to the normal time for the appropriate passenger category. For example, a passenger with an unfolded pushchair would have taken 1.81 + 7.59 = 9.40 seconds to alight from a double-deck London bus, but only 1.82 + 1.18 = 3.00 seconds from a low-floor bus. Although both measurements are subject to considerable error, the alighting times from low-floor buses is significantly less.

The total alighting time at any stop is simply the sum of the individual time for each passenger shown in Table 21. This is then used as an input to the bus stop time calculation, as explained in Section 9.2.3.

Unencumbered passengers who are fully mobile appear to alight slightly faster from low-floor buses than double-deck buses in both survey areas, but the differences are not statistically significant. They may be real, but much larger samples would be required to demonstrate them. In London, the younger ambulant disabled and encumbered passengers alight at least as fast from the low-floor buses.

The difference for the ambulant disabled passengers may be understated. In the after survey it was harder to classify them correctly because their problems were alleviated to some extent by the improved arrangement of steps. Some passengers with lesser disabilities may therefore have been classified as disabled in the before survey, but not in the after survey. Consequently, those so classified in the after survey may have been, on average, more disabled, and therefore slower, than those in the before survey. This change may off-set improvements in alighting times due to the new design of vehicle. The same argument may also be applied to elderly passengers, fewer of whom would have been classified as mobility impaired in the after survey. In principle, this accidental reclassification may also affect results for some more mobile passengers in a similar manner, but in view of the relative sample sizes the effect is liable to be much smaller.

Times for encumbered adults on double-deck buses in North Tyneside have been omitted because the definition of encumbrance (carrying one shopping bag or more) used during the first timing survey here proved unsatisfactory. A more limited definition of encumbrance (two shopping bags or a large item of luggage) was used in subsequent surveys in North Tyneside and London.

9.2.2 Boarding times

It was found in this study, as in previous research (York 1993) that boarding times were strongly dependent on fare payment methods; indeed, differences in payment methods proved more significant than differences in passenger type. Accordingly, the results of the analysis of boarding times are presented in two tables (22 and 23), showing these effects separately.

Table 22 shows how fare payment methods affect the average boarding times for fully mobile adult passengers.

The boarding times of fully mobile adults are fairly comparable between the two bus types. In London those using passes involving no cash payment are significantly, but only 0.2 seconds, quicker getting on to low-floor buses. In North Tyneside however they are somewhat slower, but the result for double-deck buses here is much lower than for any of the London routes, or for measurements in previous work (York 1993). We are unable to offer a convincing explanation of this apparent anomaly.

The only consistent difference between bus types is that those payment methods involving cash transactions are generally slightly slower on the low-floor buses than on

Table 21 Alighting times (seconds)

		London		North Tyneside	
	Passenger category	*Double-deck*	*Low-floor*	*Double-deck*	*Low-floor*
Average time per person	Unencumbered adult	1.12 (0.03) ↔	1.05 (0.04)	1.08 (0.11) ↔	0.95 (0.09)
	Unencumbered elderly	1.58 (0.08) ↔	1.53 (0.08)	1.52 (0.16) ↔	1.42 (0.13)
	Child	1.94 (0.34) ↔	1.87 (0.64)	1.47 (0.54) ↔	1.04 (0.53)
	Encumbered adult	1.81 (0.17) ↔	1.82 (0.31)		1.54 (0.37)
	Encumbered adult with child	4.41 (0.39)	3.19 (0.32)		
	Encumbered elderly	2.18 (0.24)	3.93 (0.43)		3.66 (0.35)
	Ambulant disabled adult	3.82 (0.36) ↔	2.84 (0.56)	1.03 (2.78) ↔	1.85 (1.78)
	Ambulant disabled elderly	2.75 (0.16)	3.40 (0.24)	2.60 (1.44) ↔	3.51 (0.49)
Extra times for:	Pushchair (folded/unfolded)				2.22 (0.53)
	Folded pushchair	2.73 (0.57)	0		
	Unfolded pushchair	7.59 (1.48)	1.18 (0.45)		
	Shopping trolley	1.41 (0.62) ↔	1.40 (0.59)		n/a
	Temporarily disabled	4.58 (1.59)	n/a		

Note: Standard errors in brackets; shaded cells indicate no observations; n/a indicates sample size too small to produce meaningful results; 0 indicates the model could not distinguish a coefficient different from zero, even though the sample size was reasonable. An arrow between two cells indicates the difference between the coefficients is not significant at the 95% confidence level, other changes were significant unless one of the entries was n/a or shaded.

