Assessment of Passenger Safety in Local Service PSVs

Final Report

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Undertaken on behalf of

The Department of Environment, Transport and the Regions (DETR)

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1.0 Literature Review

1.1 Review of Accident Statistics

With the high number of vehicles presently on the road, the government is now aiming to reduce road traffic by encouraging people to use public transport more, such as travel by bus. However, in order to encourage people to use local bus services, public perception of the safety and comfort of the bus ride must be improved considerably.

Bus travel has been shown statistically to be safer than car travel in terms of collision and casualty rate. For Greater London, figures for 1997 showed that there were 250 killed and seriously injured (KSI) casualties (2 fatalities) for bus and coach occupants compared to a total London road user KSI rate of 6990 (276 fatalities)(Local Transport Today, 7 May 1998 - Figure 1 and Figure A.1 (Appendix A)).

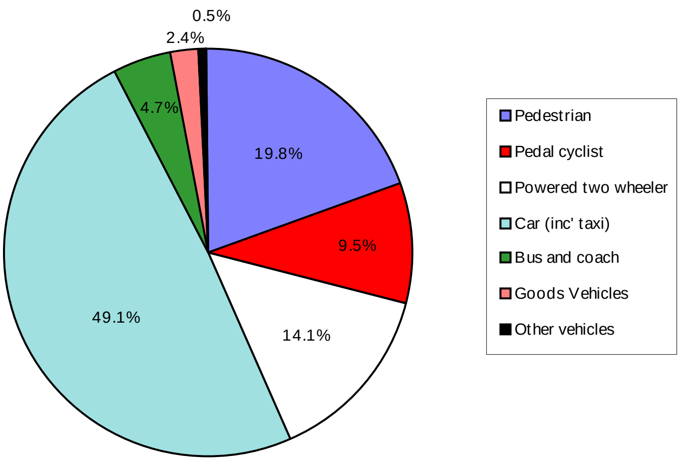


Figure 1: Proportion of casualties recorded in Greater London for each mode of travel (Adapted from Local Transport Today - 7 May 1998)

Between 1980 and 1991, the number of people killed and seriously injured on buses and coaches on Britain's roads decreased considerably from an annual figure of 1952 to 725 (63% decrease) (White et al., 1995). However, it is important to recognise this may be in part due to the decline in the number of passenger journeys made (Data for 1986-96 indicates a 22% reduction - Bus and Coach Statistics, 1995/96). Therefore if the government objective of encouraging more people into bus travel is achieved, this trend may reverse and casualty rates may climb. This is more likely to be the case if bus travel is adopted by a significant proportion of vulnerable passengers, i.e. those individuals whose physical disabilities prevented them from bus travel until the advent of accessible vehicles.

Although the number of bus casualties and fatalities are less than with other road vehicles, there are still many injuries occurring which could possibly be prevented. As well as collision incidents which involve the bus impacting with other vehicles, stationary objects and pedestrians, many injuries to bus occupants occur during non-collision incidents. Non-collision accidents can occur when the bus is either stationary or moving. When stationary, a passenger could lose their balance, fall or slip either while on the bus or while boarding or alighting. When the bus is moving, an injury could occur during an accident avoidance manoeuvre, where the bus may suddenly swerve, brake or accelerate, or through poor driving where the driver takes corners badly or accelerates or brakes hard. In addition, an accident could occur if the bus driver shows little regard for people with ambulatory disabilities and those with encumbrances, by not waiting for them to be seated before moving off.

It has been stated that about 57% of injuries to passengers were a result of non-collision accidents, 29% of injuries were sustained during emergency action to successfully avoid a collision and only 14% were a result of a collision. The types of accident cause and their frequency are displayed in Figure 2 (National Public Service Vehicle (PSV) Accident Survey in Fruin et al, 1994 and Leyland Vehicles Ltd. and MIRA, 1980). The National PSV Accident Survey reported that injuries due to an emergency action occurred the most often during the cruising stage of a bus journey, as did injuries sustained during a collision. Injuries sustained as a direct result of a passenger falling on a bus due to a loss of balance, a slip or a trip, occurred the most while the bus was stationary at a bus stop.

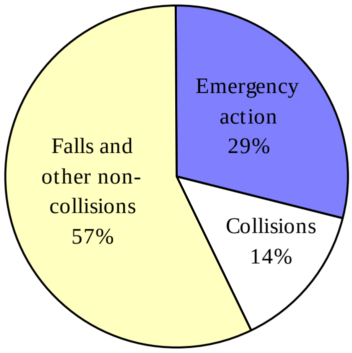


Figure 2: Causes of passenger casualties in the National PSV Accident Survey (adapted from Fruin et al., 1994)

White et al. (1995) found that 91% of the slight injuries reported by “Stats19” data between 1984 and 1989 occurred in accidents that involved no other degree of casualty and from this, it was concluded that many casualties do not result from major accidents but are more likely to just involve individual passengers who experience an accident while boarding, alighting, standing or moving within the vehicle.

Dickson-Simpson (1992) stated that most personal injuries on PSVs were on ordinary service buses rather than coaches. One reason for this may be that passenger journeys on local service buses account for approximately 62 to 65% of all bus and coach journeys, based on information provided by the Department of Transport for the past 10 years (Bus and Coach Statistics Great Britain, 1995/6), so there is likely to be more accidents on local service buses. This highlights the importance of designing local service buses with passenger safety in mind.

2.0 Stability and Balance

The likelihood of an injury occurring to a bus passenger will often depend on the quality of ride of the bus journey, for example, the driving habits of the bus driver, the quality of the road surface and the features present on the bus route, such as traffic calming measures and the severity and number of bends and stops. However, other factors, such as the features present within the bus interior and individual passenger attributes, also determine the likelihood of a passenger injuring themselves during an incident.

2.1 Motion-Related Falls

As a person grows older, their postural control declines, therefore sensory conflict will have a greater effect on the sway angle of an elderly person than someone younger. Therefore an older person is likely to be less stable on a moving bus.

If hazards such as slippery floor surfaces are accumulated with the reduction in postural control in a moving environment, such as during a bus journey, the likelihood of a fall occurring will be considerably increased.

2.3 Trips

Falls due to tripping can occur while boarding a bus if the height of the step treads are misinterpreted by the passenger and while moving along the bus if obstructions on the gangway floor, such as baggage or other passengers' feet, are present. Toe clearances during normal walking (i.e. the vertical height between the toe and the object/step being stepping on to or over) can vary between 0.95 and 3.81cm, the average being approximately 1.52cm. However, it has been suggested that standing passengers on buses could trip on lower surfaces than this (0.95cm) while adjusting their feet (Fruin et al., 1994). Again, the accumulated effect of a moving environment, such as during a bus journey, and tripping will increase the likelihood of a fall occurring.

2.4 Force and Levels of Acceleration

A study by Leyland Vehicles Ltd. and MIRA, (1980) for the Transport and Road Research Laboratory (TRRL) investigated the levels and range of acceleration and jerk experienced on buses in relation to specific events and passenger reactions. The comfort threshold for fore and aft acceleration for forward facing seated passengers was found to be between 0.11 and 0.14g, as this was when mild compensatory levels in passengers were observed to start. For lateral acceleration, the threshold was found to be between 0.23 and 0.25g. An event analysis was also carried out to investigate when high acceleration and jerk events occurred. For fore and aft acceleration, gear changes produced a large number of high level events, as did deceleration into bus stops and “jerky” final stops. The highest jerk levels (±2.6g sec^{-1}) were recorded during braking and emergency stops.

2.5 Summary

The likelihood of an injury occurring to a bus passenger can depend on a number of different factors during a bus journey. However, most injuries will be similar in that they are sustained by the passenger during a fall. Falls can be a result of slips, trips or a loss of balance due to the motion of the bus and their likelihood can be influenced by the design of the bus, the ride quality and individual passenger attributes.

3.0 The Stages of Bus Travel

3.1 Overview

This section of the report will look in more detail at the type of accidents which occur at the various stages of a bus journey and will be divided into three main sections, boarding and alighting, going to/from a seat and standing, and being seated.

The process of a bus journey has been divided into six main stages by Petzäll (Paper 1 - 1993), these being boarding the vehicle, moving within the vehicle, getting seated, sitting in the seat, rising from the seat and finally alighting. These stages have been outlined in Table 1 along with the main hazards associated with each. The second stage described by Petzäll as "moving around the vehicle" has been divided into three sub-stages in the table, which are "paying the fare", "walking to the seat" and "walking to the exit".

Table 1: The various stages of bus travel and the possible hazards associated with each

Stage of bus travel	Possible hazards
Boarding the vehicle	This is likely to involve a step or steps
Paying fare	Standing while dealing with money - no hands available to support
Walking to seat	This may involve traversing steps or stairs and avoiding obstructions in the gangway
Sitting down	May have body structure around foot areas
Being seated (including calling the vehicle to stop)	Seat design Push button - may be out of reach unless you stand up - also have to locate push-button
Standing up	Seat design
Walking to exit	Down step/steps or stairs
Exiting the vehicle	Down step/steps onto differing surface heights

Passengers are susceptible to different hazards in the different stages of bus travel. An example of the type of non-collision accidents which occur at various stages of bus travel can be seen in Table 2, which shows the results of an accident collection database of Washington (DC) Metrobus between 1984 and 1991.

Table 2: Washington (DC) Metrobus non-collision accident types

(July 1984 - January 1991)

Passenger injury on board stopping bus	**1508 (100%)**
-Getting up/down/seated	45.4%
-General	16.6%
-Standing front door area	10.3%
-Standing front seat area	7.2%
-Walking front seat area	7.1%
-Standing rear seat area	5.6%
-Walking rear seat area	4.3%
-Other	3.4%
Passenger injury alighting vehicle	**1215 (100%)**
-Tripped, slipped, stumbled	33.2%
-General	15.7%
-Struck by centre/rear doors closing	13.7%
-Between street and step at front door	9.9%
-Struck by front doors closing	7.5%
-Other	20%
Other passenger injury	**1200 (100%)**
-Injured by defective equipment while on board	24.0%
-Injured by missile while on board	19.4%
-General	17.1%
-Bus stationary: trip, slip, or stumble	13.4%
-Injured by others on board	11.0%
-Bus moving: tripped, slipped, stumbled	7.8%
-Other	7.3%

Passenger injury boarding vehicle	**681 (100%)**
-Struck by front doors closing	34.9%
-Tripped, slipped, stumbled	32.9%

-General	9.0%
-Between street and step at front door	7.8%
-Other	15.4%
Passenger injury on board moving bus	**382 (100%)**
-Getting up/down/seated	54.7%
-General	10.2%
-Standing front door area	9.9%
-Other	25.1%
Passenger injury on board starting bus	**142 (100%)**
-Walking front seat area	23.2%
-Standing front door area	19.7%
-Other	57.0%

3.2 Boarding and Alighting the Bus

Boarding and alighting accidents have been defined as occurring “within the stepwell or on the ground surface outside the bus” (Fruin et al, 1994). The type of accidents which occur when passengers are trying to board or alight the bus may involve a passenger losing their footing on a step, tripping up a step or losing their grip on a hand rail or stanchion. This could be a result of a loss of balance due to the passenger carrying a heavy load or as the bus starts to move off prematurely before the passenger is safely seated or off the bus. Other causes of boarding and alighting accidents may be design issues, such as high steps in relation to the pavement, poorly designed hand rails or malfunctioning automatic doors (Stahl, 1989).

It has been suggested that 37% of all fatalities and serious injury cases were associated with passengers boarding and alighting, due to either poor driver visibility (i.e. when looking to see whether all passengers have boarded/alighted), poor step or poor door design (Willis 1992). White et al. (1995) stated that half of all killed and seriously injured cases (KSI) in built-up areas are a result of passengers boarding and alighting.

Alighting accidents appear to be more serious than accidents when boarding, due to the fall height and harder impact as a result of gravity (Fruin et al., 1994). The PSV accident survey discussed in Leyland Vehicles Ltd. and MIRA (1980) found that over 14% of casualties from the PSV accident database were boarding the bus when the accident occurred and 27% were alighting. In addition, Fruin et al (1994), reported on a study where 94% of step falls by passengers with ambulatory disabilities were downward falls.

As well as accidents involving slip, trip and loss of grip falls, another type of accident which could result in injury when boarding and alighting is being trapped in the bus automatic doors. Leyland Vehicles Ltd. and MIRA (1980) found that 3% of casualties studied from the PSV accident survey were trapped by bus doors and another study reported that of all injuries sustained on buses of 20 or more seats over a six year period, 4% involved bus doors (Injury Bulletin No.27, 1994). However, the Washington (DC) Metrobus Non-collision accident survey (previously displayed in Table 2) found a much higher rate, with passengers being trapped by bus doors found to be the most common type of injury cause when boarding (35% of casualties) and the second most common when alighting (21% of casualties). The type of injuries which were sustained from accidents with bus doors included fractures and other injuries to the limbs, cuts and bruising to the head and upper back (Injury Bulletin No.27, 1994). It appears that whatever is hit or trapped by the bus door is where the injury occurs. The Independent and Times Newspapers (13 August 1992 and 26 October 1993) reported on two very extreme cases of accidents which involved bus door entrapment. One of the incidents involved a ten year old girl who died from multiple injuries when the toggle of her coat become caught in the bus door. In the other incident, the bus door automatic mechanism had been switched off and an eight year old boy was operating the door, and the driver was himself unable to see anything below 4½ ft. This case brings to light a number of issues which resulted in this accident, which includes the driver not being in control or being able to see the bus doors and its surroundings, both inside and outside, and the predicament of the young passenger not being known until it was too late. These issues will be discussed in later sections.

3.3 Moving to/from a seat or standing

Mabrook (1994) reported that just over 50% of passengers received their injuries when moving to alight the bus, while just over 20% occurred when passengers had just boarded and were moving to a seat. The type of injuries involved in these non-collision accidents included fractures of the rib, pelvis and various bones in the arm, as well as bruising.

The National PSV accident survey (in Leyland Vehicles Ltd. and MIRA, 1980) found that about 23% of casualties were involved in accidents while on the gangway while Colski (in White et al., 1995) reported that in 1990, 36% of passenger casualties over the age of 60 were standing at the time of their accident. In addition, Dickson-Simpson (1992) wrote that of the personal injuries which occurred on local service buses, 29% occurred to standing passengers. Willis (1992) outlined a figure of 28% of all serious and fatal cases involving passengers who were standing at the time of incident, compared to 27% for seated passengers. As it is anticipated that the number of standing passengers on a bus will generally be smaller than the number who are seated, it is likely that overall, the proportion of all standing passengers who sustain injuries will be greater than the proportion of all seated passengers. Therefore it could be argued that the case for banning standing passengers is greater than the argument for installing seat-belts into buses.

One observation of a study by Leyland Vehicles Ltd. and MIRA (1980) was that a high proportion of accidents on buses were a result of passengers moving up the gangway in accelerating vehicles, particularly with regard to elderly passengers. Similar to the stages of boarding and alighting, passengers with mobility difficulties and those with encumbrances are highly susceptible to falls and injuries while standing or moving about the bus and the likelihood of falling and injury causation is dependent on many bus features, such as the floor of the bus, availability of handrails, obstacles such as bags, other passengers and litter. This suggests that safety could be improved by limiting the amount of standing passengers within a bus, but as a report in The Independent (27 June 1994) suggests, this may not be simple to implement because of the efforts which would be involved in changing present driver and passenger behaviour as well as the financial implications to bus operators.

3.4 The process of being seated

Accidents involving passengers who were or were about to be seated appear to be not as frequent as those who were standing. Only 29.4% of casualties included in the study by Mabrook (1994) were seated at the time the injury was sustained compared to the 70.6% who were standing. These injuries occurred when the bus braked quickly causing the passenger to hit their head on the back of the seat in front, resulting in a number of nasal fractures. Bowrey et al. (1996) reported on two injury cases of seated bus passengers which were results of the bus traversing road humps. The first passenger received a crush fracture of a lumbar vertebrae after being jolted off her seat and the second sustained a flexion/extension injury to her neck and a soft tissue injury to her shoulder after she was thrown forward, hitting the rear of the seat in front.

A study carried out by the Parliamentary Advisory Council on Transport Safety (PACTS, 1995) investigating the trends of elderly bus and coach casualties found that of the 969 seated casualties in London between 1991 and 1993, 262 casualties fell and 41 casualties were thrown forward. The circumstances of the remaining 666 casualties were unknown.

3.5 Summary

In summary, the types of accidents and injuries sustained at each stage of bus travel vary due to the different hazards passengers are exposed to. For example, while moving about or standing on the bus, passengers are more susceptible to slips, trips and loss of balance falls, resulting in impact with the floor.

4.0 Physical Designs of the Bus

4.1 Handrails and stanchions

Handrails and stanchions (vertical handrails) are present on buses to provide support for passengers throughout their bus journey, therefore they should provide enough grip and be available to passengers at every stage of their bus journey from boarding to alighting. They not only assist in balancing the body, but help to take some of the weight off the legs when boarding or alighting the bus. Stanchions have been described by Shaw (1989) as being the key feature for buses in terms of safety. In order that handrails and stanchions are of an optimum use for all bus passengers including those who are elderly, those with mobility difficulties and those with encumbrances, a number of rail characteristics should be considered, including the shape, placement, positioning, texture and visual qualities.

The main advantages and disadvantages of both round and oval handrails, as described by Byman and Hathaway (1994), are as follows. The advantage of round handrails is that they are easily available and are general standard issue. The disadvantages are that people with hand-gripping impairments such as arthritis and those with artificial hands or arms find it difficult to grip this type and the likelihood of the hand slipping using this type is greater. The advantages of oval handrails are that this type requires less gripping ability for the passenger to keep stable and artificial arms can grip easier and also the oval shape means that much less knuckle space is required, therefore leaving wider spaces for passengers to manoeuvre, particularly in doorways. The disadvantages are that the cost will be more, as this type is not standard issue and is presently difficult to find until demand increases.

In a study by Petzäll (Paper III - 1993), the requirements of people with ambulatory disabilities were investigated in order that buses could be modified to cover these needs. From the results for participants with serious, less serious and slight ambulatory disabilities, it was concluded that handrail height should be approximately 900mm above the edge of the step with the diameter being between 25 and 35mm. These results are very similar to those in the current regulations.

Another study by Leyland Vehicles Ltd. & MIRA (1980) for TRRL concluded that the sloping portion of a doorway handrail should be approximately 1000mm above foot level with a minimum hand clearance of 70mm.

Handrails and stanchions should ideally have a textured surface which helps to reduce the possibility of slippage occurring. Leyland Vehicles Ltd. and MIRA (1980) found that a handrail of 25.4mm stainless steel, wrapped in white "Doverite" provided the best grip for passengers, even when under substantial force.

The visual qualities of handrails and stanchions on buses are important in determining how well they will perform when a bus passenger loses their balance, because if a passenger cannot distinguish a handrail clearly from the background, then it is less likely they will be able to grab the handrail before they fall.

However, there may also be the risk that handrails and stanchions may be the cause of some injuries. As part of the PSV passenger accident study reported by the Leyland Vehicles Ltd. and MIRA (1980), a list of the objects reported to be struck by passenger casualties was given. There were 432 occasions reported where a passenger struck a handrail or stanchion, which was just under 11% of all occasions reported of an object being struck.

4.2 Seating

A person travelling on a bus will normally spend most of their time sitting down, therefore the design of the seat will be important in determining how safe and comfortable a passenger's journey is. Current regulations state that the minimum width for individual fixed seats is 430 to 500mm, with a cushion width of 400mm, cushion depth of 350 to 400mm and cushion height of 400 to 500mm. The space (leg room) in between the front of one seat squab and the back of the seat in front is required to be a minimum of 230mm. There appears to be little variation between the standards (Mitchell, 1989).

Injuries occur to passengers while seated for a number of reasons. If a seat lacks any retention or cushioning, the passenger is more likely to move about in their seat as a result of bus motion. Injury, particularly of the back and neck, will occur when the seat is impacted by the passenger. A case study concerning this type of accident has been discussed by Bowrey et al. (1996). Alternatively, if the bus brakes hard or turns sharply, passengers may be thrown forward, hitting the seat in front with either their head or their legs, or thrown to the side, either hitting the window or falling into the gangway, causing injury.

PACTS (1995) reported that some bus seats have such low friction and are so cushioned that passengers are highly likely to slide off them when the bus is turning corners or slowing down. Fruin et al. (1994) describes a number of aspects of seat performance which should help to reduce passenger injury, such as the ability of the seat to absorb some of the kinetic energy during impact, particularly at head and knee height and strong seat anchorages to ensure seat retention.

From the PSV passenger accident study reported by Leyland Vehicles Ltd. and MIRA (1980), 456 occasions were reported where a passenger was involved in an accident where part of a seat was struck, which was just over 11% of all occasions reported of an object being struck.

There are a number of studies which describe the benefits of placing seat-belts in coaches and buses and how this could prevent the number and severity of injuries to passengers (Dickison & Buckley 1996, Banner 1996, Kecman et al. 1997). However, the use of seat belts in local service buses would not be cost-effective, firstly because of the constructional problems of installing belts into buses and also because it would be difficult to persuade bus passengers to use them if they were installed (Krüger, 1986). This would apply particularly on short journeys, where passengers would have to spend the majority of their time fastening and unfastening the belts both for themselves and to allow other passengers to get to and from seats PACTS (1995).

Additionally, as most bus accidents involving passenger injuries are non-collision accidents and predominantly involve non-seated passengers, improving vehicle design in terms of layout of the interior, entry and exit and also driving standards could be more important than fitting seat-belts and improving “roll-over” strength. These latter aspects are more important in large collision accidents, of which there are fortunately very few (White et al., 1995).

As an alternative, some studies have suggested using the seat itself as a restraint system in both collision and non-collision accidents (Krüger, 1986, The universal coach safety seat (in IMechE Conference Transactions: Bus and Coach ’96)). Krüger (1986) investigated the effects of various longitudinal distances between seat rows on the movement and force exertion of the passenger colliding with the back of the seat in front using anthropometric dummies. Typical seats used in German buses at the time were used and a minimum force exertion was achieved at a row distance of 800 - 850 mm, providing both adults and children with maximum protection.

4.3 Steps

It has already previously been mentioned that boarding and alighting a bus is a cause of a high proportion of accidents and their resulting injuries. Not only do passengers often hit the steps when they fall but, particularly when alighting, the downward direction of the fall may result in passengers hitting the pavement as well. In order that steps can be traversed by even those with the most severe mobility difficulties or encumbrances, current regulations are enforced to ensure that step heights are no more than a maximum limit. The limits vary greatly between regulations from 250mm and 300mm suggested by the British DPTAC and London Regional Transport, to 400mm stated by ECE Regulation 36 and the French Arrêté du 2 Juillet 1982. The height of subsequent steps varies from 120 to 150mm for the minimum height to 250 to 350mm for the maximum between the regulations. The minimum depth of the first step tread is established as 300mm, with subsequent steps being a minimum of between 200 and 300mm.

Leyland Vehicles Ltd. and MIRA (1980) compared casualty rates on buses with different gangway heights, specified by the number of steps at the bus entrance. The findings were that boarding and alighting casualties accounted for 9, 15 and 11% of all accidents for low, intermediate and high floors respectively. The slightly higher rate of casualties for intermediate floor buses than those with low floors was a result of the effect of more steps present on the intermediate floor bus. The reason given for the decrease in casualty rate between intermediate floor buses and high floor buses was that there may be extra support given on either side of the passenger to help them traverse the extra steps, therefore reducing the likelihood of a fall occurring.

Other aspects such as a slip resistant surface, lighting and colour contrast have been outlined as important to step performance by the regulations mentioned in Mitchell (1989).

Studies which have been carried out to find the ideal step height at bus entrances and exits for those passengers who have mobility difficulties include one undertaken by Petzäll (Paper I - 1993), who suggested that steps should have a height of 150 to 200mm and a tread depth of 250 to 300mm and that all steps should have the same dimensions. It is also suggested that the step edge is smooth, in other words, that the tread of the step does not overhang the riser, as this may increase the likelihood of tripping when boarding the bus and will result in a shorter tread depth when alighting, which could increase the likelihood of slipping if a passenger’s foot is not fully on the step.

Oxley and Benwell (1985) undertook a study investigating a number of existing bus designs and looked specifically at the ease of boarding and alighting for people with ambulatory disabilities. The main conclusions were that criticisms of step height appeared to start at a height of 200mm, with a consistent step height being preferred and a depth of 350mm being suggested as a minimum.

Little is mentioned about stairways to the upper deck in the literature, but it is assumed that the same regulatory measures as the entrance and exit steps should apply to these steps. However, all standards tend to agree that internal steps should be grouped together in a single flight and should be avoided unless completely necessary. As stairways to upper floors of double-decker buses are very rarely used by the elderly and less mobile, it may seem that the dimensions of these stairways may not be of as much importance. However this may change in the future if more elderly passengers and those with ambulatory disabilities partake in bus travel and/or the proportion of standees to seated passengers increases on the lower deck thereby encouraging more passengers to use the upper deck. Accidents on stairways leading to upper decks are potentially very dangerous, so their design for safety for all passengers, including the elderly and encumbered passengers is highly significant.

4.4 Doors and doorways

The main hazards concerning doorways are passengers being struck or becoming entrapped by doors opening or closing prematurely while boarding or alighting the bus. However, passengers could also strike their head on the top of a doorway while entering or leaving a bus or there may not be enough room to manoeuvre easily off the bus when loaded with shopping or children, which may lead to a loss of balance, resulting in a fall.

Another issue concerning the type of doors used on local service PSVs is the way in which the doors are controlled. In most buses the doors are controlled by the drivers from their seat. However, accidents, particularly door entrapments, could occur in circumstances where the driver’s view of the doorways is poor, which can often be the case when there is a centre exit door. To ensure that the frequency of door entrapments are reduced, re-cycling mechanisms to detect passengers and objects obstructing the doorways are used. In addition, to ensure that falls from bus doorways as the bus is moving off or slowing down are prevented, interlocks can be installed to prevent the vehicle from moving when the exit door is open (Spencer, 1996).

The type of injuries which are caused by an accident involving bus doors include fractures, cuts and bruises to the limbs, upper back, head and face (Injury Bulletin No.27, 1994). However, Leyland Vehicles Ltd. and MIRA (1980) reported that leg and foot cuts, bruises and grazes were most frequent in accidents involving doorways and platforms, while fractures of all kinds were reported most often for both doorway and gangway accidents.

4.5 Gangways (including floor)

As well as falls due to the motion of the bus which can occur in bus gangways, other circumstances include tripping over items obstructing the gangway, including fixed objects which are part of the structure of the bus (e.g. seat mountings or the base of handrails) or passengers' baggage. Slipping on floor surfaces which do not have good slip resistance, due to the floor being wet during poor weather conditions or the presence of foreign materials on the floor such as food or drink, are also hazardous (Fruin et al., 1994).

Byman and Hathaway (1994) suggest that slip and fall accidents can be avoided by regular maintenance and cleaning of the vehicle surfaces and floors and warns that fine sand and dust are almost as treacherous as moisture. It has been found that head and neck injuries (cuts, bruises or grazes) were most frequently reported from accidents in the gangway and when leaving or entering seats, and that fractures of all kinds were reported most often for both gangway and doorway accidents (Leyland Vehicles Ltd. and MIRA, 1980).

The PSV passenger accident study by Leyland Vehicles Ltd. and MIRA (1980) reported that there were 1232 occasions where a passenger was involved in an accident where the floor was struck, which was just over 30% of all occasions reported of an object being struck. The type of floor struck and the number of occasions is displayed in Table 6. However, it must be noted that the occasions where the bus floor was struck may well be over reported, as they may have been quoted for "falls from the bus" when no other injury sources are apparent (Leyland Vehicles Ltd. and MIRA, 1980).

Table 6: A summary of the number of occasions where the floor was struck by a passenger during an accident

(Adapted from Leyland Vehicles Ltd. and MIRA (1980))

Floor type	Number of occasions reported (percentage of all objects struck)
Platform floor	312 (7.7)
Saloon floor	886 (21.8)
Footstool for side facing seat	34 (0.8)

4.6 Other Features

There are a number of other features found on the majority of local service PSVs, the designs of which may help to prevent or cause passenger injury during both collision and non-collision incidents. These include the fare paying equipment, luggage spaces, windows or windscreens and the upstairs or downstairs front dashboards/bulkheads. Table 7 displays the number of occasions where these objects were struck by passenger casualties.

Table 7: A summary of the number of occasions where various objects were struck by a passenger during an accident

(Adapted from Leyland Vehicles Ltd. and MIRA (1980))

Object	Number of occasions reported (percentage of all objects struck)
Fare paying equipment	36 (0.9)
Overhead luggage rack	8 (0.2)
Luggage hopper	62 (1.5)
Windscreen (driver's)	4 (0.1)
Window or window frame	74 (1.8)
Windscreen	90 (2.2)
Upstairs front dashboard/bulkhead	10 (0.2)
Downstairs dashboard/bulkhead	16 (0.4)

4.7 Summary

The design of the various features found within all local service PSVs can often determine the number of injuries occurring during a non-collision accident by helping passengers to avoid injury or even being the cause of the injury itself. Table 8 outlines the important characteristics to be considered in the design of the various features of buses to maximise usability.

Table 8: Prominent bus features and the characteristics important in their design when maximising usability

Bus feature	Handrails and stanchions	Seating	Steps	Doors and Doorways	Gangways
Characteristics	-Shape -Material (texture) -Visual qualities -Positioning/ availability -Placement	-Shape (dimensions) -Material -Layout	-Number -Configuration -Dimensions, -Material, -Visual qualities	-Dimensions, -Configuration -Operational control	-Dimensions -Material -Layout -Flatness

5.0 Environmental aspects

5.1 Visual issues

The two main visual issues to consider when investigating passenger accidents on local service PSVs are lighting and colour. A reduction in visual perception will result in an individual being more susceptible to spatial disorientation. In a moving environment, such as during a bus journey, the passengers as well as the bus will be moving, but the movements of both will be different, causing a reduced visual perception, which will result in spatial disorientation. This in turn will lead to an increased likelihood that a fall will occur (Gilmore, 1994).

The purpose of interior lighting in local service buses is to enable the gangways and the seating areas to be clearly seen by all passengers during the day or night. The lighting also needs to be sufficient to enable the driver to monitor the passengers and ensure no incidents occur, for example, a passenger being trapped in the doors of a bus.

The colours and colour combinations used for the interior of buses are important in determining the likelihood of slips and falls occurring, as some colours which have poor contrast rendering properties will result in passengers not being able to define the surroundings easily. Bright contrasting colours such as yellows and reds can improve the passengers' depth perception, while darker, harmonised colours, such as brown and blue, may blend the outlines and positioning of interior features and therefore confuse those with visual impairments. It is also important to remember that some colour combinations, such as yellow and red or blue and green will be difficult to distinguish by those with defective colour vision. Contrasting colours between seat backs and floors allow passengers to readily find a point to grab preventing or minimising falls (Byman and Hathaway, 1994). Just as important is using a colour for handrails and stanchions which will make them readily distinguishable from the background and therefore easily visible to passengers. This is why in modern buses, handrails are generally a bright colour, such as yellow or orange. Standardisation of hand rail colour would also help people to locate them.

All steps on buses will often have a contrasting yellow stripe running the full width of the steps front edge. This is to aid proper foot placement while traversing the steps and so reduce incidents of tripping (Byman and Hathaway, 1994).

5.2 Hearing Issues

Improving the audible environment in particular can help to reduce falls on public service buses in terms of increasing the information conveyed to the passengers. Examples include audible announcements of the buses' next stop and for when the bus is slowing down (Shaw, 1989). This is particularly relevant to passengers with mobility difficulties, encumbrances and visual impairments.

Auditory information can also be used to assist the driver. For instance, if the drivers view of the passengers boarding and alighting the bus is limited, an audible warning of passengers or luggage in the doorway would be useful in reducing the likelihood of passenger entrapment in closing doors. (Spencer, 1996).

5.3 Summary

By combining the use of audible and visual information, the likelihood of an accident occurring can be reduced in a number of ways. These include using contrasting colours and efficient lighting make it easier for passengers to define the surroundings on a PSV and using vertical, rather than horizontal, visual cues to improve passenger spatial orientation. Auditory information can be used to provide passengers with advanced information about the bus's movements and inform the driver of doorway or other obstructions, if the visual information is inadequate.

6.0 Passenger Issues

According to current statistics, passengers who use local service PSVs are most likely to be elderly and female. For example, Leyland Vehicles Ltd. and MIRA (1980) reported from the National PSV accident survey that accident rates for females aged 60 or over were four times the rate of males over 60. The issues of passenger age and gender will be discussed in this section to determine how they could influence the likelihood of accidents occurring, as will the importance of designing buses for the most vulnerable passengers and those who are the most frequent local service bus users.

In addition, issues concerning passengers with mobility difficulties will be discussed. This includes both wheelchair users and those with ambulatory disabilities. Unlike wheelchair users, people with ambulatory disabilities can walk, but only often with difficulty, and includes those with varying degrees of illness or infirmities as well as many elderly people (Paper I - Petzäll, 1993). A study carried out in the late 1980's by the Office Population Census Surveys (OPCS) (McKee, 1996) suggested that in the UK, around 6.5 million people have some form of disability, of which 6 to 7% of these are wheelchair users, two thirds have some form of mobility difficulty (around 7.5% of the total population) and two thirds are aged 60 or over.

6.1 The Elderly and those with Ambulatory Disabilities

A number of studies from the 1970s, mentioned in Oxley and Benwell (1985), found that about 4 million people were unable to use, or had great difficulty using, public service buses and a further survey of the elderly in 1982 (also mentioned in Oxley and Benwell, 1985) found that 9% of over 65s were unable to use buses due to physical difficulty and 16% were able but with great difficulty. The main problems reported by less mobile bus passengers in using public service buses were the height of the steps while boarding and alighting and the fear of falling when the bus was in motion (Gilmore, 1994, Oxley and Benwell, 1985, Shaw, 1989). The most difficult stages of a bus journey for elderly passengers and those with ambulatory disabilities involved reaching a seat while the bus was moving and getting up from a seat to ring the bell and reach the exit before the bus stopped (Oxley and Benwell, 1985).

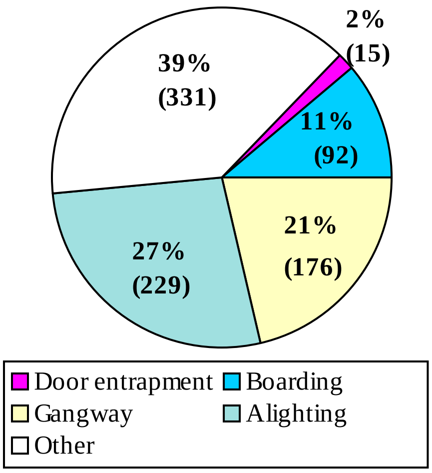
It appears that elderly passengers are over-represented in accidents, particularly in non-collision accidents (Gilmore, 1994, Leyland Vehicles Ltd. and MIRA, 1980), with the casualty rate for the over 60 age group for the years 1980 to 1984 being 56% higher than the average for all passengers (White et al., 1995). Similarly, a study by Colski (1991, in White et al., 1995) found that in 1990, 40% of bus passenger casualties were over 60. Of these, 36% were standing and 23% were boarding or alighting. As part of the National PSV Accident Survey (Leyland Vehicles Ltd. and MIRA, 1980, Fruin et al., 1994), it was found that for non-collision accidents, approximately 36% of passenger casualties were aged 60 or above compared to 48% who were under 60.

PACTS (1995) carried out a study using accident data provided by the London Accident Analysis Unit for inner and outer London areas for the years 1991 to 1993. Of the 770 accidents, there were 868 slight and 101 serious casualties aged 60 or above. The number of passenger casualties for various circumstances is displayed in Table 9 and is reproduced from PACTS (1995).

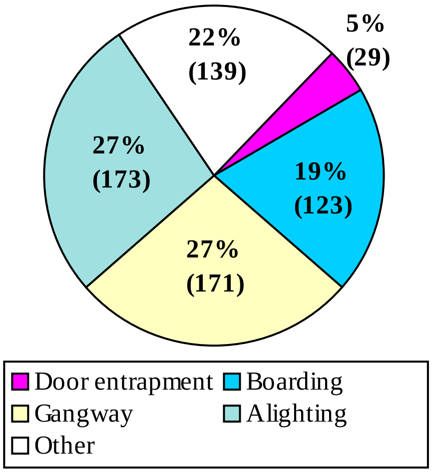
Table 9: Casualties by age, severity of injury and by impact or other circumstances (Inner and outer London, 1991 - 1993)
(Adapted from PACTS, 1995)

Circumstances	Severity	Passengers 80s	Passengers 70s	Passengers 60s	Older (60+)	Younger (- 60)	All	Driver
Impact	Serious	9	16	15	40	11	51	5
	Slight	35	100	161	296	197	493	14
	Totals	44	116	176	336	208	544	19
Other	Serious	10	25	26	61	16	77	0
	Slight	88	215	269	572	109	681	3
	Totals	98	240	295	633	125	758	3
All	Serious	19	41	41	101	27	128	5
	Slight	123	315	430	868	306	1174	17
	Totals	142	356	471	969	333	1302	22

The proportion of boarding and door entrapment accidents experienced by elderly passengers (60 or above) were found to be significantly greater than for the category of passengers under the age of 60 in the National PSV Accident Survey (Leyland Vehicles Ltd. and MIRA, 1980, Fruin et al., 1994). However, there appeared to be no difference between the proportion of alighting accidents (not including door entrapments) occurring to passengers aged 60 or above and passengers under 60. No significant difference was found between the two age groups for gangway accidents in general. However, when only gangway accidents which occurred while the bus was moving off are considered, a greater proportion of these accidents occurred to the over 60s. Figure 5(a) and 5(b) displays a comparison of the proportion of passenger casualties for each non-collision accident type with age.



(a) Under 60



(b) 60 or older

Figures 5(a) and (b): National PSV Accident Survey: Non-collision casualties by age (adapted from Leyland Vehicles Ltd. and MIRA, 1980, and Fruin et al, 1994)

The study by PACTS (1995) stated that the most frequent circumstances of injuries occurring to elderly passengers was when the bus braked suddenly to avoid a collision. This accounted for 45% of the injuries which were sustained in the 770 accidents analysed in this study, with impact accidents accounting for 35% of injuries. The trends in the type of injuries suffered by elderly passengers appear to be no different to the younger passengers, except for a slightly higher incidence of cuts, grazes or bruises to the feet and legs among the over 60s (Leyland Vehicles Ltd. and MIRA, 1980).

It has been reported that falls are a leading cause of accidental deaths in the over 65s and they are twelve times more likely to occur to this age group than all other age groups combined (Redfern et al., 1997). The main reason for this is because of a decline in postural control in the elderly which leads to an increased sway compared to younger adults. This will directly influence the likelihood of a fall occurring, particularly when this effect is added to the effect of being situated in a moving environment such as during a bus journey. It is often for this reason that passengers with ambulatory disabilities will also be more susceptible to falls.

6.1.3 Flooring Conditions and the Ability to Stand

Many passengers who have ambulatory disabilities will find it particularly difficult to stand for any period of time. Frye (1996) reported that 34% of public transport users with disabilities of could not stand up without discomfort for more than 9 minutes (20% no more than 4 minutes), while 76% of those with more severe disabilities could not stand up for more than 9 minutes (61% no more than 4 minutes). It is therefore important that some seats near bus entrances and exits are clearly signed as being priority seats for the elderly and those with ambulatory disabilities.

Petzäll (Paper III - 1993) explored the idea of adapting buses to meet the needs of the elderly and those with ambulatory disabilities by using a test bus to investigate the design of entrances and seats. It was found that low steps, of uniform height, improved boarding and alighting the bus, as did the handrails used. These consisted of two vertical stanchions on either side of the entrance, with one handrail on either side connecting the two stanchions and a further rail located from the top of the steps to the driver.

To try and overcome the main fears and difficulties many elderly people and those with ambulatory disabilities may experience with boarding and alighting a bus, due to either the height of the first step or the gap between the bus step and the kerb, modifications to buses have been introduced in the form of low floored buses and “kneeling” buses (Mueller-Hellman, 1989).