Table 22 Boarding times for mobile passengers (seconds)

	London		North Tyneside	
Payment method	*Double-deck*	*Low-floor*	*Double-deck*	*Low-floor*
Pass	2.61 (0.07)	2.41 (0.07)	1.54 (0.47) ↔	2.49 (0.20)
Pass & exact fare			5.59 (0.20)	4.99 (0.19)
Pass, fare & change			6.48 (0.51)	7.36 (0.31)
Pay exact fare	4.30 (0.17) ↔	4.47 (0.18)	4.65 (0.14)	5.49 (0.19)
Pay and require change	6.69 (0.17)	7.18 (0.17)	5.24 (0.22)	7.37 (0.21)
Return ticket			n/a	1.59 (1.77)
Smart Card	4.36 (0.44) ↔	3.31 (0.60)		

Note: Standard errors in brackets; shaded cells indicate no observations; n/a indicates sample size too small to produce meaningful results; 0 indicates the model could not distinguish a coefficient different from zero, even though the sample size was reasonable. An arrow between two cells indicates the difference between the coefficients is not significant at the 95% confidence level, other changes were significant unless one of the entries was n/a or shaded.

Table 23 Additional boarding times for different passenger categories

		London		North Tyneside	
	Passenger category	*Double-deck*	*Low-floor*	*Double-deck*	*Low-floor*
Extra time per person	Unencumbered elderly ↔	0.45 (0.13)	0.61 (0.14)	0 ↔	0
	Child	1.40 (0.61)	0	0 ↔	0
	Encumbered adult ↔	0.85 (0.32)	1.30 (0.56)	3.74 (0.77)	0
	Encumbered adult with child ↔	2.71 (0.60)	3.23 (0.39)		
	Encumbered elderly	0	0.93 (0.46)	0	2.04 (0.43)
	Ambulant disabled adult ↔	7.22 (1.38)	3.90 (1.08)	n/a	3.59 (1.38)
	Ambulant disabled elderly ↔	3.59 (0.54)	2.49 (0.46)	4.99 (1.64) ↔	3.71 (0.50)
Extra times for:	Pushchair (Folded/unfolded)				4.39 (0.44)
	Folded pushchair	5.74 (1.00)	0		
	Unfolded pushchair	n/a	0		
	Shopping trolley	4.69 (0.87)	1.66 (0.85)		4.16 (1.00)

Note: Standard errors in brackets; shaded cells indicate no observations; n/a indicates sample size too small to produce meaningful results; 0 indicates the model could not distinguish a coefficient different from zero, even though the sample size was reasonable. An arrow between two cells indicates the difference between the coefficients is not significant at the 95% confidence level, other changes were significant unless one of the entries was n/a or shaded.

double-deck buses. This could be the result of differences in the position of the ticket machine and change tray on the two buses, which was cited by some drivers as a disadvantage of the low-floor design.

Table 23 shows extra times which must be added to those shown in Table 22, for different passenger categories.

The boarding times in Table 22 are the times for a fully mobile unencumbered adult to board using each method of payment. The times in Table 23 are the extra time a passenger in the relevant category takes to board, irrespective of the method of payment. For example the average boarding time of an ambulant disabled elderly passenger using a pass on a low floor bus in London is 2.41 + 2.49 = 4.90 seconds.

As with alighting events the times displayed for the sub-categories (folded pushchair, unfolded pushchair etc) in Table 23 are in addition to the time for the passenger to board. For example, the average boarding time of an encumbered elderly passenger with a shopping trolley paying an exact fare on a low-floor bus in North Tyneside is 5.49 + 2.04 + 4.16 = 11.69 seconds.

The total boarding time at any stop is simply the sum of the individual time for each passenger derived from Tables 22 and 23. This is then used as an input to the bus stop time calculation, as explained in Section 9.2.3.

Ambulant disabled passengers are clearly able to board the low-floor buses faster than the double-deck buses (and the differences may be underestimated because of possible misclassification of disability as explained in Section 9.2.1). In London, people with shopping trolleys are also able to board low-floor buses faster.

People with pushchairs appear faster in boarding and alighting from low-floor buses. Also they no longer have to fold their pushchairs whilst negotiating the steps. On the low-floor buses only 12 per cent folded pushchairs before boarding, compared with 93 per cent on double-deck buses. Passengers encumbered with pushchairs take the same time to board the London low-floor buses as passengers encumbered with children but without pushchairs, so are boarding much faster than they were able to do on the double-deck buses.

9.2.3 Dead times

In order to estimate the time a bus is stationary at any stop, it is necessary to add a 'dead time' to the sum of total alighting and boarding times (estimated as explained in Sections 9.2.1 and 9.2.2) for a one-door bus, or, in the case of a two-door bus, to whichever of the total alighting and boarding times is greater. The dead time represents the time taken for door operation and kneeling when appropriate, and for two-door buses may be different for alighting and boarding events since different doors are used. Table 24 shows average dead times, derived from the regression analysis, for all the buses surveyed.

It must be noted that these comparisons are affected by the different characteristics of low-floor and old double-deck buses. On the latter, it is possible for the driver to open the entrance door well before the bus has come to rest but with the low-floor vehicles (owing to the requirement for safety interlocks) the handbrake must first be applied.

Table 24 Dead times

	Double-deck (not kneeling)	*Low-floor*	
		(kneeling)	*(not kneeling)*
London			
Alighting	6.92	9.88	8.49
Boarding	7.11	8.69	7.28
North Tyneside			
All stops	6.42	5.42	n/a

In North Tyneside the dead time of the low-floor buses were a second less than those of the previous double deck buses), but were a second greater than the one-door, non-kneeling single-deck Dennis Darts on route 300. The average dead time for all five London routes appears to be a fraction of a second longer on low-floor buses than on double-deckers. However, on occasions when the buses kneel, the dead time is increased by about 1.5 seconds. Trials were made on one London route (120) with the interlocking mechanism modified so that the entrance door, but not the centre door, could be opened while the vehicles were approaching stops at speeds of less than three miles per hour (5 km/h). This modification reduced boarding dead times by just over two seconds. It is thought that dead time can be further reduced by developing automatic kneeling in conjunction with a 'stop brake' separate from the parking brake.

9.3 Effects on journey times

The results discussed in Section 9.2 allow an estimate to be made of the total time either kind of bus will be stationary at any stop, provided the numbers of passengers in each category boarding and alighting are known. Differences between bus types would vary between stops along a route. It is of interest to estimate differences in total times spent at all stops along a route. Fortunately, it is not necessary for this purpose to know actual numbers of boarders and alighters at each stop. Since boarding and alighting times are additive, only average numbers at each stop, and the number of stops, are required.

The distributions of passengers between the various categories observed during the surveys are shown in Table 25.

Table 25 Passengers observed on low-floor buses during timing surveys

Type of passenger	*London (%)*	*North Tyneside (%)*
Unencumbered adult	63	42
Unencumbered elderly	25	33
Child	1	4
Encumbered adult	3	11
Encumbered adult with child	3	
Encumbered elderly	2	6
Ambulant disabled adult	1	0
Ambulant disabled elderly	3	5

9.3.1 North Tyneside

The number of boarders and alighters in each category at an average stop in the before survey was known from the observations made on the buses. An average stop time of double-deck buses on routes 325/326 was then estimated using average times per person and the dead time[3] derived in Section 9.2. The total stop time was then estimated by multiplying this value by 37, the average number of stops along the route.

The average number of boarders and alighters had changed in the after survey. In order to compare the two bus types, the average number of passengers observed in different categories was scaled so the total number of boarders and alighters was the same as in the before survey. Total stop time along the route, for low-floor buses, could be estimated using the same procedure as above.

There is little difference, less than 10 seconds, between the time spent at stops by low-floor and double-deck buses on routes 325/326, see Figure 21. This extra time at stops is small in comparison with the natural variation of travelling time, and would have no perceptible effect on the scheduling of buses.

9.3.2 London

A similar process to that used on the North Tyneside data was used to estimate the total time spent at stops by the double-deck and low-floor buses operating on a hypothetical route which has on average 37 stops. The only differences are that:

i the buses in London are two door buses. Average stop times at alighting and boarding events were separately estimated using the method described in Section 9.2.3. The stop time was then estimated by weighting these two values in accordance with the observed proportions of alighting and boarding events.

ii in London a separate kneeling time was estimated and was added to the boarding or alighting time for an appropriate proportion of the stops.