Kneeling buses reduce the height from the ground to the first bus entrance step to within four to six inches therefore increasing the safety, comfort and accessibility of boarding and alighting, especially for passengers with ambulatory disabilities. However, this mechanism has a number of disadvantages which cause drivers to dislike it. It has been known to lock in the kneeling position, particularly in extreme weather conditions.

Kneeling buses are also more expensive to maintain and require more maintenance compared to other buses and using the mechanism may increase journey times (Byman and Hathaway, 1994, Fruin et al., 1994). The effect of using a kneeling mechanism on journey time can be curbed by allowing the driver to control the mechanism and decide whether it is required at a bus stop for a particular passenger (Paper I - Petzäll, 1993). Also, some European countries use a driver pre-selected automatic kneeling.

A low floored bus provides a permanent reduced distance between the ground and the vehicle floor. Its main advantage is that it will take a reduced amount of time for less able passengers to board and alight the bus (Fruin et al., 1994). However, due to the tyre size used on buses, the main disadvantage will be that the wheel housing will take up a substantial space inside the bus, leaving less space for seating (Petzäll (Paper I), 1993). The new European directive for bus and coach construction, as described by Lancastrian (1997) does not make the current design of low-floor buses mandatory, but does favour them.

6.2 The Wheelchair User

Up until recent years, accessibility for wheelchair users has not really been considered in the design of local service buses. However, due to changes in current European regulations (Lancastrian, 1997), passengers using wheelchairs are required to be considered in bus design so that there is at least enough space for one wheelchair user at any time on a bus. It is therefore important that safety issues concerning wheelchair using passengers travelling on local service PSVs are considered when designing new vehicles.

6.2.1 Mechanisms to Assist Boarding and Alighting

Passengers using wheelchairs will experience similar stages of bus travel to most bus passengers. However, they will require some form of assistance in boarding and alighting in the form of either physical help from attendants or from a mechanical appliance and they will need to have their wheelchair restrained in the vehicle instead of taking a seat (Petzäll (Paper I), 1993). There are a number of mechanisms which can be used to assist wheelchair users when boarding and alighting buses including ramps and lifts.

Two categories of lifts have been identified (Byman and Hathaway, 1994), either passive or active. Passive lifts extend from the entrance steps to provide a platform and can perform as vehicle stairs when not in use. Active lifts consist of a platform which is fitted into the vehicle and can be operated by a number of mechanisms.

The placement of the lift within the bus can have its advantages and disadvantages (Byman and Hathaway, 1994). Placement at the front of the vehicle can mean that the passenger is close to the driver, therefore it is easier for the driver to assist passengers using wheelchairs and the passenger will experience a more comfortable ride. However, it may be extremely difficult for both wheelchair users and passengers with ambulatory disabilities to board at the same time through the same door and securing wheelchairs into position may interfere with other passengers boarding.

Lift placement at the centre of the vehicle, rather than at the back, will mean that the passenger will be closer to the driver. It would be simpler for passengers with ambulatory disabilities and wheelchair users to board simultaneously and wheelchair passengers will have the most comfortable ride travelling at the centre of the bus. The main disadvantage is that the bus has to be at least 28 feet long for a lift to be placed at the centre of the vehicle (Byman and Hathaway, 1994).

Placement of a lift at the side/rear of the bus can be the easiest location to load and secure passengers using a wheelchair as it does not interfere with other passengers boarding. However, rear placement gives the roughest ride to those who are motion sensitive, increases the time it takes the driver to assist passengers with disabilities and those waiting to board or alight may have difficulty in gaining the attention of the driver. In addition, rear wheelchair lift placement may block the emergency exit and debris from the rear bus wheel may get under the lift and cause malfunctions.

One alternative to using lifts to board and alight wheelchair users is to use ramps, either manual or mechanical. The ramps should have similar safety requirements to lifts in terms of load, surface and barriers. One main disadvantage of using ramps as opposed to lifts is that there will be a greater physical demand placed on the driver or operator (Byman and Hathaway, 1994). Spencer (1986) describes three main types of access ramps. The under-floor telescopic ramp is the most common form of powered ramp and is located below the floor, where, when required, it projects outwards and hinges downwards to reach the kerb or road. In-floor telescopic ramps are located within the structure of the floor. The process of operation involves the whole unit hinging downwards followed by the extension of a further telescopic component from within the device. Both of these devices can be complex to install in the vehicle. A third device, known as the hinged ramp, is the simplest available configuration which can be either manually or mechanically operated. When not in operation, it is kept “folded” within the entrance door structure, but when deployed, it “unfolds” until the end of the ramp makes contact with the kerb or road.

Low-floored buses can also make it possible for wheelchair users to board and alight buses by eliminating the need for entrance steps, particularly when coupled with a kneeling mechanism. This should ensure that wheelchair users will be able to board the bus with minimal help from an attendant or the driver.

6.2.2 Safety During the Bus Journey

Up to now, only the process of wheelchair users boarding and alighting has been discussed. However, passenger safety during the bus journey is equally important. Mobility aids such as wheelchairs need to be secured within the bus in case of sudden braking, jerks or sharp bends during the bus journey, as do the wheelchair users themselves, so they are provided with postural support (Petzäll (Paper II), 1993).

6.3 Gender differences

A report by Leyland Vehicles Ltd. and MIRA (1980) on the National PSV accident survey found that more female passengers were injured than male passengers in all types of accidents (72% were female compared to 25% male). When only collision accidents are analysed, 66% were female casualties and in non-collision accidents, 73% were female. When these figures are compared with the proportion of male and female passengers using buses, it can be seen that the proportions are similar (69% female and 31 % male - figures from survey carried out by the National Bus Company in Leyland Vehicles Ltd. and MIRA, 1980). However, in most of the industrial towns surveyed, the percentage of male passengers increased to 40%, therefore suggesting that female passengers have been involved slightly more often in accidents.

The characteristics of accidents occurring to male and female passengers were outlined by the national PSV accident survey (in Leyland Vehicles Ltd. and MIRA, 1980). No significant differences were found for most of the accident characteristics, with the exception of accidents occurring in the gangway, where accidents to females were highly represented, and for staircase accidents were the proportion of male casualties was much higher than for female casualties.

Very few notable differences were found in the type of injuries sustained by male and female casualties using the data from the National PSV accident survey (Leyland Vehicles Ltd. and MIRA, 1980). It appeared that shock made up a larger percentage of all injuries sustained by female passengers compared to male passengers (15% compared to 9%), as did cuts, grazes and bruises to the leg or foot (25% of all injuries sustained by female passengers compared to 14% of all injuries sustained by male passengers). However, cuts, grazes and bruises to the head or neck made up a larger percentage of all injuries sustained by male passengers compared to female passengers (41% compared to 25%). Figure 7 shows how the percentages differ for all types of injuries sustained by male and female passengers.

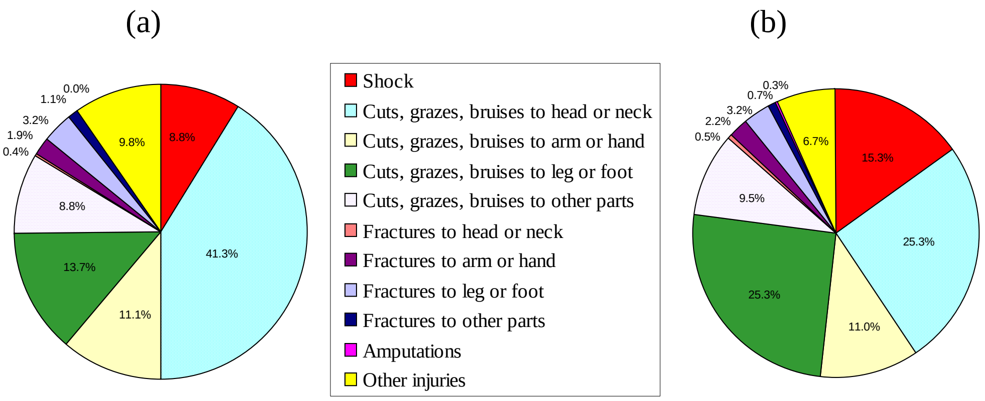


Figure 7: Frequency of types of injuries for (a) male and (b) female passengers casualties (adapted from Leyland Vehicles Ltd. and MIRA, 1980).

6.4 The encumbered bus passenger

As well as the large proportion of people using buses who have to some degree ambulatory disabilities, many other passengers may have mobility difficulties when using buses, in the form of encumbrances such as luggage, heavy shopping, young children and prams, or the slightly longer term burdens of a broken limb or pregnancy (Frye, 1996). Many passengers are very reluctant to use luggage pens provided in the bus for their encumbrances such as shopping or prams as they dislike being separated from their possessions because of security reasons and, particularly on busy occasions, it may be difficult to collect baggage before alighting if other passengers are standing by the luggage pens. This therefore leaves many luggage pens under-used and passengers encumbered for the duration of their journey.

There are a number of safety issues related to passengers keeping their encumbrances with them throughout their journey. Firstly, the passenger would have greater difficulty finding a seat as they would not be able to manoeuvre around as easily, then, if a seat was found, there would be little room for encumbrances to be placed. This may lead to aisles being blocked by baggage, creating a tripping hazard for other bus users. If a seat was not found and an encumbered passenger was required to stand, their ability to stand with ease while the bus was in motion would be reduced. Standing while carrying a load may also be a hazard to other seated bus users, as when the loaded passenger attempts to move up or down the aisle, seated passengers may be struck by standing passengers' encumbrances, depending on what height the encumbrances are being carried at. Unfortunately, none of the literature studied contains any information on the frequency of accidents involving encumbrances.

Encumbered passengers were found to have difficulty with most stages of bus travel, including boarding, alighting, paying or showing passes, moving up or down the aisle and being seated (Field, 1993). Features on buses which are implemented to make buses safer and more accessible to elderly passengers and all those with disabilities can also increase accessibility for encumbered passengers. Features such as lifts and ramps particularly help passengers with small children in push chairs and prams, as can low-floored and kneeling buses. In fact, it was reported by Frye (1996) that the introduction of low-floor buses brought about a much higher rise in the average number of trips made by passengers with push chairs than other passengers both with and without mobility difficulties (Figure 8).

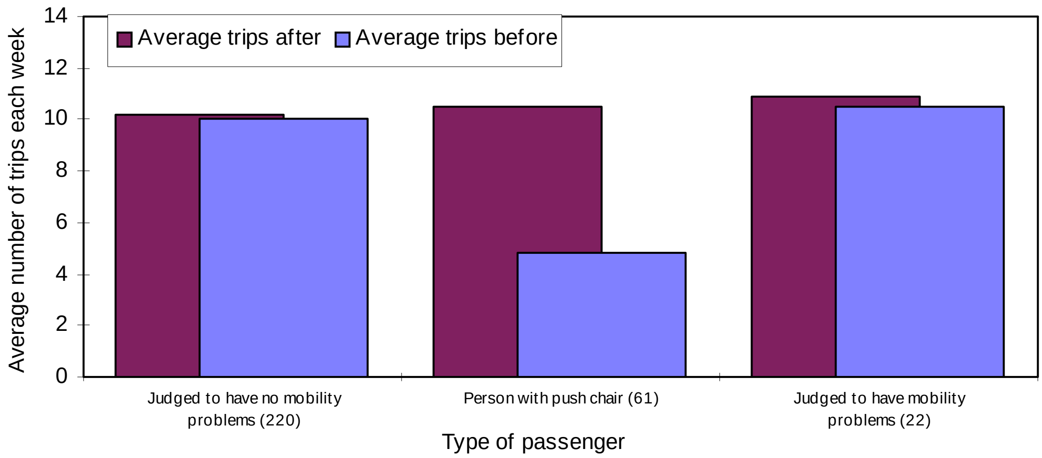


Figure 8: Average number of trips made before and after low floor introduction (adapted from Frye,1996).

A comprehensive study by Field (1993) on bus design for the encumbered passenger found that the problems experienced by encumbered passengers can be sufficient to dissuade them from bus use. It was also found that luggage pens are under-used, but when they are used, they were described as being poorly designed for the users' needs. Some passengers did not even realise that luggage pens were available. Another suggestion was that luggage pens would be more frequently used if passengers could sit close by.

An innovation which could ease the burden of passengers with young children in push chairs is the tip-up seat. The tip-up seat could be used as seating for all passengers, but when required, could be prioritised for use by passengers with young children to accommodate push chairs and would mean that passengers would be able to sit nearer their push chairs, and their children would not need to be removed from them (Coach and Bus, 26 March 1998). The ability to move seats or fold them away would also be helpful during certain times of the day to increase the amount of luggage and standing space, so that passengers could be nearer to their encumbrances without causing as much of an obstruction as they would do in the gangway (Churchill, 1997).

6.5 Summary

6.5.1 The Elderly and those with ambulatory disabilities

It appears that the over 60 age group are over-represented in bus accident casualty rates and in the bus user population as a whole, therefore their needs and the needs of those with ambulatory disabilities should be a high priority in the design of local service PSVs. Boarding, alighting and reaching or leaving a seat were found to be the most difficult actions, while nearly half of all injuries sustained by elderly passengers occurred when the bus braked suddenly. Traversing steps, grabbing on to rails and controlling posture in a moving bus were found to be the most difficult actions to accomplish. A number of modifications have been introduced to improve accessibility and safety for less able passengers, including low floor and kneeling buses and auxiliary steps.

6.5.2 The wheelchair user

Although some mechanisms have already been introduced to assist and encourage elderly passengers and those with ambulatory disabilities to use local service PSVs more often, there is still some way to go in assisting the wheelchair user. However, new innovations are being introduced in modern PSVs to achieve this. Mechanisms to allow easier entry and exit for passengers using wheelchairs include various lift or ramp mechanisms, as well as low floor and kneeling mechanisms. When boarded, it is important that the wheelchairs and their occupants are both secured in case of sudden movements and that sufficient space is set aside for wheelchair users.

6.5.3 Gender differences

Statistics show that bus accident casualties are more often female than male. Female passengers were found to be highly represented in gangway accidents, whereas males accounted for a high proportion of staircase accidents. Head and neck injuries were found to be associated more with male passengers while female passengers tended to suffer more from shock or leg and foot injuries.

6.5.4 The encumbered passenger

Encumbered bus passengers have similar problems in using local service buses to the elderly and those with ambulatory disabilities. The encumbrances they carry often reduce their postural control, increasing the likelihood of a fall occurring. In addition, encumbrances can be a safety hazard to other bus passengers, if aisles are blocked or seated passengers are struck by baggage being carried by standing passengers. To overcome this, luggage bays and spaces for children in prams should be located nearer to seats. Boarding and alighting could also be made easier by introducing mechanisms similar to those which would be useful for elderly and all passengers with disabilities.

6.5.5 The hazards of moving buses

As this literature review shows, there are numerous issues involved in passenger safety when using Local Service PSVs, including the designs and placement of features, bus accessibility and the requirements of passengers including the elderly, those with disabilities and the encumbered. However, one issue which has not yet been discussed in any detail, which if ignored will result in the re-design of buses being of little effect to passenger safety, is driver behaviour and operational practice. If the bus did not move off from the bus stop until all passengers were safely seated or passengers did not stand from their seat until the bus had stopped, it would be inevitable that the number of accidents on buses would be reduced. The introduction of this practice may cause some concern to bus operators regarding journey times and operating costs. However, a study by Oxley and Benwell (1985) found that, for the worst possible circumstances where each passenger boards one at a time and is allowed to get seated before the bus moves away and stays in their seats until the bus stops, only adds about 40 seconds in the hour of running time, which is approximately a 1% increase.

7.0 Review of accident data

7.1 Definition of local service buses

The definition of a local service Public Service Vehicle was determined as the following:

> 'any vehicle used for local bus services. These are likely to include single and double decker vehicles and Mini/Midi vehicles. All of the above could be either low floor designs or standard floor designs. Some coaches (generally older vehicles) are also used for local services and would therefore be included.'

One main group of public service vehicles that have been excluded from this study are vehicles used for school bus services, as these are generally operated by, or on behalf of, the local authorities and therefore come under different legislation. However school children travelling on normal local bus services/routes have been included in the research.

7.2 STATS 19 data

The national census of accidents in Great Britain was used to provide an overview of the numbers and crash circumstances of PSV collisions that result in injury. The years 1991 - 1996 inclusive were considered. Accidents involving PSVs with injured passengers were selected for examination, however the appropriate correlations were not available in the published Road Accidents of Great Britain (RAGB), and therefore the STATS 19 division at DETR provided a detailed data set based on selected criteria.

7.2.1 Criteria for STATS 19 search

7.2.1.1 Speed limit (section 1.15 in STATS 19 form)

Local service buses spend the majority of their time in the urban and suburban environments and therefore most incidents/accidents occur at relatively low speeds. As STATS 19 does not identify buses and coaches separately, a method was needed to minimise the number of coaches appearing in the dataset. Therefore the main identifier for local service buses which was available from STATS 19 information was the speed limit in force at the accident location.

In order to focus on urban roads and to filter out any accidents happening to vehicles such as intercity coaches, a 40mph speed limit was selected. As a consequence, the majority of A-roads, duel-carriageways and motorways would be excluded.

However it was considered that there may be a limited number of accidents occurring which fall outside the general criteria. For example, it was envisaged that there may be some intercity coach accidents that occur during the time that the coach is in the urban environment. Also some local service routes may take in some rural roads which have speed limits higher than 40mph.

For the purpose of the data set only accidents that have occurred to any bus, coach or Minibus, on roads with a speed limit of up to and including 40mph have been reviewed.

7.2.1.2 Type of vehicle (section 2.5)

Two coded categories of the vehicle type were used for the selection criteria:

10 - Minibus/motor caravan. Included within this category would be Minibuses equipped to carry less than 17 seated passengers, micro-buses, post buses, Dial-a-bus services and motorised caravans;

11- Bus or coach. This category is determined by the construction of the vehicle rather than its use. All buses or coaches equipped to carry 17 or more seated passengers would be in this category regardless of whether or not they were being used ‘in stage’ operation.

7.2.1.3 Casualty records (section 3.16 Bus or Coach Passenger)

All codes under this heading were included within the selection criteria other than ‘not a bus or coach passenger’. This criteria was excluded as it covers people who have successfully alighted from a vehicle and are then involved in an accident.

Because of the definitions of the coding system, care had to be taken while reviewing data. For example, an alighting or boarding passenger would still be classed as such even if they had been hit by another vehicle in the process. However a passenger who was walking towards a door to alight would not be classed as an alighting passenger, but as a standing passenger.

Drivers/conductors are excluded from the definition of passengers, however depending upon the data source they may appear in the accident statistics as passengers.

7.2.1.4 Severity of Casualty (section 3.9)

Accidents in RAGB are usually categorised by the accident severity rather than the casualty severity. For example, when a passenger in a car which has been hit by a bus is killed the RAGB classification would count it as a fatal accident involving a bus.

When developing the selection criteria for the STATS 19 data search all information relating to the severity of the accident is based on the severity of injury of the bus passengers and not the general accident.

Fatal cases are classified where death occurred within 30 days of the accident, as a direct result of the accident.

Serious injuries were classified as those generally requiring hospital treatment, and slight cases were those who suffered bruises, slight cuts, shock, etc. which did not require hospital treatment.

7.2.1.5 Age of casualty

Finally, information relating to the age of the subjects was collected. This was further classified at a later stage into the following definitions as defined in bus and coach legislation:

0-2 years - babies
3-15 years - children
16-64 years - adults
65+ years - elderly

7.3 STATS 19 results

The following figures show the breakdown of all injury severities against the passenger action at the time of the incident. These have been grouped for both collision and non collision accidents.

Figure 9: Fatal cases 91-96 by activity (collision and non collision accidents)

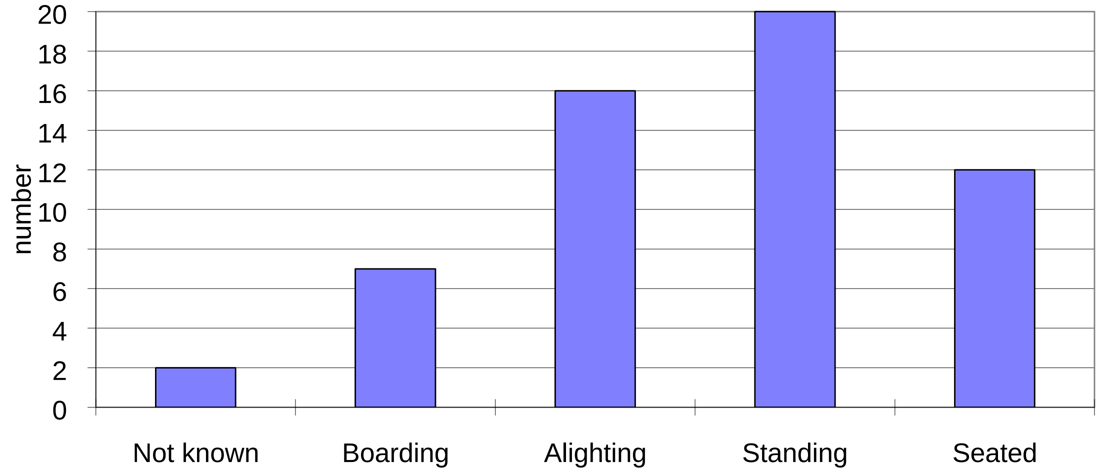


Figure 10: Serious cases 91-96 by activity (collision and non collision accidents)

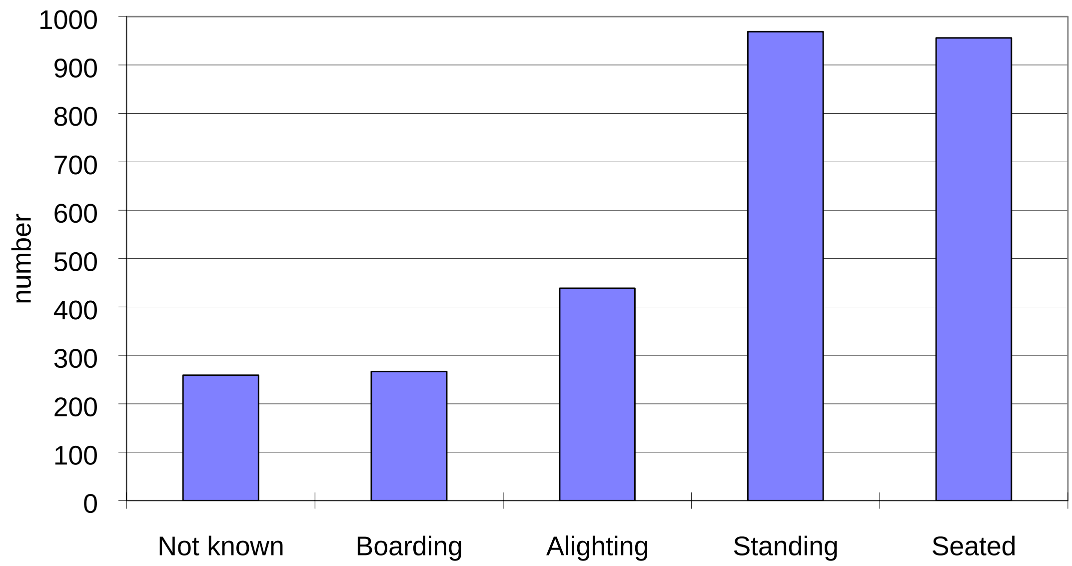
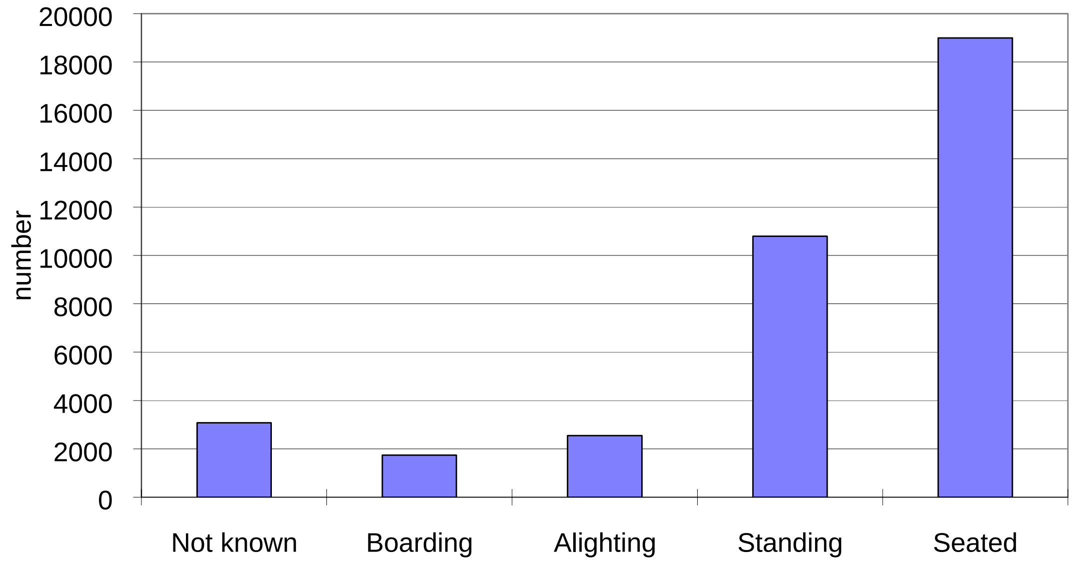


Figure 11: Slight cases 91-96 by activity (collision and non collision accidents)



The tables show that there is a similar pattern occurring with all severities regarding the actual passenger action. What is interesting is that the number of standing fatalities is double that of those who were sitting, however the number of slightly injured, seated passengers is nearly double that of the standing passengers who received a slight injury. This information was used as a bench mark to compare and contrast the more local information.

7.4 Police information

detailed data the STATS 19 data set was initially refined by DETR to give the following information:

- a five year time span was considered for the years 1992-1996. This highlighted a total of 44 cases where a passenger had been killed;

- for all the fatal cases the police reference code was obtained together with the date of the accident and road number. These were collected to allow individual cases to be identified more effectively;

- The same information was collected for the serious cases, and a total of 66 serious cases were received, covering the years 1993 to 1996 inclusive. This sample was selected from both Nottinghamshire and Leicestershire as the Vehicle Safety Research Centre (VSRC) at ICE Ergonomics has good working links with these forces and this would be paramount when following up individual cases.

7.6 Bus Operators' records

A number of major operators in the Midlands region were approached to provide detailed information about their records. Four major Midland operators agreed to provide details.

Arriva Fox County	31 cases
Derby City Transport	29 cases
Travel West Midlands (TWM)	26 cases
Nottingham City Transport (NCT)	159 cases
Total of	245 cases

A questionnaire was devised so that the appropriate information could be recorded from individual accident records.

More cases were reviewed from NCT because of their more varied vehicle fleet and the way in which their records were kept.

The sample from each operator was selected from recent records and generally covered the years 1997-1998. These years were selected to avoid duplication with the STATS 19 and Police data.

7.7 Operators' views

While collecting the accident data the views were sought of the operators themselves. Most of the contacts were with the staff within the insurance divisions of the company. They were asked to comment on any specific problems about the interior design of buses and the most frequent types of incidents that occur.

One operator, whose fleet covered over 14 million miles a year, stated that on average they get about 200 injuries per year. It was stated that most incidents that caused passenger injuries were either when buses braked sharply to stop or while they were travelling around corners. Another cause was pulling away sharply, and the reason given was that on some buses the automatic transmission engages second gear with a jerk almost as soon as the bus pulls away from the stop. Regarding the design of the interior of buses the following comments were received:

- where seats are positioned with no grabrails in the immediate area for the occupant to use there was a general feeling that the occupants on these seats have a higher risk of being thrown from their seat;

- in particular for mini/midi buses, passengers sitting on the central seat at the back of the bus tended to be exposed to a number of incidents. It was thought that they tend to get thrown off their seat as there are generally no grabrails to hold on to;

- floors were highlighted as causing some problems. Operators commented on wet floors causing people to slip. In autumn and winter, leaves and snow exaggerate this problem. Worn floors on older buses, or floors that have been patched, were also highlighted to cause slipping;

- on a number of low floor bus designs, some anniversary (sideways facing) seats are mounted on plinths. It has been found that these plinths, which protrude into the aisle, cause tripping hazards. The height and shape of the plinth has also caused cuts and bruises to passengers' shins;

- steps on the inside of the bus were generally considered to be satisfactory as long as they are marked well with edge markers. On low floor buses the change in floor height towards the rear of the bus tends to be greater. This necessitates a greater number of steps, or steps that have a higher rise. One vehicle, based on a Volvo Olympian chassis, was considered to have a design problem as a result of internal steps. The steps at the rear of the bus effectively reduced the headroom significantly for the rear-most passengers. The operator had found that while passengers were negotiating the steps, they banged their heads on the ceiling. Complaints by passengers had resulted in the operator positioning ‘mind your head’ signs in the vicinity;

- passengers have been found to struggle with luggage racks, but no injuries have been reported. It was considered that the problem with luggage racks was as a result of their positioning within the vehicle. On most standard buses they tend to be placed directly over a wheel arch which results in them having high sides, making it difficult to lift objects into them. This problem is exaggerated on low floor vehicles. A number of incidents had been caused by passengers tripping over luggage/obstacles which had been left in the isle, perhaps as a result of finding it difficult to use the racks;

- road humps have caused a few problems on some buses. The problem is when the rear wheels tend to jump over the hump and any passenger who was sitting on the rear seat would be subjected to high vertical forces. It was stated that this phenomena is particularly relevant to mini/midi buses as the short wheel base and relative light weight add to the effect. However the speed at which the bus transverses the humps has the greatest effect on the safety of the occupants;

- A number of incidents were described that occurred as a result of passengers getting trapped in the centre doors. Some of these were put down to children playing with the doors. It was suggested that one of the main problems with centre doors is the fact that the driver of the bus in many cases cannot see what is happening at the centre doors.

7.7.1 Issues of passenger safety other than the internal bus design

There are a number of issues that have been highlighted by the bus operators which effect the safety of bus passengers and are secondary to the internal bus design. One operator stated that 90% of complaints received from passengers who had been injured are directed at the driver or the way in which the bus had been driven. Passengers have mainly complained that they have been injured as a result of the driver braking and accelerating too quickly.

Passengers have also complained of jerky driving and drivers who allegedly had a bad perception/anticipation of road traffic or conditions.

7.8 Limitations of the collected information

STATS 19 data. Because of the way the information is collected, the accuracy depends on who filled in the original form and the circumstances in which it was completed. It was noted that while following up some of the fatal cases the information recorded in the accident file did not tally with that recorded on the STATS 19 form. Information relating to the bus type was in many cases very vague.

Police information. The police files record details and witness statements in addition to the information recorded on the STATS 19 form. There tended to be a lack of detail about the bus type and the type of injuries sustained.

Operator information. There are a number of factors which tend to effect the accuracy of the operators' records. Records are usually based in the company's insurance section and therefore may be biased to control the amount of any insurance payments when considering insurance claims. Likewise, statements given by bus drivers may be biased in order to avoid responsibility or blame. Finally, statements from complainants may be biased to exaggerating the extent of the injury in order to claim more damages. In some cases it was even noted that people who were not on a bus involved in an incident claim they were injured on the bus after the incident was reported in the local paper.

7.9 Database

A central database was constructed in 'Access' so that the STATS 19, police records and Operator records could be entered. This would allow approximately 300 cases of all severities to be examined for trends.

7.9.1 Injury Coding

Wherever possible each injury was coded in order to facilitate the analysis. The coding system selected for use was the AIS (Abbreviated Injury Scale). It must be stated that due to possible inaccuracies with the original data collection, this system was used as a guide rather than to be a scientifically accurate recording of the injuries.

7.10 Data analysis

The age range of the all passengers involved in incidents is shown on the following charts.

Figure 12: Age range of fatalities

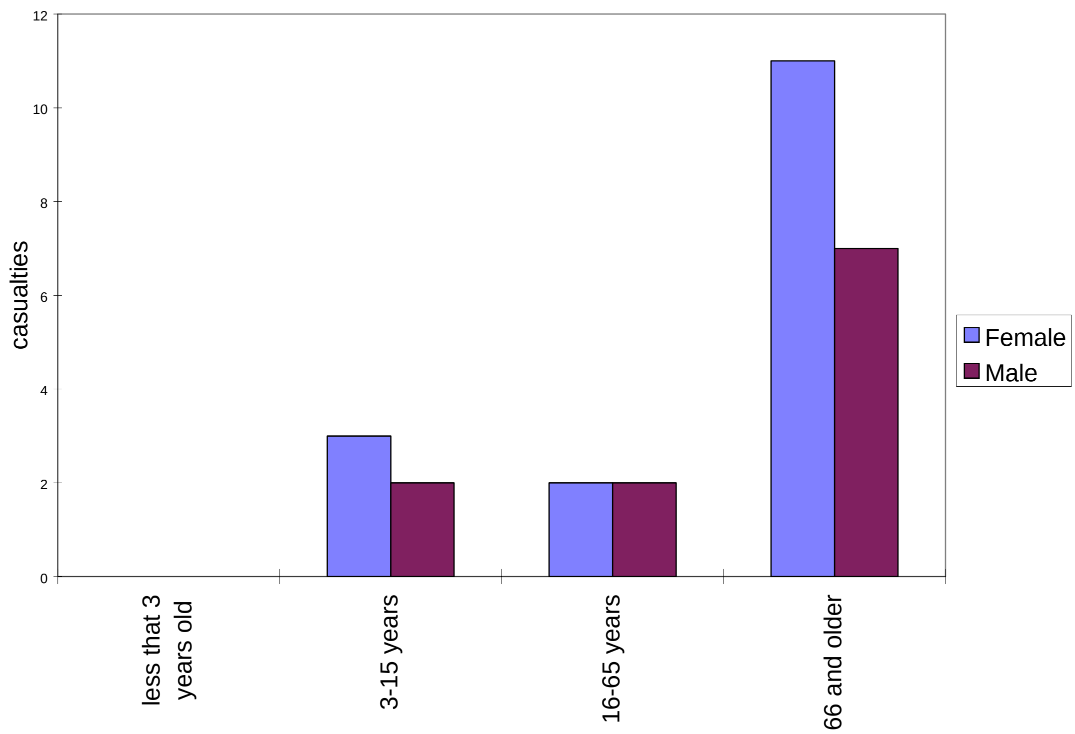
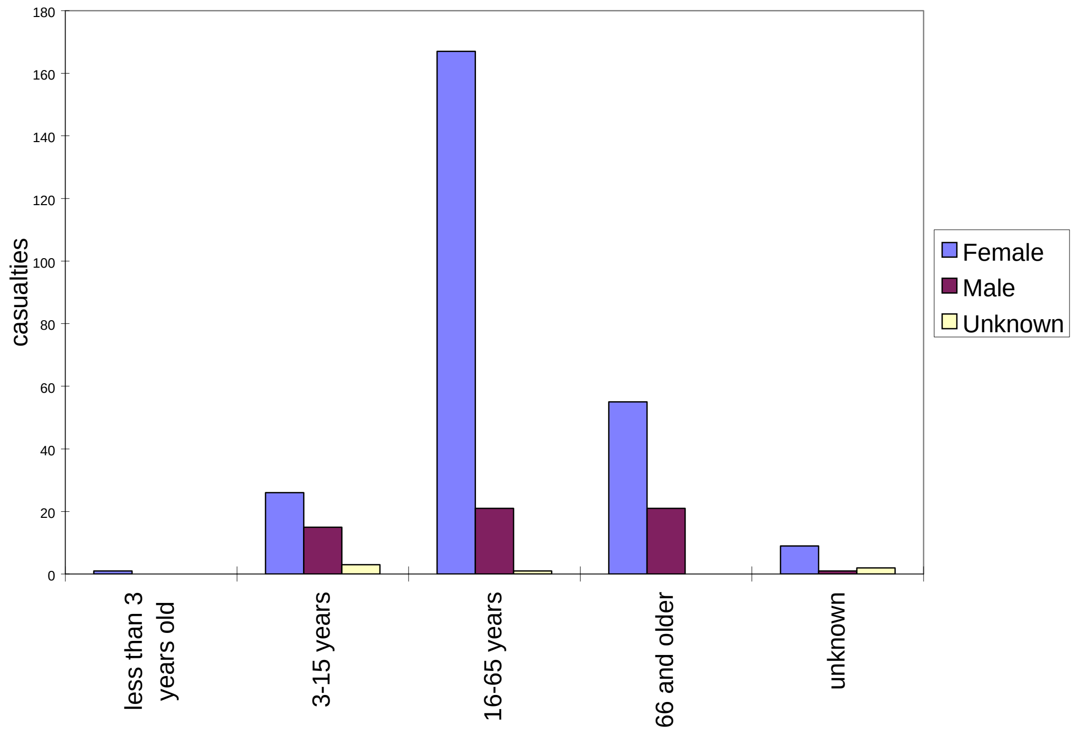
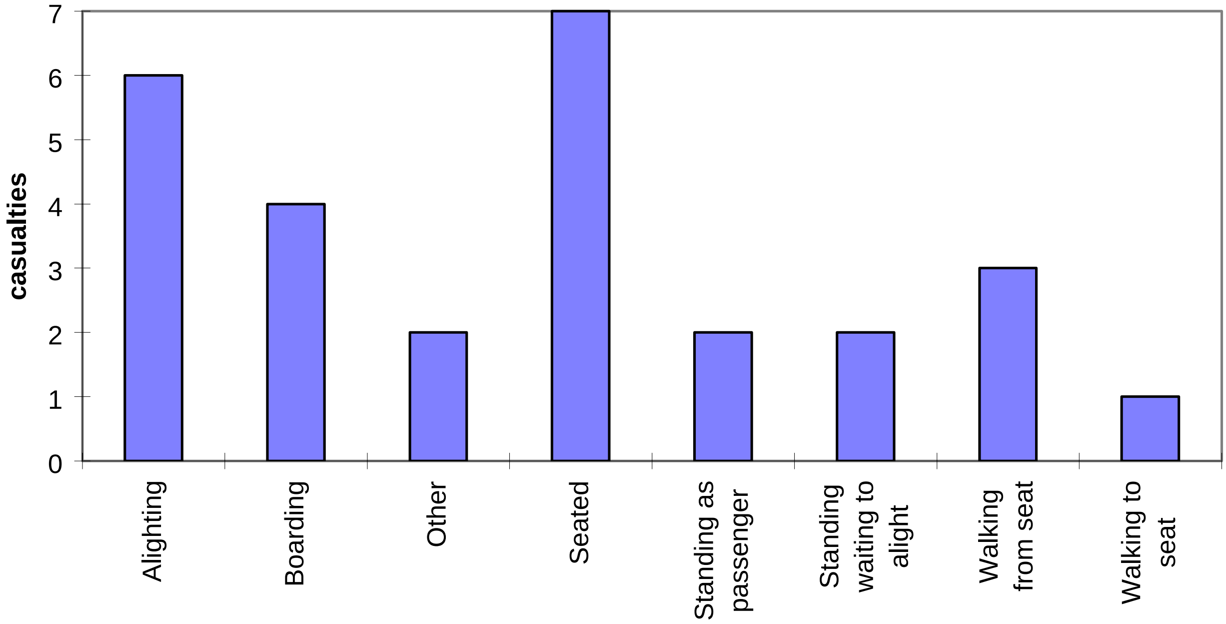


Figure 13: Age range of all severities



Considering the age range of passengers, as a percentage of all passengers elderly people are more likely to be killed in an accident. However, when considering all severities, adults suffer the greatest number of incidents. This is probably due to the fact that they are likely to be the largest bus user population although no national figures on passenger numbers were available. Elderly adults are also more likely to die from injuries. The following chart shows the passenger actions for the fatalities at the time of the incident:

Figure 14: Passenger action of fatalities



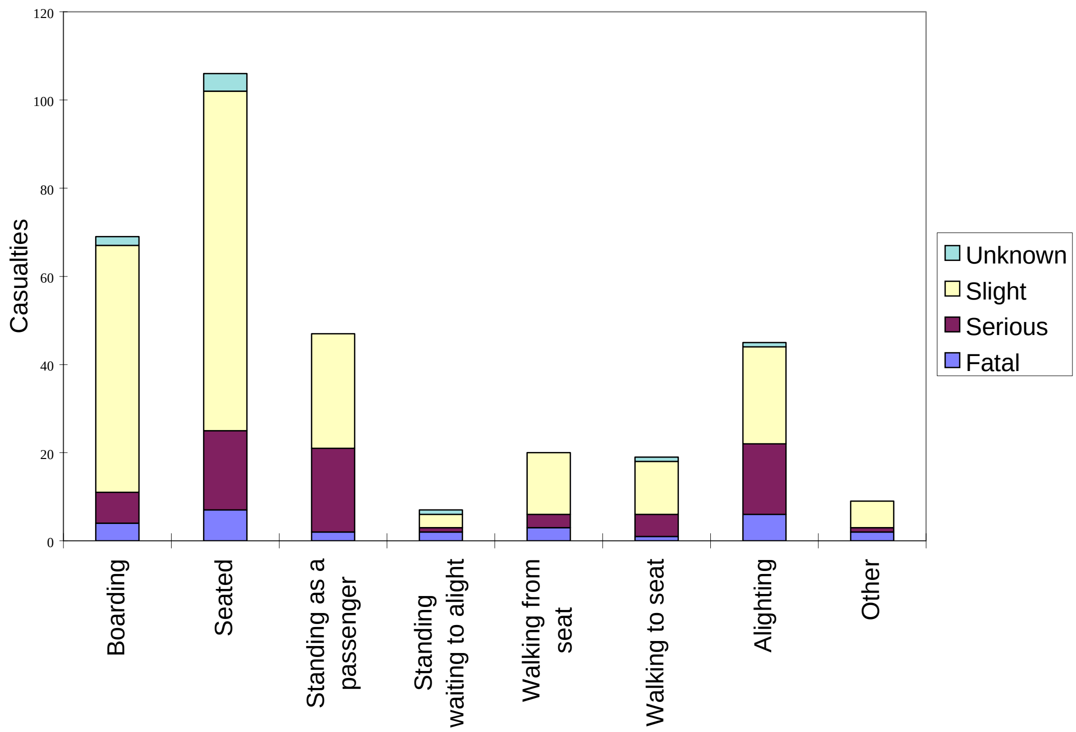
The seated casualties are biased by 5 people being killed in one incident. They were seated when the bus they were travelling on hit a bridge. All other fatalities were individual cases occurring in separate accidents.