Once more the difference in time spent at bus stops (Figure 21) is small, less than one minute on average. This difference would vary according to average numbers of passengers boarding and alighting. At busy times, the increased individual speed of most passengers on the low-floor buses would tend to compensate or even outweigh the increased dead time, whereas at slack times the increased dead time would predominate. Thus, overall differences in bus running times are likely to be small, or even negative, at peak periods when keeping to schedule is most difficult.

10 Operating costs

Low-floor buses are electronically and mechanically more complex than standard single deck buses. They are thus likely to be more expensive to maintain. Further, the additional sophistication adds to the capital costs of such vehicles. When low-floor buses were introduced in London during 1994, the price differential above standard single-deck vehicles was approximately £35,000 . Subsequent growth in the market has reduced this differential to some £5,000 by 1997, and it is expected to fall further as demand for low-floor designs increases and manufacturers build them in greater volume.

In order to compare overall operating costs for low-floor and conventional buses, a survey was made of all five London bus companies taking part in the trial, and CoastLine in North Tyneside. These companies were asked to complete questionnaires asking for details of fuel consumption, scheduled miles and actual miles run by low-

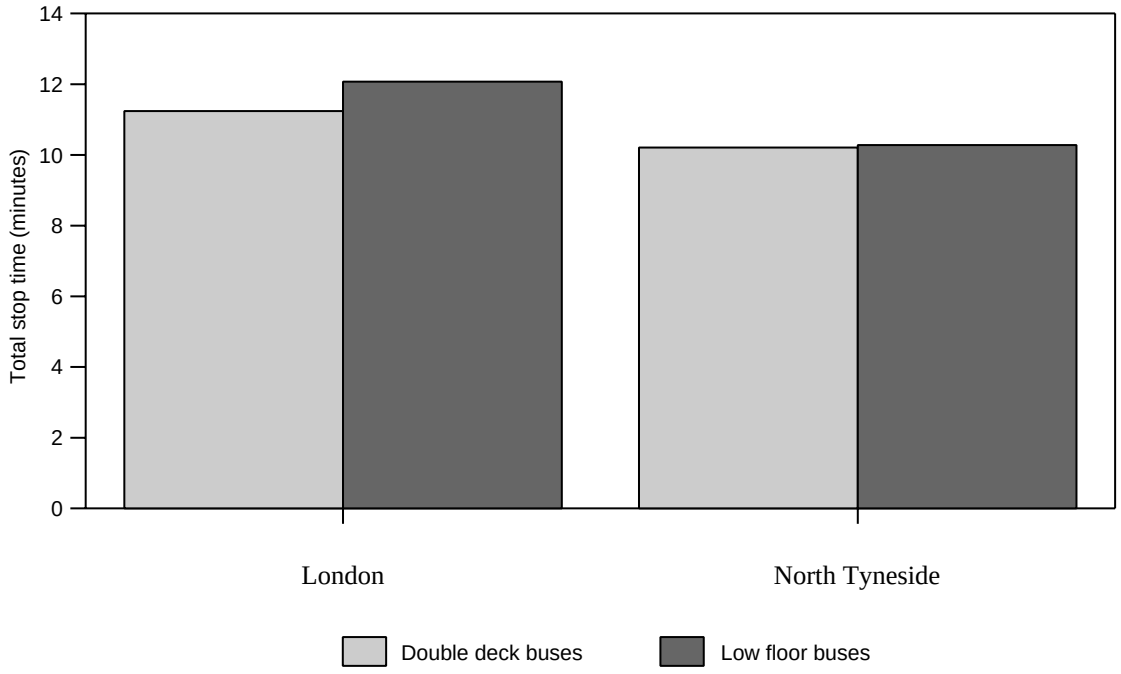

Figure 21 Time spent at bus stops along a hypothetical route (37 stops)

floor buses on each route over four weeks. Similar information on a another route run from the same garage, considered to be of average performance, was also collected for purposes of comparison. Details were also requested of the cost of parts and number of hours labour during the past year specific to the maintenance of low-floor buses, for example the work on kneeling mechanisms, ramps and sensitive strips. Assumptions about the capital costs and rates of interest were combined with the maintenance and fuel consumption costs to give the total additional cost of running low-floor buses compared with other single deck buses.