Of all the other fatal cases, the individual killed was the only known casualty of any severity on the specific bus.

Discounting the five people killed in the single accident, most of the fatalities occurred to standing passengers. To gain some insight into what the bus was actually doing at the time of the accident the following figure shows for all fatalities, the bus action.

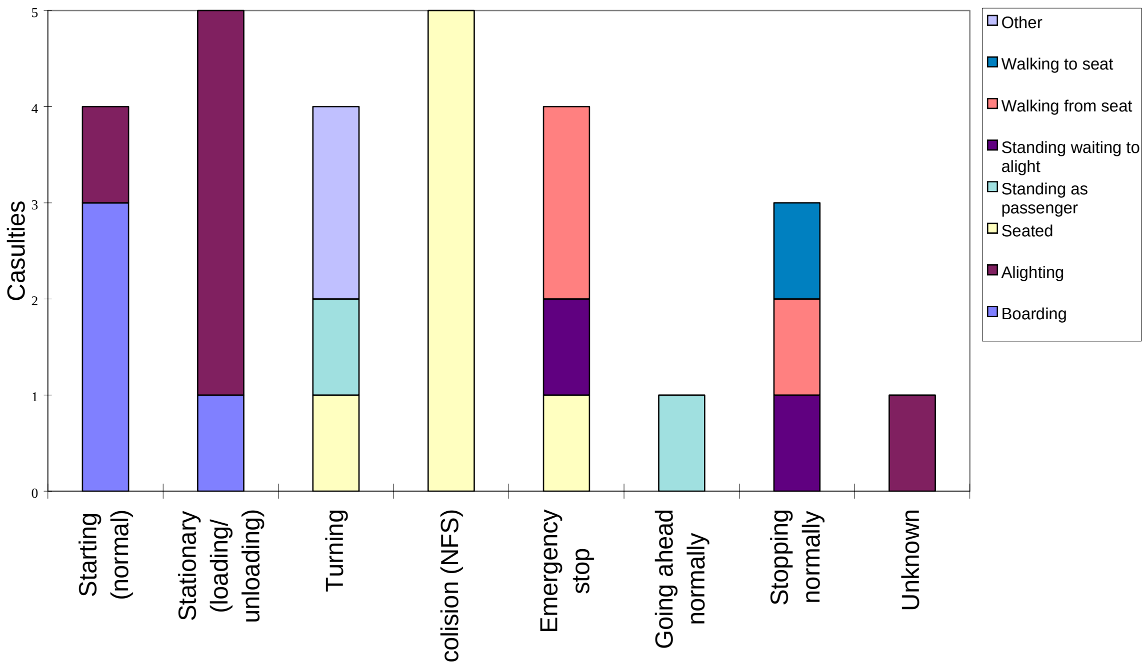
The following figure shows the passenger action for all severities.

Figure 15: Passenger action for all severities



There are a large number of slight injuries caused to seated occupants.

Figure 16: Passenger action and bus action for fatalities



NFS - Not further specified.

This chart shows the range of bus actions which have caused fatalities. The first column (bus starting to move off normally) shows that three passengers have been killed while boarding and one while alighting. However because of the way in which the data were recorded in STATS 19 it is not possible to be certain whether these 4 fatalities occurred whilst boarding or alighting with the bus stationary or whilst moving to or from the seat with the bus moving. This highlights the problems with the coding used in STATS 19 as described earlier.

The chart also shows that the majority of fatal injuries are caused when the bus is either accelerating or decelerating, as a result of normal road conditions, or as a result of an emergency situation. However, there is a distinct group of passengers who are involved in an incident with the door of the bus while alighting and boarding when the bus is stationary.

The following table shows for each of the fatalities, the passenger action, the AIS code (where information was sufficient to enable coding possible) and any notes which describe the circumstances of the incident.

Table 10: Passenger actions of fatal passengers (ranked using AIS code)

Passenger action	**AIS code**					**Accident notes**
Boarding	0	0	00	00	0	fell as doors closed and bus moved off while trying to get on
	1	1	50	99	9	getting on - fell when bus moved off - Routemaster (no door)
	1	1	50	99	9	lost grip on hand rail as boarded- fell off banged head on road
	1	1	50	99	9	got leg stuck in closing door- dragged along a bit as bus moved - stopped - door opened - fell to floor hitting head
Walking to seat	1	1	50	99	9	Passenger walking up stairs - hand rails wet slipped
Seated	0	0	00	00	0	bus hit bridge
	0	0	00	00	0	bus hit bridge
	0	0	00	00	0	bus hit bridge
	0	0	00	00	0	bus hit bridge
	0	0	00	00	0	bus hit bridge
	1	1	50	99	9	hit head on internal body work
	1	1	50	99	9	No information

Passenger action (cont.)	**AIS code**	**Accident notes**

Passenger action (cont.)	AIS code					Accident notes
Standing as passenger	0	0	00	00	0	passenger opened door while bus was going along- fell off
	1	1	50	99	9	Fell and hit head on internal body work
Walking from seat	1	1	04	02	1	Fell and suffered a head bruise
	1	1	50	99	9	No information
	1	1	50	99	9	No information
Standing waiting to alight	0	0	00	00	0	bus stopped suddenly -fell off
	0	0	00	00	0	bus stopping - fell onto road
Alighting	0	0	00	00	0	fell from platform onto road
	8	5	26	00	2	fractured hip
	8	5	20	00	2	broken foot, tried to grab rail while carrying shopping
	8	5	06	99	1	hip injury
	8	1	30	00	2	leg crush
	1	1	50	99	9	allegedly under the influence of alcohol - fell off bus and hit head
Other	0	0	00	00	0	passenger forced door open - fell off bus
	0	0	00	00	0	passenger hanging onto outside of bus - fell under wheels

7.11 Discussion

The data collected comprises over 300 cases including all severities of injury. The fatal cases are representative of all fatalities because they are a sample taken from the national population.

It is not known if the information regarding the serious and slight cases is representative of all the vehicle types involved in incidents. This is because the sample was based on a selection of Midland operators and it is not known whether those operators have a representative vehicle fleet. The age of the vehicles varied considerably from being less than a year old to over 20 years old and included a limited number of low floor single deckers. However the passengers are likely to be a good representation of the bus travelling public because of the catchment area considered within the study.

When reviewing the data no specific features on the inside of buses have been identified as causing a number of passengers to be injured. However there were a number of individual incidents which may have been avoided with different design. Likewise, no one particular vehicle had a higher percentage of incidents occurring on them.

7.11.1 Features causing injuries

Among the features which caused individual injuries were many items that are likely to be fitted to the bus, for or by the operator. Items such as ticket machines, card readers, change machines, waste bins etc. all caused a number of individual injuries. These items have been observed to be placed in a number of different areas on the same type of bus. Different operators have different specification requirements for these items and they tend to be added as a bolt on item rather than being integrated into the design of the bus. As these products tend to be a robust design they tend to have reasonably hard or sharp edges and their positioning usually results in them protruding into the space around the paying area or, in the case of card readers, positioned on the side of internal bodywork protruding into the aisle. A number of people have received cuts to the head from these items, some of which have been serious enough to require hospital treatment.

7.11.2 Stairways to upper deck

Stairways to the upper deck were only mentioned in a few cases. These generally tended not to cause too many problems. The instances reported were as a result of the passenger slipping when the bus braked or accelerated. Someone slipped on wet stairs and 2 people lost their balance and fell.

7.11.3 Aisle

A number of head injuries were caused by standing passengers who fell over in the aisle and hit the front bulkhead of the bus (the facia area to the left of the driver’s dashboard). In most buses the finish of this area tends to be either metal bodywork or hard plastic capping and is therefore a hard surface to impact. Other areas mentioned as being hit on the inside of the bus tended to be bodywork or grabrails.

7.11.4 Seats

Facial injuries were the most common injuries received by seated passengers. These tended to be as a result of passengers falling forward and hitting their face on the seat in front, as a result of a vehicle collision or emergency stop. Other incidents occurring to seated passengers involved passengers falling off their seat while the bus was negotiating a corner. One trend observed amongst the seated passengers was that on many occasions a number of passengers were injured as a result of one incident. This was the case for both cornering and braking related incidents.

7.11.5 Alighting

When walking from the seat and alighting most of the injuries were caused as a result of falls along the aisle, in the footwell, or actually falling off the bus. Almost all of the incidents in the aisle and footwell occurred when the bus braked suddenly, causing the passenger to loose balance. The majority of cases where passengers fell off the bus occurred when the bus was stationary although there were no cases reported where a passenger fell off a low floor bus.

7.11.6 Boarding

Injuries sustained while boarding and walking to the seat tended to be caused by passengers falling on steps and slipping on the floor. There were also a number of cases where passengers, or passengers’ luggage, was trapped in closing doors. A number of falls while boarding were blamed on wet floors. Passengers were also injured when they lost their balance and fell as the bus accelerated away from the bus stop. Internal steps were mentioned in a couple of instances where the passenger tripped while walking to their seat as the bus accelerated. When boarding a number of cases mentioned that the injured passenger was carrying shopping or bags and therefore did not have a free hand to hold onto a grab rail.

7.12 Conclusions

Passengers while standing or moving. Injuries occurring to seated passengers The accident data analysis has shown that, of the known cases which have been followed up, 66% of all fatal accidents occur to passengers while they are standing or moving on the bus. Discounting the case where five people were killed on the upper deck when the bus hit a bridge this percentage rises to 81%. When serious and slight cases were considered 73% and 63% of passengers respectively were standing or moving on the bus. Considering the known cases of all severities, 66% occur to tended to be less serious.

8.0 Review of vehicle design and current vehicle safety assessment

The review considered the safety of all passengers including children, the elderly and mobility and visually impaired passengers. The safety of the passengers was considered across a range of activities associated with bus use. Therefore such tasks as stepping onto the bus, paying for the ticket, walking to a seat, getting into and out of the seat, moving between decks and manoeuvring luggage/items such as shopping bags and pushchairs. The review also addressed the features which were highlighted in the accident and literature review and was undertaken by two means:

- Ergonomics and safety audit;
- Practical testing of current designs.

8.1 Ergonomics and safety audit

An audit was undertaken to review the key features that were highlighted from the accident information with the DPTAC guidelines and the DETR - Government's Proposals for Buses and Coaches - Consultation Document were considered which used relevant information from the Disability Discrimination Act 1995.

This audit was then compared with existing buses in service. A total of 20 buses were reviewed by measuring and making observations about the key features that had been highlighted in the accident review.

It was considered that the DPTAC guidelines took a thorough approach and represented in most cases, best ergonomics practice. The comparisons of the different bus dimensions, guidelines and legislation are shown in appendixes B1- Double Decker, B2- Midi/Mini and B3- Single Decker.

The principal areas highlighted in the accident review are discussed below:

8.1.1 Entrance and exits

The DPTAC guidelines and the consultation document state for a fixed suspension vehicle the initial step height should be no more than 250mm from the ground. With a kneeling suspension DPTAC states that the height of the first step before kneeling, must be less than 325mm. Of the buses measured the range of heights was between 230mm and 375mm. It was obvious that the older buses tended to have higher initial steps. All measures were from the top of the step to the road surface and therefore do not take into account kerb heights. As kerb heights tend to vary considerably, it would be unrealistic to measure the height of the step from the kerb.

As a number of injuries occur in the footwell it was considered that any subsequent steps after boarding should be avoided. DPTAC and the consultation document state that any additional steps should be between the heights of 150mm and 200mm. The heights of subsequent steps measured on the buses in service ranged from 120mm to 265mm. DPTAC also stated that any subsequent steps should have consistent heights (within 10mm).

The nosing on the risers on steps were well marked on some buses and very inconspicuous on others. DPTAC states that the nosing should be in a bright contrasting colour. It was noted that on some of the buses measured, in particular the older vehicles, in service repairs to the surfaces of the steps had resulted in them having different colours and materials/textures around the step area which could confuse the visually impaired.

8.1.2 Area for standing or paying for the ticket

There is no mention in either the DPTAC guidelines or in the consultation document of avoiding protrusions in the aisle and considering the front area for possible injury devices. Of the buses measured, most were considered to have a number of items which protruded into the aisle which could cause injuries. Items such as ticket machines, card machines, leaflet holders and bins all appeared to be added on to the bus as an afterthought rather than to be included in the original design of the internal environment.

On more modern buses the front bulkhead tended to be covered in plastic cappings, but there appears to be less consideration given to the design of this area to reduce the possibility of injuries from impact. Some minibuses also had ticket machines bolted to hand rails which were positioned across the front bulkhead.

8.1.3 Slopes

The maximum degree of sloping is stated by the DPTAC guidelines as 3 degrees and 5 degrees within 1metre of any door area. The consultation document recommend a maximum of a 5 degrees slope for mini/midi buses and a 3 degrees for standard buses. On the buses measured floor slopes ranged from 0-5 degrees for minibuses and 0-6 degrees for standard buses. The literature considered that slopes should be avoided wherever possible. On some older buses a number of small abrupt slopes in the floor, as if to mask articles under the floor, were observed. These were considered to be a tripping hazard.

8.1.4 Aisle

The aisle width on the more modern buses tended to be wider than older models. DPTAC states that the minimum width of the aisle at a height of 765mm should be 460mm, or in the vicinity of priority seats, between 700mm and 800mm. The audit found that this measurement ranged from 445 to 690mm.

For mini/midi buses the draft propsals state that the aisle width should be 300mm up to 900mm from the floor and at least 550mm at a height of 1400mm.

8.1.5 Handrails

The positioning of the handrails depends very much on the design of the layout of the inside of the bus. DPTAC and the consultation document cover the provision adequately. The positioning of the handrails on the measured buses varied considerably, but it was noted that the common practice among the more modern vehicles of having vertical rails positioned diagonally on each side of the aisle on every second seat, as suggested by DPTAC, seem to offer a good compromise.

On many minibuses grabrails fitted on the inside of the doors were noted to move when held with the flexing of the door. DPTAC states that handrails at service doors should be rigid.

The material used for the grabrails on the buses measured tended to be of two types. Stainless steel was used on most older buses while a ribbed coated steel was generally used on the more modern buses. The literature review suggested that oval shape rails are easier to use than cylindrical rails although no applications of such a rail were observed or are known to exist. The colour of the coated rails tended to vary. The most popular colours used were blue, yellow and natural stainless steel. It was observed that buses fitted with yellow coated rails were more conspicuous.

8.1.6 Bell pushes

Although not highlighted by the accident review the location of the bell pushes is paramount to their safe use. DPTAC state that passengers should not have to leave their seat to use them. Both DPTAC and the consultation document recommend that the bell pushes should be able to be pressed with the palm of the hand and must be bright coloured. The height of the bell pushes was specified in both the guidelines as, not more than 1200mm above the floor for those positioned adjacent to seats and not more than 1500mm at all other locations.

8.1.7 Seats

The minimum seat width for normal seating was specified by DPTAC as 450mm. The consultation document give figures of 430mm to 500mm On the measured buses this ranged between 425mm and 450mm. For vehicles less than 2.5 metres wide DPTAC give a minimum figure of 425mm. Seat width is likely to always be a compromise due to the need for a sufficient aisle width and seat width within the confines of the size of the vehicle.

8.1.8 Seat spacing

The distance between the seat spacing (front surface of seat back to back of seat in front) was stated in DPTAC as a minimum of 680mm. On the measured buses this dimension ranged between 660mm and 790mm. Information from the literature recommended seat spacing of between 800mm and 850mm to minimise injury in the event of an impact.

8.1.9 Priority seating

The draft proposal indicates a priority seat width of not less than 440mm with a 650mm seat spacing. DPTAC recommendations for all seating offers a more advantageous solution by providing more space for the passenger. On the buses which were measured the width of the seat base varied between 420mm and 450mm and seat spacing ranged from 660mm to 790mm.

8.1.10 Seat bars

DPTAC states that the tops of seats should have rigid hand rails. While this gives the passenger something to hold onto in practice the vast majority of seating used on buses have metal rails positioned across the top of the whole seat. In practice this type of seat has been seen to cause a number of injuries from people banging their faces on these bars. Other buses have been observed where pads are fitted around these bars and seating is available with higher backs which not only provide a soft pad which would be hit by the passengers face but also appear to offer some level of protection from whiplash, while still offering hand rails. One bus was observed to have soft pads mounted at the base of the vertical handrails to minimise any facial injuries to seated passengers.

8.1.11 Luggage space

DPTAC suggests that luggage areas over the wheel arch should be between 800mm and 900mm high, and that consideration should be given to providing floor space for heavier items. No mention is given to luggage space in the consultation document. The height recommended by DPTAC is still considered excessive and it was observed that most of the luggage areas on buses tended to be placed over the wheel arch or under the stair well. Those positioned over wheel arches were considered to be poorly designed as most require items to be lifted high over a lip and therefore they are difficult to use.

8.1.12 Wheelchair/pushchair provision

The wheelchair and pushchair provision as suggested by DPTAC and the consultation document appear to offer the best compromise within the internal environment of the bus. On the buses measured which conformed to DPTAC guidelines, the wheelchair/pushchair area seemed to offer good space for manoeuvring onto the bus and into the area designated for their use.

9.0 Practical assessment of current designs

Practical testing using participants was carried out in order to review and evaluate the different features found on the inside of buses.

Consideration was given to alternative methods of obtaining information, but at an early stage while developing the trials, it was decided to take regular bus users onto normal bus routes in the Loughborough area. This method was selected as the participants would be subjected to all the normal variables likely to be encountered on a normal bus trip and therefore their responses would be as realistic as possible.

Using a selection of similar vehicles to those measured in the review of vehicles, 4 buses were selected that had a range of features to represent a wide range of features of the type of vehicles currently operated.

The four buses selected are shown below:

Bus number 1

Volvo Olympian chassis with an East Lancashire 'County Bus' body.

The high floor Olympian chassis necessitates the bus to have internal steps. This design also has a split entry steps. Once on board, the aisle is fairly flat with only a minimal slope.