10.1 Fuel consumption

Average fuel consumption figures achieved by low-floor buses, and buses on a comparison route, are in shown in Table 26. On all but two routes low-floor buses appear to consume more fuel than the standard vehicles with which they are compared.

Table 26 Fuel consumption over four weeks

	low-floor		*comparison*	
Route	*l/km*	*(miles/gallon)*	*l/km*	*(miles/gallon)*
London				
120	0.5	(5.8)	0.6	(5.1)
222	0.5	(6.3)	0.4	(6.7)
186	0.8	(3.8)	0.6	(5.0)
144	0.6	(5.0)	0.5	(6.1)
101	0.5	(6.2)	0.2	(12.3)
North Tyneside				
325/326	0.3	(8.9)	0.4	(7.3)

10.2 Average cost of repairs

Details of the costs of rectifying faults specific to low-floor buses during the past year, were collected from the operating companies, and combined to provide estimates of the average additional maintenance costs of a low-floor vehicle compared with a standard one. These are shown in Table 27. The extra compressor is only fitted on three of the routes in London (Dennis but not Scania buses), and has been averaged for these routes only.

Components are required which allow the bus to kneel, which on some models required an extra compressor. Sensitive strips were fitted on the bottom edges of the bus to ensure people could not become trapped when the buses knelt. By projecting beneath the bus they are vulnerable to catching on high curbs and road humps, and once damaged the bus is unable to kneel until the strip is replaced. The requirement for these devices has been removed subsequent to the survey.

Maintenance costs are less in North Tyneside than in London. Part of the reason for this is the different doors fitted to the buses and the absence of TV monitoring in North Tyneside.

On the Dennis buses the extra compressor was the most expensive part to maintain: there were problems with the mounting bracket and pipework on one route, and the exchanger units on the other. On all routes the independent front suspension was expensive to maintain: the main problems were with the suspension struts, ball joints and air bags. Adjustments to the kneeling mechanism resulted in a high labour cost to keep it working correctly. Sensitive strips were vulnerable, and sometimes torn off the buses, with one route needing to replace an average of one strip per bus each year. Replacement of microswitches and drive motors led to a high maintenance cost of the ramp. Maintaining all these parts and the others specifically associated with the low-floor concept (TV camera and monitor) accounted for 85.6% of the extra maintenance costs.

Table 27 Average additional annual maintenance costs of a low-floor bus

	London Average cost of ... (£)			*North Tyneside Average cost of ... (£)*		
Item	*parts*	*labour*	*total*	*parts*	*labour*	*total*
Sensitive strips	166.43	19.76	186.19	16.00	5.05	21.05
Non-starts (interlock problems)	0	14.70	14.70	0.00	0.00	0.00
Ramps	81.82	33.10	114.92	0.00	73.20	73.20
Kneeling mechanism	38.15	59.34	97.49	0.00	0.00	0.00
Independent front suspension	168.31	27.45	195.76	0.00	5.05	5.05
Extra compressor (where applicable)*	330.78	39.57	370.35	n/a	n/a	n/a
TV camera & monitor	41.76	18.11	59.87	0.00	0.00	0.00
Exhaust system	76.70	15.30	92.00	0.00	0.00	0.00
Fuel tank	29.27	10.99	40.26	0.00	0.00	0.00
Driver seat	8.83	1.09	9.92	0.00	0.00	0.00
Centre doors	0	12.62	12.62	n/a	n/a	n/a
Front doors	0	2.58	2.58	0.00	0.00	0.00
Total (with extra compressor)	942.05	254.61	1196.66	n/a	n/a	n/a
Total (without extra compressor)	611.27	215.04	826.31	16.00	83.30	99.30

**The average cost shown here applies only to those buses fitted with dual compressors, on three of the London routes: vehicles with single compressors were used elsewhere*

Other problems are a result of the design of the particular low-floor bus. Much of the pipe work and components on a conventional vehicle are accommodated under the floor; in the low-floor vehicles much of the pipe work etc is in the ceiling. A lower than normal exhaust system is more vulnerable to catching bumps. Whereas in conventional vehicles fuel tanks are located in the centre of the body, they are positioned towards one side in low-floor vehicles, making them more vulnerable in side impacts.

10.3 Extra cost of running low-floor buses

In this section we combine the additional maintenance costs (Section 10.2), and the fuel consumption figures (Section 10.1), with the increased interest and depreciation charges resulting from the higher price of low-floor vehicles, to provide an estimate of the annual difference in overall running costs between low-floor and standard vehicles.

The price of a new standard single-deck bus was assumed to be £90,000[4] and its value to depreciate to zero after 15 years. Combining this with an assumed 8% interest rate over the 15 years gives the depreciation and interest costs.

The same calculation was performed twice for low-floor buses making two different assumptions about the initial price. In the first case a low-floor bus was assumed to cost £5,000 more than an ordinary single deck bus. This figure was a rough estimate (which would vary from order to order), given by a bus manufacturer, of the current differential for a low-floor bus without a ramp. Secondly, the extra cost was taken as £35,000, the differential at the time the buses were purchased in London. The difference between the annualised capital costs of low-floor and standard single-deck buses, divided by the scheduled kilometres gives the cost per scheduled kilometre in Table 28.

Table 28 Extra cost of running low-floor buses (pence per scheduled km)*

	120	*222*	*186*	*144*	*101*	*325/ 326*
Maintenance costs	1.5	1.9	2.2	1.9	2.2	0.1
Fuel costs	-0.8	0.3	2.1	1.2	2.7	-0.8
Depreciation and interest						
a price differential: £5000	1.1	0.9	1.1	1.1	1.0	0.9
b price differential: £35000	7.5	6.0	7.3	7.8	6.7	5.9
Total						
a price differential: £5000	1.8	3.1	5.4	4.2	5.9	0.2
b price differential: £35000	8.2	8.2	11.6	10.9	11.6	5.2
Percentage of normal running costs						
a price differential: £5000	1.2%	2.1%	3.7%	2.8%	4.0%	0.3%
b price differential: £35000	5.6%	5.6%	7.9%	7.4%	7.9%	6.5%

**Percentage increases are calculated from the 1994/95 figures*

The extra maintenance costs associated with low-floor buses are discussed in Section 10.2. For each route they were converted into a cost per scheduled kilometre. The extra fuel costs of running low-floor buses were calculated using the fuel consumption figures in Table 26 and assuming fuel costs of 11.9 pence per litre after fuel duty rebate.

The extra costs of low-floor operation in the last row of Table 28 are based on comparison of additional low-floor costs with those of average costs per km in London, taken from statistics published by the Government Statistical Service (1996). Comparisons in North Tyneside are with the average values outside of London. However, there is little difference between these and those calculated from average metropolitan or shire counties values.

The bus company operating route 120 (which used the first of the London low-floor buses to be built) claimed that there were further costs incurred over and above the normal servicing and repair of buses shown in Table 28. Over the year in question these would have increased the extra costs to 3.7 or 10.0p/km, or 2.5 or 6.8 per cent of standard operating costs.

At current prices the additional costs per km of running low-floor buses, compared with conventional buses, range between 1 and 4 percent. At the original prices this estimate would have been between 5 and 8 per cent.

It should be noted that all the figures quoted for additional running costs are to some extent influenced by the prototype nature of the first low-floor buses built for service in the UK.

10.4 Capacity considerations

On all the routes in these trials a change from double-deck to single-deck vehicles was already planned prior to the entry into service of the low-floor buses. There was, as a result, some reduction in overall capacity as basic service frequencies were not changed and the number of seats in each new vehicle was broadly half that of the double decks replaced. Alongside the severe problems described earlier of unreliability arising from roadworks on two of the London routes, and the general chaotic traffic conditions, the reduction in capacity contributed to overcrowding at peak times thereby limiting the passenger appeal of the low-floor concept. These problems could obviously be overcome, at some cost, by increases in frequency but the additional vehicles and drivers required would clearly represent much more than the modest uplift in unit costs discussed in Section 10.3.

That is not to say that operators would not benefit from frequency increases, since better levels of service might well attract higher demand, as has been demonstrated by the success of high-frequency minibus operations in several areas in recent years (Watts et al, 1990). The optimal frequency for a particular service depends on many factors which are beyond the scope of this report (see for example Bly and Oldfield, 1974), but which must be taken into account in forming commercial, or social welfare judgements.