The internal environment shows yellow grabrails and the step towards the rear of the cabin. As this step drastically reduces headroom the operator has positioned a number of posters warning passengers to mind their head.

Bus number 2

The Optare 'Excel' is one of the new generation of low floor designs and this example is equipped to DPTAC guidelines.

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The Excel has kneeling suspension and a wide open aspect to the entry area.

The wide aisle, individual seats, high roof and large windows give an impression of comfort which can affect passengers perception of their safety. Steps to the rear section were clearly marked with edge markers and the ceiling height in the rear section was more than adequate. The seats have a higher back than normal and have plastic coated grab rails positioned along the top.

Bus number 3

Dennis chassis with the Plaxtons 'Pointer' body. This bus is a low floor design

The pointer has a similar internal layout to the Optare Excel, with a wide entry area .

The internal design appears to be more compact than the Excel, and has overhead hand hold straps hung from the ceiling. This photograph also shows an example of the protrusions within the aisle by the positioning to the left of the picture of an automatic card reader. The seats on this bus are of the basic bus type and feature stainless rails along the entire top.

Bus number 4

Mercedes D814 with a Plaxtons 'Beaver2' body. For the trials both the Beaver and Beaver2 were used. The Beaver is a high floor midibus.

The Beaver has a wide door opening but has 2 internal steps once aboard. The handrails attached to the door help boarding and alighting but they tend to move with the door when they are used. The standing area at the side of the driver is also quite small and this example has a waste bin attached to the drivers door.

The internal floor on the Beaver is gently sloped from front to back and due to the short wheel base the ride at the rear is very bouncy. This example is fitted with basic bus seats which feature hand rails across the top of the entire seat.

9.1 Methodology

A questionnaire (see appendix C) was developed in order to gain the views of participants during each journey.

Participants were briefed before each journey, and were asked to consider the design aspects of the inside of the bus while they went through the various stages of travelling on the bus. The information sheet read to the participants is included in appendix C. At this stage the participants were asked general questions regarding their bus use and some general questions about themselves.

The participant was briefed to get on the bus in their normal way and sit in any seat. The researcher then boarded and sat next to them. Questions were then asked about the initial stages of getting onto the bus, paying for their ticket, walking to the seat and sitting down.

After each bus ride, which lasted for approximately 20 minutes, the researchers and the participants alighted from the bus and participants were asked to rate and comment on getting up from their seat, walking to the door and getting off the bus.

In order to control confounding factors, the bus routes taken were the same for all participants on all buses.

9.1.1 Population sample

Sixteen participants were involved in the bus trials, all sixteen tested Buses 1 and 4 and nine tested Buses 2 and 3. This was because bus 3 and 4 had very similar internal features. A total of 50 questionnaires were completed in all.

Eleven participants were over 65, five male and six female. Four were between the ages of 25 and 65, all were female. Three of these participants tested the buses whilst travelling with children under five years old together with their pushchairs.

All the participants were regular users of bus services in the Loughborough area primarily using buses to travel to the shops in Loughborough and Park and Ride into the shops at Nottingham.

9.2 Results of initial questions

Initial questions were asked regarding the participants bus use. The participants responses are shown on the following tables and text:

Table 11: Results of initial questions

Q1 How often do you use a bus (not coach)	
	No. of responses
Daily	1
Two or more times per week	6
Once a week	2
Once a month	6
Less than once a month	1
Total	**16**
Q2 What do you travel on a bus for?	
	No. of responses
To and from work	1
Shopping in town	16
Visiting family and friends	4
Recreational	4
Total	**25**
Q2.1 What type of bus do you mostly use?	
	No. of responses
Mini/ midi	3
Single deck	14
Double deck	3
Coach	1
Total	**21**

Q3 Where on the bus do you prefer to sit?	
	No. of responses
Upstairs	1
Downstairs	3
Near the front	10
Near the back	0
In the middle	4
Front facing	4
Rear facing	0
Side facing	2
Anywhere	3
Stand	0
Total	**27**

Q3.1 If you have a preference, where do you sit and why?

Various reasons were given for choice of seating position on the buses, as follows:

‘I sit near to a vertical rail as it makes it easier to sit down’. (Lady aged 60 years)

‘I sit near to the front’. (Lady aged 68)

‘I sit near to the front because of the pushchair’.

‘I like to sit in the side facing seat because it is for three and it gives me more room’.

‘I like to sit near the front’. (Gentleman age 68)

‘Being near the front makes it handy for the driver’. (Gentleman aged 70 years)

‘I feel safer sitting in the middle’. (Gentleman aged 75)

‘I normally sit in the first empty seat’.

‘If I sat sideways I would have nothing to grab hold of.’ (Lady aged 70 years)

‘I feel sick if I sit at the back of the bus’.

The results shown in Table 11 above and the general comments made show a major preference for people to sit at the front of the bus.

Q4 Have you ever seen priority seats on buses?

Nine out of sixteen participants said they had never seen priority seats on buses.

Q.1 If yes, what are they for and why are they different from normal seats?

When asked what priority seats were for only five participants answered the question. Priority seats appear to be perceived as being for mothers and children, elderly people and people who are infirm and people with shopping or luggage.

Q4.2 Have you ever sat in priority seats?	
	No. of responses
Yes	5
No	8
Don't know	2
Total	**15**

Only five people said they had knowingly sat in priority seats even though eight of the participants were between the ages of 65 and 75.

Q5 What do you normally carry while you are travelling on buses?	
	No. of responses
Personal bags	6
Shopping bags	13
Luggage	1
Child	5
Pushchair	5
Other	1
Total	**31**

Q6 Do you ever use luggage storage racks that are provided on buses?	
	No. of responses
Often	2
Sometimes	5
Never	9
Total	**16**
6.1 If sometimes or often - what do you place in the racks?	
	No. of responses
Personal bags	1
Shopping bags	5
Luggage	2
Push chair	6
Other	0
Total	**14**
Q6.2 If never, why not?	
	No. of responses
Security reasons	2
Rack placed in bad position	1
Difficult to use	1
Luggage not stable in rack	1
Other	1
	6

The most popular items carried on buses were shopping bags. Out of 16 responses, 9 people never used storage racks for storing items, while 5 people said that they sometimes used them. Of those who did use the racks they were generally used for pushchairs and shopping bags. One participant stated that she no longer uses the racks to store her pushchair because low floor buses allow her to leave her child in the pushchair.

Only six comments were received as to why people did not use the storage racks. Most participants when asked could not give a reason. However it was stated by a few participants that they tended to keep their bags beside them when ever possible for privacy and security reasons.

9.3 Results of rating questions

This part of the questionnaire was divided into sections representing the series of activities normally undertaken by people when travelling on a bus, including; boarding and alighting the bus, sitting and standing, getting to and from the seat and purchasing a ticket**.**

Firstly, for each activity, participants were shown two rating scales and asked to give rating scores as follows:

- To rate their perceived degree of difficulty on a scale of 1 - 7, 1 being ‘very difficult’ and 7 being ‘very easy’.
- To rate how safe they felt on a scale of 1 - 7, 1 being ‘very unsafe’ and 7 being ‘very safe’. A copy of the rating scales is given in Appendix D.

Secondly, they were asked to indicate whether they felt that particular design features or sub-activities relating to each main activity were good or bad from the point of view of ease of use, safety and comfort. For example, in Section 7, Stepping onto the bus, participants were asked to state whether they thought ‘The area in which you are standing’ was good or bad. If the feature or activity was found to be ‘bad’ then they were asked to state the reason why and make any other comments which they felt would be useful.

9.3.1 Rating scores

The following figures were constructed showing the rating scores for ‘how easy’ they found each activity to undertake and ‘how safe’ they felt at the time.

Each of the figures show a very similar average rating scores for ‘ease of performance’ and ‘safety’ for each activity, indicating a possible link between participant perception of difficulty and safety.

For each bus very similar ratings were given for each of the activities, for example, the range of scores for Bus 4 over all activities for both ‘easy’ and ‘safety’ is 4.13 - 5.40, for Bus 3 it is 6.11 - 6.67.

9.3.2 Perception of safety

The range of ratings for perception of safety was very small, from 4.13 to 6.63, none of the overall ratings showed that people felt particularly unsafe during any of the activities.

For each activity, Buses 2 and 3 were rated the highest followed by Bus 1 and then Bus 4. The most marked differences in ratings were for stepping on and off the buses when Bus 4 had a marked lower average rating score than the other three buses.

9.3.3 Ease of performing activity

The pattern of rating scores were very similar to those for perception of safety as described above. The following figures show the average rating scores for the various stages of the journey.

Key

- Bus 1 Volvo Olympian - East Lancs ‘County Bus’
- Bus 2 Optare Excel
- Bus 3 Dennis - Plaxton ‘Pointer’
- Bus 4 Mercedes D814 - Plaxton ‘Beaver2’