Nevertheless, the fact that the current generation of low-floor buses cost more per place km than conventional buses is inescapable, and should not be ignored. Extending the low-floor concept to larger vehicles, if technically and commercially feasible, may offer a solution to this problem. This is already being examined by the principal manufacturers of buses for the UK market, with the development of low-floor double-deck designs suited to London and other cities' requirements.

11 Discussion

In the course of this study a number of positive and negative features of low-floor bus operation have been investigated. We have discovered a marked passenger preference for low-floor buses, largely due to improved ease of boarding and alighting, particularly among people whose mobility is affected by age or disability. This may have led to increases in demand, at least on some routes, but their magnitude cannot be determined with much certainty. However, the apparent increases in demand are of the same order of magnitude as the long-term additional costs of low-floor operation (where service frequencies are the same), suggesting there is commercial scope for low-floor buses.

Some of the conclusions drawn in this report must at this stage be considered somewhat tentative. It was no surprise that the first low-floor buses to go into service were subject to a number of technical problems, requiring consultation between operators and manufacturers, and development of solutions. Operators and drivers had to learn from experience how best to handle the new vehicles, and this took some time. It was unfortunate that some of the first low-floor buses were put into service on two London routes where there were extensive roadworks at the time, causing severe congestion and adding to the problems of overall service reliability.

While the impact of these transient problems is impossible to quantify, it would be expected to impair the judgement of passengers, so they should be borne in mind in any assessment of the potential of low-floor operation.

At the individual level, people most likely to benefit from more accessible buses are those who find standard buses difficult or impossible to use. Their numbers are relatively small, so any increase in their use of buses will have little effect on operating economics, but there is social value associated with any increased personal mobility. There is indeed evidence that such people take advantage of the new low-floor buses, going out more often and being less reliant on others for lifts, errands or home visits. The ability to use the same transport system as other people is greatly appreciated, and people regard the low-floor service as a useful back up to their normal transport arrangements. These benefits are undoubtedly real, but there is no reliable method of quantifying them.

Low-floor buses, although technically accessible to some people who cannot use standard buses, will not necessarily satisfy their transport needs. Bus services are useful only if they go where the passenger wants, at the right time. People living near the trial routes had access to only one low-floor service, in contrast to the comprehensive networks operated with standard buses. If all services were converted to low-floor operation, disabled people and others whose mobility is impaired would have greater choice of destinations and journey times, and would be likely to make more use of buses. However, while only relatively low-capacity low-floor buses are developed, there will be economic obstacles to using them on busy routes currently served by double-deck buses.

Accessibility is also affected by distances between home or destination and bus stops, which need to be shorter for less mobile passengers. Generally, such distances could be reduced only by increasing network density (ie increasing numbers of services and running them closer together). The cost of so doing, while maintaining service frequencies, is not likely to be offset by increased demand for buses, and could imply prohibitive increases in subsidies.

There are therefore many imponderables in projecting from the experience of this early trial to the long-term future of low-floor bus services. Provided some important technical problems are solved, low-floor buses may prove to be a viable alternative for bus operations in general, and their enhanced passenger appeal may contribute to efforts to attract people from private to public transport. All passengers will experience benefits, and less mobile passengers will, individually, benefit most. However, it will not be possible for low-floor bus services to cater for all the transport problems of disabled people, any more than public transport in general can meet all the transport needs of the public. Low-floor buses should prove a valuable addition to, but not a replacement for forms of transport services currently used by disabled people.

12 Conclusions

1 Most categories of passengers have found low-floor buses easier to use than double-deck vehicles. The improvement, which is mainly associated with boarding and alighting, is particularly significant for passengers whose mobility is affected by disability or encumbrance with children in pushchairs, and by people in wheelchairs for whom access to standard types of bus was impossible.

2 Low-floor buses were used by significant proportions of ambulant disabled passengers and wheelchair users (25 per cent in London, nearly 50 per cent in North Tyneside) living in the catchment areas of the trial services.

3 Low-floor buses provide some wheelchair users with more opportunities to go out, providing a useful alternative form of transport, and in some cases reducing their need for help from others. Wheelchair passengers particularly appreciated the ability to use the same transport as other members of the public.

4 The use of low-floor buses by disabled passengers is often limited by distances between homes (or destinations) and bus stops, and the lack of escorts to accompany them. In the trial situation, only one route was available which did not suit all their needs, and considerations of service frequency, reliability and fare levels which affect all passengers affected their use.