Figure 17: Stepping onto the bus

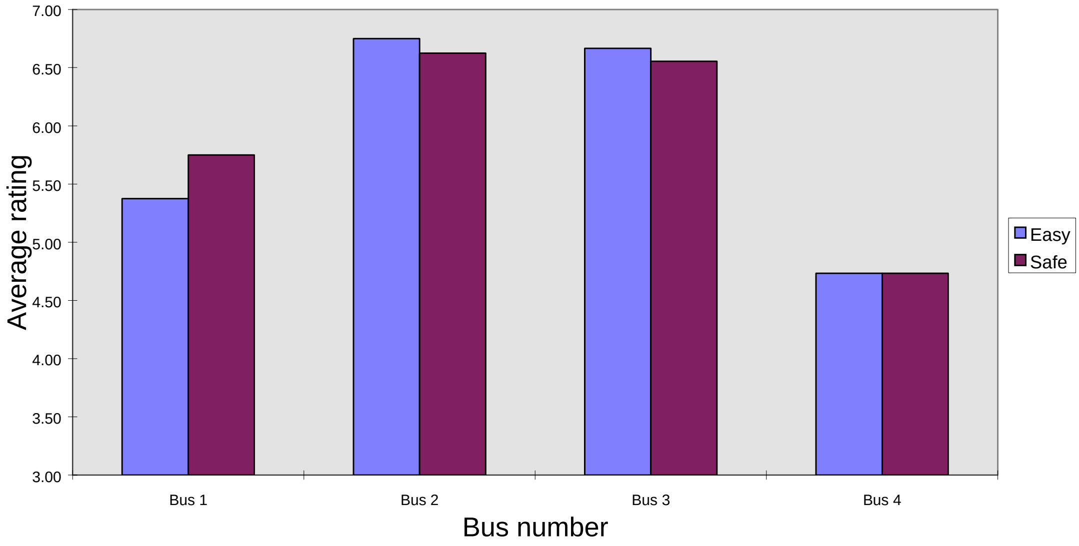


Figure 18: Paying for and collecting a ticket

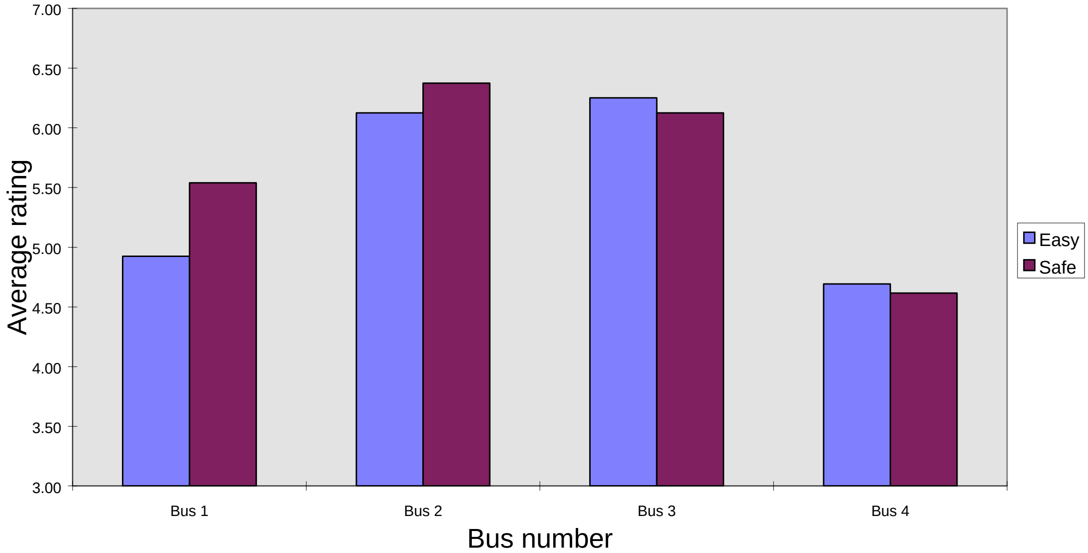


Figure 19: Walking to the seat

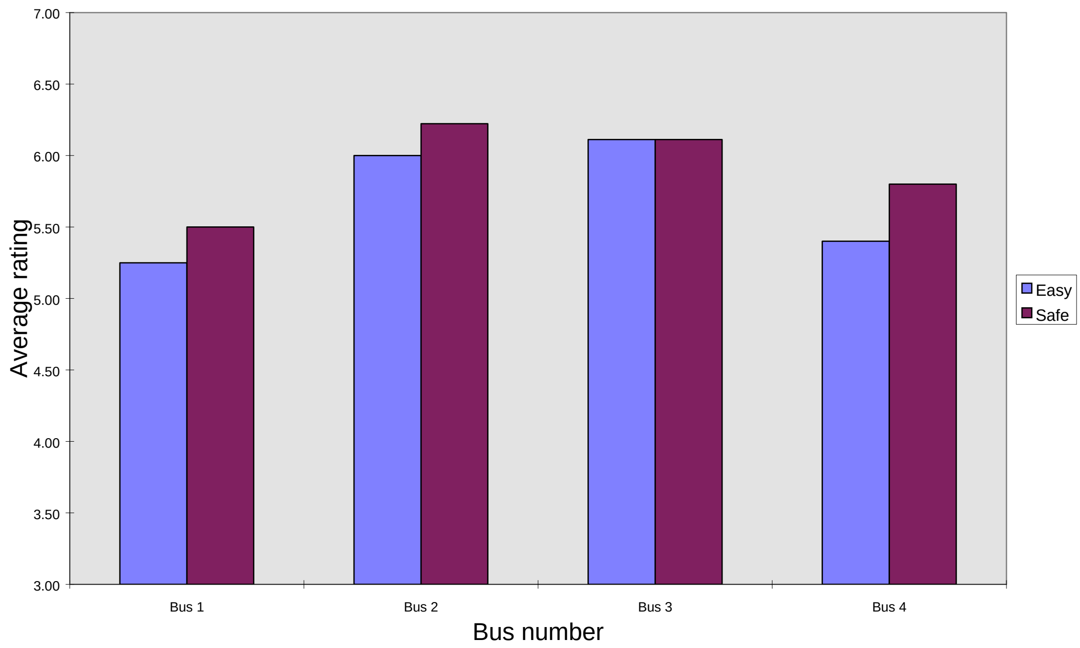


Figure 20: Sitting down

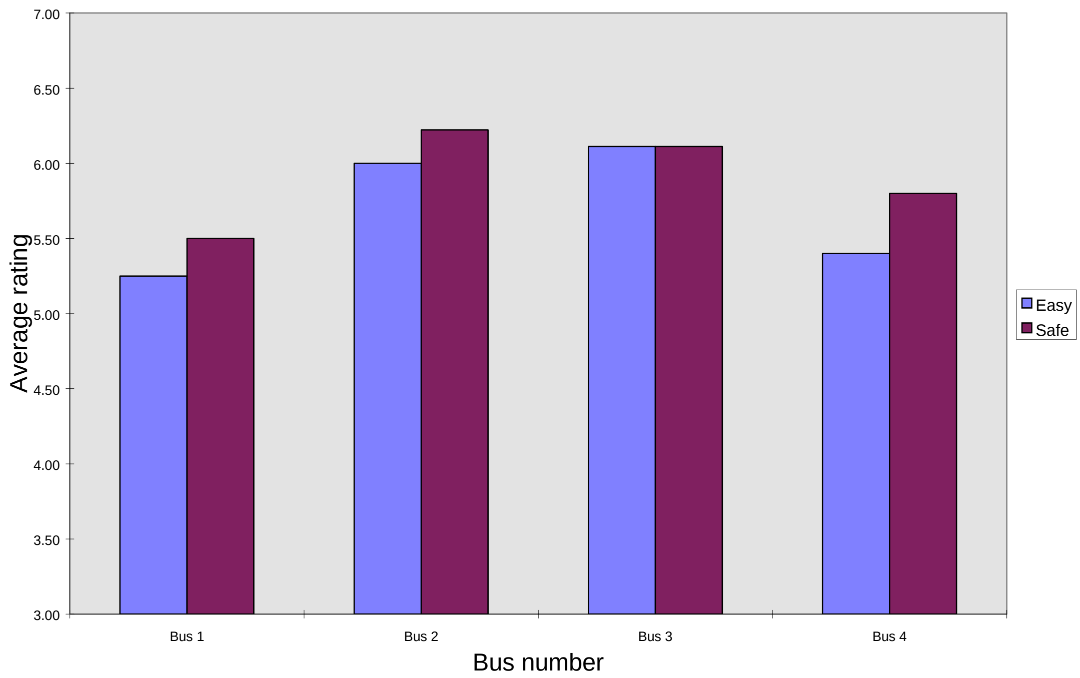


Figure 21: Standing to get off from seat

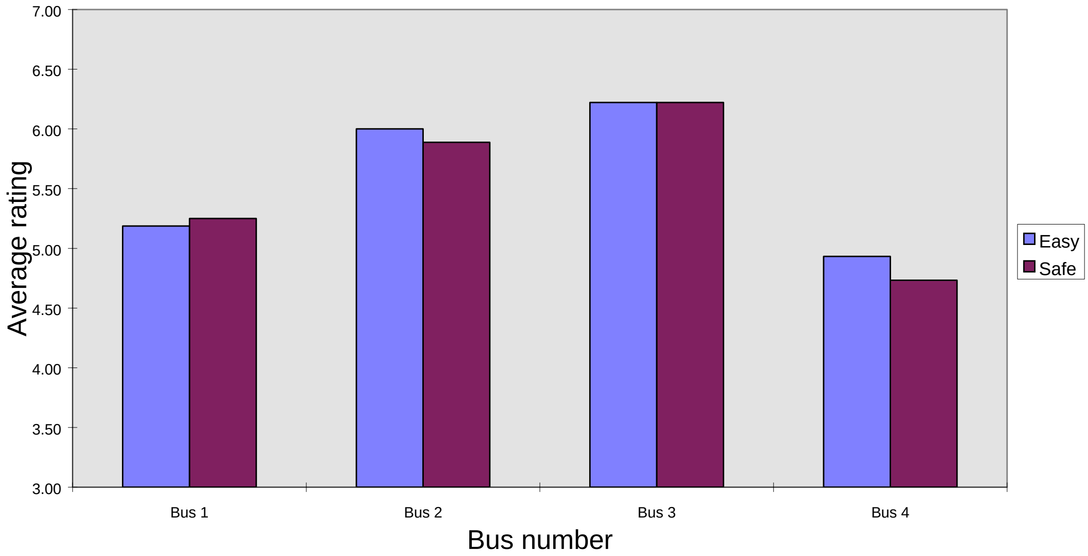


Figure 22: Walking to the door

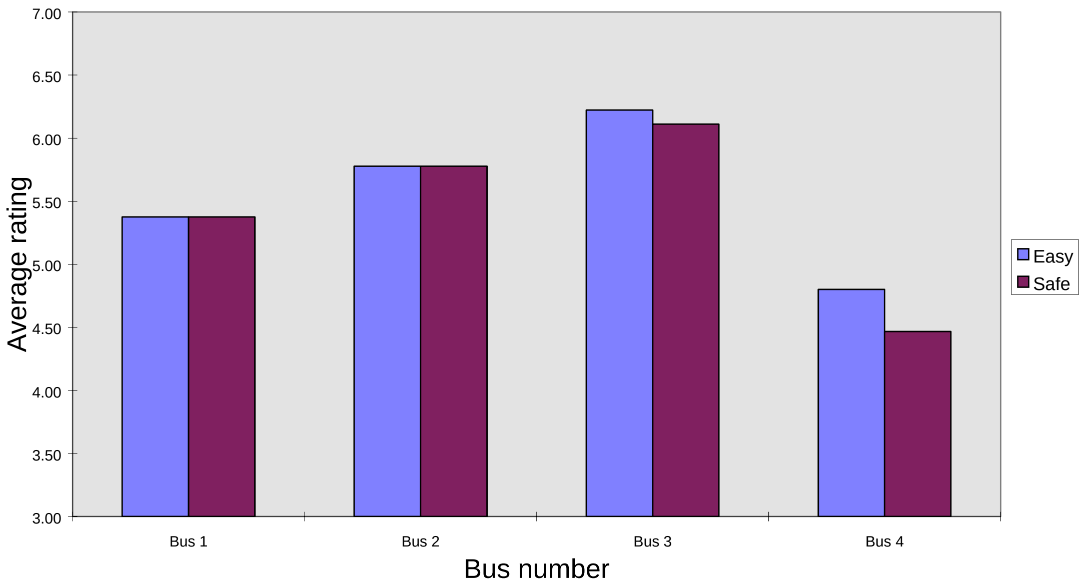
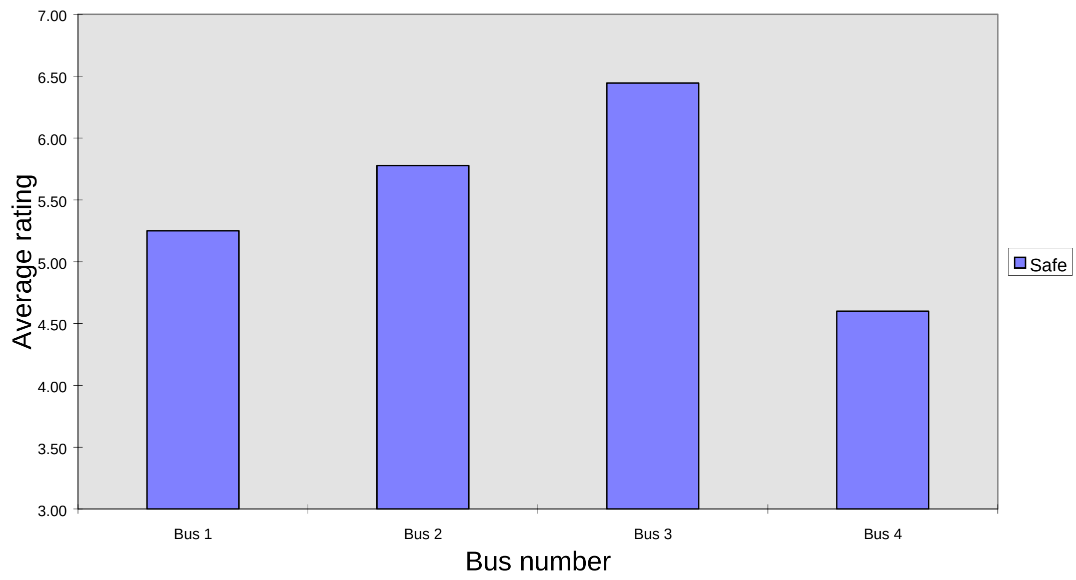


Figure 23: Comments while seated



9.4 Discussion of assessment of features and activities

9.4.1 Stepping onto the bus

Bus 1 and Bus 4 were found to have initial steps up from the pavement which were regarded as problematical. Comments included such things as ‘the first step is high’. The first step on a non kneeling bus would always be dependant on the height of the kerb to which the bus has parked against.

It was mentioned that on some of the journeys the buses were often parked too far from the kerb making it difficult for people to step up to board the bus.

The door handle was mentioned as a problem on Bus 4 and example of a comment made was ‘handrail is insecure because it is attached to the door’ and ‘grabbed onto door handle, it moved and I felt a bit insecure’. On examination the type of door fitted opened to reveal handrails attached on the inside of the door. Because of the way the door was hinged, when the rail was held and used as a support, it tended to move around.

9.4.2 Paying and collecting a ticket

On Bus 4 five out of 16 participants said they found ‘Paying for ticket’ difficult. The step area was commented on as being ‘too narrow’ and the ticket machine was said to be in the way. On Bus 1 a lady said there was not enough room for herself, her baby and the pushchair in the standing area whilst paying for her ticket. The problem with the standing area was considered to be a direct result of the area taken up by any boarding steps. This accounted for why there were no comments relating to buses 2 and 3 because they had no internal steps in this area.

9.4.3 Walking to the seat

People generally did not notice the slopes in the gangways. On bus 1 there was a slope in the aisle 2-3 degrees over approximately 2m in the area between the two front wheel chairs. On bus 2 and 3 there was a more gradual slope over a larger area and on bus 4 the whole floor was sloped from the front to the back of the passenger cabin by about 2-4 degrees. However, they complained about the gangways being too narrow especially on Bus 4. No participants expressed any particular problems with handrails in the gangway.

9.4.4 Sitting down

Five out of sixteen participants on Bus 1 and seven out of sixteen on Bus 4 mentioned that there was inadequate floor space for getting into their seat and sitting down. This did not appear to be much of a problem on Buses 2 and 3. On Bus 1 and Bus 4, four out of 16 people said that the seat legs got in their way when transferring into their seat. The seats on both of these buses were of similar designs. Steps were not mentioned as being a specific problem on any of the buses.

9.4.5 Seated position

Seat comfort was a particular problem on Buses 1, 2 and 4, this appeared to be related to three main things; restricted leg room, hard seats and seats which were not wide enough for two people. People also commented that the seats were OK for short journeys only. Typical comments were as follows; Bus 2, ‘seats not comfortable, not wide enough’, Bus 1, ‘not comfortable or adequate for 2 people’, Bus 4, 'seat too narrow and hard', 'tight leg room, the seat is too narrow'. However, as the size of the seats were very similar across all the busses it was considered that the overall environment of the inside of the bus could effect this judgement. Grab rails around the seat area were not mentioned as being a problem on any of the buses.

9.4.6 Standing to get off

It was observed that most of the participants held onto the rail on the back of the seat in front of them as they moved to stand up from their seat. None of the participants reported any problems on any of the buses while in the process of standing.

9.4.7 Walking to the door

All the comments were similar to those made by people when walking to their seats. Five out of 16 people on Bus 4 and three out of 16 on Bus 1 said the gangway was bad, indicating that it was too narrow. On Bus 2 and 3 the gangway was wider towards the front of the bus. It was observed that none of the subjects used any grabrails along the aisle while walking to the door. This may have been because on every occasion the bus was stationary before the participants began to walk to the door. There did not appear to be any problem with slopes on any of the buses, in fact most participants did not notice the slopes in the aisle.

9.4.8 Stepping off the bus

Seven out of 16 participants on Bus 1 and six out of 16 on Bus 4 said that the final step was 'bad', implying that the step was too high. Other steps in the footwell on both these buses were indicated 'bad'. One participant mentioned that there was no handrail to hold onto whilst alighting Bus 1.

9.5 Discussion

The inside of a bus is a compromise resulting from the requirement to get the maximum number of people onto the bus in a safe manner while meeting current safety and dimensional requirements.

Bus 2 and 3 obtained the highest ratings across all of the questions. The participants who travelled on both bus 2 and 3 also rated the features on the bus to be very similar. It has to be made clear that consideration has to be given to issues such as it is likely that peoples' perception of safety and ease of use are affected by their previously formulated opinions. In other words, if a person generally prefers Bus 2 or 3, they are likely to give higher rating scores for each of the activities than they would for the other buses. However, the low floor and kneeling properties of both of these buses were observed to make it very easy for people with pushchairs, the elderly and therefore the majority of the bus travelling population to board and alight these vehicles. The high ceiling and large windows on low floor buses give a feeling of openness and lightness which may also add to the perception of comfort.

One problem that the people complained about was the gangways being too narrow for moving to and from seats with luggage and children. The relationship between seat and gangway width needs to be explored. The wider aisle especially towards the front on both the low floor buses was liked by the participants.

The most popular area to sit was considered to be near the front of the bus and the least favourable areas to be were near the back, rearward facing or standing. There were different reasons given for this choice but they ranged from being able to see the driver/road ahead to that its easier to sit at the front with a pushchair. The comfort of the seat was also a concern for bus users. This is tended to be related to three main areas, width of the seat, leg room and comfort of the seat itself.

There is a definite reluctance for people to use the luggage racks and yet people complain that there is insufficient room in the seats and for moving up and down the gangway because of bags and luggage taking up space. This is mainly because people like to keep their belongings near to them for privacy and security reasons. With this in mind various alternative options for luggage storage need to be explored. In particular, consideration should be given to 'user friendly' storage for pushchairs, as some mothers appear to be less worried about leaving their pushchairs unattended than they are about being able to get on and off the bus with children and luggage in tact.

It was noted that during the trials most of the participants did not use grabrails along the aisle when the bus was stationary. The grabrails that were used most frequently were the ones placed on the sides of the door on bus 4 as the participants boarded and those placed around the seats on all of the buses which were used as the participant stood up or sat down on the seat. A number of participants commented on the fact that bright yellow grabrails with a textured surface were easier to see and use than stainless rails.

10.0 Bus user questionnaire

In order to obtain the opinions of a larger sample of bus users and to gain more general information about passengers preferences an interview questionnaire was conducted. The questionnaire (see appendix D) was based on that used for the participant trials and was conducted as a series of one-to-one interviews in the Nottingham and Loughborough areas. The questionnaire was originally going to be administered to people waiting for buses but because of the time it took to complete in it was found to be more efficient to conduct street interviews on people who were bus users.

The information from the questionnaire has been reviewed considering the principal issues highlighted in the earlier sections of the report.

10.1 Results

10.1.1 Population Sample

Interviews were carried out in Loughborough and Nottingham. A total of 211 people were questioned, comprising 175 people aged between 16 and 65 and 36 people aged 66 or over. All the respondents were regular bus travellers, 40% travelled on buses daily and 73% travelled on buses between two and three times a week. There were 71 male and 141 female respondents, reported heights ranged between 4ft 11ins and 6ft 5ins, reported weights ranged from 7st 7lb and 17st 9lb.

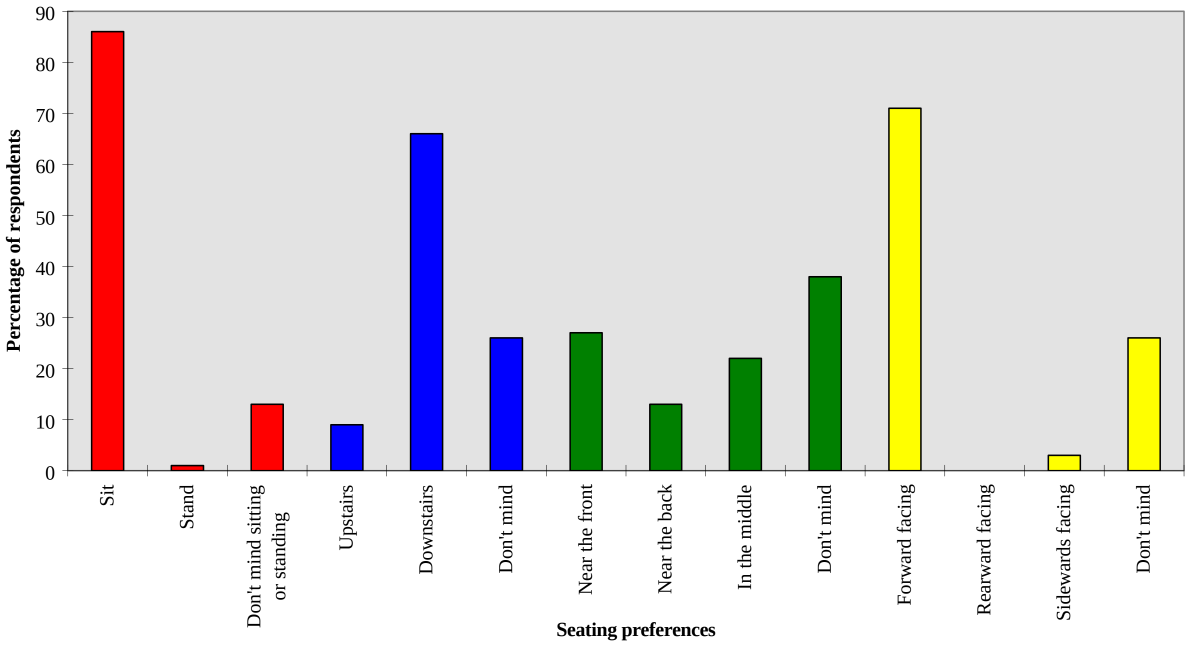
The main reasons respondents gave for travelling on buses were for going shopping in town and travelling to and from work. The most commonly used type of bus was the single decker, 134 respondents said they mostly travelled on single deckers, 70 on double deckers and 42 on mini/ midi buses.

10.1.2 Seating preferences

Respondents were asked about their seating preferences when travelling on buses. The aim was to discover whereabouts in the bus they preferred to sit and the reasons for their choice.

Figure 24 below shows the percentage of subjects who preferred particular seating positions. The chart shows that 85% of respondents preferred to sit rather than stand and 66% preferred to sit downstairs in preference to upstairs. Only 13% of respondents said they preferred to sit near the back, there was little difference in preferences for sitting in the front and middle. No respondents said they preferred rearward facing seats, however, 26% said they didn't mind which way they faced.

Figure 24: Seating preferences



Reasons for choice of seating position in order of preference (1. being most preferred) were as follows:

1. Can see where bus is going;
2. Like to see out of the window;
3. To avoid feeling sick;
4. Feel more secure;
5. To avoid going up stairs;
6. Can see what driver is doing.

Some respondents gave specific reasons for wanting to sit at the front of the bus, seven said they liked to sit near the front because it is easier to get on and off.

Comments made were; ‘shopping too heavy’, ‘because of pushchair’, ‘bad legs’, ‘smoother ride’.

Two people said they liked to sit at the back because there was more room.

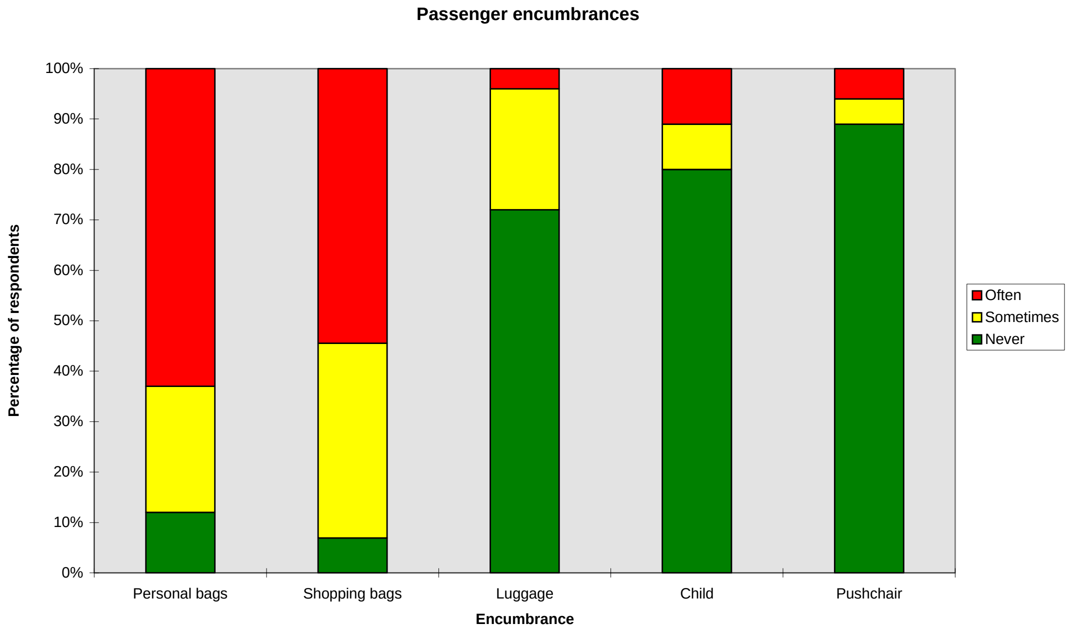
10.1.3 Priority Seats

Respondents were asked if they had ever seen priority seats on buses and if they knew what they were for. 73% of people said they thought that the seats were for old people, 54% said the seats were for people with disabilities and 35% thought the seats were for mothers with children/pushchairs.

10.1.4 Luggage

Respondents were asked what sort of encumbrances they might have on a bus and how often, ‘never’, ‘sometimes’ or ‘often’. Personal bags and shopping bags were reported as being the most common encumbrances. As the population sample was made up of a high proportion of people who used buses for shopping and travelling to work it is not surprising that children, pushchairs and other luggage were not reported as being taken onto buses very often.

Figure 25: Passenger encumbrances



The questionnaire results showed that people tend to avoid using the luggage racks and storage and 66% of respondents said that they never used them. The main reasons given for not using the luggage storage were issues of security. Several people said they preferred to keep their shopping with them and another said the luggage rack was always full of pushchairs.

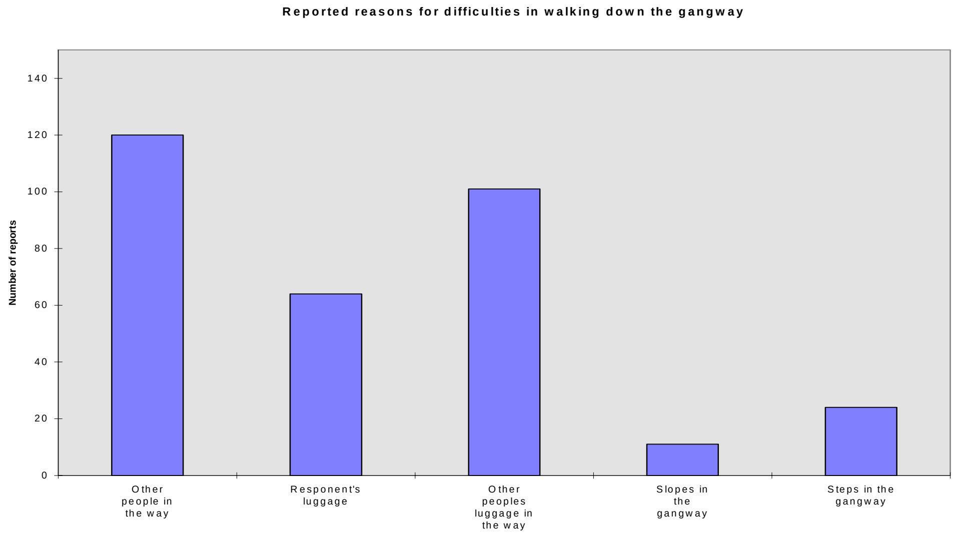
10.1.5 Entrance/exit

People were asked how they generally found the height of the initial step up from the pavement, 78% said they felt it was acceptable and only 11% said they thought it was too high. When asked how they generally found the width of the entrance/ exit doorways 84% of respondents said it was an acceptable width and only 15% said they thought it was too narrow.

10.1.6 Aisles

When considering any difficulties while walking down the aisle on the bus most respondents commented on other people getting in the way and luggage belonging to other people blocking the aisle. Other people getting in the way was usually put down to seated passengers who were protruding into the aisle. Carrying bags while walking down the aisle was also found to be a problem. The respondents views are shown on figure 26.

Figure 26: Causes for difficulties in aisles



10.1.7 Seating

Respondents were asked their opinions about different aspects of seating design and comfort. 85% of people who responded said they found the seats to be comfortable as opposed to 15% who said they normally found the seats to be uncomfortable. 28% of people said they generally found bus seats to be too wide and 68% said they normally found them to be an acceptable width. 39% of respondents said there was generally not enough knee room whilst seated.

10.2 Conclusions of questionnaire results

10.2.1 Priority seating

The respondents' perception of which bus users take precedence with regard to designated priority seating showed that the majority think priority seating as a seat which is designated for those in need, including, the disabled the elderly and people with small children or those with luggage. This perception mirrors that laid down in the DETR proposal for buses and coaches which specifies that priority seats will be designated for disabled passengers being placed in the most easily accessible part of a bus and space also being required for a guide/hearing dog. However, from reviewing manufacturers literature there are currently only a small number of buses known to include priority seating in which the design conforms to the specifications laid down in the current DETR proposals. Furthermore, further confusion may be caused by notices which bus companies place above standard bus seats, as designating them for use by elderly and disabled people.

10.2.2 Passengers travelling with small children and pushchairs/ buggies

The bus trials clearly showed that new low floor buses are very popular with those passengers who regularly travel with small children in pushchairs and buggies. Mothers with small children were observed at bus stops deliberately avoiding travelling on high-floor chassis buses preferring wait an extra few minutes for a low floor bus to come along.

Some bus manufacturers are now offering alternative seating plans with specially designed seating and spacing for passengers with accompanying small children and wheelchairs/ buggies. However, the current DETR proposals do not make any specific mention for seating design and spacing which fulfils the specific requirements of this sector of the user population. The user trials showed that currently spacing specifically designed for occupied wheelchairs is also being used by passengers travelling with small children and pushchairs/ buggies. Therefore, current DETR specifications for wheelchair spacing may need to be updated to include specific design and safety requirements for occupied pushchairs. This may also include consideration to such things as safety restraints for occupied pushchairs and the numbers of occupied pushchairs which should be allowed to take up any designated wheelchair/ pushchair space. Provision of alternative storage for pushchairs/ buggies may be required for use instances where designated spaces are fully occupied.

10.2.3 Seating preferences

Although no respondents said they actually preferred to face in a rearward direction, 26% said they did not mind. This indicates that if necessary the provision of a small number of rearward facing seating would be acceptable.

10.2.4 Storage space for luggage

The user trials and the literature review showed that the main reasons for people not using luggage pens and racks are that people like to keep their belongings near to them in case they are stolen or they forget them and that they find luggage pens difficult to use.

Luggage pens on low-floor chassis buses are often built in order to make use of wheelarch space rather than take account of encumbered passengers' requirements and physical capabilities. These pens are too high to easily lift luggage into and too far away from passengers for convenient use.

Field (1993) undertook a detailed assessment of six luggage pens, it was found that designs were varied and that the main complaints of passengers were related to height. Pen rail heights were found to range from 680mm to 960mm and that all people would be expected to find difficulty in lifting large heavy items over the top of pen rails. During the trials women were observed having difficulty in lifting folded pushchairs into luggage pens whilst the buses were moving as they also had to consider the safety of accompanying children and hold onto other luggage such as shopping bags.

Consideration may need to be given to the possibility of the provision of appropriately designed luggage storage nearer to the seated passenger which would be more likely to be used, therefore, reducing problems of obstruction to the gangways and increasing the comfort of seated passengers by relieving them of their encumbrances.

10.2.5 Seating design

The main complaint appears to be lack of knee room, 39% of respondents said they found they generally had insufficient knee room when seated on buses.

There are no guidelines for standard seat spacing in the consultation document, Governments proposals for buses and coaches, only those for priority seating. In the case of priority seating, the minimum specified distances proposed for seats facing in the same direction is 650 mm between the front surface of the seat back and the back of the seat in front. DPTAC gives a minimum distance between the front of the seat cushion and the back of the seat in front as being 680mm minimum. The 95th percentile UK male seated buttock to knee measurement is 673mm, therefore, allowing a little additional room for clothing a seat distance of a minimum of 675mm should accommodate 95% of the UK population, this being appropriate for all seating within the bus. While the above recommendations would improve the comfort of the passengers, they may not improve the passengers safety.

The consultation document specifies a minimum space between the front of the seat cushion and the top of the back of the seat in front as being 230mm. The bus evaluation found the range of measurements for this dimension ranged from 100 – 290mm. Without undertaking fitting trials the optimum distance for this dimension would be difficult to establish. This dimension is dependant on three criteria, the depth of the seat cushion, the angle of the seat back and the distance between the front of the seat back cushion and the back of the seat in front (when measured in the horizontal plane).

On ergonomic criteria the seat cushion depth should be no greater than 460 mm as this would accommodate the 5th percentile UK female having a buttock to back of knee (popliteal) length of 459.6mm. Seat cushion depths measured in the bus evaluation study ranged from 360 – 410mm, which is acceptable.

10.2.6 Communication devices bell pushes

Bell push heights measured during the bus evaluation study ranged from 1060mm to 1685mm. On some individual buses there were inconsistencies in button heights, for example, on a Leyland Lynx the bell heights located on vertical rails ranged from 1355 – 1685mm.

The DPTAC specifications (1995) recommend that passengers should not need to leave their seats to use bell pushes and they should have a mechanism which can be activated with a palm push action. The recommended height adjacent to seats is 1200mm, the mean overhead pinch grip at full stretch directly above the head for 5th percentile UK females is 1135mm. Bearing in mind that it would be difficult for anyone to achieve an overhead grip at full stretch while seated on a moving bus wearing outdoor clothing the recommended height to reach from a seated position should be a maximum of 1100mm. This would also be a more appropriate height for people with upper limb disabilities such as arthritis and muscle weakness who find it difficult to comfortably lift their arm above shoulder height.

The specified maximum height for bell pushes for use from standing where there are no seats is 1500mm. The armpit height for 5th percentile UK females is 1128mm. The armpit height is that which could reasonably be expected to be comfortably reached by people with upper limb disabilities. Therefore, it is recommended that the maximum height of bell pushes for convenient comfortable use from a standing position should be 1200mm. It is also more likely that children would be able to comfortably reach a bell push at this height.

Lowering the maximum height of the bell pushes to 1200mm may introduce problems in that it may make them more accessible to children who may be likely to miss use them, however, it is believed that the benefits of increased user friendliness outright this problem.

11.0 Recommendations to improve passenger safety

11.1 Recommendations

The inside of a bus is a compromise resulting from the requirement to get the maximum number of people onto the bus in a safe manner while meeting current safety and dimensional requirements.

Travelling on local service buses is a safer way to travel than by car. The population as a whole is now being actively encouraged to use buses. This is apparent not only by government initiatives but by more modern vehicles which are more accessible for more people. By making buses more accessible with features such as low floors, wheelchair parking areas etc., this enables older people, people with disabilities and people with pushchairs to be able to use buses reasonably safely.

The accident information has shown that the more significant injuries are caused to adults and the elderly. Therefore by allowing more vulnerable groups of people such as those discussed above to be able to travel on buses, there may be more injuries occurring on modern buses. Therefore the internal design of the bus should cater for the needs of these people.

Considering the design aspects, the design of the bus will always be a compromise between the many factors affecting its operation. However the DPTAC guidelines have driven a significant change in recent years of the design of local service buses and these have certainly enabled more people to be able to travel on buses.

However there are other factors more significant than the design of the internal environment that have been shown to affect the safety of bus passengers. The external environment in which the bus operates has changed in recent years. With ever increasing traffic congestion an increasing amount of pressure has been placed on the driver. One operator buses, and more commercial pressures such as keeping to tight deadlines have also put more pressure on the driver.

Improvements in the performance of the buses which enables them to integrate better in the traffic flow could also have a detrimental effect on the safety of the passengers due to higher levels of acceleration and deceleration possible.

A large percentage of serious and fatal injuries have been found to occur to standing passengers, be they getting on or off the bus or walking to and from the seat. It has also been apparent that most injuries occur on buses when they are moving. Therefore the following recommendations are made:

- ensure that buses are stationary before any passengers move around the inside of the bus - this would significantly reduce the number of incidents occurring;
- research the workload of the driver - to investigate whether task and environmental conditions demand on driving style which may conflict with optimised passenger safety.

As a secondary measure the following design recommendations are made in addition to the areas covered within the DPTAC guidelines, and the consultation document:

- ensure re-circulating doors are fitted to avoid passengers getting trapped;
- ensure that the driver can easily see all door/footwell areas;
- minibuses should have a greater standing space in the area for paying for tickets;
- seat backs should have padding in the area likely to be hit by a head falling forwards, while still having hand holds;
- standardise the height of bell pushes throughout to 1200mm above the floor;
- any additional steps in the entry area and in the ticket buying area should be avoided - low floor buses already meet this;
- avoid placing ticket machines, card machines etc. in a position which causes them to protrude into the aisle and act as an impact hazard - these should be part of the integral design of the bus;
- avoid sharp edges on any internal bodywork especially around the front bulkhead and other areas in close contact to passengers;

- avoid having standing passengers as these are going to be at more risk from injury;
- the positioning and design of luggage racks should be reviewed to make them convenient and easier to use;
- consider soft feel grab handles when suitable materials become available;
- consider updating the wheelchair provision requirements to include design and safety requirements for occupied pushchairs.

The following observations were made relating to peoples perceptions of bus design and condition:

- ensure any maintenance carried out to the inside of the bus does not compromise safety issues;
- most people do not notice, and are not affected by small slopes in the aisle on buses;
- low floor buses have been shown to be preferred by most of the participants;
- high ceilings, wide aisles (especially near to the front of the vehicle) and large windows give a more pleasing visual environment that adds to the perception of comfort and safety;
- although taller passengers complained about being cramped in seats, it was considered by most of the subjects that seat spacing on the vehicles used in the trials was satisfactory for the purpose of the vehicle.

12.0 Assessment of design changes

Bus design is currently going through a fundamental design change as a result of the DPTAC guidelines and the Governments consultation document. This has been led by the popularity of the new designs and the fact that they offer a marketing advantage to attract more customers.

We have found that, in general, bus design is improving in many areas making it easier for people with disabilities and therefore the population as a whole to use buses in a safer and more comfortable way.

Most local service bus manufacturers are now manufacturing low floor single deck buses as standard vehicles. Following close behind are double deckers. In 1999 the major double decker chassis manufacturers are now only making low floor designs.

However consideration should also be given to geographical areas where low floor opperations would be unrealistic because of grounding hazards. It is perceived that standard height service buses for use in these areas will end up being more costly to purchase that the low floor equivalents.

From studies completed in the late 1980s and early 1990's the cost of implementing low floor buses was considered excessive because at that time the technology involved in designing and manufacturing the buses was in its infancy. In the late 1990's this differential has reduced considerably with respect to single deckers. In fact some low floor unitary construction designs are cheaper than standard floor models with a chassis.

Therefore as the fundamental change has already taken place there is little going to revolutionise bus design in the foreseeable future and as a consequence there are no significant future design modifications have been available for review or evaluation.

13.0 Cost benefit analysis

It is practically and ethically difficult to asses the death and injury savings of the design recommendations and therefore it is only possible to obtain an estimate.

Because the most fundamental recommendation of this report is an operating issue rather than a design issue the cost implications to the operator for such are not known and would require investigating. However the casualty savings and therefore the casualty saving values can be estimated in a number of ways.

As there are no major modifications which need to be done to the existing vehicle fleet, the vehicle on costs of its recommendations are minimal. The design recommendations should be considered when developing new vehicles and therefore any cost implications would be insignificant as they would be considered at the design stage. Only those features which are added to the bus and are therefore able to be costed have been considered in that assessment.

13.1 Casualty costs

In order to place a figure on the costs, the DETR Highways Economic Note No.1 1997 “Valuation of the benefits of prevention of road accidents and casualties” has been considered. This document, published in October 1998, gives the most up to date costs for different types of road casualties. All figures are calculated for June 1997.

The average value of the prevention of all casualties for bus and coach occupants is £15,190. STATS 19 division was consulted to see if this figure could be broken down for the different severity classes. This was not possible as this figure is an estimate. Therefore the average value of prevention per casualty, by severity for all classes of road users were used for the purposes of the cost benefit analysis. These figures are shown below.

Figure 27: Average value of prevention per casualty, by severity

1997	**June 1997**
Fatality	£902,500
Serious casualty	£102,880
Slight casualty	£7,970

13.2 Estimating casualty savings

In the absence of any data to quantify the likely reduction in casualty we have used the qualitative results of the safety perception ratings obtained during this study.

Both of the low floor buses used for the trials had higher subjective ratings for safety. Therefore the percentage differences between the low floor buses and the standard floor double decker bus have been averaged across the tasks of walking to and from the seat and boarding and alighting. This figure has then been assumed as a percentage reduction in the number of casualties.

Percentage reduction of casualties: 12%

The casualty numbers for each severity have been calculated by using the figures from the STATS 19 review. The figures have been compounded for each severity for the actions of boarding, alighting and standing for both collision and non collision accidents (see section 7.9). An average figure has then been calculated for a one year period.

Figure 28: Average number of casualties per year

Severity	Number per year	Cost per year
Fatality	7.16	£6,461,900
Serious casualty	279.16	£28,719,980
Slight casualty	2511.5	£20,016,655
Total cost per year		£55,198,535

Therefore on the assumption of a 12% reduction in casualties the following costs could be saved:

Figure 29: Estimated savings based on occupant perception of safety

Severity	Number (12% of year)	Saving
Fatality	0.859 x cost per fatality	£775248
Serious casualty	33.49	£3445451
Slight casualty	301.38	£2401998
Total saving per year		£6,622,697

13.3 Cost of implementing changes

When evaluating low-floor bus trials in London and North Tyneside (I York 1998) stated that when low floor buses were first introduced in London in 1994 there was a price differential above standard single deck vehicles of some £35000. In 1997 this differential had come down to £5000. It is not known whether or not the price differentials were for vehicles manufactured to DPTAC guidelines. The most radical design change has been the introduction of low floor designs and as these are now in widespread manufacture and are increasingly becoming the new standard vehicle, the bulk of the costs have already been excepted by operators and manufacturers. Other features recommended by both the Governments consultation document and the DPTAC guidelines would cost a significantly less amount to implement

Through talking to a number of operators and manufacturers the current thinking regarding the price differentials between low floor and standard floor single decker buses range considerably, but generally it is considered that low floor buses are between 5% and 10% more expensive. One manufacturer stated that the unitary construction some low floor buses actually make them cheaper than conventional buses that require chassis. For double deckers the differential is somewhat greater at the moment and range between 10% and 20% because of the fact that production is in the process of switching over to low floored vehicles. However, as is the case for single deckers, it will only be a matter of time before the majority of vehicles being manufactured will be low floor.

Manufacturers and operators consider the cost of implementing DPTAC guidelines adds on average cost of approximately £3500 per bus.

Therefore from the above differences and the design recommendations which can be costed, the following figures have been estimated for the additional costs involved per vehicle. The other recommendations are not possible to place figures against as they relate to the design aspects of the inside of the bus and are therefore not additional features.

Figure 31: Additional costs per vehicle (single decker)

Feature	**cost per vehicle**
Single Decker	
Low floor (assuming 5% differential on £100,000)	£5000
DPTAC	£3500
High back seating (assuming 50 seats and 66% differential)	£2000
Camera system for visibility of door/footwell areas	£200
Recirculating doors	£500
Total	£11200
Double Decker	
Low floor (assuming 10% differential on £130,000)	£13000
DPTAC	£3500
High back seating (assuming 75 seats and 66% differential)	£2600
Camera system for visibility of door/footwell areas	£200
Recirculating doors	£500
Total	£19800

These prices include some consideration for maintenance but it is impossible to consider the operational (revenue) costs (see proposed work).

It is impossible to consider costs for implementing recommendations to minibuses as manufacturers and operators could not provide figures and there is currently only one manufacturer offering a low floor minibus and therefore cost differentials are likely to be excessive.

From the Transport Statistics Great Britain (1997) in 1996, 6500 vehicles of the bus taxation class were registered. Assuming a 50/50 split of single and double deckers, using the figures presented on the table above the cost implications per year would equate to:

3250x19800	=	64,350000
3250x11200	=	36,400000
		£100,750,000

A break-even point on the cost would be achieved after 15 years from implementation (100m costs ÷ £6.7m saving) assuming that vehicles remained in service for at least 15 years. The actual annual cost benefits will depend on vehicle replacement rates.

14.0 Areas for further work

As a result of the findings of this study the following areas have been highlighted in which further work is considered necessary.

14.1 Executive Report

As the reports delivered to meet the contractual requirements of the project on passenger safety on local service PSVs are of necessity somewhat lengthy, a summary report is required for circulation to interested parties for consultation purposes. ICE will prepare this and it will describe the objectives, methods, results and recommendations of the project. It is envisaged that the summary should be no more than 6 – 8 pages in length including figures and tables. A draft of the summary report will be submitted to DETR for their comment and approval prior to producing the final version.

14.2 Passenger safety leaflet

Not withstanding any safety design measures, moving around in a moving bus will always carry some risk to passengers. The leaflet will draw upon the findings of the current work to provide advice to passengers on how they can move on, off and around the vehicle with minimum risk to themselves and also the actions they can take to ensure they do not add to the risks of other passengers.

Whilst ostensibly aimed at passengers it is intended that the leaflet will act as a strong reminder to drivers that their driving style has a key role to play in passenger safety. By emphasising to passengers the most risky times (while the bus is moving off or pulling up) the driver will be reminded of how the manner in which he/she does this affects the risks of falls and injury to passengers, especially the old, disabled and encumbered.

A sticker or small poster reminding passengers to take care when moving about the bus will also be developed. Consideration will be given to a design which can be placed where it will be on view to the driver as well as passengers so as to act as a constant reminder to the driver.

The content of the leaflet will be drawn from the results of the current work and may include for example:-

- the ***three points of contact*** rule (never have more than one hand or foot out of contact with a fixed object);
- do not impede others' movement by obstructing gangways;
- if you do have problems moving tell the driver not to move off until you are seated and that you will not be able to get up from your seat to get off until the bus has stopped;
- the use of priority seating;
- Etc.

14.3 Effects on dwell time of passengers remaining seated until the bus is stationary

A major cause of passenger accidents on local service PSVs could be eliminated if passengers did not have to move to or from their seats whilst the bus is in motion.

This could have significant negative cost and operational consequences for bus operators and it is therefore necessary to make an objective investigation into these effects. This will enable a cost-benefit analysis to be made comparing the injury savings with operational costs.

We have undertaken a number of similar studies looking at the effects of vehicle design on dwell times for rail vehicles where these critically affect headways.

The study would comprise three phases:-

1) Preparation and definition of testing

The vehicles, passenger boarding/alighting configurations to be tested would be defined on the basis of field observations.

2) Dwell time trials

A series of trials would be undertaken to measure the effects on the time a vehicle spends at a bus stop of not permitting the vehicle to move off until passengers are seated and of alighting passengers remaining seated until the vehicle is stationary.

Four vehicles representative of the bus fleet will be tested for a range of boarding and alighting configurations and passenger mixes young, elderly, encumbered, disabled etc.

3) Cost benefit analysis

The results of the trails will be used to estimate the on-cost to operators of any increase in dwell times. Data from the current study will be used to estimate casualty savings.

14.4 The in-service effectiveness of the DPTAC guidelines.

Now that a number of buses which incorporate some or all of the DPTAC guidelines have been in service for a period of time it would be valuable to obtain feedback from reduced mobility passengers on their effectiveness.

This study will include:-

- the extent to which each of the specific recommendations in the guidelines, as implemented, have improved access to vehicles;
- any aspects which have not provided the anticipated benefits;
- any areas not adequately covered by the implementation of the guidelines;
- the extent to which the new designs of vehicle have improved mobility choices and quality;
- user feedback of the design and accessibility of DPTAC vehicles;
- recommendations for further development of the guidelines.

14.4.1 Method

The work will take account of the original DPTAC user feedback studies undertaken in London, North Tyneside and Merseyside. Consultation with the Mobility Unit at DETR will be maintained throughout the study.

A number of methods can be used to gain feedback from users with impaired mobility:-

- postal questionnaire. This would be sent to regular users and could include a diary for them to record their experiences over a period of time;
- interviews with regular PSV users with a mobility impairment;
- interviews while travelling with regular PSV users with reduced mobility on their regular journeys;
- interviews while travelling with people with reduced mobility who do not usually travel by PSV. The inclusion of non-experienced users of any design or system often provides a more sensitive test as users have not adapted to any shortcomings in the design.

In order to recruit a range of participants for this study our database currently has a number of people with various disabilities which influence mobility. These include elderly people and those with physical and sensory disabilities. Also included are people who have young children and who therefore use pushchairs.

Through a recent study, in conjunction with the Health Research Institute at Sheffield Hallam University, on behalf of the Physical and Complex Disabilities Programme of the National Health Service Executive, we have contacts for over 800 wheelchair users who have been identified by NHS wheelchair centres and local disability groups. These include people of different ages, working and non-working, who use services such as public transport.

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APPENDICES A - D