5 The residual difficulties in using low-floor buses were due to the location of handrails (too close together for wheelchair, too far apart for standing passengers or those moving between doors and seats), overcrowding, obstruction of floors by pushchairs, failure of the bus to kneel at stops, and large gaps between buses and kerbs when access to stops was impeded by illegally parked vehicles. In North Tyneside attempts were made to alleviate

access problems by improvements in bus stop layout and kerb height (which few passengers appeared to notice) and more rigorous enforcement of parking regulations.

6 Low-floor buses are preferred to standard vehicle types by most categories of passengers. Fully mobile, unencumbered passengers tend to be more indifferent between bus types, but more express preference for low-floor than for double-deck buses.

7 Low-floor buses attract more passengers than standard vehicles, mainly from less mobile sections of the population, particularly people with pushchairs. Overall increases in patronage on the trial services (compared with changes observed on 'control' routes) ranged between -1 and +12 per cent.

8 There would appear to be potential for greater growth in patronage if whole networks of bus services could be converted to low-floor operation, and overcrowding problems could be reduced (possibly by using higher capacity vehicles, or increasing service frequencies).

9 Marginal boarding and alighting times are slightly shorter on low-floor buses for fully mobile passengers, and substantially shorter for ambulant disabled passengers. These gains can be offset by increased 'dead time' at stops associated with kneeling and its interaction with door operation. However, it may be possible to remove this effect by improvements in design, and overall changes in total time spent at stops along a typical bus route amount to less than one minute. It is thought that dead time can be further reduced by developing automatic kneeling in conjunction with a 'stop brake' separate from the parking brake.

10 Operating costs are slightly higher for low-floor buses than for conventional vehicles, as there are additional mechanisms and parts to maintain or replace, fuel consumption is a little higher, and capital costs are higher. It is estimated that with the current price differential between low-floor and other buses (which has fallen substantially since these trials began) the difference in overall operating costs per vehicle kilometre lies between one and four per cent.

13 References

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Notes

[1]Unless otherwise stated, 'ambulant disabled passengers' are those interviewed on buses, and judged by interviewers to have some disability.

[2]More complicated, non-linear formulations are possible, but more data than are available in this study would be needed to justify them.

[3]These buses knelt at almost every stop, and the dead time consequently includes this.

[4]This value was estimated after discussions with a London bus company and a bus manufacturer.

Abstract

Difficulties are encountered by a substantial minority of bus passengers when boarding and alighting, due to the steps at the entrance/exit of conventional buses. Some of these people encounter problems because of impaired mobility, with those in wheelchairs being unable to use conventional services, whilst others have difficulties with luggage or assisting small children.

Efforts are being made to make bus services more accessible. Commercially, this increases the proportion of society who are potential passengers, whilst allowing less mobile people access to a useful alternative form of transport. New low-floor buses are able to kneel at stops to reduce the vertical gap between the kerb and the floor of the bus, and have no steps at the doorways to negotiate. Ramps were provided on the services surveyed, which bridged the gap between the bus floor and kerb, allowing access for wheelchair users.

Surveys have been performed to appraise the impact of these buses on five routes in London and one in North Tyneside. Amongst the information collected was passengers' perception of the services, bus type preference, and any improvements in ease of access (including their effect on boarding and alighting times). Information from operators was used to assess the difference in running costs of low-floor buses, and their effect on patronage.

Since the London and North Tyneside trials were commenced there has been rapid growth in the use of low-floor buses in the UK and it is evident that vehicles of this type will become the norm in order to meet the forthcoming regulations under the Disability Discrimination Act 1995 which will require new buses to be fully accessible.

Related publications

RR269 *Urban minibuses in Britain: development, user responses, operations and finances* by P F Watts, R P Turner and P R White. 1990 (price £15, code B)

RR137 *Features on buses to assist passengers with mobility handicaps* by C G B Mitchell. 1988 (price £15, code B)

RR33 *An experimental study of the use of buses by elderly and disabled people* by P R Oxley and M Benwell. 1985 (price £10, code AA)

CR22 *Study of demand for wheelchair – accessible bus service* by P R Oxley. 1986 (price £23, code F)

LR521 *Bus boarding and alighting times* by M A Cundill and P F Watts. 1973 (price £15, code)

SR27 *Optimisation of a simple model bus network* by P H Bly and R H Oldfield. 1974 (price £10, code AA)

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